Ref. Ares(2024)4597533 - 26/06/2024

Europe's Rail

ADOPTED BY GB DECISION N° 10/2024 ON 21 JUNE 2024

EUROPE'S RAIL JOINT UNDERTAKING

Consolidated Annual Activity Report 2023

In accordance with Article 26 of Council Regulation (EU) No 2021/2085 of 19 November 2021 and with Article 23 of the EU-Rail Financial Rules.

The Europe's Rail Joint Undertaking (EU-Rail) became the legal and universal successor of the Shift2Rail Joint Undertaking (S2R JU or S2R). Hence, EU-Rail has succeeded in the management of the S2R JU Research and Innovation Programme.

However, in this report, references may still be made to S2R Programme, S2R Other Members, S2R R&I, S2R Regulation, S2R JU, S2R etc. to identify all the activities and governance inherited by EU-Rail and related to the former S2R JU.

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FACTSHEET

Name	Europe's Rail Joint Undertaking – as of 30/11/2021 (hereinafter "EU-Rail")
Objectives[1]	EU-Rail is an autonomous body with its own legal personality. It is an institutional European partnership as per Article 187 of the Treaty on the Functioning of the European Union dedicated to managing and coordinating mission-oriented R&I activities for a major transformation in rail systems in Europe. The general objectives of EU-Rail are to: (a) contribute towards the achievement of the Single European Railway Area; (b) ensure a fast transition to more attractive, user-friendly, competitive, affordable, easy to maintain, efficient and sustainable European rail system, integrated into the wider mobility system; (c) support the development of a strong and globally competitive European rail industry. The main task of EU-Rail is to deliver a high-capacity integrated European railway network by eliminating barriers to interoperability and providing solutions for full integration, covering traffic management, vehicles, infrastructure and services, aiming to achieve faster uptake and deployment of projects and innovations.
Legal basis	Article 187 of the Treaty on the Functioning of the European Union[2]. The founding legal Act of EU-Rail is the Council Regulation (EU) 2021/2085[3] of 19 November 2021, which entered into force on 30 November 2021, establishing the Joint Undertakings under Horizon Europe (hereafter the "Single Basic Act" or the "SBA"). By means of the SBA, the EU-Rail was established and became the legal and universal successor of the former S2R JU, which it replaced and succeeded as from that date. In addition, in its first meeting, the EU-Rail Governing Board approved the list of decisions adopted by the S2R JU that will continue to apply for EU-Rail in accordance with Article 174(12) of the SBA[4].
Executive Director (ED)	Mr Carlo M. Borghini, until 28 February 2023[5]. Mr Giorgio Travaini, appointed ED ad interim as from 1 March 2023[6].
Governing Board of EU-Rail	***European Commission (EC) members:*** • Henrik Hololei, DG MOVE until 31 March 2023 • Magda Kopczynska, DG MOVE ***EC alternates:*** • DG MOVE Kristian Schmidt • DG RTD Rosalinde Van Der Vlies

1 The key objectives pertaining to the S2R Programme, pursued by the former Shift2Rail Joint Undertaking, and inherited by its successor – EU-Rail, are the following:
- a 50 % reduction of the life-cycle cost of the railway transport system (i.e. costs of building, operating, maintaining and renewing infrastructure and rolling stock),
- a 100 % increase in the capacity of the railway transport system,
- a 50 % increase in the reliability and punctuality of rail services (measured as a 50 % decrease in unreliability and late arrivals).

2 OJ C 202, 7.6.2016, p. 131–131

3 OJ L 427, 30.11.2021

4 EU-Rail GB Decision n° 02/2021

5 Based on the confirmation of early retirement of Mr Borghini by means of the EU-Rail GB Decision n° 01/2023.

6 Based on the EU-Rail GB Decision n° 02/2023.

	Industry members: • ADIF — Luis Fernando López • ALSTOM — Richard French • ANGELRAIL consortium led by MER MEC — Francesco Inzirillo • AŽD — Vladimir Kampik • CAF — Jorge De Castro • CEIT — Juan Melendez • ČD — Jan Ilík • DEUTSCHE BAHN — Ralf Marxen • DLR — Christian Sattler • eSGR JV — Noemi Jimenez Redondo • Faiveley Transport — Paolo Pagliero • Ferrovie dello Stato Italiane — Roberto Tundo • HITACHI RAIL STS — Antonella Trombetta • INDRA-TALGO — Jose Miguel Rubio Sanchez • Jernbanedirektorate — Preben Saethre • KNORR-BREMSE — Hans-Christian Hilse • ÖBB — Mark Topal Goekceli • PKP — Jancewicz Zbigniew • ProRail-NS Groep — Julien Cayet • SIEMENS — Roland Edel • SNCF — Christophe Cheron • Strukton — Tjark de Vries • THALES — Amaury Jourdan • TRAFIKVERKET — Bo Olsson • Voestalpine Railway Systems — Jochen Holzfeind ***Industry alternates:*** • ADIF — David-Ibán Villalmanzo Resusta • ALSTOM — Michael Haddad • ANGELRAIL consortium led by MER MEC — Vincenzo Scarnera • AŽD — Michal Pavel • CAF — Imanol Iturrioz Villalba • CEIT — Jaizki Mendizabal • ČD — Petr Jindra • DEUTSCHE BAHN — Hans-Peter Lang • DLR — Michael Meyer zu Hörste, Svenja Hainz • eSGR JV — David Sanz, Jose Solis Hernandez, Celestino Martinez • Faiveley Transport — Matteo Frea • Ferrovie dello Stato Italiane — Davide Pifferi • HITACHI RAIL STS — Carlo Crovetto • INDRA-TALGO — Alfredo Gonzalez Moreno • Jernbanedirektorate — Pal Midtlien Danielsen • KNORR-BREMSE — Martin Ertl • ÖBB — Strohmeier Flora • PKP — no alternate • ProRail-NS Groep — Tijmen Voet • SIEMENS — Lars Deiterding, Ralf Kaminsky

	• SNCF — Gilles Quesnel • Strukton — Henk Samson • THALES — Mounir El Said • TRAFIKVERKET — Christer Lofving • Voestalpine Railway Systems — Uwe Ossberger ***Other participants:*** • Giorgio TRAVAINI, Acting Executive Director of EU-Rail (until 29 February 2024, the Executive Director ad interim) ***Observers:*** • Josef Doppelbauer (ERA) • Ana Gigantino (ERA) • Ny Tiana Tournier (ERA) • Hugo Tabouret (ERRAC) • Angela Di Febbraro (SC) • Miroslav Haltuf (SRG)
Other bodies	System Pillar Steering Group Deployment Group States Representatives Group (SRG) Scientific Steering Group (SSG)
Number of staff	28 posts as at year-end 2023[7]
Total budget 2023	At the year-end 2023, the JU had implemented 100% of its commitment appropriations made available in its active budget (Titles 1 to 4). The payment appropriations were implemented up to 85,2% (79,1% in 2022) of the active funds (or 82,4% of implementation when compared to the full JU budget (including Title 5)). By means of the GB Decision 14/2022 of 30 November, the EU-Rail Governing Board adopted the initial Annual Work Plan and Budget for 2023-2024. There were two amendments to this initial Decision adopted during 2023 having impact on the budget. - Amendment number 1: This amendment recognised and balanced (Revenue and Expenditure) unused appropriations of the S2R Programme operational expenditure due in relation to the previous budgetary years, in accordance with EU-Rail Financial Rules Article 6.5. Furthermore, and in accordance with the SBA (recitals 10 and 12 and Article 5(2) c)), to achieve maximum impact, the joint undertakings should develop close synergies with other Horizon Europe initiatives and other Union programmes and funding instruments, particularly with those supporting the deployment of innovative solutions. Following the identification of synergies between them, joint undertakings should aim to determine budget shares which should be used for complementary or joint activities between joint undertakings, including by dedicating, where appropriate, a part of the joint undertaking's budget to joint calls. EU-Rail and SESAR3 Joint Undertakings launched a joint topic call. EUR 2.500.000 was increased in the section "EU Contribution" in accordance with the structure of the EU-Rail budget but was coming from SESAR 3 JU and not from the Union. In accordance with the Single Basic Act

[7] The full staffing as per the JU's Staff Establishment Plan comprises 29 posts. As at yearend 2023, the Executive Director post was not yet filled. As of 1 March 2023, the Head of Programme executed the post of the ED ad interim.

	Article 10.4, the EUR 2.500.000 of new revenue in 2023 are considered as additional Union funds complementing the contribution allocated to the EU-Rail Programme implementing Horizon Europe. In this respect, and in accordance with SBA Article 10.6, this additional contributions from Union programmes corresponding to additional tasks entrusted to EU-Rail shall not be accounted for in the calculation of the Union maximum financial contribution to the EU-Rail Programme. - Amendment number 2: The Executive Director proposed to the Governing Board adaptation of the Budget in order to recognise the inscription of new assigned revenue (recovery from projects or administrative expenditure) and adaptation of the Budget appropriation (mainly in payment appropriations) per line was proposed considering the evolution of budget needs and payment budget forecast expected until year-end, lower than planned, in particular for staff expenditure and associated costs (turnover in 2023). As a result, the budget as finally adopted amounted to: **Commitment appropriations: EUR 102,6 million** **Payment appropriations: EUR 120,3 million**
Budget implementation	The implementation rate of the operational budget in commitment appropriations was 100% and 85% in payment appropriations (79% in 2022). In 2023, an important portion of payment appropriations was used for the second pre-financing of the grants resulting from the first 2022 call for proposal. **Commitment appropriations total consumption: EUR 99,6 million – 100%** Further breakdown by Titles in EUR and in % of total, excluding unused appropriations: Title 1 – EUR 3,6 million – 100% Title 2 – EUR 1,4 million – 100% Title 3 - 4 – EUR 94,6, million – 100% **Payment appropriations total consumption: EUR 99,1 million – 85%** Further breakdown by Titles in EUR and in % of total, excluding unused appropriations: Title 1 – EUR 3,0 million – 96% Title 2 – EUR 1,3 million – 95% Title 3 - 4 – EUR 94,8 million – 85% The reported implementation also includes payments to the Expert Evaluators which is managed by the REA Services. In 2023, the second instalment of the grant agreements derived from the first call of 2022 and the award of 6 Flagship Projects have been covered with complementary budget (commitment appropriations) and also the payment of the second pre-financing. Additionally, in 2023 the JU launched a third call, that included the joint synergy topic call with SESAR 3 JU as indicated in the section above. This latter call is still under grant agreement preparation, as planned, at Q1 of 2024.

	For the Shift2Rail Programme, the year 2023 mainly entailed ensuring the proper execution of ongoing activities. By the end of 2021, the JU had signed 101 grant agreements in total since its autonomy in 2016. With the Calls 2021 R&I activities up and running, the R&I activities performed in the Programme will reach EUR 800 million (including Lighthouse Projects as part of the S2R initiative), of which EUR 649,5 million performed by the S2R Other Members with a funding made available by the JU up to a maximum of EUR 303,3 million. At the end of 2023, 66 of the 101 S2R projects were closed. The S2R Programme is continuing its phasing out and all technical activities were concluded by the end of December 2023, with the objective of overall closure of that Programme by 2024, with the execution of all the final payments related to grant agreements.
Grants/Tenders	The value of 8 signed grants resulting from the second 2022 call[8] corresponds to EUR 11,4 million of eligible costs, and EUR 14,1 million of total project value, that will be funded by EU-Rail up to EUR 11,4 million. In 2023, contracts/orders (legal commitments) amounting to EUR 24,8 million were signed, of which EUR 22,5 million resulted from operational procurements and EUR 2,2 million from administrative procurements.
Strategic Research & Innovation Agenda	In the context of EU-Rail, as defined in the SBA, the "Strategic Research and Innovation Agenda" (SRIA) represents the document covering the duration of Horizon Europe that identifies the key priorities and the essential technologies and innovations required to achieve the objectives of the JU. In accordance with SBA Article 86(5), the SRIA of EU-Rail is constituted by its Master Plan[9].
Call implementation	Number of calls launched in 2023: 1[8] Number of proposals submitted: 24 Number of evaluated proposals: 21 Number of proposals retained for funding: 7
Participation, including SMEs	Total number of beneficiaries in funded projects: 72[8] • 25% of which are SMEs receiving 19,2% of total EU funding provided by EU-Rail, • 36,1% of which are private for-profit companies receiving 33,20% of total EU funding provided by EU-Rail. • 2,7% of which are non-EU entities receiving 0,52% of total EU funding provided by EU-Rail. 31 SME participations were part of the evaluated proposals in the 2022-02 call of which 16 SME participations were included in the proposals retained for funding.

8 The grants resulting from the second 2022 call were awarded in the course of 2023. The grants resulting from the 2023 call will be awarded in the course of 2024, hence, the grant agreement figures related to that call will be presented in the 2024 CAAR. However, the information about the evaluation procedure for the 2023 call is already provided in this CAAR, in Section 1.5.

9 https://rail-research.europa.eu/wp-content/uploads/2022/03/EURAIL_Master-Plan.pdf

FOREWORD

2023 has been the year where EU-Rail has successfully run two R&I Programmes and largely closed the S2R R&I operational activities according to plan and in advance to the end date of 31 December 2024.

2023 was an intense year for the operational activities of the JU where all the technical demonstrators of Shift2Rail Programme have delivered and demonstrated their final results. At the same time, in 2023, the 6 Flagship Projects responsible for undertaking the initial implementation of the Flagship Areas (FAs) launched their activities. All FPs have also established collaboration and working methods among themselves, but also with the EU-RAIL System Pillar. The established System Pillar works in 2023 provided the first outputs.

During 2023 EU-Rail set up the launch for two calls for proposals and diverse tender to the implement the R&I programmes, among which the second year for the System Pillar activities, the call for expression of interest for the new Scientific Steering Group and the setup of the EU-Rail Deployment Group. EU-Rail kick-started in 2023 the first set of Exploratory research activities with 8 new Grant Agreements and the new Scientific Steering Group (SSG).

2023 was also marked for the first ever (across JUs) definition of synergy topics calls, with SESAR3 JU under the EU-Rail call 2023-1 launched in October 2023 and with the Smart Network Services (SNS) JU under the EU-Rail call 2024-1 launched in January 2024. As a result, EUR 2.5 million coming from SESAR3 JU and EUR 1 million from SNS JU are enlarging the EU-Rail Programme field of action, respectively for the Traffic Management and the next EU rail communication system, where rail cooperates and works with other modes to ensure attractive, innovative and tailor-made rail services.

The next EU rail communication system is a key enabler for further innovation that has been added to the EU-Rail Programme, building up on activities previously performed within different organisations, outside the EU governance. The sector and the Commission have entrusted EU-Rail to drive and to ensure as from 2024 the rail system ability in embracing this new solution, with R&I through the activities of its Innovation Pillar, with preparation for TSI updates with its System Pillar, and with migration planning and deployment recommendations with its Deployment Group. It is a cooperative work to be done with the European Union Institutions and Bodies for policy setting, including the EU Agency for Railways (ERA), with the rail sector and in particular working with the organisations having heavily invested in FRMCS[10], with the telecommunication sector, with the JU private Members contributing with additional in-kind activities, and with many other researchers contributing to the EU-Rail Programme under Horizon Europe.

Following the successful Space for Innovation in Rail event in 2023[11] under the Spanish Presidency of the Council of the European Union, EU-Rail has set up in 2023 the elements for a concrete project on EGNOS for rail in cooperation with the EU Agency for the Space Programme (EUSPA)[12], and with the European Space Agency (ESA)[13], under the strategic leadership of the Commission and in full coordination with ERA[14], for delivering through R&I the technical and operational elements to reach competitive and resilient satellite-based rail services.

Additionally, in the 2023 Greening Freight Transport communication[15] of the EC to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, the deployment of digital automatic couplings (DAC) technology, supported by the R&I of EU-Rail, is highlighted as a game-changer for European rail freight. The Commission is looking forward to developing a comprehensive migration strategy to coordinate deployment, with the help of EU-Rail.

In the same package, the Commission also published a proposal for a Regulation on the use of railway infrastructure capacity in the Single European Railway Area[16], where the rail Infrastructure Managers are called on ensuring alignment, in particular regarding digitalisation of capacity and traffic management, with

10 https://uic.org/rail-system/telecoms-signalling/frmcs
11 https://rail-research.europa.eu/calendar/space-for-innovation-in-rail-towards-satellite-based-ertms/
12 https://www.euspa.europa.eu/
13 https://www.esa.int/
14 https://www.era.europa.eu/
15 https://transport.ec.europa.eu/system/files/2023-07/COM_2023_440.pdf
16 https://transport.ec.europa.eu/system/files/2023-07/COM_2023_443_0.pdf

the work of the Europe's Rail Joint Undertaking as well as they shall contribute to the EU-Rail works in this regard.

The EU-Rail Research and Innovation activities are designed to deliver concrete solutions addressing the climate change crisis the world is facing, addressing climate mitigation and adaptation – the JU Programme Office and its Members are well aware of this urgency and the importance that the work of our integrated Programme has, covering innovative solutions' lifecycle, from exploratory research to pre-implementation and deployment. In 2023, for the preparation of its call 2024-1, EU-Rail has planned in its R&I activities new call topics on the Flagship Area on Digital & Automated up to Autonomous Train Operations and on the Flagship Area Sustainable Competitive Digital Green Rail Freight Services. This additional effort is expected to lead to a faster increase in competitiveness and attractiveness of the rail sector, and its European industries worldwide, that can contribute to deliver upon the Union policy expectations. Furthermore, EU-Rail continued to support disruptive innovations in the preparation of its call 2024-1, with the launch of a topic covering new approaches for guided transport modes, on hyperloop.

The launch of the Research and Innovation activities of the EU-Rail integrated Programme, building upon the results and advances of the S2R programmes, shapes the mission-oriented nature of the JU, building on openness and inclusiveness, answering the call of the Member States and Parliament to deliver impact and added value to European citizens. Synergies with other Union, as well as national and regional, programmes and partnerships shall provide opportunities to complement the series of actions expected from the rail sector, including interacting with ERRAC on complementary activities. Stakeholder relations, communication and dissemination of results ensure the visibility and uptake of the progress achieved. Sound financial and risk management and compliance will underpin the implementation of the Programme along its lifecycle. The cohesion that EU-Rail has created within the European rail industry builds upon a small team of passionate professionals dedicated to deliver this new ambitious integrated Programme.

With its decision 17/2023, the EU-Rail Governing Board takes note of the collective political commitment expressed by the EU-RAIL private members, or their constituent or affiliated entities, to increase the amount of their contribution to EU-RAIL by EUR 30 million over the period until 31 December 2031 (i.e. for a total contribution of minimum of EUR 630 million), in case necessary to match a possible increase in the Union financial contribution to EU-RAIL as a result of the association of the United Kingdom to the Horizon Europe Programme. An expected positive impact was acknowledged in terms of accelerating the delivery on the relevant policy objectives and rapidly progressing in key areas.

EU-Rail also implemented a Phasing-Out Plan, approved by the Governing Board in December 2023, highlighting the steps for the administrative closure of the Programme, without precluding a possible continuation of the Union investment in a possible successive partnership under the next Union's Framework Programme, in accordance with the SBA.

The recovery plan for Reports and Payments put in place in 2023 was implemented thanks to the contribution of a committed team, and the actions taken by the EU-Rail Members. This resulted by the end of the year to execute 85.2% of EU-Rail payments appropriation (95% reached on the administrative payments), for operational activities divided as 67% for S2R projects (increase compared to the 41% in 2022) and 95% for EU-Rail projects. In 2024 the S2R projects will be administratively concluded with the last payments released, a Reports and Payments plan has been built to this effect.

The Acting Executive Director would like to express all his gratitude to the EU-Rail Founding Members, the S2R Members, the EU-Rail staff, the Member States representatives and the observers for the collaboration and support during 2023 making those significant results possible.

INTRODUCTION

EU-Rail was established by Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC) No 219/2007, (EU) No 557/2014, (EU) No 558/2014, (EU) No 559/2014, (EU) No 560/2014, (EU) No 561/2014 and (EU) No 642/2014 (hereinafter also the "Single Basic Act" or "SBA"), which entered into force on 30 November 2021. In accordance with Article 174(6) of the SBA, EU-Rail is the legal and universal successor in respect of all contracts, including employment contracts and grant agreements, liabilities and acquired property of the Shift2Rail Joint Undertaking which it replaced and succeeded.

EU-Rail is an autonomous body with its own legal personality having its seat located in Brussels, Belgium. It is an institutionalised European partnership as per Article 187 of the Treaty on the Functioning of the European Union dedicated to managing and coordinating mission-oriented Research and Innovation (R&I) activities for a major transformation in rail systems in Europe.

The Vision of EU-Rail is

To deliver, via an integrated system approach, a high capacity, flexible, multi-modal, sustainable and reliable integrated European railway network by eliminating barriers to interoperability and providing solutions for full integration, for European citizens and cargo.

The mission statement of EU-Rail is

"Rail Research and Innovation to make rail the everyday mobility"

In accordance with article 87(1) of the SBA, the members of EU-Rail are the Union, represented by the Commission, and 25 Private Members[17]. The Private Members of EU-Rail were selected via an open and transparent process, started with an "invitation to manifest the interest to become Candidate Founding Member of the Transforming Europe's Rail System European Partnership" on 13 August 2020 and concluded with the listing of 25 entities retained as Founding Members in Annex II of the SBA. The Private Members of EU-Rail signed a Letter of Commitment in accordance with the provisions of the SBA to deliver the contributions established in its Article 89.

The objective of Europe's Rail Joint Undertaking is to deliver a high-capacity integrated European railway network by eliminating barriers to interoperability and providing solutions for full integration, covering traffic management, vehicles, infrastructure and services, aiming to achieve faster uptake and deployment of projects and innovations. That should exploit the huge potential for digitalisation and automation to reduce rail's costs, increase its capacity and enhance its flexibility and reliability, and should be based upon a solid reference functional system architecture shared by the sector, in coordination with the European Union Agency for Railways (ERA).

In addition to the General and Specific Objectives common to all JUs established in Title II, Chapter 1 of the SBA, EU-RAIL is also entrusted with the following:

General Objectives

(d) contribute towards the achievement of the Single European Railway Area;
(e) ensure a fast transition to more attractive, user-friendly, competitive, affordable, easy to maintain, efficient and sustainable European rail system, integrated into the wider mobility system;
(f) support the development of a strong and globally competitive European rail industry.

Specific objectives

(a) facilitate research and innovation activities to deliver an integrated European railway network by design, eliminating barriers to interoperability and providing solutions for full integration, covering traffic management, vehicles, infrastructure also including integration with non-standard national gauges, such as 1520, 1000 or 1668 mm railway, and services, and providing the best answer to the needs of passengers and businesses, accelerating uptake of innovative solutions to support the Single European Railway Area, while increasing capacity and reliability and decreasing costs of railway transport;
(b) deliver a sustainable and resilient rail system: by developing a zero-emission, silent rail system and climate resilient infrastructure, applying circular economy to the rail sector, piloting the use of innovative processes, technologies, designs and materials in the full life cycle of rail systems and developing other innovative solutions to guided surface transport;
(c) develop through its System Pillar a unified operational concept and a functional, safe and secure system architecture, with due consideration of cyber-security aspects, focused on the European railway network to which Directive 2016/797 applies, for integrated European rail traffic management, command, control and signalling systems, including automated train operation which

[17] As per Article 2(5) of the SBA, "Private Member" means any legal entity established under public or private law that is a member of a joint undertaking other than the Union, participating states or international organisations.

shall ensure that research and innovation is targeted on commonly agreed and shared customer requirements and operational needs, and is open to evolution;
(d) facilitate research and innovation activities related to rail freight and intermodal transport services to deliver a competitive green rail freight fully integrated into the logistic value chain, with automation and digitalisation of freight rail at the core;
(e) develop demonstration projects in interested member states;
(f) contribute to the development of a strong and globally competitive European rail industry;
(g) enable, promote and exploit synergies with other Union policies, programmes, initiatives, instruments or funds in order to maximise its impact and added value.

As defined in the SBA, the "Strategic Research and Innovation Agenda" (SRIA) represents the document covering the duration of Horizon Europe that identifies the key priorities and the essential technologies and innovations required to achieve the objectives of the JU. In accordance with SBA Article 86(5), in the case of EU-Rail, its Master Plan shall constitute the SRIA.

The EU-Rail's Master Plan builds also upon the "Rail Strategic Research and Innovation Agenda"[18] of the European Rail Research Advisory Council (ERRAC). ERRAC is a research platform composed of representatives from most of the major European railway research stakeholders: manufacturers, operators, infrastructure managers, the European Commission, EU Member States, academics and users' groups. Its mission is to deliver a vision of the railway's future enabled by Research and Innovation activities.

The Master Plan provides guidance for the Europe's Rail Joint Undertaking's more specific tasks, namely:

- develop in its System Pillar a system view that reflects the needs of the rail manufacturing industry, the rail operating community, Member States and other rail private and public stakeholders, including bodies representing customers, such as passengers and freight and staff, as well as relevant actors outside the traditional rail sector.
The 'system view' shall encompass:

- the development of the operational concept and system architecture, including the definition of the services, functional blocks, and interfaces which form the basis of rail system operations;
- the development of associated specifications including interfaces, functional requirement specifications and system requirement specifications to feed into Technical Specifications for Interoperability (TSI) established pursuant to Directive (EU) 2016/797 or standardisation processes to lead to higher levels of digitalisation and automation;
- ensuring the system is maintained, error-corrected and able to adapt over time and ensure migration considerations from current architectures;
- ensuring that the necessary interfaces with other modes, as well as with metro and trams or light rail systems, are assessed and demonstrated, in particular for freight and passenger flows;

- perform the research and innovation activities necessary to achieve the objectives of EU-Rail, including low TRLs rail-focused research and innovation activities. In that respect, EU-Rail shall:

- define and organise the research, innovation, demonstration, validation and study activities to be carried out under its authority, while avoiding fragmentation of such activities;
- exploit standardisation and modularity opportunities, and facilitate the interfaces with other modes and systems;
- develop demonstration projects;
- develop close cooperation and ensure coordination with related European, national and international research and innovation activities in the rail sector and beyond as necessary, in particular under Horizon Europe, thereby enabling the Europe's Rail Joint Undertaking to play a major role in rail-related research and innovation while also benefiting from scientific and technological advances reached in other sectors;
- perform any tasks necessary to achieve the objectives set out in SBA Articles 4 and 85.

- facilitate the market uptake of rail innovation developed in the Europe's Rail Joint Undertaking and to support deployment of the innovative solutions through the establishment of a Deployment group pursuant to Article 22 of the SBA.

[18] https://rail-research.europa.eu/wp-content/uploads/2020/12/RAIL-Strategic-Research-and-Innovation-Agenda-2020-_FINAL_dec2020.pdf

Five areas of priority for EU-Rail have been determined in its Master Plan:

1) European rail traffic management and supporting rail's key role in a multimodal transport system
2) Digital and automated train operations
3) Sustainable and digital assets
4) Competitive digital green rail freight
5) Smart solutions for low density traffic lines (cost-efficient regional lines)

These priorities will be underpinned by a system view to ensure a harmonised approach to the evolution of the Single European Rail Area. They will be complemented by forward-looking activities, tackling disruptive technologies and thinking, through performing exploratory research and other complementary activities.

EXECUTIVE SUMMARY

2023 marked the year of operational closure of the S2R Programme and its projects; all the technical demonstrators of Shift2Rail Programme have delivered and demonstrated their final results. At the same time, in 2023, the EU-Rail Programme started effectively with the 6 Flagship Projects responsible for undertaking the initial implementation of the Flagship Areas (FAs); they all reached at the end of the year 2023 with already defined, in most cases, key use cases and requirements for the main technical enablers. All FPs have also established collaboration and working methods among themselves, but also with the EU-Rail System Pillar. The System Pillar works established in 2023 provided the first outputs, including:

- Interfaces for trackside assets, EULYNX Baseline 4 release 2,
- System Engineering Management Plan (SEMP), Version 2,
- Issuance of draft Version 1 of the Standardisation and TSI Input Plan,
- Issuance of the report on the Version 2 and Version 3 specifications for the Future Railway Mobile Communication System (FRMCS),
- Issuance of the first version of the Control Command and Signalling (CCS) / Traffic Management System (TMS) data mode.

During 2023 EU-Rail set up the launch for two calls for proposals and diverse tenders to implement the R&I programmes, among which the second year for the System Pillar activities, the call for expression of interest for the new Scientific Steering Group and the setup of the EU-Rail Deployment Group. EU-Rail kick-started in 2023 the first set of Exploratory research activities with 8 new Grant Agreements and the new Scientific Steering Group (SSG).

The vision of EU-Rail is to deliver, via an integrated system approach, a high capacity, flexible, multi-modal, sustainable and reliable integrated European railway network by eliminating barriers to interoperability and providing solutions for full integration, for European citizens and cargo.

EU-Rail aims to accelerate research and development in innovative technologies and operational solutions. This will support the fulfilment of European Union policies and objectives relevant for the railway sector and the competitiveness of the rail sector and the European rail supply industry. In this way, EU-Rail will accelerate the penetration of integrated, interoperable and standardised technological innovations necessary to support the Single European Railway Area (SERA).

2022 and 2023 activities were influenced by a new crisis resulting from the illegal aggression of Ukraine by Russia. Although EU-Rail research and innovation has not been directly impacted by the situation, it is not possible to anticipate at this stage the consequences of such dramatic events.

Beyond the operational activities, 2023 was the second year of implementation of Article 13 SBA, where EU-Rail took over the responsibility for the coordination of the Back Office Arrangement (BOA) Accounting Services. Other 3 BOAs led by other JUs were established, where EU-Rail also took a supporting role.

The year 2023 sought the continuation of the close collaboration established between EU-Rail and:

- the European Railway Research Advisory Council (ERRAC),
- the European Union Agency for Railways (ERA),
- other programmes, partnerships and other bodies, with the objective to establish synergies that will result in coordinated and consistent activities, or joint R&I projects or administrative synergies, such as for example under the Back-office arrangements with other JUs,
- different associations representing the key stakeholders of the rail sector and beyond,
- third countries programmes, in line with the policy priorities of the Commission and considering the key objective of the competitiveness of the European rail industry.

Finally, in 2023, conveying the message to European citizens continued that rail can answer their concerns about unsustainable and unreliable mobility options. The JU's key messages and events continued to reinforce the objectives of the initiatives such as the European Green Deal, the Sustainable and Smart Mobility Strategy or the Digital Decade by disseminating R&I results and showing the future evolution of rail in terms of services for passengers and freight clients. In this respect, in line with its communications strategy, Europe's Rail aims to:

- showcase the innovative technological and operational solutions that result from the research and innovation activities, and in particular those ready to enter industrialisation and deployment, in particular demonstrating concrete impact;
- raising awareness on the research and innovation activities outreaching to the stakeholders at European level as well as engaging at global events/conferences to promote Europe's Rail results;
- enhance the partnership nature of the JU through communications and dissemination activities that will create opportunities for inclusiveness.

In terms of organizational changes, at the meeting of the Governing Board of 30 November 2022, the Executive Director informed the Board of his intention to step down from his position in advance to the end of his second mandate. He notified the Governing Board that his decision would have been formalized in 2023, once the necessary administrative steps would be completed. This was formalized on 9 January 2023, when the ED notified his end of service as from 28 February 2023; on 30 January 2023 the Governing Board appointed Mr Giorgio Travaini, Head of the Programme, as Executive Director ad interim as from 1 March 2023.

S2R Programme Status

2023 was a closing year for operational R&I activities under the innovation programmes of Shift2Rail. All the technical demonstrators have been finalised, demonstrating their results after 7-8 total years of programme implementation since its launch, in advance to the S2R JU Programme implementation end date of 31 December 2024.

The operational impact of Covid-19 pandemic, as reported in the previous years, that had generated a number of additional extension amendments, impacted also the ability to administratively close at the same time those projects, and impacted as well the planned last payment in 2023 which has been postponed to 2024 for some of them. All S2R projects will be administratively closed during 2024.

As per 2022, in this context, the work of S2R Other Members, other beneficiaries and of the JU staff shall be commended because they have collectively and individually ensured the conclusion of the research and innovation activities.

By the end of 2023, the S2R Programme reached its operationally closing milestones in term of Programme implementation:

- On average, about 99% of the full S2R Programme has been realized from an operational perspective and 101% in term of financial Programme execution in total project costs (98% of co-funding executed with payments), in view of reaching the TRL6/7 operational demonstrations planned for conclusion during 2023. In total, it is estimated that the Total Value of the activities performed in 2023 amounts to EUR 62.9 million, of which EUR 54.6 million delivered by the Members other than the EU (hereinafter S2R Other Members).

During 2023, the JU assessed its R&I activities through a fifth Control Gate exercise[19]. This exercise took into account the deliverables and reports submitted in the context of the Annual Review of the active Projects coordinated by the S2R Other Member. The JU also ensured through this process that the recommendations made during the previous Control Gate Assessment had been properly applied. The overall result is that the Programme benefited from such feedback, built upon also external expertise.

This Programme assessment allowed the JU to confirm that overall, the progress of the activities has been in line with the expectations for a possible operational conclusion of the activities in 2023.

Only four Technical Demonstrators (TDs) (out of 49 TDs) show delays in submitting the last deliverables, not having submitted them by the end of 2023. Such cases have been closely followed up by the JU to ensure that administratively the S2R projects can be closed in principle in the first half of 2024.

IP1

In 2023, Innovation Programme (IP) 1 TDs advanced significantly towards the completion of the full activities of IP1, estimated in 2023 to 97%. The reason for the non-full completion is due to deliverables not

[19] In accordance with the procedure set in the S2R Governance and Process handbook, transparently published on the JU's website: https://rail-research.europa.eu/wp-content/uploads/2024/01/ED-DECISION-ED-23-09_Annex_GovProc.Handbook.pdf

submitted by the end of 2023 by TD1.3 and TD1.7, for which mitigation actions have been taken. Overall IP1 finalised with submission of 83% of the deliverables 8 planned in 2023.

All TDs except for TD1.3 (Car body) and TD1.7 (Train modularity) have been finalised during 2023, all TDs contributed effectively to catch-up with the delays incurred the previous year, mainly for TD1.3 and TD1.4. The progress on TD1.7 was not at the same pace. Within TD1.3, each elementary part (composite and metallic) was built for the final assembly of the HS demonstrator together with all the tooling needed and this was reflected in the submission of the related deliverables. The development of smart running gear components could be finished and TD1.4 also supported the development of a universal cost model (UCM 2.0) in coordination with S2R Project NEXTGEAR. In term of notable technical quantifiable achievements, TD1.4 on running gear reports significant weight reduction with the used of optimised alternative materials and have bene demonstrating meeting and even surpassing requirements in current EN standards. Lab-testing and on-track testing were performed to validate the prototypes. Within TD1.5, newly developed high-SIL braking system were installed on the train provided by EUSKOTREN and validated as a field demonstrator. Together with a simplified architecture for weighed emergency brake, a novel strategy for distribution of braking force along the train was implemented to optimise the brake's performance in low adhesion conditions. The system has been proven in terms of performance and safety level during operational conditions (qualified with Notified Bodies). TD1.7 still needs to report on the final KPIs and details of the final concepts and the benefits of the new modular concepts for train interiors.

IP2

100% of progress has been reported on all TDs and thanks to this IP2 have has completed its operational activities at the end of 2023.

Regarding TD2.1 on Adaptable communication, tests have taken place in Italy for regional line, concluding all planned segments of the demonstration of this TD. Bearer flexibility between different technologies such as 3G, 4G, 5G, WiFi, Satellite transparent to the applications were proven and public networks proved to be a valuable complementation to private railway radio networks by improving service availability and usable bandwidth. Input has been provided to the UIC project FRMCS.

Other worth noting results, due to last year slow progress and point of attention reported for TD2.4, is the good progress with the demonstrations finalisation of Virtual Balise (VB) based and Stand-Alone Fail-Safe Train Positioning System.

In the demonstrator of VBs in Czechia, the position errors are mostly a few meters, in only one case the error is above ten meters and incorporating track data into the onboard algorithm has emerged as a crucial factor in enhancing safety and accuracy. In the demonstrator in Italy both a local augmentation network and EGNOS, in a fully integrated ETCS (European Train Controlling System), both on-board and trackside operating on a real line, was tested. Position error with local augmentation is below 5 meters; also, with EGNOS the error is usually around 5 meters, but with a higher variance.

In the demonstrators of Stand-Alone Fail-Safe Train Positioning System in Spain integrated GNSS, IMU, tachometer and Digital Map to achieve a position confidence interval (3σ) below 20 m. In France, was based on multi sensor acquisitions, using EGNOS V3 DFMC emulator. Average distance error was below 0.2 m and average speed error was below 0.02 m/s. but results are not yet from a real time algorithm execution and do not include track selectivity functionality. In Germany was based on dual channel of GNSS, IMU, speed sensors and Digital Map, and used the first track position as a given position (no track discrimination). Speed confidence interval did not always cover demanding performance requirements and position errors were sometimes above the 10 m +2%, under non-favorable GNSS conditions.

The other TDs progressed to completion closing the remaining open points from 2022.

IP3

In 2023, this IP has closed all its activities with minor deviations to the initial objectives of the MAWP. As a result, IP3 have reached 94% of the estimated work planned in 2023, with deliverables not submitted by the end of 2023 by TD3.4 and TD3.5, for which mitigation actions have been taken. The mentioned deviations resulting to a total IP3 Programme completion at 99%.

It worth noting on the different R&I works of this Innovation programme, that the TD3.3 has established a new parameter for evaluation if the wheel or the rail in a good condition regarding passenger comfort (vehicle stability). Now this parameter called GIP has reach the EN 15302 technical report CEN/TR17792.:2022. As a new geometrical parameter for judging the stability on track.

In TD3.8, 15 workers utilized a dedicated exoskeleton developed in the programme for approximately 100 hours, engaging in real work activities, such as carrying and positioning concrete conduits weighing between 20kg and 30kg. The results indicated a noteworthy 50% reduction in ergonomic risks for the musculoskeletal system, particularly in the lumbar region. Fatigue levels were reduced by up to 30%, and muscle activity saw a decrease of 25%.

Among the promising results on unmaned and remotely controlled maintenance inspection, a semi-autonomous motorised trolley has been validated in-field tests in TD3.4 to use contactless Electro Magnetic Acoustic Transducers sensors that are able to detect rail surface defects which are difficult to monitor with current technologies, enhancing the defect detection.

The other TDs progressed to completion closing the remaining open points from 2022.

IP4

100% of progress has been reported on all TDs and thanks to this IP4 have has completed its operational activities at the end of 2023.

In 2023, the Interoperability Framework of TD4.1 has allowed up to 31 services for the pilots, that were located in Athens, Padua, Warsaw, Liberec, Osijek and Barcelona, to be integrated and demonstrated. It has proven the technical feasibility of the Interoperability Framework to aggregate different Transport Service Providers and services. Improvement to the overall architecture have been developed and tested in the remainder part of the programme and overall increase of performance of 42% from the initial delivered system for the different aspects such as shopping orchestrator, Issuing Orchestrator.

Other R&I work in TD4.3 for booking and ticketing have led for example to the development of an intermodal best price which covered public transit legs and also bike sharing and car sharing legs. If the costs for single trip tickets of a user exceed a threshold within a day, for example, a MaaS day pass is granted and invoiced that can be valid for different modes of transport. Technically showing the feasibility of applying such scheme for passenger journeys. Similarly, the work under TD4.4, allowing the traveler to have a new optimal route calculated in case of disruption in real time, was demonstrated in a pilot in Liberec included trip tracking for a Travel Service Provider (TSP).

The other TDs progressed to completion closing the remaining open points from 2022.

IP5

In 2023, the TDs reached submitted 100% of their planned deliverables by the end of 2023. Due to some deviations to the initial objectives of the MAWP an implementation rate of 99% is estimated concerning the TDs completion.

On Condition Based Maintenance, IP5 completed the end-to-end solutions including new processes, data processing analytics and dashboard for locomotives and wagons. IP5 was as well a key contributor, with the project DACcelerate, to the European DAC Delivery Programme (EDDP). IP5 also delivered good results on improve timetable planning and yard management with a successful demonstration in the Malmö yard. Laboratory test and field test for the bogie with aluminium frame were also successful. The first testing campaign for the Extended Market Wagon was largely successful.

The other TDs progressed to completion addressing the remaining open points from 2022.

CCA

The Cross Cutting Activities (CCA) reach 100% level of implementation of planned activities for 2023. The focus for 2023 was put on continuing and closing the activity of the Noise and Vibration Work Area, as all other areas were completed in 2022.

Regarding exterior noise prediction tools, focus was put on evaluating the measuring campaigns held and analyse the results for the accuracy of exterior noise prediction. Noise separation techniques proved to be extremely of use for pass-by certification tests. Following the campaign on exterior noise prediction, R&I work has been concluded for simulating and predicting the separation of different noise sources. One of the results will directly be used for the improvement of the standard CEN/TR 16891.

For ground vibration prediction, R&I focused on a holistic approach capable of the assessment of vibration levels for large-scale studies and followed a hybrid approach, combining numerical prediction with experimental results. Validation of a prototype tool in 2023 was successful showing promising future.

Finally, regarding auralisation and visualition, enhanced Virtual Reality scenarios were developed and demonstrated on regional test cases.

IPX

2023 represented the official handover of the System Architecture activities within the IPX to the EU-Rail System Pillar, following the ramp-up activities of 2022. the projects delivered the prefigurating elements for the System Pillar:

- Two consecutive releases of the System Functional Architecture
- The specification and the set-up of the formal definition of the Conceptual Data Model (CDM)
- The demonstration of the applicability of the CDM to concrete railway scenarios through 4 relevant use cases
- Keeping up to date the ontology dictionary OntoRail by regularly uploading the newest versions of the source models

For the low TRL and PhDs research involving Artificial Intelligence (AI) adoption of AI in rail, the work focused on developing methodological and experimental proofs-of-concept, developing Benchmarks, Models and Simulations. Proof-of-concepts were finalised to support the definition of roadmaps, covering the following topics:

- Railway Obstacle Detection and Collision Avoidance;
- Cooperative Driving for Virtual Coupling of Autonomous Trains;
- Predictive Maintenance for Rolling Stock;
- Smart Maintenance at Level Crossings;
- Graph Embedding for Primary Delay Prediction;
- Big Data on Incident Attribution Analysis.

Exploratory activities on environment perception for automation and remote driving and command demonstrated final successful results at the end of 2022 and beginning of 2023. The results of these exploratory activities were prepared for transfer to EU-Rail's FP2-R2DATO project for further work and step change in TRL.

S2R Programme Management

In terms of Programme Management, 2023 was the fourth year during which reviews of Lump Sum projects took place. Experience confirms so far has shown that from an operational perspective the use of Lump Sum for members' projects does not only result in an administrative simplification, but also effectively bundles efforts in the project review to focus on the achievements of results. The fact that the proof of concluded work packages (hence related focus on deliverables and milestone approval) provides the basis for the reimbursement of costs has allowed the JU and consortia to focus their efforts in an effective way in order to ensure the delivery of the projects.

2023 Programme Management continued to be influenced by the need to continue monitoring projects affected by the pandemic consequence of previous restrictions. The Programme Management was also characterised by a monitoring of the activities closure by the end of 2023, with focus on results and achievement of the Reporting and Payment planning for 2023.

With a holistic approach, the role of the JU is also to ensure that interactions between the various IPs are adequately considered and managed, as technological developments in one part of the system could lead to changes in performance, or even create barriers, in other parts. In addition, cross cutting activities include research on long-term economic and societal trends such as customer needs and human capital and skills, which must be taken into account by the different IPs.

EU-Rail Programme Status

The EU-Rail programme kickstarted in 2022 with an anticipated ramp-up phase of the System Pillar, while the Innovation Pillar underwent to the assessment of the first 6 Flagship Projects that started their R&I activities in December 2022, with the notable exception of FP5 which already started in July 2022 with a fixed early start date (before the signature of the Grant) to ensure the swift ramp-up of DAC prototypes in views of the 2025-6 demonstration activities.

Additionally, in 2023 EU-Rail kick-started the first set of Exploratory research activities with 8 new Grant Agreements, complementing the work of the FPs in often different areas of research and innovation of the EU-Rail Innovation Pillar.

A framework for continuous exchanges between the System Pillar and Innovation Pillar activities, as part of the Integrated R&I Programme, has been setup in 2022 and operationalised in 2023, allowing for a bi-directional flow: both pillars should provide input and output to each other against a clearly defined series of priorities and objectives to be achieved.

The selection process and specific criteria for establishment of the Deployment Group of the Europe's Rail Joint Undertaking, following consultations with the European Commission and private Founding Members of the JU, as well as the States' Representative Group and Scientific Steering Group (at that time still acting as the Scientific Committee), has been adopted by a GB written procedure in June 2023. At the end of November 2023, the Commission requested support to EU-Rail for the selection process and to propose a number of preselected candidate members (i.e., representatives of EU-Rail Founding Members and of representative bodies), after consulting the System and Innovation Programme Board and considering potential candidates proposed by the SRG. The Deployment Group, the third pillar of the integrated Programme, is expected to be operational in 2024.

In general, the objectives of the integrated Programme include the following:

- contribute towards the achievement of the Single European Railway Area;
- ensure a fast transition to more attractive, user-friendly, competitive, affordable, easy to maintain, efficient and sustainable European rail system, integrated into the wider mobility system;
- support the development of a strong and globally competitive European rail industry.

The System Pillar

The System Pillar is the "generic system integrator" for EU-Rail, and the architect of the future EU's railway system. It is established under the Single Basic Act as a fundamental activity of EU-Rail, alongside the Innovation Pillar and Deployment Group.

The System Pillar will provide governance, resource, and outputs to support a coherent and coordinated approach to the evolution of the rail system and the development of the system view, based on a formal functional system architecture approach to speed innovation and deployment. The System Pillar brings rail sector representatives under a single coordination body.

To achieve this, the System Pillar will deliver a unified operational concept and a functional, safe and secure system architecture, with due consideration of cyber-security aspects, focused on the European railway network to which Directive 2016/797 applies (i.e. the heavy rail network), for integrated European rail traffic management, command, control and signalling systems, including automated train operation which shall ensure that research and innovation is targeted on commonly agreed and shared customer requirements and operational needs, and is open to evolution.

During 2023 the following work of the System Pillar Tasks and Domains was fully established and the outputs detailed in section 1.3.1.

Highlights included

- Interfaces for trackside assets, EULYNX Baseline 4 release 2
- System Engineering Management Plan (SEMP), Version 2
- Issued draft of Version 1 of the Standardisation and TSI Input Plan
- Issued report on the Version 2 and Version 3 specifications for FRMCS
- Issuance of the first version of the CCS/TMS data model

The Innovation Pillar

The Innovation Pillar is set up to deliver user-focused research, innovation and large-scale demonstrations. It is tasked to deliver the operational and technological solutions which provide the necessary capabilities to transform the European rail system. Its activities are organised in seven FAs and the Transversal Topic.

In 2023, as a result of the conclusion of the grant agreements in December 2022, the first 6 Flagship Areas and the Transversal Topics have been covered by a first year of activities of the 6 Flagship Projects.

Eight new Grant Agreements were signed and projects covering the FA7 on "Innovation on new approaches for guided transport modes" and the "Exploratory Research and other activities" started their R&I activities in 2023.

Additionally, EU-Rail launched a new call for proposals for "Exploratory Research and other activities", but also anticipating some activities related to the Flagship Area 1, on Traffic Management and synergies with the aviation sector. This latter topic is the first ever (across JUs) synergy topics calls, which was achieved in coordination with SESAR3 JU under the EU-Rail call 2023-1 launched in October 2023. This call is still under evaluation, as planned, at the beginning of 2024.

The preparation of the call 2024-1, launched already in January 2024, has been another significant addition to the Innovation Pillar output anticipation. In 2023, EU-Rail has planned in its R&I activities new call topics on the Flagship Area on Digital & Automated up to Autonomous Train Operations and on the Flagship Area Sustainable Competitive Digital Green Rail Freight Services. Another new synergy topic call has been built (the second ever across JUs), together with SNS JU, for the next EU rail communication system using 5G technologies to ensure attractive, innovative and tailor-made rail services. The next EU rail communication system is a key enabler for further innovation that has been added inn 2023 to the EU-Rail Programme, building up on activities previously performed within different organisations, outside the European Union governance.

This additional effort is expected to lead to a faster increase in competitiveness and attractiveness of the rail sector, and its European industries worldwide, that can contribute to deliver upon the Union policy expectations. Furthermore, EU-Rail continued to support disruptive innovations in the preparation of its call 2024-1, with the launch of a topic covering new approaches for guided transport modes, on hyperloop.

The European DAC Delivery Programme under the leadership of EU-Rail

In July 2020, the Governing Board of the JU endorsed the creation of the EDDP proposed by the ED, voicing the request of the railway sector. Building upon the outcomes achieved in S2R's freight related R&I activities (IP 5), this Programme brings together the rail sector beyond the Membership to bridge the research work with innovation, including migration planning, towards the deployment of a European DAC solution, built on open and transparent standard specifications. This activity constitutes a major step ahead of the digital rail freight, enabling new operations and services that will contribute meeting the expectations of the Sustainable and Smart Mobility Strategy of the European Commission.

The EDDP integrates, with an independently managed delivery programme, projects like DAC4EU, funded by the German Federal Ministry of Transport and Digital Infrastructure, as well as relevant results from S2R projects under its Innovation Programme 5 on European rail freight.

The following was achieved:

- The EDDP participation continuously increased, counting on more 300 experts and more than 80 companies and organisation involved across Europe and beyond;
- DAC target operational procedures for the first DAC use cases ready;
- EU-Rail Flagship Project 5 (FP5-TRANS4M-R, 2022-2026) started its activities with 27 beneficiaries and 71 partners in order to achieve:
    - The DAC specification for "mechanical/pneumatical", "energy" and "communication";
    - The Demonstration of Digital Freight Trains in 2025 with DAC Type 4 & 5 incl. Energy and Data Supply, Hybrid Coupler and automated brake test (at TRL 8);
    - Preparing further development of Full Digital Freight Train for future demos.
- Operational DAC tests took/are taking place in European countries;
- The development of solid and feasible migration scenarios, for the first time in Europe
- A first iteration of the Cost-Benefit Analysis (CBA) was performed under the leadership of the European Commission, supported by the previous LCC analysis commissioned by EU-Rail;

- A first European Investment Plan was contracted by EU-Rail and finalised in early 2023[20] by the company EY, setting the basis for further steps for the DAC implementation and deployment strategy.

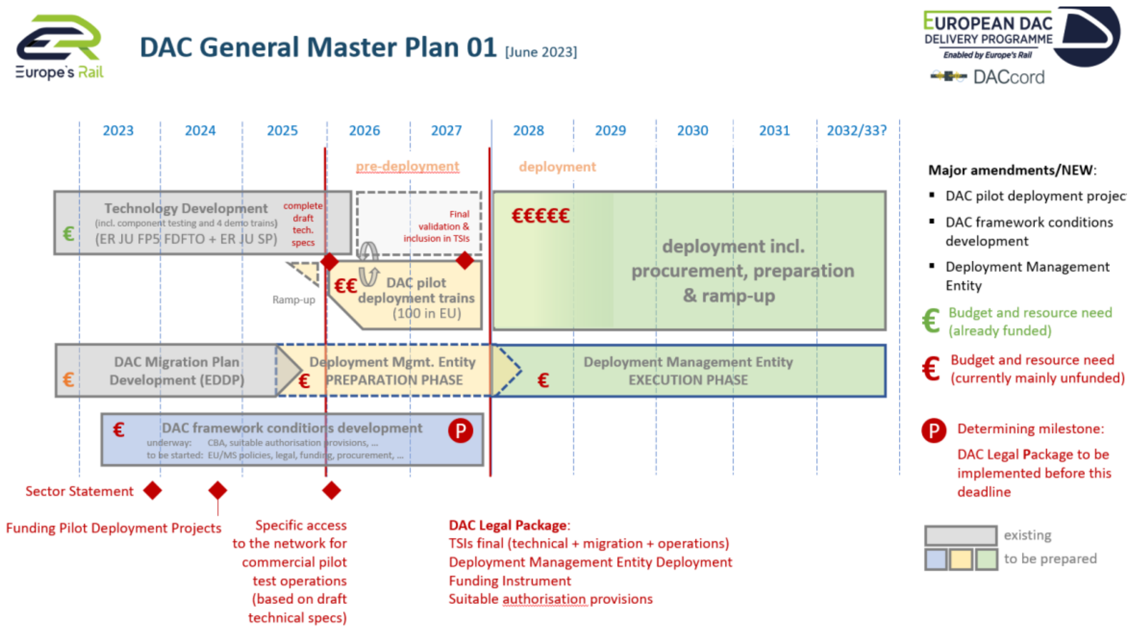
In 2023 several meetings continued with the ERA DAC Topical Working Group with the aim to agree a DAC spec that could be adopted in future TSI, supporting the harmonization all across EU rail network.

In 2023, the **DACcord** Coordination and Support Action, supported the running of EDDP in 2023. It further worked on the DAC migration roadmap and on a EDDP Stakeholder Management. A main achievement was the development of the revised DAC General Master Plan 01, taking into account all recent evolutions/insights and incorporating a large-scale testing phase of around 100 trains before embarking on a fully fledged DAC roll-out. An updated DAC CBA was coordinated in EDDP and led by the European Commission, followed by the creation of a Task Force on Intermodal Traffic with stakeholders from Intermodal and EDDP to better reflect Intermodal aspects in the CBA. This WP permanently interacted with all other DACCord WPs and with FP5-TRANS4RM-R. A regular cross-coordination of the works of the EDDP, FP5 and EU-Rail System Pillar (Task 4) was implemented.

Furthermore, the project supported the work of the migration roadmap update, especially on the collection of the European vehicle fleet data. A major milestone was the coordination and decision on the so called "DAC basic package" in September and November 2023. This package defines the DAC and DAC applications that the FP5-TRANS4M-R project will deliver by 2025/2026, for test in the pre-deployment trains and later for the full deployment.

In addition, the project coordinated in the first half of 2023 a "DAC Sector Statement" (taking into account the new Master Plan), which was signed by 50 companies and associations from the European rail freight sector and handed over from the Sector to the European Commission) in July 2023.

The project also worked together with FP5 TRANS4M-R project for setting-up three so called EU-Rail "sounding boards". The results of these sounding boards were reported to the EDDP programme board and used for evaluation by the FP5 TRANS4M-R project.



Other activities

The EU-Rail Staff Establishment Plan covering, from the resources needs perspective, the EU-Rail activities of 2023, was adopted by the Governing Board on 1 March 2022. In December 2023 the GB adopted the Staff Establishment Plan for 2024 introducing 3 staff members of the Back Office Accounting

20 https://rail-research.europa.eu/publications/european-dac-investment-plan/

arrangements, which covers accounting services for all Joint Undertakings. According to the Staff Establishment Plan applicable to 2023, EU-Rail should have been staffed with 29 staff members including 2 Seconded National Experts. In 2023, the JU experienced four departures of staff members and the vacant posts were progressively filled in. The Executive Director post has been covered *ad interim* in order to ensure business continuity, while recruitment was ongoing. To fill temporary gaps or long-term absences, the JU also made use of external competencies and expertise to achieve its operational activities, as well as of temporary outsourcing of some administrative tasks.

With regard to communication and dissemination activities, the JU focussed primarily on the supporting activities of the Europe's Rail Joint Undertaking, with a particular focus on the promotion of the new Programme and its objectives and mission, the introduction of the role of the new System Pillar and the Deployment Group, while also enhancing Europe's Rail focus on demonstration activities and dissemination of relevant results for market uptake for the ongoing, and also for the finished Shift2Rail projects. Particular focus was placed as well on the promotion of the objectives of the six new Flagship Projects, including the development of a dedicated website area and launching an in-depth article campaign describing the expected benefits of the projects.

Furthermore, project results were disseminated at various events with Europe's Rail participation, including at the UIC World Congress on High-Speed Rail, SIFER, Rail Transport Day, UITP Global Public Transport Summit, Space for Innovation in Rail, Rail Live and during the Europe's Rail General Assembly (online).

In addition to the efforts on stakeholder involvement, the JU further continued improving its internal organisation as to provide continuous support to its Members and beneficiaries. Attention was paid to the continuous implementing of the internal control framework and to the assessment and management of risks. The JU cooperated with different stakeholders engaged in audit activities, such as the European Court of Auditors, the Internal Audit Service of the Commission, the Common Audit Service exercised by DG RTD or the external auditors auditing the Annual Accounts of the JU. All of these activities have contributed to the continuous assurance regarding the sound financial management of EU funds managed by the Joint Undertaking.

In 2023, the JU submitted to the European Parliament a follow-up report on Parliament's observations provided in its Resolution related to the decision on discharge in respect of the implementation of the JU's budget for the financial year 2021. In this follow-up report, the JU explained its way in which it addressed these observations or intends to address them in the upcoming period. More specifically, it was elaborated, besides other, on how EU-Rail contributes to the EU goals related to transport (e.g., in highspeed rail, carbon-neutrality of some types of collective travel, automated mobility, increasing the rail freight traffic, advanced levels of automation etc.). In response to some HR-related issues that were pointed out by the Parliament, the JU explained objective conditions, in which it operates, and the feasible actions that it took or will take in that area. Furthermore, the JU confirmed how the deficiencies identified and reported by the Court of Auditors were addressed, as well as EU-Rail provided an update on the fulfilment of the action plan tackling the outstanding recommendations following from the "Audit on H2020 grant implementation and closing" conducted by the EC Internal Audit Service.

It can be concluded that thanks to the commitment of both the JU Members and the Programme Office, 2023 has seen the JU further continuing its important progress towards delivering both the Shift2Rail and the EU-Rail Programmes.

The next sections of this 2023 CAAR present in detail the achievements, risks and opportunities, and the developments pertaining to the JU during the past year.

1. IMPLEMENTATION OF THE WORK PROGRAMME 2023-2024

1.1. Key objectives 2023, associated risks and corrective measures

European Green Deal, the United Nations Sustainable Development Goals, the Sustainable and Smart Mobility Strategy and the Digital Decade

The European Green Deal was presented in December 2019, setting out a clear vision of how to achieve climate neutrality in Europe by 2050[21]. Transport accounts for a quarter of the EU's greenhouse gas emissions, and still growing. To achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050. As a matter of priority, a substantial part of the 75% of inland freight carried today by road should shift onto rail and inland waterways.

"To transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use." (European Green Deal, p. 2).

Priority areas include accelerating the shift to sustainable and smart mobility: "Automated and connected multimodal mobility will play an increasing role, together with smart traffic management systems enabled by digitalisation. The EU transport system and infrastructure will be made fit to support new sustainable mobility services that can reduce congestion and pollution, especially in urban areas" (European Green Deal, p. 10).

In July 2021, the so-called "Fit for 55"[22] package was introduced by the Commission – a package consisting of a set of inter-connected proposals making the existing legislation more ambitious, where possible, and even putting on the table new proposals, where needed. The main ambition of the EU under this package is cutting emissions by at least 55% by 2030 by also supporting a faster roll-out, relative to prior objectives, of sustainable transport solutions such as rail. Overall, the package strengthens eight existing pieces of legislation and presents five new initiatives, across a range of policy areas and economic sectors: climate, energy and fuels, transport, buildings, land use and forestry.

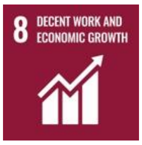
The European Green Deal is also an integral part of the Commission's strategy to implement the United Nation's 2030 Agenda and the 17 Sustainable Development Goals (SDGs).[23] The JU has been reporting in its Consolidated Annual Activity Reports already under the S2R Programme on its contribution to the SDGs since 2018. The Joint Undertaking, under its current Programme, will continue in this endeavour, more specifically with regard to these SDGs[24]:

SDG 9: Building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

SDG 12: Ensure sustainable consumption and production patterns

21 European Commission (2019). The European Green Deal. COM(2019) 640 final, Brussels
22 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0550 and https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
23 United Nations General Assembly (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. Draft resolution referred to the United Nations summit for the adoption of the post-2015 development agenda by the General Assembly at its sixty-ninth session. UN Doc. A/70/L.1. New York
24 As also indicated in the Biennial Monitoring Report 2022 on Partnerships in Horizon Europe, page 295: https://op.europa.eu/en/publication-detail/-/publication/a6cbe152-d19e-11ec-a95f-01aa75ed71a1/language-en/format-PDF/source-search

SDG 13: Take urgent action to compact climate change and is impacts



SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

SDG 5: Achieving gender equality and empower all women and girls

More specific insights into how EU-Rail aims at contributing to the broader objectives represented by the SDGs can be obtained from Annex E and Annex F providing information on the Key Performance Indicators/Key Impact Pathway Indicators. However, it should be noted that the precising of indicators for following-up on the EU-Rail Programme under Horizon Europe was not yet finalised in 2022, and this process will still continue in 2023.

Further to the above, the Sustainable and Smart Mobility Strategy of the Commission, launched in December 2020[25], includes more concrete milestones for the railway sector to enhance a smart and sustainable future. Its underlying Action Plan of 82 initiatives lays the foundation for how the EU transport system can achieve its green and digital transformation and become more resilient to future crises. In particular, it provides the visionary ambitions that the next rail R&I Programme will have to contribute to insofar as possible and notably:

- By 2030 the high-speed rail traffic will increase by 50%; the scheduled collective travel of under 500 km should be carbon neutral within the EU and automated mobility will be deployed at large scale.
- By 2050 rail freight traffic will double; high-speed rail traffic will triple and the multimodal Trans-European Transport Network (TEN-T) equipped for sustainable and smart transport with high-speed connectivity will be operational for the comprehensive network.

Additionally, rail transport will also need to be further electrified; wherever this is not viable, the use of hydrogen should be increased. And the roll out of the European Rail Traffic Management System (ERTMS) will be pursued including further efforts to develop train automation, for instance through joint undertakings.

Further to the topic of "Digital Decade", the Commission indicated in its Communication of March 2021[26] how digital transformation can improve the ecosystems related to mobility and transport. Digitalisation can improve environmental and cost performance and simultaneously increase safety levels contributing to a higher quality of life. It will be achieved through more advanced levels of automation, faster and more reliable connectivity, and IT enabled profound transformation of the management of mobility services. The public could also benefit from fast internet connectivity for passengers on most stations and lines, user-oriented telematics and facilitated multi-modality.

In this context, EU-Rail and its Programme strived for speeding up the development and deployment of innovative technologies in railway transport in order to contribute to achievement of the above-mentioned milestones. This will require a significant transformation of the railway sector, addressing long overdue changes in legacy operational processes, systems and governance models, as well as integrating with other transport and mobility solutions for passenger services and cargo logistics.

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[25] European Commission (2020). Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM(2020) 789 final, Brussels

[26] European Commission (2021). 2030 Digital Compass: the European way for the Digital Decade. COM(2021) 118 final, Brussels

Besides the efforts made via its R&I Programme, the JU itself and its staff, to the extent corresponding to the size of the organisation, also strived to contribute to the fight against climate change when conducting the day-to-day business. Those "little things" that the JU applies to be as green as possible include:

- Separating waste in the JU's premises,
- Suppression of single-use items,
- Reducing paper consumption by applying paperless workflows to the extent possible,
- Encouraging staff not to commute to work by car by providing a scheme for reimbursement of public transport cost and arrangements supporting commuting by bike.
- Increased usage of online/hybrid meetings and events to reduce the carbon footprint related to travelling.

While the option of moving office in 2022 or early 2023 was eventually not realized, any future decision-making of EU-Rail in this respect will include due considerations regarding the energy-efficiency parameters of the respective premises.

Key objectives 2023

The JU objectives of 2023 were met with the full commitment of the budget appropriations related to the Horizon Europe funded EU-Rail Programme for the operational activities for that year. This demonstrates that the JU was able to engage the railway sector to an effective resource commitment to progress in delivering the railway system evolution, through an increasingly integrated Programme.

The Work Programme (WP) and budget 2023-2024, initially adopted in November 2022, were amended on two occasions mainly to address the updates regarding operational activities and the related financial figures:

(1) The WP Amendment no. 1 adopted in June 2023 to include the topic descriptions of the Call for proposals 2023, and among which, EU-Rail and SESAR3 Joint Undertakings decided to launch a joint topic call "Integrated air and rail network backbone for a sustainable and energy-efficient multimodal transport system" for a total of EUR 5.000.000 of co-funding and EUR 7.143.000 of total costs at 70% funding rate with a fairly shared contribution between SESAR and EU-Rail. This could be done in accordance with the SBA (recitals 10 and 12 and Article 5(2) c)), to achieve maximum impact, the joint undertakings should develop close synergies with other Horizon Europe initiatives and other Union programmes and funding instruments, particularly with those supporting the deployment of innovative solutions.

(2) The WP Amendment no. 2 adopted in December 2023 to recognize the inscription of new assigned revenue, to adapt the budget appropriation (mainly in payment appropriations) considering the evolution of budget needs, and finally to amend the multi-annual IKAA plan 2023-2024 following a proposal of private founding members.

The progress achieved and the launch of these additional core activities represented another key step towards the digitalization and automation of the railway system, to contribute delivering sustainable (climate neutral, life cycle cost efficient, connected, integrated through a system approach) mobility and transport for passengers and supply chain.

In 2023, and indicatively in 2024, the operational priorities consisted of:

- Innovation Pillar:
    - the ramp up of the 2022 Flagship Projects, following the conclusion of the grant agreements signature, to ensure that by the end of 2023 the planned milestones are achieved. The monitoring and performance analysis of the first results of the 2022 Flagship Projects, including the achievement of the planned milestones, in preparation for the demonstration activities of 2025 and 2026, → achieved;
    - the launch of the Call 2023-1 during Q4 2023 to create new opportunities for inclusiveness and participation; the scope of this call to be defined during Q2 and Q3 2023, taking into consideration the aforementioned activities and their progress. The scope of the Call 2023-1 will result from an extensive open consultation of the rail stakeholders and beyond. The ramp-up, following the conclusion of the grant agreements in 2024, of the projects resulting from the Call 2023-1 that as part of the Integrated Programme complement the Flagship

Projects with additional Exploratory research activities and enlarge the horizon of rail ability to serve European citizen with the development of tools, digital platforms and services for a better integration of aviation and railway transport modes, in collaboration with SESAR 3 JU, → achieved;
    - the launch of the Call 2024-1 during Q1 2024, followed by the conclusion of the grant agreements, to create new opportunities for inclusiveness and participation, enlarging the Flagship Projects with additional anticipated activities of the related Flagship Areas, as well as provide a platform for more disruptive innovation linked to hyperloop technologies and concepts, → achieved;
- System Pillar:
    - the delivery of the first results of the System Pillar Tasks and Domains, following the signature of the first Service Request(running from October 2022 to October 2023), → achieved;
    - delivering the first Standardisation and TSI Input plan to the European Commission and verify in the mid of 2024 the results on the new mandate to allow a continuation of the activities and a clear prioritisation of the expected implementation of harmonised results, → achieved;
- Deployment Group:
    - The respective GB decision setting the selection process and specific criteria for its establishment in 2023 and the operationalisation of the high-level and topical working group(s) in 2024, aiming at closing the innovation gap towards deployment with addressing European migration and implementation plans, → achieved;
    - supporting the activities of the European DAC Delivery Programme (EDDP), in particular working with the European Commission towards the development of a comprehensive migration strategy to coordinate deployment, in accordance with the Commission communication on "Greening Freight Transport" COM(2023) 440, → partially achieved and ongoing (objective not only of 2023). Significant progress in the European DAC Delivery Programme, the comprehensive migration strategy to coordinate the deployment needs would require additional support;
- Membership:
    - the preparation of a call for expression of interest to select Associated Members, in accordance with articles 7 and 87(1) point c of the SBA , to be launched by the JU to be launched by the end of the first half of 2024, after having made an in-depth assessment of the EU-Rail Programme, an update of the Multi-Annual Work Programme (MAWP), and after identifying possible gaps to be filled by new entities' commitment. → achieved and ongoing in accordance to the plan presented to the EU-Rail Governing Board;

In addition, the R&I activities related to the projects launched in the previous years under the S2R Programme entered in their final phases, focusing on:

- the execution of the research and innovation activities previously signed and needed to advance in delivering the Technology Demonstrators, and in view of reaching the complete phase of the S2R Programme by 2024, having achieved its targets. → Achieved and ongoing. Largely all operational activities are concluded, thanks also to the R&I efforts in particular from the private Members, and a plan has been set to conclude the projects' payments in 2024.

The year 2023 sought the continuation of the close collaboration established between EU-Rail and:

- the European Railway Research Advisory Council (ERRAC),
- the European Union Agency for Railways (ERA),
- other programmes, partnerships and other bodies, with the objective to establish synergies that will result in coordinated and consistent activities, or joint R&I projects or administrative synergies, such as for example under the Back-office arrangements with other JUs,
- different associations representing the key stakeholders of the rail sector and beyond,
- third countries programmes, in line with the policy priorities of the Commission and considering the key objective of the competitiveness of the European rail industry.

Finally, in 2023, continued conveying the message to European citizens that rail can answer their concerns about unsustainable and unreliable mobility options. The JU's key messages and events continued to reinforce the objectives of the initiatives such as the European Green Deal, the Sustainable and Smart Mobility Strategy or the Digital Decade by disseminating R&I results and showing the future evolution of rail in terms of services for passengers and freight clients. In this respect, in line with its communications strategy, Europe's Rail aims to:

- showcase the innovative technological and operational solutions that result from the research and innovation activities, and in particular those ready to enter industrialisation and deployment, in particular demonstrating concrete impact;
- raising awareness on the research and innovation activities outreaching to the stakeholders at European level as well as engaging at global events/conferences to promote Europe's Rail results;
- enhance the partnership nature of the JU through communications and dissemination activities that will create opportunities for inclusiveness.

The following sections of this CAAR describe how the JU's objectives have been pursued, the activities performed on the way towards achieving its goals, and the resources used. In Annexes E and F, the JU's performance is measured against the set of agreed KPIs.

More details related to call for tenders, procurements and contracts concluded and/or launched in 2023 are presented in Sections 1.4 and 2.5.

Delivery of S2R Programme R&I activities

During 2023, through the operational activities, the Programme Office continued the supervision of the implementation of the 105 Projects and operational contracts of the S2R Programme[27], awarded and signed since 2016, for an estimated R&I total value of EUR 805,1 million. Additional details are provided in Section 1.6.

The Programme supervision and monitoring was implemented through 41 specific Control Gates for the S2R Programme (23 project reviews of CFM projects, 18 project reviews of OC projects) and 161 specific issue reviews from the S2R Programme (105 specific issue reviews of 20 CFM projects, 56 specific issue reviews of 17 OC projects) and 33 specific issue reviews from the EU-RAIL Programme (32 specific issue reviews of FP projects, 1 specific issue review of Exploratory Research projects) in order to continuously assess the submitted technical deliverables with the support of external experts (in the specific field of the deliverables), when needed. The continuous assessment of deliverables has allowed the JU to be efficient in providing timely feedback to the projects for an effective implementation of recommendations and/or requests for changes.

The process of continuous assessment of deliverables consists in the engagement for each output of the project in a swift review, which may need the support of external technical expertise, and in that case, the JU triggers a specific issue review. This process allows EU-Rail to provide in-depth technical feedback to the project not linked only to the reporting period review (the control gates), but throughout the lifetime of the action, allowing a better fine-tuning of the activities in relation to the objectives.

Risks

In Q4 2022, the JU performed a risk assessment exercise with the aim of updating the elements related to risks and opportunities already included in its risk register, as well as identifying potential new ones. The corresponding risks relevant for 2023 associated with the Programme activities and the financial administration of the JU, requiring continuous ED attention (and when relevant, the attention of GB), as well as the corresponding risk mitigating actions have been communicated via the EU-Rail Work Programme 2023-2024. They are summarised in the table below together with an update on follow-up and mitigation actions performed in 2023.

As for the average JU's risk profile pertaining to 2023, as followed from the annual risk assessment performed, and also from the continuous monitoring of risks and opportunities during the year, this was determined by having moderate to high net criticality of the most relevant risks identified.

[27] 4 Light house projects (2015) not included.

Risk identified for 2023 in the Work Programme	Action plan/measures	Follow-up on action plan/measures for 2023
Proposals of participants submitted in response to JU's calls do not adequately reflect in the part providing the foreseen budget of the action the current and future expected inflation rate. This might have negative influence on the successful delivery of the work packages at a later stage of the projects.	- Continuous Programme monitoring will be instrumental to assess the capacity to deliver the programme in the determined resources or anticipate the need for prioritization and adjustments. - Drawing the attention of potential applicants on this issue during the Info Days.	Actions/measures have been implemented on an ongoing basis. Info Days or other communication opportunities were used to also point out the importance of adequate anticipation of development in price levels.
Intrinsic to the JU's Staff establishment plan and its actual fulfilment, efficiency of operations is impacted by extensive workload of JU's staff. In combination with high staff turnover, difficulties for the JU to attract new people, vacant positions might be filled with delays resulting in shortage of resources becoming critical especially during peak periods. Specific accumulation of tasks and activities following from the transition between the two JUs and from launching of the new Programme may also contribute to difficulties in getting the work done in time and in the desired quality, deteriorating employees' motivation and, eventually, jeopardizing achievement of the JU's objectives.	- Once the actual staffing according to the EU-Rail Staff Establishment Plan is accomplished, the envisaged positive effects on workload allocation and back-ups should become visible. - Design/apply a replacement plan (back-ups) where possible. - Within the current budget constraints, a career plan for staff has been prepared and business continuity is ensured. - Enhancing of the overall planning of activities will allow for better personnel risk management. - Recruitment of short-term resources (interim or trainees) has been extended. - Outsourcing of some activities, as applicable, making use of existing Framework contracts or by executing own procurements. - Implementation of back-office arrangements among the JUs might decrease the EU-Rail's internal workload in some areas. - Introduction of a multi-annual learning and development policy will be considered. - Team-building activities are performed to the extent possible.	Actions/measures have been implemented: Vacant posts as per the new Staff Establishment Plan have been gradually filled. Internal planning and organisation were refined. Bluebook Trainees were deployed in accordance with the SLA signed with DG EAC, as needed. Synergies under BOA HR have been utilised. Activities aimed at enhancing team spirit and work-life balance have been carried out.
Given the interdependencies of complementary R&I projects, considering as well the startup of a complex and integrated new Programme (including input/outputs between System and Innovation Pillars), delays and misalignments in the completion of activities may lead to negative project cascading effects impacting Programme outputs.	- Ensure, through adequate Programme management strengthened monitoring and reporting of projects, including gate reviews, to determine whether specific actions need to be taken with regard to a specific project (re-orientation, early closure, etc.). - Addressing during the GAP any possible alignment issues between ongoing and future R&I activities. - Follow the high-level interactions as detailed in the MAWP.	Measures have been implemented: Adequate Programme monitoring was continuously ensured and any issues related to the R&I projects were addressed.
The ambitions of the System Pillar sector/EU are not matched by the outcomes of EU-Rail Programme due to the limitation	- Controls of requirements and appropriate management of expectations. - Application of maturity check points.	Measures have been implemented: Adequate continuous management of the

Risk identified for 2023 in the Work Programme	Action plan/measures	Follow-up on action plan/measures for 2023
in terms of available resources to cover the related activities. This might negatively affect the image of the JU.	- Constant communication on outputs, focusing on concrete results that can be implemented taking into account the legacy system, migration aspects, business cases, etc.	System Pillar activities was carried out including communication with the relevant stakeholders.
Breach of intellectual property rights due to unauthorised access and misuse of information related to EU-Rail's Programme by contractors or subcontractors of the Commission, such as service providers maintaining the EC-owned IT tools/systems used for Programme management purposes (SyGMa, Compass, Corda, Cortex, etc.). If materialized, the situation could have an impact on EU-Rail e.g., in terms of disruptions of good relations with the respective JU's member/beneficiary, or even financial and reputational impact (stepping out from the project(s)/Programme, litigation, etc.).	- Communication by the JU about this risk towards the Commission.	Actions have been implemented: DG MOVE was provided with the JU's risk register.
Due to deployment/application of diverse processes, methods and tools, the integration between the Flagship Projects and the System Pillar could experience problems, including negative effects on inputs for specifications and standards, and overall architecture. Therefore, the effectiveness of management of the Programme as a whole could suffer, eventually jeopardizing achievement of the Programme objectives.	- Continuous efforts to converge on common approaches. - Correct utilisation of System Pillar tools and processes for architecture and specification work. - Clearly defined IT framework.	Actions have been implemented on an ongoing basis. Meetings of the System Pillar Steering Group and of the ED System and Innovation Programme Board were held.
Unbalanced distribution of personnel and technical capacities of the participants to JU's R&I projects between the ongoing ones (S2R Programme) and the new ones (EU-Rail Programme), e.g., due to unjustified preferences of the participant or overall lack of capacities, might result in difficulties with parallel delivering of outcomes of the S2R/EU-Rail Programmes and thus jeopardizing the JU's key objectives.	- Addressing the potential issues in the GAP phase of the new EU-Rail projects. - Ongoing monitoring of projects and actions and timely reactions to identified issues at project/participant level. - Formal reminders sent for projects with delay of more than 30 days.	Measures have been implemented: Adequate monitoring of S2R/EU-Rail Programmes was continuously ensured and any issues related to the R&I projects were addressed. Meetings of the ED System and Innovation Programme Board were held.

Risk identified for 2023 in the Work Programme	Action plan/measures	Follow-up on action plan/measures for 2023
Vulnerabilities in IT infrastructure or human failures/omissions enabling unauthorized computer network access or cyber-attacks may lead to compromising of data with potential financial losses and/or reputational damage. Delays might also occur, e.g. if data relevant to day-to-day operations became unavailable due to a successful ransomware attack.	- VPN connection encryption. - Two-way authentication. - VLANs used for LAN segmentation/ separation. - Secured Wi-Fi. - Cybersecurity testing with regard to the Cooperation Tool and website. - Computer disk encryption in place. - Lock, change user password remotely; intunes security policy for mobile phones. - Implementing the mitigation measures resulting from the DPIA performed with regard to the migration to Office365. - Continuous awareness-raising of JU's staff members with regard to cyber security and protection of IT tools and assets. - Sharing of information with the staff about detected actual phishing attempts (also from the EC or other EU bodies) and providing advice on the appropriate way of procedure in such cases. - Joint ICT strategic plan for all JUs is in place.	Technical measures have been implemented on an ongoing basis. Several reminders and awareness-raising activities to JU's staff were provided with regard to cybersecurity and phishing. Joint activities among the JUs were carried out in the context of BOA.
Timely and qualitatively adequate execution of the daily Programme management activities may be jeopardized due to accumulation of tasks within the SyGMa/Compass workflows (GAP for the new projects in combination with REPA for the existing projects). This could result, for example, in late payment or late delivery of approval of reports/deliverables, or even delaying the start of a grant.	- Increased frequency of meetings between the Executive Director and the Heads of Units to monitor the current status of workflows and possible delays. - Increased intensity of the current status monitoring by the Heads of Units. - Temporary partial reassignment of tasks of some of the existing staff members to support the POs, FOs and LOs involved in the respective SyGMa/Compass workflows. - Potential deployment of temporary external resources allowing POs, FOs and LOs involved in the respective SyGMa/Compass workflows transferring some of their clerical/administrative tasks to such temporary external resources.	Measures have been implemented on an ongoing basis. Adequate planning and follow-up were carried out to ensure proper management of the Programme.
Failure to achieve the requirement of Article 13 of the SBA, starting with the assessment of the cost effectiveness of the possible services to be included in the back office arrangements (BOA), may result in a missed opportunity to achieve efficiencies. It may also represent a non-compliance with	- Utilisation of the flexibility that the SBA provisions provide regarding BOA so as to find the best possible solutions with regard to their practical establishment. - Preparing a proper planning of implementation, with efficient monitoring and regular meetings at appropriate level (EDs, Heads of Units) to discuss the modalities of BOA, including setting up the SLAs, with the	Actions have been implemented on an ongoing basis. BOA for accounting services is fully operational. Progress has been made in establishing SLAs for other services (IT, HR, procurement) (see also Section 2.7.2).

Risk identified for 2023 in the Work Programme	Action plan/measures	Follow-up on action plan/measures for 2023
the respective provisions of the SBA with a negative impact on JU's reputation. In addition, the lack of clarity may negatively impact the JU's staff in terms their motivation, should the BOA arrangements experience delays.	support of DG BUDG and DG RTD (CIC). - Involvement of decision-making bodies (GBs). - Steering of the process and active guidance is ensured by the Commission via DG RTD. - Early involvement of the respective EU-Rail staff members. - Timely launch and execution of recruitment procedures to hire additional EU-Rail staff for the purposes of the accounting BOA.	Adequate planning and coordination were ensured at various levels among the JUs. GBs were kept updated on the BOA developments.
Deficiencies in dissemination of results may develop in vague information to the end-user/interested parties and could compromise the intended JU's impact. That can also negatively impact the overall reputation of the EU-Rail Programme.	- The JU provided a series of guidelines to the projects and fostered the use of the H2020 instrument as the Common Dissemination Booster. - Proper planning and regular follow up at IP SteCo/SIWG and within the projects' control gates. - Demos at EU-Rail stand at InnoTrans and other relevant events. - Every time possible, involvement of presence of high-level EU/national (political) representatives in events presenting EU-Rail's results. - Communication via social media channels might be expanded from providing general information about EU-Rail to also reporting on results of individual projects.	Actions/measures have been implemented on an ongoing basis. Various channels were deployed for communication and dissemination of R&I results related to the JU's Programmes (see also Section 1.9). Cooperation with relevant stakeholders was ensured.
Delay or lack of expected inputs from the Flagship Projects into the continuous integration architecture activities under the System Pillar. This would also impact the topic on the Standardisation and TSI input plan and the respective specifications that would accompany the results of the plan. Eventually, effective implementation of EU-Rail Programme could be affected.	- Continuous alignment and interaction between the System Pillar and the Innovation Pillar. - Involvement of the System Pillar steering group in the grant agreements preparation phase.	Actions have been implemented on an ongoing basis. Adequate monitoring of the JU's Programmes was continuously ensured. Meetings of the System Pillar Steering Group and of the ED System and Innovation Programme Board were held.

In the months of October and November 2023, the JU performed a new risk assessment exercise with the aim of updating the elements related to risks considered relevant for 2024. Within this exercise, due account was taken of topical internal and external factors and developments having influence on JU's business. Attention was given also to the fraud risks. The updated EU-Rail risk register was provided to its parent Commission service – DG MOVE, and the JU also actively participated within the respective cluster of JUs and Agencies in the peer assessment/review of most relevant risks steered by the EUAN Performance Development Network.

The risks identified in the above-mentioned risk assessment activities which require, due to their criticality, continuous attention and treatment of the Executive Director and, where relevant, of the Governing Board, are presented in the JU Work Programme 2024 and the follow-up outcomes regarding these risks will be presented in the 2024 CAAR.

Further to the risk assessments mentioned above, in Q4 2023, the IAS performed at EU-Rail their in-depth risk assessment which resulted in the establishment of their Strategic Internal Audit Plan 2024-2026 for the JU.

1.2. Research & Innovation activities/achievements: the S2R Programme

The S2R MAAP translated the S2R Master Plan into detailed, result-oriented R&I activities to be performed with the objective of delivering the S2R vision as from 2016 onwards.

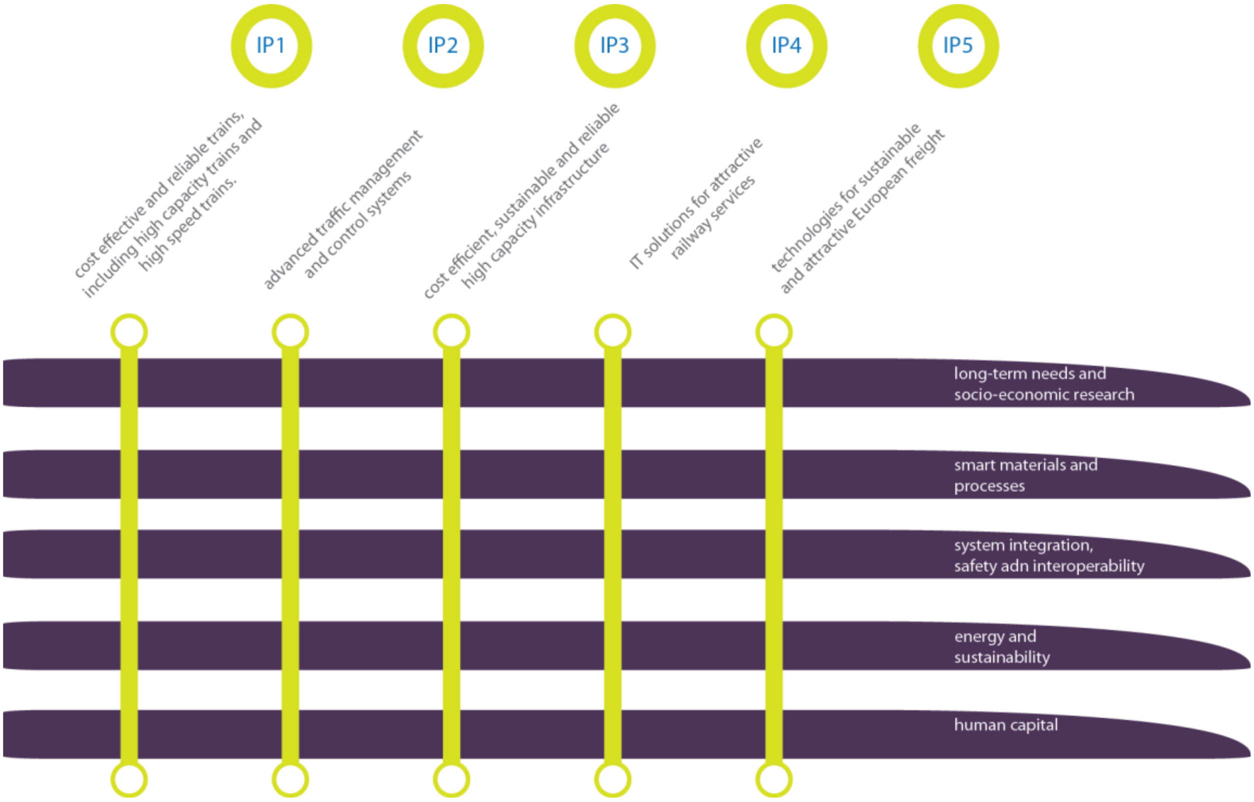
Addressing through R&I the challenges as they were detailed in the MAAP Executive View opened three opportunities for the railway:

- To become the backbone of current and future mobility concepts (e.g., mobility as a service-MaaS) and on-demand future logistics, through integrations with other modes in view of reaching a climate neutral European economy by 2050;
- To identify and establish new market segments for exploitation;
- To enhance the overall competitiveness of the industry, both in Europe and globally.

This is what the S2R Regulation tasked the JU to do when requesting it to manage all rail-focused research and innovation actions co-funded by the Union. Developing the Innovation Capabilities required a coordinated effort among different rail and non-rail stakeholders to drive innovation at all levels in Europe. The S2R Programme was designed to make a decisive contribution to delivering the essential knowledge and innovation that will provide the building blocks to develop the Innovation Capabilities.

The work conducted within the S2R Programme was structured around five asset-specific Innovation Programmes (IPs), covering the different structural (technical) and functional (process) sub-systems of the rail system. These five IPs are supported by work in five cross-cutting areas (CCA) covering themes that are of relevance to each of the projects and which address the interactions between the IPs and the different subsystems:

- IP1: Cost-efficient and Reliable Trains, including high-capacity trains and high-speed trains
- IP2: Advanced Traffic Management & Control Systems
- IP3: Cost-efficient, Sustainable and Reliable High-Capacity Infrastructure
- IP4: IT Solutions for Attractive Railway Services
- IP5: Technologies for Sustainable & Attractive European Freight.



S2R introduced additional IPx activities, R&I designed to look beyond currently planned technology applications (of the Technology Demonstrators) and how to integrate the S2R TDs with new operational concepts. IPx activities help to realise the global optimal approach for this System of Systems which is railway mobility, by starting to build a railway Functional System Architecture and a Conceptual Data Model (CDM).

In addition, in 2020, the JU set up the European DAC Delivery Programme, to bridge the gap towards future industrialization and deployment of a European DAC solution, building upon the work delivered in IP5 on DAC (see the following sections).

With a holistic approach, the S2R Programme ensured that interactions between the various IPs were adequately considered and managed, as technological developments in one part of the system could lead to changes in performance, or even create barriers, in other parts. In addition, cross cutting activities included research on long-term economic and societal trends such as customer needs and human capital and skills, which must be taken into account by the different IPs.

Different types of activities contribute to the Programme development, including:

- studies, fundamental and "blue-sky" research (TRL 0 – 2),
- scientific/applied research and laboratory demonstrations (TRL 3 – 6),
- operational demonstrations and innovation activities (TRL 6-7),
- other supporting activities.

In addition to these activities that were co-funded by the JU and conducted within the scope of the S2R Programme, the former S2R Other Members were required to conduct Additional Activities with a view to leveraging the effect of the overall R&I. These Additional Activities were not eligible for financial support from the JU but had to contribute directly to the broader objectives set out in the S2R Master Plan.

Since 2020, the management of the Programme benefited also from the regular activities of the ED Programme Board. The ED Programme Board was established as a formal advisory support to the ED and has the role of:

- monitoring the progress of the Programme,

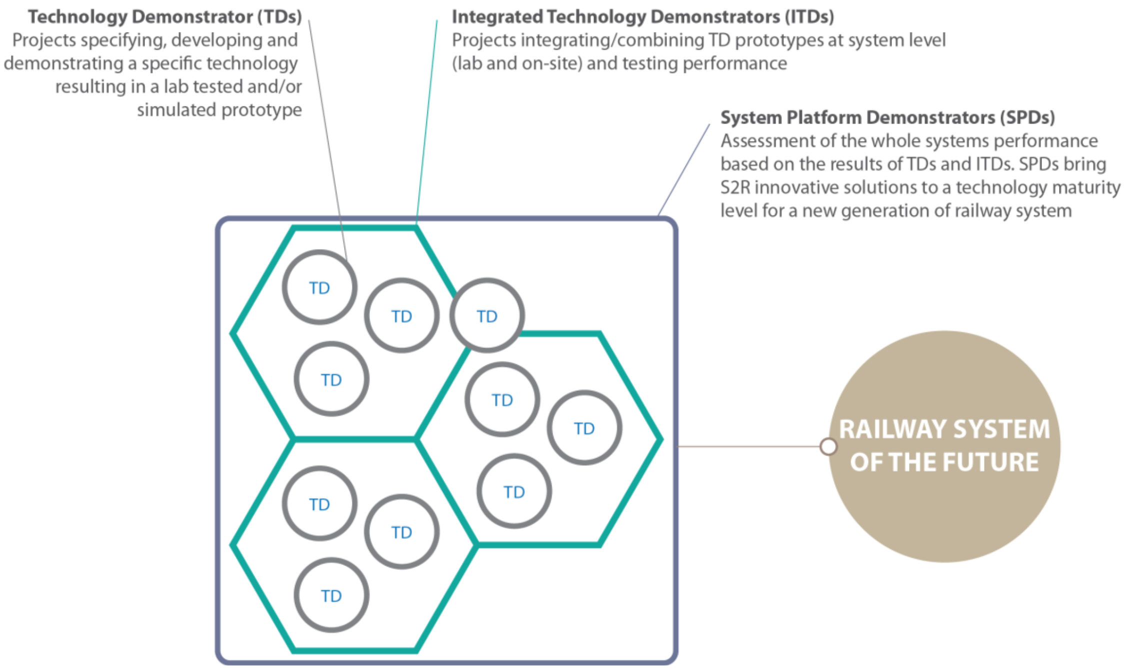
- identifying risks and opportunities and related mitigating actions,
- providing strategic guidance and making recommendations with regard to the management Programme,
- advising the Executive Director in solving issues escalated to his attention in accordance with the S2R Regulation on Programme implementation and propose a way forward,
- advising the Executive Director on the need to complement the Programme with specific expertise to be contracted,
- assisting and advising the Executive Director in any other matter of relevance.

Through its monthly advisory meetings with the Executive Director, the Programme Board has actively supported reflections on and integration of new concepts, ideas, solutions that impacted the Programme. Several change requests have been processes, ensuring among other sectorial coherence of initiatives, notably with the integration of relevant concepts from OCORA or RCA into the S2R R&I activities (projects) that will deliver concrete demonstrations.

The ED Programme Board proved to provide clear benefits to the overall Programme management, anticipating risks and opportunities, ensure higher integration and synergies, addressing issues to avoid negative impact on the expected deliverables.

The progress of the Programme was shared with a wide range of stakeholders during the S2R Innovation Days in December 2022[28].

The practical demonstration of S2R R&I activities is carried out using a combination of single technology demonstrators (TDs), integrated technology demonstrators (ITDs and resulting into the Innovation Capabilities) and theoretical system platform demonstrators (SPDs).



The following sections illustrate the progress achieved in the Technology Demonstrators at the end of 2022. The contributions from the TDs to the delivery of the innovation capabilities, as mentioned in the S2R MAAP (Part A), were elaborated in the S2R MAAP (Part B), adopted by the GB in November 2019.

Towards delivering the S2R Programme
An overview of demonstrators with a Technology Readiness Level reaching at least 6 (technology demonstrated in relevant environment), and of which activities have been performed in 2023 is displayed below.

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[28] https://rail-research.europa.eu/calendar/europes-rail-2022-innovation-days/

IP	Research Area	Specific Technological demonstration of	characteristics					Overall high level focus/objective
			Market	Testing time	Testing time	Country	TI	
IP1	TD1.1 Traction	New Traction Architectures	High Speed	2022	2023	ES	6/7	Traction motor and traction drive architecture
	TD1.2 Train Control & Monit. System (TCMS)	Wireless TCMS	Metro	2023	2023	ES	6/7	Incorporate wireless technologies to the train communication network solutions (i.e. train backbone, consist network and train to ground communication).
			Regional	2023	2023	DE	6	
		Drive-by-data	Metro	2023	2023	ES	6/7	Provide a train-wide communication network for full TCMS support including the replacement of train lines, connecting safety functions up to SIL4 (incl. signalling).
			Regional	2023	2023	DE	6	
		Functional distribution architecture	Metro	2023	2023	ES	6/7	New architectural concept based on standard framework & application profiles, distributed computing to allow execution of compliant functions on end devices distributed meeting different safety & integrity requirements (*) TRL of the Regional demonstrator for FDF may be updated.
		Virtual Certification	Generic	2022	2023	ES	5/6	Standardised simulation framework in which all subsystems of the train will be simulated, allowing remote and distributed testing including hardware in-the-loop through heterogeneous communication networks.
			Generic	2022	2023	DE	5/6	
	TD1.3 Carbody Shell	New materials in train carbody structures	High Speed	2023	2023	ES	6	Full high speed intermediate coach interfacing with the adjacent coaches and the running gear, together with the internal interfaces of the main
	TD1.4 Running Gear	Sensoring functionality	Generic	2022	2023	ES, UK, AT/DE	6/7	New health monitoring systems that allows a condition based maintenance of the track with Novel sensor system (hardware), Wireless communication of some sensor, Innovative algorithms
			Regional	2022	2023	HU	6/7	Hardware architecture that allows to combine sensor signals for different monitoring and supervision purposes in an efficient and modular way
		Optimised Materials	Regional	2022	2023	FR	6/7	Composite Antenna Beam: Design of an Antenna Beam out of composite material to reduce weight
		Optimised Materials	High Speed	2020	2023	ES	6	Composite runnning gear from for independently rotating wheels
	TD1.6 Door and Intelligent Access system	PRM access and communicating door	Regional	2021	2023	FR, ES	6/7	New door functionalities like platform detection, passenger detection, passenger protection during boarding aid deployment and retract…: - tests of laser-based solution in operation - data collect on a train in operation with the proposed camera - with the recordings, tests of the algorithms based on IA and/or image treatment
		Light and high comfort door	Regional	2021	2023	FR	6	Opening and closing mechanism and the leaves new innovative design: - one door will be based on metallic solutions - another door will be based on composite solutions
	TD1.7 Interiors	New Passengers Interiors	Regional	2022	2023	FR, ES	6	New users experiences on board thanks to modular interiors. Physical mock-up and virtual mock-up

IP	Research Area	Specific Technological demonstration of	characteristics					Overall high level focus/objective
			Market	Testing time	Testing time	Country	TI	
IP2	TD2.1 Advanced Communication System	markets applications	Mainline/High Speed	2021	2023	FR/DE	6/7	The demonstrators will be used to validate aspects and capabilities defined in the ACS specification documents (incl. support VoIP communication) and assess them in the context of related FRMCS specifications.
		markets applications	Urban/Suburban	2021	2023	UK	6/7	
		markets applications	Regional/Freight	2021	2023	IT	6/7	
	TD2.2 Automatic Train Operation	Demonstrate the feasibility of GoA3/4 solution on actual pilot train and line	Urban/High Speed/Regional/Freight	2022	2023	CZ	6/7	For GoA3/4, to check the behaviour of the system (ATO on board and ATO trackside) in a real pilot line.
	TD2.4 Safe Train Positioning	functional block integrated into an ERTMS based solution	Regional/Freight	2021	2023	IT	6	Under review for successful Fail Safe Train positioning demonstration innovative solution integrated with an ERTMS based system
		Fail-Safe Train Positioning Module	Low density traffic lines	2021	2023	Spain	4/6	
		standalone train positionning demo	All	2021	2023	DE, ES, FR, CH	4/6	
	TD2.10 Smart radio-connected all-in-all wayside objects	Verification of Multiple Networks Scalable SWOC	Generic	2021	2023	IT	6	A prototype of wayside object controller that will be able to communicate using the available heterogeneous wireless public networks (e.g. 2G/3G/4G, satellite, ..)
		Verification of SWOC network for managing WOs demonstrator		2021	2023	NL	6	SWOC and a Wireless Sensor Network for a safe and secure communication as well as transparent routing for the IXL to the object to be controlled.
		Verification of a LX Smart wayside objects		2021	2023	CZ	6	SWOC connected via radio connection to the IXL or to the level crossing (LX) controller to control wayside objects commonly used at an LX – axle counter, gate signal, warning light, light signal or barrier drive.
		Verification of SWOC for points machines		2021	2023	ES, DE	6	Controlling of point machines with wireless communication, advanced diagnostic features, optimized distribution, low power consumption + autonomous power supply and storage
		Verification of adaptable Wireless sensor Network for way side objects		2021	2023	FR	6	New generation of low-power and resource-constrained wireless sensor networks (WSN) for adaptive data collection and forwarding for railway environment

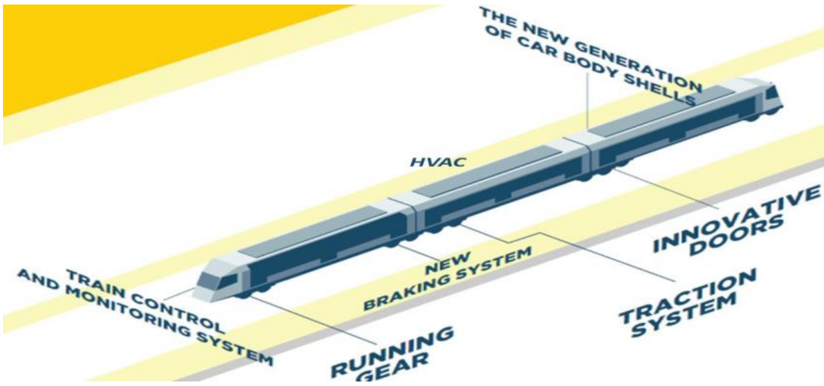
IP	Research Area	Specific Technological demonstration of	characteristics: Market	characteristics: Testing time	characteristics: Testing time	characteristics: Country	characteristics: TI	Overall high level focus/objective
IP3	TD3.1 Enhanced Switch & Crossing System Demonstrator	RAMS optimised S&C	Generic	2019	2023	AT	6/7	Monitoring programme foe S&C including: Geometry and overrunning, casting, novel rail grade, resilient pads, rail fastening system, base plates, switch roller system, etc.
		Joint Welding of bainitic components		2020	2023	FR	5/6	Experimental evaluation of fatigue of cast manganese-crossing for welding technology to join bainitic with pearlite steel components.
	TD3.2 Next Generation Switch & Crossing System Demonstrator	Next Generation S&C System	Generic	2021	2023	UK	5/6	Test next generation design, control, materials and manufacturing to provide a step change in asset performance as a whole (sub)system
		Low N&V Tramway Crossing	Urban/Suburban	2021	2023	TBD	6/7	Test overall performance of a girder rail swing nose crossing in service for the reduction of N&V
		Materials and Components	Generic	2019	2023	UK, SE, FR	4/7	Next generation S&C materials and components tests (*i.e.* adjustable fastening systems)
		Asphalt Track		2021	2023	UK	6/7	A site trial for demonstration to assess future assessment of asphalt performance.
	TD3.3 Optimised Track System	Transition zone	Generic	2019	2023	SE	5/6	tests on improvement of the transition between open track and bridges, open track and S&C, ballasted track and slab track
		new slab track		2019	2023	SE	7	test of a Modular Slab track solution reducing maintenance costs
		Innovative use of materials		2019	2023	AT	5/6	test of innovative use of materials and advanced manufacturing techniques
		Laser clad coating on rails		2020	2023	AT	5/6	test of laser clad coatings on rails nearby and on rail joints; laser hardening and laser cladding of worn rail zones
	TD3.4 Next Generation Track System	Rail Defect Repair	Generic	2020	2023	UK	7	Thermocouple instrumented trials on process for different rail steel grades
	TD3.5 Proactive Bridge and Tunnel Assessment, Repair and Upgrade Demonstrator	Tunnel improvements		2020	2023	FR, UK	7	Reduce track and tunnel closure by offsite manufacturing and increase quality
				2020	2023	AT	7	Predict calcite clogging over time
		Bridge improvements	Urban/Suburban	2020	2023	DE	6	Efficient monitoring of noise emission and installation of passive noise dampers.
			Generic	2020	2023	UK	7	Extend bridge service life by lowering fatigue
				2021	2023	SE	7	Increase bearing capacity and remaining fatigue life of concrete bridges and increasing safety.
			High Speed	2020	2023	SE	7	Make high speed traffic possible on existing bridges with proven dynamic properties
	Integrated Technological Demonstrators Asset Management (TD3.6, TD3.7, TD3.8)	Strategic long-term	Generic	2021	2023	PT, UK	6	Test of a strategical decision support tool based on the tactical planning tool
		Tactical and Operational short term		2021	2023	UK, SE DE NL, ES, FR	6/7	maintenance process and strategies through knowledge extracted from information coming from available data and monitoring systems

IP	Research Area	Specific Technological demonstration of	characteristics: Market	characteristics: Testing time	characteristics: Testing time	characteristics: Country	characteristics: TI	Overall high level focus/objective
IP3	TD3.1 Enhanced Switch & Crossing System	RAMS optimised S&C	Generic	2019	2023	AT	6/7	Monitoring programme foe S&C including: Geometry and overrunning, casting, novel rail grade, resilient pads, rail fastening system, base plates, switch roller system, etc.
IP4	Integrated TDs of all IP4 ecosystem	Towards the MaaS concept	Shared modes and on-demand	2021	2023	GR,IT,FI,CZ	6/7	Test of a scalable eco-systems which enables pan European multimodal travels and MaaS. Demonstration of the functional ecosystem with the full integration of Ride-sharing and MaaS. Scalable (near-) market ready eco-systems enables pan European intermodal travels and MaaS, including cross-plattform approaches.
		Fully dynamic door-to-door travel	Multimodal (rail, bus, metro,…)	2022	2023	IT, GR, HR, ES, CZ, PL	6/7	Demonstrations of IP4 technologies in 6 different locations involving different transport operators, translating/combining IP4 solutions into specific demo sites solutions:

IP	Research Area	Technological demonstration of	characteristics					Overall high level focus/objective
			Market	Testing time	Testing time	Country	TI	
IP3	TD3.1 Enhanced Switch & Crossing System	RAMS optimised S&C	Generic	2019	2023	AT	6/7	Monitoring programme foe S&C including: Geometry and overrunning, casting, novel rail grade, resilient pads, rail fastening system, base plates, switch roller system, etc.
	TD5.1 Fleet Digitalization and Automation	Condition based maintenance		2020	2023	DE	6/7	End-to-end solution for predictive maintenance, including processes, data handling, analytics and dashboards, for locomotives and wagons.
	TD5.2 Digital Transport Management	Improved terminals		2021	2023	SE	6	A gate equipped with intelligence as part of a connected decision platform optimizing the work process in a terminal. Sata exchange platform to ensure efficiency and security (of data handling) in the transport chain. Equipment prototypes with HMI interface validated in live demonstration for a selected large and complex terminal.
IP5		Core market wagon	Freight	2022	2023	SK	7	Modular, logistics-capable and cost-efficient, low weight, high-payload and aerodynamically optimised freight wagons
	TD5.3 Smart Freight Wagon Concepts	Core market wagon		2022	2023	SK	7	Modular, logistics-capable and cost-efficient, low weight, high-payload and aerodynamically optimised freight wagons
		Extended Market Wagon		2022	2023	CZ	5/6	Modular, logistics-capable and cost-efficient, low weight, high-payload and aerodynamically optimised freight wagons
		Telematics		2021	2023	SE	7	Demonstration activities of the intelligent wagon based on telematics and electrification

1.2.1. IP1 Cost-efficient and Reliable Trains, including high-capacity trains and high-speed trains

The picture below gives a visual perception on where the TDs will introduce improvements.



TD 1.1. Traction systems Demonstrator

The TD develops new traction components and subsystems using mainly silicon carbide (SiC) technologies leading to new architectures. The aim of the activities was to produce SiC Technology Demonstrators implemented into a tramway, a metro, a sub-urban train, a regional train as well as a traction system based on independently rotating wheels demonstrated on a high-speed train. All demonstrations have been successfully realised.

The SiC application opens up many improvements in Key Performances Indicators (Life Cycle Cost and technical). Besides improved energy efficiency and maintenance costs, it gives additional optimisation possibilities enhancing customer value, such as noise reduction and efficient cooling.

TD progress

Throughout the S2R programme, this TD has been implemented via the following projects: Roll2Rail (Completed in 2017), PINTA (completed in 2018), PINTA2 (completed in 2021) and RECET4Rail and PINTA3 (both completed in 2023).

The main objective for 2023 was the finalisation of on-train demonstration of prototypes of Traction components at TRL7. The work carried out in 2023 has brought the following main results:

- SiC based Traction components demonstration metro completion. The results are satisfactory.
- On HST, the on-train test of a wheel motor prototype has been realised and completed.

One of the main advantages of using SiC technology has been proved to be the possibility of reducing the number of secondaries of the transformer for the same power train, due to the capacity of SiC MOSFET of handling much more current with approximately the same losses. The tests performed within PINTA3 proved an improvement of 20% in the total losses of the system changing from two secondaries to one. In addition to this, the possibility of increasing the switching frequency makes it possible to reduce the leakage inductance and thus further improve the efficiency of the system. A total reduction of 47% of losses has been obtained with the optimum system design.

From the point of view of the possible impacts on Electromagnetic Compatibility (EMC) of the systems, it has been tested that the use of this new technology with high voltage derivatives creates harmonics at different frequencies that may affect the common mode design of the system. These high derivatives also affect the design of the peripherals, and for this reason simulation and tests were performed to estimate and measure the voltage peaks generated, which is important to consider the transformer isolations design to withstand those peaks.

Related with the efficiency improvement, all the configurations identified were tested in an Euskotren unit. The fact that the train had one SiC based inverter and another Si based inverter in the same unit allowed a real comparison which achieved improvements greater than the 7% in terms of energy savings compared to the original solution.

As for the use of SiC MOSFET in other converter topology, the tests carried out with a SiC based designed DC/DC plus inductance have demonstrated that it is possible to reach an improvement of 34% in losses, hence validating the results of the simulations made in the previous phase of PINTA3 project. It has also been possible to go a step further in the design of the transformer and a first design optimised for SiC has already been realised with very promising results, in which a loss reduction of 47% for the optimum system design has been reached. With the foreseen improvement on the cost of SIC devices, the technology is expected to reach higher market share levels.

The main point to be underlined is that major energy savings have been demonstrated. This opens the path toward reduced energy consumption, both for electric trains and diesel-electric trains, as the SiC technology can be used in all train types. The SiC technology is a good solution to better fight climate change and opens promising possibilities for further R&D action in the next decade, as this technology is expected to be used for decarbonised alternative Traction systems like Hydrogen hybrid or Batteries-powered trains.

In relation to the wheel motor prototype, tests have confirmed that the computer aided engineering (CAE) tools produce accurate values for the main motor parameters. The modelled motor matched within the designed values of the development and the software control was validated successfully. The tests indicated that the model and the measured motor were in good agreement at higher torque/power. One of the most challenging aspects was the packaging of the motor as one of the requirements is to maintain the current envelop of the independent rotating wheel (IRW) frame. Tests were performed on the test train Talgo AVRIL G3, which is composed of twelve coaches and two power heads. The motorized running gear was located at the axle number 6 of the unit. The motors were tested on torque steps up to 900Nm with 100Nm increments reaching up to 25 rps.

The tests have confirmed the results test on bench and CAE values. The efficiency values delivered a result of 94.5% when calculating the power supplied and the losses resulting on around 2% less than simulation predictions. The main objective was achieved which was realising the distributed traction concept on low floor with the independent rotating wheel.

The temperatures and behaviour of the components also confirmed the design parameters to ensure a long-lasting life cycle of 30 years. No issues were detected on the interaction of the guiding system and the motor due to the good response of the control system. The motors will be the basis for further improvements on Rail4EARTH project, adding extra functionality like active guiding system. The motors will be the basis for further improvements on FP4-Rail4EARTH project, where extra functionality such as active guiding system will be added.

TD1.1 Traction Systems Demonstrator

2015	2016	2017	2018	2019	2020	2021	2022	2023	...
			Finished: Roll2Rail, PINTA, PINTA2						
							Ongoing: PINTA3, RECET4Rail		

During 2023, the last 13 deliverables were released. TD 1.1 has reported having accomplished 100% of the planned work up to the end of 2023.

TD 1.2. Train control and monitoring system (TCMS)

The development of a new-generation TCMS (Train Control and Monitoring System) will allow overcoming current bottlenecks caused by physically coupled trains. The new drive-by-data concept for train control, along with wireless information transmission, aims at making new control functions possible; it involves interaction between vehicles and consists, providing high safety and reliability levels with very simple physical architectures.

TD Progress

The TD1.2 builds on the progress made by CONNECTA and Safe4Rail in the first phase, and the work made by CONNECTA-2 and Safe4RAIL-2 projects in the second phase, which have been completed in 2021. In December 2020, the projects CONNECTA-3 and Safe4RAIL-3 were launched with the objective to reach high TRL in the technologies introduced in the next-generation TCMS.

After having reached in the first phase of the projects the definition of general specifications for the next generation TCMS, including a comprehensive list of use cases and the corresponding high level system architecture, the prototypes developed in 2020 (based on those specifications) have been tested and validated throughout 2021. The laboratory test execution has served to overcoming some gaps and specification mistakes made in the CONNECTA project, resulting in a specification update publicly available on the CONNECTA-2 project website. The achieved degree of maturity in prototypes made in CONNECTA-3 allowed the implementation and deployment of NG-TCMS technologies in the high TRL demonstrators planned in the project (up to TRL 6/7).

The main objective of 2023 was the integration of the high TRL prototypes developed together by CONNECTA-3 and Safe4Rail-3 in relevant urban and regional demonstrators in order to validate the NG-TCMS pillar technologies. Within this process, the following achievements and findings have been reached:

- The signal-based Functional Distributed Framework (FDF) for SIL2 applications has been integrated in both urban laboratory demonstrator with a TCMS application and in field test running. On top of it, a Safe Location Application from TD2.4 was demonstrating how the FDF concept could be used to run safe and non-safe application.
- The signal-based FDF for SIL4 architecture has been developed using 1oo2 scheme. Two channels have been synchronized using onboard Ethernet TSN 802.1AS protocol. This FDF has been developed with a TRL4/5 and tested in laboratory as the TCMS market is not yet demanding SIL4 applications.
- Due to the discontinuation of the use of the service-oriented FDF based on Autosar AP to be used in the regional demonstrator[29], a FDF simulator have been deployed for the regional demonstrator.
- The Functional Open Coupling and Application Profiles have been validated over the FDF simulator mentioned above demonstrating its viability in a relevant laboratory demonstrator.
- The Simulation Frameworks (SF) allowing software and hardware in the loop simulations have been configured and complemented to create relevant laboratory environments for both demonstrators to test over them the pillar technologies of the NG-TCMS.
- The Drive by Data (DbD) tests that failed in CONNECTA-2 for TSN features have been repeated with the new network equipment provided by Safe4Rail-3 including higher maturity level and with all features having been validated.
- The Wireless Train Backbone (WLTB) tests that failed in CONNECTA-2 have been repeated with newer radio devices coming from Safe4Rail-3 and new functionalities such as the neighbouring discovery using RFID sensors and multidomain support, validating all features in laboratory for

[29] The reason behind it was the lack of deterministic execution function for Autosar AP within the Autosar foundation's roadmap.

different radio technologies and different inter-consist distances emulated in laboratory with variable RF attenuators.
- For the Train to Ground (T2G) communications, a new service for the IEC 61375-2-6 has been developed: video streaming service. Together with that, T2G implementations have been validated in field test in both urban and regional demonstrators.
- Safe4Rail-3 has performed a proof-of-concept for the synchronization of Virtual Machine running on top of hypervisors using the TSN reference clock of the ECN.

During 2023, TD1.2 has continued the cooperation with OCORA and has actively participated in the ERA Topical Working Group Architecture (TWG ARCHI), together with LinX4Rail, on the topics related to a One Common Bus.

The overall progress is largely in line with the plan established in the Multi-Annual Action Plan, even though one demonstration activity had to be simulated as the development of an external tool (to rail, AUTOSAR) was not confirmed. TD1.2 has experienced some delays due to issues in the electronics supply chains. Nevertheless, these problems have been already solved and the contingency plans applied have limited the impact on the demonstrators. The work accomplished throughout the last years have allowed to successfully complete the High TRL Demonstrators planned for 2023.

TD1.2 Train Control and Monitoring System Demonstrator									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
Finished: Roll2Rail, CONNECTA, SAFE4RAIL, CONNECTA2, SAFE4RAIL2									
						Ongoing: CONNECTA3, SAFE4RAIL3			

During 2023, CONNECTA-3 and Safe4Rail-3 projects have finished within the time planned in their respective grant agreements submitting all deliverables on time and achieving the 100% of progress for TD1.2. Out of the 23 deliverables expected in 2023, all of them have been delivered.

TD 1.3 Car body shell

The new generation of car body shells using composite or other lightweight materials will lead to significantly lighter vehicles that carry more passengers within the same axle load constraints, using less energy and reducing impact on rail infrastructure.

TD Progress

This TD has been implemented via the following projects: Roll2Rail (Completed in 2017), Mat4Rail (Completed in 2019), PIVOT (Completed in 2019), CARBODIN (completed in 2022) and PIVOT2 and GEARBODIES (both completed in 2023).

In 2023, the TD1.3 has been focused on integration of the demonstrator with the subcomponents and tools developed on the previous year and testing the structures, to correlate with the models and checking the requirements of the EN 12663-1 "Structural requirements of railway vehicle bodies - Part 1: Locomotives and passenger rolling stock".


Carbon Fibre Reinforced Plastic (CFRP) Headstock demonstrator

CFRP End module

CFRP HS Carbody on the integration tool

The manufacturing of the demos was achieved proving the reductions in weight following previous assumptions (PIVOT Project) and the results show that the reduction in weight is greater than 20%. All the demonstrators developed (Siemens' section of carbody, Bombardier's section of carbody and Talgo demonstrator full coach of High-Speed train) in different scales using composites achieved the targets in weight reduction. TD1.3 has continued its active contribution to the activities of the working group in CEN/TC 256/SC 2/WG 54 for standardization composites materials aiming to establish a new "Process standard for the introduction of new materials".

The demonstrators have shown the fulfilment of criteria developed for new materials with the loads and procedures described on the EN 12663-1, together with the other functionalities intended for a carbody: fire requirements, conductivity, etc.

During 2023, the HS body in composite material has been presented at JEC 2023, continuing the success obtained from the section presented at InnoTrans 2022. The carbody has received the Innovation award finalist. Visitors could see the possibilities of using alternative materials in the railway industry.

In summary the activities within TD1.3 have proved the use of innovative composite material for primary structural application on railway. The experience and know-how from other industries have been also proved to be adapted for railways understanding the specificities of railway environment (e.g., Fire, smoke and toxicity (FST) compliant, isolation and conductivity). Composites carbody are ready for each railway stakeholder to make their business case considering the needs (full/partial composite) and opens up possibilities for further applications.

TD1.3 Carbody Shell Demonstrator									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
		Finished: Roll2Rail, Mat4Rail, PIVOT							
						Ongoing: PIVOT2, CARBODIN, GEARBODIES			

During 2023, 6 out of 10 deliverables expected in 2023 were released. TD 1.3 has reported having accomplished 94% of the planned work up to the end of 2023.

TD 1.4 Running gear

TD 1.4 continued to work on innovative developments of new architectural concepts, new actuators in a new lighter wheelset, frame and other components, leading to innovative functionalities and improved efficiency and performance levels.

This TD has been implemented via the following projects: Roll2Rail (Completed in 2017), Run2Rail (completed in 209), PIVOT (Completed in 2019), NEXTGEAR (completed in 2022) and PIVOT2 and GEARBODIES (both completed in 2023).

- *Sensor and health monitoring functionality*

The work of PIVOT2 in 2023 included the development of health monitoring systems for Condition Based Maintenance (CBM) of running gears where several research topics were addressed:

The hardware development for CBM allows combining sensor signals for different monitoring purposes. The software solution developed allows different Human Machine Interfaces (HMI) to evaluate condition of several key elements of the bogie (bearings, wheel surface, dampers, …). The results include a description of all the demonstrators carried out by the different partners, such as the novel hardware architecture that allows to combine sensor signals for different monitoring and supervision purposes in an efficient and modular way, intelligent Vehicle Running Instability Detection Algorithm for High-Speed rail vehicles, HW architecture for wireless and wired sensors for CBM monitor solutions, the development of a wayside system to analyse running gear key parameters such as on board and Landside Bogie Health Monitoring System (including subcomponents), on board analysis of bearings, guiding condition, accelerations, etc. as well as Health Monitoring of Tracks.

The aim of all developed systems is to reduce the maintenance cost and increase the availability and safety.

- *Active suspension and control technology*

The main goal of TD1.4 has been to study the impact of semi-active and active suspensions systems on comfort through simulations considering flexible components in multibody simulation. Comfort requirements have become more and more demanding over the years for passenger vehicles in the railway industry.

The vehicle design is usually optimized for a specific vehicle speed and track quality so comfort performance might not be optimal under all operational conditions. A way to improve comfort results under several operational conditions is introducing semi-active or active suspension systems that can modify vehicle performance depending on vehicle velocity and track irregularities. A semi-active suspension system can adjust damping for the components without introducing energy into the system usually by adjusting damper valves. An active suspension system introduces energy into the system to modify system behaviour usually with a force actuator. Disadvantages of semi-active and active suspension system are development and maintenance costs.

The results provided within the activities of TD1.4 show that semi-active and active suspension systems can improve comfort for passenger vehicles in different operation conditions, from Metro to High-Speed application. The largest improvements are achieved with active suspension systems. For semi-active suspension systems comfort index is like passive systems for worse track quality sections but performance can be improved for other sections. The more sophisticated active suspension systems are dependent on a large number of sensors, control units and electrical components.

- *Noise and vibration reduction*

The acoustical environment is cited by train passengers as an important element of comfort, which for railway vehicles traditionally has been defined as pleasant. However, higher running speeds and lighter structures adversely affect vehicle acoustic performance and require an additional effort to ensure an adequate level of comfort. The activities within PIVOT2 are focused on:

- Evaluation of the use of lighter materials in running gear structural components (e.g., composite materials) on the vibroacoustic transmission to the interior of the train, in comparison with the use of conventional materials (e.g., steel) by testing on a High-Speed train on track.
- Evaluation of the interior noise reduction by the optimization or removal of the main direct vibroacoustic transmission paths from wheel to carbody structure, by testing a prototype on lab. Application of the methodology developed to analyse the vibration transmission to a real case.

Simulation and experimental studies results help to analyse the transmission path through mechanical component of the running gear together with the influence of lighter structures. As expected, as it is, composite structures could lead to increase the level of interior noise. Some deep studies should be carried out to explore geometrical alternatives together with other possibilities to compensate the possible increase of noise transmissibility.

- *Optimised Materials*

The single axle running gear frame has proven to be a promising concept for light weight rail vehicles that offers a potential for weight reduction. From a purely technical perspective the estimated weight reduction in terms of running gear weight per wheelset amounts to 20%. By excluding one suspension step the complexity of the system and the number of components can be reduced. The composite frame is built in one piece, meaning less assembly efforts and fewer components.

The life cycle cost of the running gear frame is favourably influenced by the reduced energy consumption and track wear that occurs during the use phase thanks to the reduced system weight. There is also a potential for increased vehicle payload.

A composite antenna beam used in railway bogies can influence the overall weight of the bogie, as well as the maintenance and durability. While this might not directly impact the bogie's weight significantly, it can indirectly affect maintenance cost.

Implementing the thicknesses optimisation along the beam length the weight reduction of the unsprung mass could be achieved up to 70% using the composite antenna beam compared to the steel version. The composite antenna beam underwent several testing steps to cover relevant requirements of bogie component. A light track test showed the behaviour of a better vibration resistance and the ability of deformation of the beam to compensate negative influence caused by various track conditions. Bench test with impact damages and repair of such on the beam was successfully performed.

Weight reduction of the partly unsprang mass could be achieved up to 60% using the composite primary suspension. The composite primary spring underwent several testing steps to cover relevant requirements of the primary suspension. The spring characteristics was validated successfully. The values defined in the specifications were respected and potential effects of temperature were tested without issues (-20°, 0°,

+50°). Assembly of the composite springs comparable to coil springs was checked and process time recorded, with no time increase to perform the task.

The roller rig test validated the dynamical reaction of the suspension under various speed. The behaviour satisfied the expectations. Further, the fire protection showed full compliance with EN 45545 although the fatigue test failed.

The lightweight rodal frame has been manufactured by using non-traditional materials in railway sector for structural parts (composites). To develop this demonstrator, several calculations have been performed, taking present standard for bogie frames as reference (EN 13749:2011). Lightweight rodal frame prototypes one and two have been tested in bench according to bogie frame standard EN 13749:2011 achieving acceptable results. Both prototypes were even subjected to higher requirements than included in EN 13749:2011 standard:

- Higher load levels (25% over exceptional load) have been applied during static loads tests in prototype 1, not founding failure in the structure.
- After fatigue load test in prototype 2, exceptional static load cases were tested, not founding failure in the structure.

In terms of weight reduction, a 46% of total weight has been decreased after the manufacturing of the demonstrator, which is in line with the expectation of 50% of reduction at the beginning of Shift2Rail.

The Lightweight Axle is a new concept of wheelset, where the main components are connected with screws and the shaft is realised as a steel tube with big diameter but small wall thickness. This new wheelset concept benefits the customer in different ways, such as less weight, improved safety, easy assembly, and potentially reduced maintenance costs. A field test with a realised first freight wagon prototype was performed from summer 2021 till summer 2022 and successfully finished. The measurement provided data to create load spectra which allowed a positive validation of the load assumptions and furthermore allowed to perform a positive proof of fatigue strength.

- *Virtual certification*

The activities in PIVOT2 desired to enable easier vehicle homologation processes, in which the running gear plays an important role. This is done by using simulation for the acceptance of running characteristics of railway vehicles. The results are basically proposals to improve the current methodologies, such as:

- proposal to avoid over-speed and/or over-cant deficiency tests, which are difficult to achieve and are costly. It gives a solution based on simulations, without infringing safety.
- highlight possibilities to merge different existing methodology for validation of model. This is an important point as model validation remains a difficult point in every project of virtual testing. New static and dynamic tests with more results (raw measurement on forces, track geometry, rail profile and corresponding accelerations…) should be investigated in the future.
- exploring in detail the influence of wheel/rail friction coefficient and rail profile. These parameters were known as influencers.

These propositions and concrete applications will help the whole sector to use more frequently and more deeply simulations in assessment process of dynamic behaviour. That will lead to reduction of costs, and when mastered, reduction on delay.

- *Universal Cost model 2.0*

The uptake of innovative running gear solutions into the market has often been limited by the lack of evidence of the economic benefits derived from these solutions. The overall objective of the project Roll2Rail was the development of a Universal Cost Model (UCM), a tool that would help incentivising the application of those innovative solutions through the development of an assessment methodology that can quantify the impacts of the running gear performance on the whole rail system economics. The UCM was developed in Roll2Rail and been adjusted and improved by NextGear Project to a new version. One of the main improvements has been the consideration of the damage to switches and crossings, which were not included in the previous version as well as the track settlement or ballast module. PIVOT2 has been guiding the development of the UCM tool by performing validation case studies. It can also be concluded that the

UCM has proven to be a good methodology to analyse the economic effects that innovations of the running gear have on both the vehicle and the infrastructure. It is to be noted that the physical models proposed are empirical and can therefore be concluded that the UCM can only be used to estimate the relative performance, not predicting absolute figures.

TD1.4 Running Gear Demonstrator									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
Finished: Roll2Rail, Run2Rail, PIVOT									
					Ongoing: PIVOT2, NEXTGEAR, GEARBODIES				

During 2023, the remaining 9 deliverables have been submitted. TD 1.4 has reported having accomplished 100% of the planned work to the end of PIVOT2.

TD 1.5 Brakes

The main objective of this Technology Demonstrator is to develop novel braking systems and contribute to the achievement of overall Shift2Rail's mission of increasing the attractiveness of railway by:

- improving the performance, reliability and punctuality,
- increasing line capacity
- reducing lifecycle costs.

Building on the results achieved by the already completed projects Roll2Rail, CONNECTA, PINTA, PINTA-2 and PIVOT, the focus of TD Brakes in 2023, in projects PIVOT2 and CONNECTA-3, was on developing innovative solutions in five areas:

1. Ability to implement brake control functions on electronic platform compliant with safety integrity level SIL 3 and 4,
2. Innovative friction pairing solutions to reduce noise and dust emissions,
3. Electro-mechanic braking system to replace conventional pneumatic and hydraulic technology,
4. Methods and tools for virtual validation and certification of braking system,
5. Improved adhesion management systems for traction and braking; improved virtual testing for WSP systems.

TD Progress

High SIL electronics

To ensure the safety of passengers and goods and achieve the required safety integrity level (up to SIL4) for certain braking functions, modern railway vehicles rely on conventional technology, i.e., pneumatic signals and brake control. The development of an electronic brake control function compliant with high-safety integrity level (SIL3/SIL4) will provide more accurate control and reduction of overall vehicle weight.

After the technical work has been successfully completed in 2022, the task force focused on documentation and creation of deliverables. Final results show the demonstrator activities for High SIL electronics, EM brake, innovative friction pair and adhesion management and contains the final report on the results of the work.

Innovative friction pairings

This research area focuses on the development and design of a new generation of disc and friction material to reduce noise and braking dust and improve braking performance. Furthermore, by reducing the wear of the materials, a longer lifetime is possible, which reduces LCC costs.

After the technical work has been successfully completed in 2022, the task force focused on documentation and creation of deliverables. Final result show the demonstrator activities for High SIL electronics, EM brake, innovative friction pair and adhesion management and contains the final report on the results of the work.

A new, eco-friendly friction pair prototype has been conceived, manufactured and tested at dynamometer during the previous project phases. The results of the test bench trials showed that this new, innovative prototype is able to reduce brake dust as well as brake noise emissions.

As final step of the research development work, a field test with the friction pair prototypes was carried out in collaboration with the company Trenord. The field test aims to validate in service the new developed friction pair under consideration of brake pad and disc wear as well as the brake pad and disc suitability in service.

The field test covered a total mileage of 19.397 km and has included three inspections of the installed brake pads and discs. A visual inspection of the braking components as well as wear and dimension measurements have been taken into consideration. All performed investigations show that the eco-friendly friction pair has properly operated in service. In addition, both components of the friction pair are able to return reasonable wear rates in field. Finally, no indications of a material aggressivity of the brake pad on the brake disc surface could be detected and together with the low amount of measured disc total wear, provide evidence of a good suitability of the brake pad for the brake disc.

Summing up, based on the results obtained from the tests at dynamometer and in field, a full validation of the new, eco-friendly friction pair has been achieved. This innovative prototype is able to make a fundamental contribution to the environmental targets of the contemporary railway.

Electro-mechanic braking system

Currently, railway vehicles deploy either pneumatic braking system in form of purely pneumatic systems, electro-pneumatic system or electronically controlled pneumatic braking systems. Technological trends like electrification and the vision of airless train together with the urge to reduce vehicle weight and lifecycles costs drive the development of electro-mechanic solution. Effective transfer of braking signal, better diagnostics and fewer components and, thus, significant reduction of system weight, energy consumption and lifecycle costs are just some of the advantages of electro-mechanic braking systems.

After the technical work has been successfully completed in 2022, the task force focused delivering the final documentation. The results of the work on the validation campaign performed on EMB confirm that the technological concept is a suitable alternative to the pneumatic brake system. The selected profiles of force, representative of a generic application, have been successfully implemented and achieved with adequate level of accuracy. The next step was to the study of the integration of the electro-mechanical brake into a train system. The test campaign accomplished 180 brake manoeuvres during 4 days when the measurements of movement, acceleration, vibration and functional data of the actuators were performed. These measurements included the following brake manoeuvres: Stopping brakes from 160/ 120/ 80/ 40 km/h to 0 km/h, drag braking constant speed of 160/ 120/ 80/ 40 km/h with applied brake force (up to 36 kN total brake pad force) and braking at track switches with various speeds.

The tests proved successfully to validate the existing samples and provide the necessary prerequisites to release the system to a higher level. The tested samples were validated in the field by exposing them to true vibrations, environmental conditions under true 1:1 brake force. The equipment was successfully integrated into one axle of an existing bogie. The findings of the test campaigns will serve as an essential input for the further development process.

Virtual validation and certification

One of the major cost drivers for the authorization of braking systems currently stems from the necessity to perform comprehensive laboratory and on-train tests as a final validation of the system performance. Building on the work of Roll2Rail and PIVOT, the main objective of this task is to propose improvements to reduce homologation costs and shorten the time necessary for putting rail vehicles in service by using simulation.

After the technical work has been successfully completed in 2022, the task force focused on documentation and creation of deliverables. Tests have been conducted for the brake operations emergency braking and different types of full-service braking (FSB1 to FSB3) characterized by different triggers of the braking action and different brake types (direct / indirect brake). Only air pressure brake tests have been used for the validation of the simulator. Maintaining the safety of the EU railway system was an important objective for the PIVOT2 VVC. In dialogues with NB-Rail and ERA it became obvious that this target could be reached by applying a CSM-RA as defined in EC IR (EU) 402/2013.

A modular and open (in a sense that relevant stakeholders may contribute) simulation framework for collaborative integration and implementation of a VVC simulator for a specific vehicle type has been developed. The applicability of this framework has also been demonstrated. The validation of the simulator counted a total of 54 physical test runs (18 test cases, each repeated 3 times) of an anonymized 10-car EMU has been replaced by 24 physical test runs and 28 virtual test runs (54% less). The applicability of the simulation process defined could be demonstrated. The simulator produced deviations of the mean braking distances compared with the vehicle measurement data within a range of 4%. The reasons for this deviation could not be identified beyond doubt until project end. One working hypothesis is an error in the measurement data.

Adhesion management

Unpredictable physical phenomena in wheel-rail contact make exact determination of braking distance very difficult and hinder all efforts in increasing capacity by taking sufficient braking distance reserves into account. The main objective of this task is the development of solutions (and testing methods) capable of better management of adhesion condition variation to significantly reduce braking distance and torsional vibration during traction and increase capacity and punctuality.

After the technical work has been successfully completed in 2022, the task force focused on documentation and creation of deliverables. With the objective to have a reduction of the negative effects of low adhesion conditions, some solutions have been tested and validated in real vehicles. Based on the outcome of the tests, the torsional vibration detector and traction control optimisation strategies were defined and integrated in the software for EMUs train types. The algorithm had been tested in Euskotren EMU with the improvement in the reduction of torsional vibration values in the conditions tested. The new blending concept was also specified with the simulation test process and integrated into a real system implemented in software. The simulation of the control was improved to have better accuracy with reality, reducing testing time. This new blending concept is tested obtaining satisfactory results and complying the requirements set: improving braking distance, increasing energy recovery to catenary and reducing friction brake elements wear.

Overall, the test runs on the advanced TrainLab confirmed the effectiveness of the adhesion management solution, showing that under low adhesion conditions, the system delivered improvements in terms of vehicle deceleration achieved and braking distances, which could already be shown during test series previously conducted on the test rig. The additional knowledge gained from observing, for example, the system dynamics during braking, or analysing the effects of different control strategies, provided valuable information on how to further develop the solution. The findings are now used to be transferred to series solutions.

The new WSP function shows for UIC water-soap conditions similar behaviour, compared to systems currently used. For extreme low adhesion conditions an increased mean train deceleration up to +25% could be achieved. The adhesion management solution showed on water/soap preparation deceleration values which were comparable to dry conditions. Even on the track conditioned with oil, a significant improvement of the deceleration could be achieved compared to brake applications without adhesion management being active.

TD1.5 Brake Systems Demonstrator									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
Finished: Roll2Rail, CONNECTA, SAFE4RAIL, PINTA, PIVOT, PINTA2									
				Ongoing: PIVOT2, CONNECTA-3					

During 2023, all 6 planned deliverables were submitted. TD 1.5 has reported having accomplished 100% of the planned work up to end of 2023, which represents 100% of the overall TD. All 6 demonstrators of TRL4-6 have been delivered by mid-2023.

TD 1.6 Doors and Access Systems Demonstrator

The challenge of the TD is to provide the public with seamless, flexible and safe access to the train, including persons with reduced mobility, in addition to improve comfort features like noise and thermal insulation. On top of that, this TD is bringing more functionality to the door and access systems toward self-managed and autonomous door for automated train operations till GoA4. Everything must be done with costs and weight constraints.

TD Progress

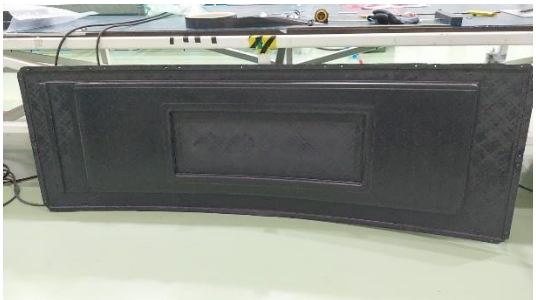
The TD 1.6 has been implemented via the following projects: PIVOT (Completed in 2019), CARBODIN (completed in 2022) and PIVOT2 (completed in 2023).

Door leaves design for acoustic attenuation, thermal insulation and weight reduction

Metallic door leaves: The new design was developed around the use of the new type of structural profiles for thermal insulation and the innovative filling for acoustic attenuation in the new structure of the door leaves (complex arrangement of rigid and flexible materials inside the door leaves instead of rigid foam). The prototypes were manufactured, and the performance tests were finished at the end of December 2022.


Bonding of the insulated pillars (left). Innovative filling material (right).

Composite door leaves: In 2023, the activities concerned the final adjustment of the process, successful manufacturing of the composite door leaves and the final assembly of the doors. Metallic profiles, latches, windows, and handled were installed followed by the 100% successful selected validation tests. Several specimens have been manufactured.




Composite part (left). Composite door leaf (right).

Accessibility

The activities ended in 2022.

Bridging plate on the vibration test bench

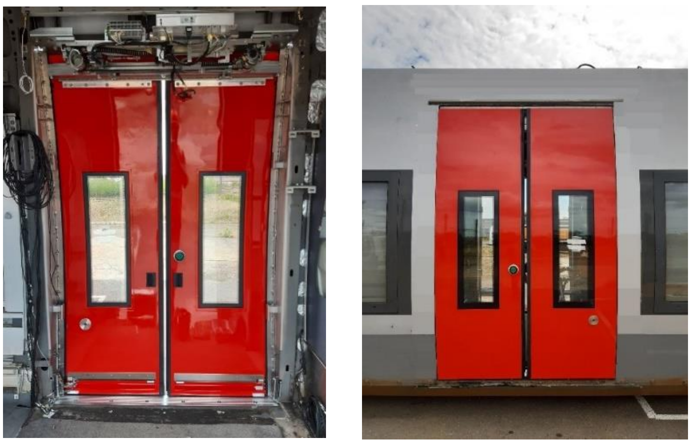
Door surveillance and safety

In 2023, the Euskotren vehicle equipped with a laser sensor centrally positioned above the door continued to be operated. The sensor is located on the inner faces of door leaves for touchless detection of passengers and obstacles between the door leaves and includes a camera implemented on the external face of the vehicle.

View of laser scanner for touchless obstacle detection

Integrated door and demonstration

The double sliding plug doors with metallic door leaves has been implemented in 2022 on an SNCF static train and tests were successfully performed in Autumn 2022. In 2023, the opposite door was equipped with the composite door leaves and 100% successfully tested.



Door mounted on a static SNCF train equipped with door leaves, swinging arm and handles developed with PIVOT2

With the tests performed (reaching at TRL6), the following equipment was validated: Insulated profiles for an improved thermal insulation to be used in metallic door leaves, acoustic box for an improved acoustic attenuation in metallic door leaves, plastic handle, high load swinging arm for a lower weigh, metallic door leaves with insulated profiles and acoustic boxes, composite door leaves based on a single composite core and aluminium profiles and the integrated door.

TD1.6 Doors and Access Systems Demonstrator									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
			Finished: PIVOT						
					Ongoing: PIVOT2, CARBODIN				

In 2023, TD1.6 has reported having accomplished 100% of the planned work up to year end, which is estimated to represent about 100% of the overall TD. Out of the 4 deliverables expected in 2023, all of them have been delivered.

TD 1.7 Train Modularity in Use (TMIU)

The TD develops new modular concepts for train interiors (face and roof) that allow operators to adapt the vehicle layout and atmosphere to the actual usage conditions more quickly and at a lower cost. The objective is to provide the operators with better opportunities of being flexible to the demand and reducing the global cost and the global time to integrate new interiors.

The TD also includes rethinking the driver's cabin to be more compact and evolutive, less costly and more human-centred. It is a prospective design for new driving which impacts the space, the use, and the technologies.

TD Progress in 2023

The TD1.7 builds on the progress made by the following projects: Roll2Rail (Completed in 2017), Mat4Rail (Completed in 2019), PIVOT (Completed in 2019), CARBODIN (completed in 2022) and PIVOT2 (completed in 2023).

INTERIORS and CABIN:
At the end of 2022, all the results and mock-ups have been realised and shown at InnoTrans 2022. During 2023 the TD was focused to finalise the last deliverables and the work ended in March 2023.

TD1.7 Train Modularity In Use (TMIU)									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
	Finished: Roll2Rail, Mat4Rail, PIVOT								
					Ongoing: PIVOT2, CARBODIN				

In 2023, 5 of the deliverables planned were not delivered. TD 1.7 has reported having accomplished about 86% of the overall TD.

TD 1.8 HVAC

The TD1.8 builds on the progress made by the following projects: PINTA3 and PIVOT2 (both completed in 2023).

The main objective of the field test was the comparison of the HVAC-units between a conventional system with an HFC as refrigerant (R134a) and a unit with natural refrigerant CO_2 (R744). The new and a state-of-the-art HVAC-unit were installed on one train and on similar coaches. Except the passenger load, both units are exposed to the same ambient and similar room conditions and therefore the energy consumption can be compared directly.

During field test both units have fulfilled the functional requirements in real operation. No failures have been found in any CO_2 specific component during the tests carried out. With respect to maintainability there is no general difference between the CO_2 and reference unit. Due to the higher complexity of the refrigerant circuit and the longer operation times of the compressor (heat pump mode) the maintenance effort is expected to be slightly higher (10 – 20%), although this can only be verified by practical results from several operating years. In terms of noise, the main sources are the fans which were not changed from the original

R134a HVAC unit, and underly the same control regime in cooling mode. The dominant acoustic source is therefore independent of the refrigerant and no additional measurements were performed.

In terms of readiness for commercial application, HVAC unit with the refrigerant CO2 and integrated heat pump are ready for application in commercial regional single and double deck trains (TRL 7 – Integrated pilot system demonstrated). First units for trams are already in sales order. Hence, the use of natural refrigerant can be changed to a mandatory requirement in HVAC specifications to reduce the climatic impact of future HVAC units and to overcome the shortage of availability of artificial refrigerants. The drawbacks of CO2 HVAC units are mainly the higher capital costs (10 – 20%), the restricted availability of components, the higher weight and the restrictions in coefficient of performance (COP) and cooling capacity at high ambient conditions, which make it more difficult to use this technology for trains in hot or very hot climatic zones. These disadvantages can be partly compensated by reduced annual energy consumption. This is especially important due to the rising energy prices and for application in battery trains to increase the operational range of the trains.

In the current context of reducing refrigerant quotas established by the F-Gas regulations, the use of natural refrigerants is the alternative for air conditioning in railway sector. During the field tests, the cooling and heat pump technology with refrigerant R744 (CO2) was tested on a double-deck regional train under different use conditions and compared to R134a units that represent the current state of the art. In terms of comfort, R744(CO2) is able to maintain comfort conditions according to the EN 14750 standards. Regarding energy consumption, in cooling mode, CO2 technology shows good performance with intermediate ambient temperatures (between 15 and 20°C) and lower efficiency compared to R134a with high temperatures (above 30°C). In heat pump mode, energy consumption behaviour is good, but there is room for improvement in control to increase hours of work in heat pump mode compared to the use of electric resistances.

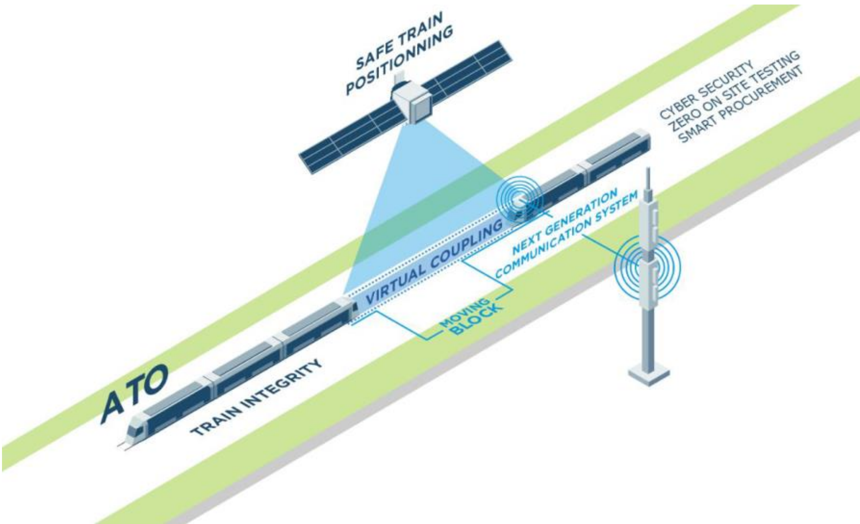
From reliability and maintenance perspective, no failures of the components associated with CO2 technology were detected. Due to high operating pressure, the refrigerant charge is a point to be controlled to ensure optimum efficiency and reliability.

TD1.8 HVAC									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
					Ongoing: PIVOT2, PINTA3				

In 2023, the last 3 deliverables were delivered, achieving the 100% of progress for TD1.8. TD 1.8 has reported having accomplished 100% of the planned work up to 2023.

1.2.2. IP2 Advanced Traffic Management and Control System

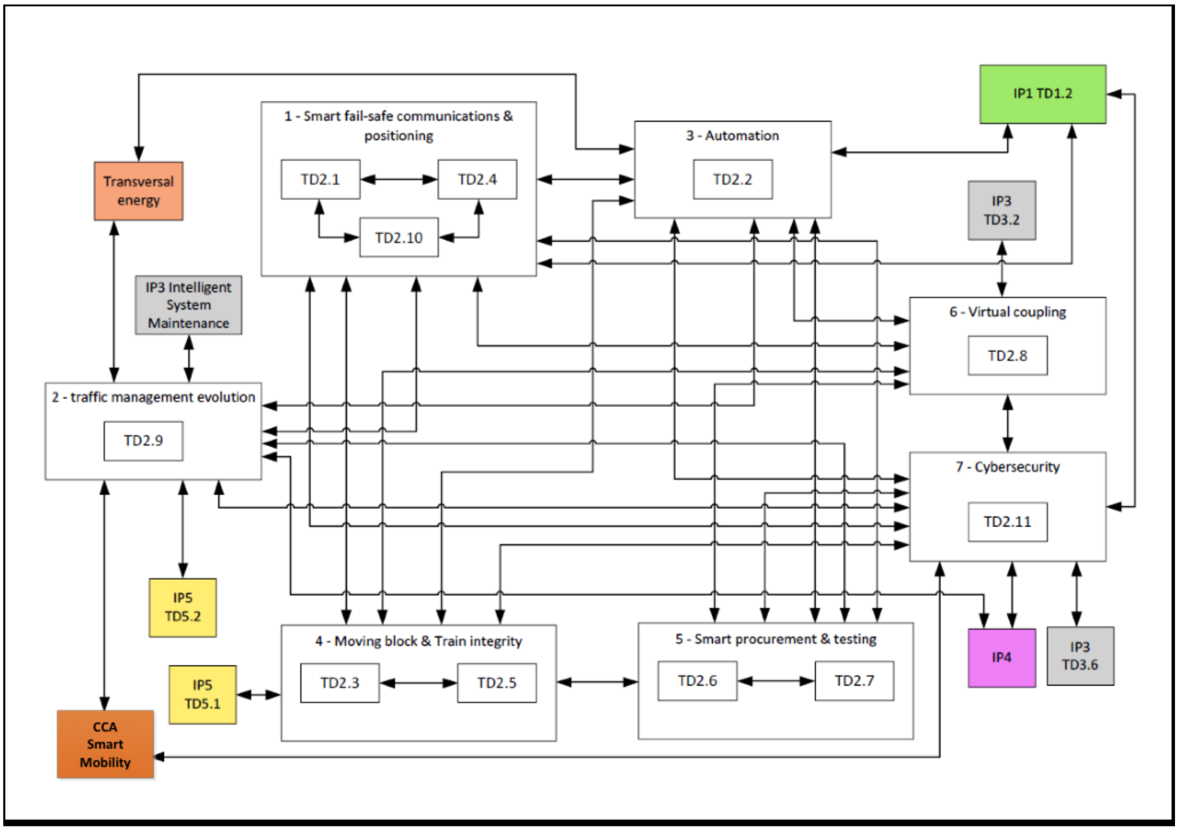
The picture below gives a visual perception on where the TDs will introduce improvements.



The aim of IP2 is to design and develop a control, command and communication systems that goes beyond being only a contributor to the control and safe separation of trains, and to become a flexible, real-time, intelligent traffic management and automation system.

IP2 builds on ERTMS, that, although deployed in Europe to a limited extent, including on core rail corridors, is a worldwide dominant solution for railway signalling and control systems. Current ERTMS systems do not sufficiently take advantage of new technologies and practices, including use of satellite positioning technologies, high-speed, high-capacity data and voice communications systems (Wi-Fi, 4G/LTE), automation, as well as innovative real-time data collection, processing and communication systems. These have the potential to considerably enhance traffic management (including predictive and adaptive operational control of train movements), thereby delivering improved capacity, decrease traction energy consumption and carbon emissions, reduce operational costs, enhance safety and security, and provide better customer information – all in all, the potential for achieving major cost efficiency results for railway operations.

The picture below shows the TDs connections and dependencies within IP2 and with other IPs and CCA.



TD2.1 Adaptable communications for all railways

The purpose of this Technology Demonstrator (TD) is to design, develop and deliver an adaptable train-to-ground communications system using packet switching/IP technologies (GPRS, EDGE, LTE, Satellite, Wi-Fi, etc.) for supporting digital train control applications in all railway market segments. The system will facilitate migration from existing systems such as GSM-R, providing enhanced throughput, safety and security functionalities to support the current and future needs of signalling systems and well beyond; it will be resilient to interference and open to further developments in radio technology.

TD Progress

Throughout the S2R programme, this TD has been implemented via the following projects: the OC project MISTRAL (completed in October 2018), EMULRADIO4RAIL (completed in November 2020), X2RAIL-1 (completed in June 2021), X2RAIL-3 (completed in November 2021), AB4RAIL (completed in 2022) and finally X2RAIL-5, completed in 2023.

The main achievements in 2023 are the following:

- Execution of the field tests for Regional Line in Italy with RFI.
- Finalisation of the confidential field test report with all results included from the different field tests.
- Finalisation of the Executive Summary of the field test results which are public available.
- Finalisation of the System Specification Update based on the field test results of the Adaptable Communication System including an update of the Guideline of Technologies.
- Update of the Business Model for the ACS.

Based on the development activities carried out in previous projects, the last of the three demonstrators with integrated prototypes has executed the field tests in 2023 as planned. The others performed the field tests already in 2022.

With the field test of the regional demonstrator performed in 2023, all segments have been covered.

In the test report all field test results were described per Demonstrator. Furthermore, conclusions were retrieved from the results valid for all demonstrators which are briefly listed here:

- The choice and implementation of Mission Critical (MCX) based control plane and user plane with VPN tunnels and application specific policy-based routing performed well in field test scenarios for the urban, regional and mainline railways. The applications did benefit from the robust and flexible train2ground communication of the ACS, unaware of the underlying radio bearers (public LTE/5G, private 5G, public EDGE, GSM-R (GPRS), WiFi hotspot and Satcom) and their temporal, spatial and performance limitations.
- Public networks proved to be a valuable complementation to private railway radio networks by improving service availability and usable bandwidth. It is assumed that the realized bearer switching approach is robust enough to also cover other than the already tested bearers. This applies to current telecoms networks but may also extend to future ones as envisaged by the AB4Rail project.
- Future research is likely to cover topics such as the integration of specific cybersecurity measures, interoperability aspects as described in the System Specification and performance, in particular in relation to the prioritization of services.
- Bearer flexibility between different technologies such as 3G, 4G, 5G, WiFi, Satellite transparent to the applications were proven.
- One type of bearer handover mechanism is not enough to manage all ACS use cases. A combination of automatic and location-based bearer handover optimizes the bearer changes between multiples radio technologies for railways application.
- The satellite communication is a valid bearer to guarantee the safe runs of the trains in areas where no service interruptions are foreseen. The satellite communication under testing was the Geostationary and it didn't offer the needed bandwidth for the high demanding applications. Future and more advanced constellations can be considered (e.g., Low Earth Orbit - LEO) in order to explore the possibility to ensure higher throughput for concurrent applications.

Some lessons learned are also listed here:

- Field tests have proven to be valuable and gave further results not only due to the dynamics at different speed, but also in terms of stability and maintainability.
- At least 2 set of field test runs would be recommended to fix issues which cannot be solved immediately and also address issues in the environment of the system under test e.g., simulations of applications.

Furthermore, the system specification, on which base the demonstrator were built, was updated taking into account the results from the field tests. The Guidelines of Technologies was also updated and attached to the System Specification. For both documents the results from AB4Rail were incorporated.

In the System Specification the following results were incorporated regarding the Suitable Transport Protocols running over ACS infrastructure.

The investigation was performed taking into consideration:

- different type of traffic sources (constant bitrate, variable bitrate, File Transfer upload and download, periodic message transmission like ETCS/TCS like traffic). In particular relevant ACS traffic classes like signalling, Critical Voice, Critical Video, critical and non-critical data have been considered,
- different transport protocols: TCP with different congestion control algorithms as BBR (Bottleneck bandwidth and round-trip propagation time) and Cubic, UDP, SCTP and QUIC,
- different application layer protocols: HTTP and FTP and their secure versions (HTTPS, SFTP).

In case of lossy channel, results have shown that in every scenario the TCP, BBR and QUIC protocols offer the better performance due to the following (but not only) observations:

- The above-mentioned protocols are able to track the available transmission channel capacity that can vary with time in railway scenario.
- The protocols are resistance (i.e., practical insensitivity) to packet loss; in fact, it was observed that in all cases the CDF of the throughput at packet loss equal to 1% are similar to that obtained at packet loss equal to 0%.
- Coexistence issues among different flows in the same tunnel using TCP protocol with different congestion control algorithms have been observed. This should be considered in the design stage (e.g. TCP-BBR can starve TCP-Cubic).

In the attachment "Guidelines of Technologies" of the System Specification, the additional bearers investigated in AB4RAIL were added such as Wireless Optics, Power Line Communications, Low Energy Bluetooth, Zigbee, UWB, Low Power Wide Area Network, High Altitude Platform Systems, Novel Sat Leo Constellations.

Finally, the Technology Demonstrator continued its cooperation with the UIC project "FRMCS" (Future Railway Mobile Communication System) which led to further updates of the System Specification of the ACS. The System Specification from TD2.1 was discussed in detail with the FRMCS project and have influenced the Functional Requirements Specification as well as the System Requirement Specification for FRMCS.

In 2023, the three deliverables expected for the period have been delivered and approved. TD2.1 has reported having accomplished 100% of the planned work in 2023, which represents 100% of progress of the overall TD.

TD2.2 Railway network capacity increase (ATO up to GoA4 – UTO)

ERTMS/ETCS, the current generation of mainline signalling, faces a growing challenge to provide the performance improvements and increases in line capacity needed by (European) Main Line operators.

Using Automated Train Operations (ATO) with ETCS is an answer to this challenge. This technology is already vastly deployed in urban transport where different grades of automation are implemented including driverless and unattended operations. The objective of this technology demonstrator is to develop and validate a standard ATO (up to GoA/4) over ETCS, where applicable, for all railway market segments (mainline/high speed, urban/suburban, regional and freight lines).

TD Progress

During the S2R programme, the Technology Demonstrator (TD) built on the following projects: ASTRAIL (completed in 2019), X2RAIL-1 (completed in 2021) and finally X2RAIL-4 (completed in at the end of 2023).

ATO GOA 2 activities

Regarding ATO over ETCS on GoA2, the requests for change raised by TD2.2 (further to interoperability tests performed on the Reference Test Bench in January 2019) have been addressed together with the European Union Agency for Railways (ERA) in the context of the ERA Extended Core Team meetings (EECT), responsible for the maintenance and update of the ERTMS/ETCS specifications (in the context of the preparation of the new CCS TSI).

The reports of the two pilot tests executed in 2020 in the United Kingdom and Switzerland have been delivered in March and June 2021, respectively. These reports were also used as the basis for the update of the GoA2 specifications at EECT level.

The following GoA2 specification documents have been delivered discussed and agreed in EECT meetings with the ERA, for integration in the new CCS TSI:

- ATO over ETCS System Requirement Specification (SUBSET-125);
- ATO over ETCS ATO-OB/ATO-TS FFFIS Application Layer (SUBSET-126);
- ATO over ETCS ATO-OB/ETCS-OB FFFIS Application Layer (SUBSET-130);
- ATO over ETCS ATO-OB/TCMS FFFIS Application Layer (SUBSET-139);
- ATO over ETCS Interface Specification - Communication Layers for On-board Communication (SUBSET-143).

These SUBSETs have been officially integrated in the CCS TSI, approved in 2023 (Annex A). They are used for product development by several suppliers and applied in current and future revenue service projects.

ATO GoA3/4 activities

The TD has continued working on the System Requirements Specification for Automatic Train Operations up to Grade of Automation 4 (unattended train operations), further elaborating on the following chapters:

- The operation contexts and the associated actors;
- The operation Use Cases;
- Logical Architecture;
- Interface definition;
- The functional requirements allocated to the Logical Architecture;
- Interface specifications (FIS level) between the Logical Components.

These ATO (up to GoA4) Specification have been frozen in September 2022 to allow the start of the development of the prototypes which will be used for the pilot tests in factory and on site in 2023.

The specification of the Reference Test Benches has been completed being used for the interoperability tests in factory. Two Reference Test Benches have been developed and used for interoperability tests in ALSTOM and STS premises.

The test scenarios for site tests have been specified. And a pilot train belonging to AZD has been fit to support ATO.

The interoperability tests on-site have been successfully performed in November 2023.

In parallel with these activities dedicated to the pilot tests, TD2.2 has continued to refine the specification of ATO (up to GoA4).

To perform this refinement, the TD has collaborated with the following projects (joint workshops):

- OCORA: the aim was to align that the logical architecture issued by TD2.2 and the OCORA initiative;
- CONNECTA series: the aim was, first, to agree on the standard interfaces between the ATO (up to GoA4) system and the TCMS; and, secondly, to agree on the functions exported to the TCMS;
- SFERA: the aim was to agree on a common specification for the track/train communication for Driver Advisory System (DAS) and ATO application.

The work performed in 2023 via factory and on-site testing constitutes a major input for the work to be taken a step further in the Europe’s Rail Programme.

In 2023, the six deliverables expected were delivered. The project reports having accomplished 100% of the work for 2023 which corresponds to 100% of the overall TD activities.

TD2.3 Moving Block

Improving line capacity by decoupling the signalling from the physical infrastructure, and removing the constraints imposed by trackside train detection is the key objective of this technology demonstrator. This will allow the transit of more trains on a given (main) line, especially for high-density passenger services. The system is expected to be compatible with existing ERTMS specifications.

TD Progress

Throughout the S2R programme, the Technology Demonstrator (TD) has been implemented via the following projects: X2Rail-1 (completed in 2021), X2Rail-3 (completed in 2021), ASTRAIL (completed in 2019), MOVINGRAIL (completed in 2022) and PERFORMINGRAIL and X2RAIL-5, both completed in 2023. The work of the TD was however officially completed in 2022.

The TD updated the System Requirements, Operational and Engineering Rules and Safety Analysis, and created a report on the three Moving Block Technical Demonstrators within X2Rail-5:

- The updated System Requirements Operational and Engineering Rules reflect validation of the work from X2Rail-3 via the examination of a number of "Use Cases", and examination of number of specific topics, including Train Location, and Track Status. There are now much more clearly described in the updated documents.
- The Safety Analysis includes the Risk Analysis and has been updated to be compatible with the new version of the System Requirements, Operational and Engineering Rules.
- The report on the three Moving Block Technical Demonstrators highlights the achievements of these Demonstrators, and validates the approach taken within the System Requirements.

The TD has created two main Moving Block concepts:

- Full Moving Block (FMB): The system can issue Movement Authorities based on the reported location of the rear of the preceding train. End of Authority can therefore be at an arbitrary location in the railway.
- Fixed Virtual Block (FVB): The system determines occupancy of the Fixed Virtual Blocks based on reported train locations. In this system the end of a Movement Authority can only be at discrete locations predefined during system design.

Three Moving Block demonstrators were created. Two of the demonstrators were implemented for the Fixed Virtual Block System Type. The other demonstrator was implemented for the Full Moving Block System Type. In each case, the demonstrators showed a number of different scenarios, which are listed in the report. For example:

- Normal Train Movement
- End of Mission, Start of Mission
- Loss of Communications
- Loss of Train Integrity

The demonstrators addressed respectively the following market segments: high speed, flow traffic and urban/suburban traffic. Full moving block was tested and proven on the high-speed demonstration. The concept has been proven allowing some aspects to be fine-tuned in the delivered specifications.

The work in X2Rail-5 represented the final round of improvement to the Moving Block specification. The TD worked to answer some of the open points remaining at the end of the work in X2Rail-3 and re-assessing the specification against the Use Cases. One new Use Case Description was prepared, Use Case Reserved, which covers the processes for requesting and extending a Reserved area of track for a train. The specification was released at the end of 2022. This deliverable specifies the behaviour of the ETCS Trackside in Level 3 Moving Block, together with Operational and Engineering Rules and safety analysis.

During 2023, the X2Rail-5 team completed the final deliverable "D4.2 Moving Block Enhancements", which was submitted at the beginning of the year. This deliverable encompasses recommendations for Moving Block related "enhancements" i.e., impacts on introducing the Moving Block concept in the ETCS specifications.

In 2023, the TD has delivered the remaining deliverable. TD2.3 has reported having accomplished 100% of the planned work up to the year end, which represents 100% of the overall TD.

TD2.3 Moving Block									
2015	2016	2017	2018	2019	2020	2021	2022	2023	…
	Finished: X2Rail-1, ASTRail, X2Rail-3, MOVINGRAIL								
					Finished: X2RAIL-5, PERFORMINGRAIL				

TD2.4 Fail-Safe Train Positioning (including satellite technology)

This Technology Demonstrator aimed at developing an innovative Fail-Safe Train Positioning (FSTP) system, using Global Navigation Satellite Systems (GNSS) as the preferred technology to compute absolute positioning.

Two possible approaches towards introduction of satellite-based positioning technology for railways have been analysed and tested. On one side, the FSTP has been realized as a functional block of the current core of ERTMS/ETCS and absolute positioning has been based on the Virtual Balise (VB) concept, reducing the impact on current specifications. On the other side, the FSTP has been implemented as a Stand-Alone (SA) subsystem that calculates the train travelled distance, speed and absolute train position via an enhanced, safe, multi-sensor apparatus.

Both approaches aimed at enabling the use of new technologies to boost the quality of train localisation and integrity information, while also reducing the overall life cycle costs, by enabling a significant reduction in all conventional trackside (train) detection systems, such as balises, track circuits or axle counters.

Throughout the S2R programme, this Technology Demonstrator (TD) was implemented by the following projects: X2RAIL-2 (completed in 2021), GATE4RAIL (completed in 2021) as well as X2Rail-5 and PerformingRail, both projects completed in 2023. X2Rail-5 aimed at completing the remaining activities foreseen in TD2.4 by bringing the work to higher TRL levels, via demonstrators.

TD Progress

A dedicated activity aimed at defining an interoperable solution for the Satellite-Based Fail-Safe Train Positioning system, through the continuation of the work done in previous projects. Interaction with other projects and collaboration with relevant organizations (ERA, EUSPA, ESA, etc.) was also managed within this task.

This objective has been achieved through three main workflows which proceed synergically:

- specification of the Satellite-Based Fail-Safe Train Positioning requirements, orientating the implementation of the Stream 1 and Stream 2 demonstrators with a top-down approach, and taking into account the feedback from the demonstrators with a bottom-up approach;
- collaboration with the EUG-S2R JWG for the definition of an interoperable solution which includes the Augmentation and Digital Map identified by the JWG as main topics of interest;
- definition of the roadmap for the introduction of the Satellite-Based Fail-Safe Train Positioning system within the TSI associated with the ETCS SRS.

During 2023, the following objectives have been addressed:

- Handover to the System Pillar and to the technical teams in the Europe's Rail Programme of the updated set of documents, recommendations, and strategic issues about the EGNOS services integration for safe rail applications, collaborating with the Space Agencies (EUSPA, ESA, ESSP).
- Analysis of the Digital Map (DM) topic and provision of the main subjects of interest within the documents provided by the EUG-S2R JWG, such as the definition of the minimum dataset to be contained in DM Data for positioning functionalities and the consolidation of DM Management functionalities.
- Significant results in the roadmap for the definition of an interoperable solution for the Satellite-Based Fail-Safe Train Positioning, through the analysis of the functional and architectural aspects

to allow substantial progress towards the objective of the integration of the two Streams, and to define a common interoperable solution. In particular, big effort has been spent in consolidating an effective proposal for the integration of a Stream 2 FSTP (i.e., Stand-Alone FSTP) in the ERTMS/ETCS system. The resulting solution foresees the introduction of a new "Balise Telegram Reporter" functional block whose functional outputs are analogous to those provided by the "Detect Virtual Balise" functional block of the Stream 1 FSTP in the ERTMS/ETCS. Given this, the two Streams converged to an aligned functional architecture for the location related functional blocks of the future ERTMS/ETCS on-board, whereas some architectural differences between the two Streams come out when a physical architecture is defined.
- Definition of the further steps and structure of the future required activities needed for introduction of the fail safe and interoperable train positioning solutions into an effective use, issuing the Roadmap and Migration Strategy to reach the common resulting solution.

Two additional streams of the work have been dedicated to the finalization of the activities carried out in previous projects concerning the development of both Virtual Balise based and Stand-Alone Fail-Safe Train Positioning System demonstrators.

Regarding Virtual Balise based Fail-Safe Train Positioning System, trial sites for the demonstrators have been set up and used to complete the data-acquisition campaign and tests. Each demonstrator exhibited unique results, aligned with their design and the technical solutions used in supporting the Virtual Balise Detection, showcasing noteworthy overall performances. These performances highlighted important takeaways and best practices implemented in the different demonstrators.

In AŽD TRL 4/6 demonstrator in Czechia, the position errors of VBs are mostly a few meters, in only one case the error is above ten meters. The confidence interval has huge variability (from 20 m to beyond 200 m), in relation to the surrounding environment. Incorporating track data into the onboard algorithm has emerged as a crucial factor in enhancing safety and accuracy.

Hitachi tested in Italy a TRL6 demonstrator with both a local augmentation network and EGNOS, in a fully integrated ETCS system (both on-board and trackside operating on a real line). Position error with local augmentation is below 5 meters; also with EGNOS the error is usually around 5 meters, but with a higher variance. SIL4 confidence interval was about 20 meters with the local augmentation and exhibited a stronger variability using EGNOS.

Results of MERMEC TRL 4 demonstrator in Italy are similar, with a position error typically below 5 meters and a 3σ confidence interval typically below 10 meters.

Regarding Stand-Alone Fail-Safe Train Positioning System, the proposed demonstrators have been developed and tested to assess the feasibility of a solution according to the analysis of previous projects as well as the new requirements, to support the definition of an interoperable solution for a stand-alone train positioning system.

CAF TRL 5/6 demonstrator in Spain integrated GNSS, IMU, tachometer and Digital Map to achieve a position confidence interval (3σ) below 20 m. Track discrimination was also implemented, but balise integration is still required for deterministic first position fixing.

SNCF TRL 5/6 demonstrator, tested in France, was based on multi sensor acquisitions, using EGNOS V3 DFMC emulator. Average distance error was below 0.2 m and average speed error was below 0.02 m/s. but results are not yet from a real time algorithm execution and do not include track selectivity functionality. Thales TRL 5 demonstrator in Germany was based on dual channel of GNSS, IMU, speed sensors and Digital Map, and used the first track position as a given position (no track discrimination). Speed confidence interval did not always cover demanding performance requirements and position errors were sometimes above the 10 m +2%, under non-favourable GNSS conditions.

TRL 5/6 developed in collaboration between Siemens, Airbus and DB port ed the sensor fusion algorithms developed in the CLUG project (limited to along-track position and speed) onto a life demonstrator onboard a train, for comparison with the other demonstrators.

Moreover, a broader statistical evaluation on a dedicated commercial line for error repeatability analysis has been executed.

PerformingRail, the complementary open call project, aimed at delineating through formal modelling and optimised traffic management, a moving block railway signalling using advanced train positioning approaches that mitigates potential hazards for the different type of traffic.

In 2023, the validation of the GNSS Location Simulator has been completed, by designating various scenarios to simulate possible hazards that can potentially degrade position estimates based on GNSS, including a series of test campaigns performed with the loosely coupling implementation of the GNSS + IMU positioning engine.

TD2.4 has reported having accomplished 100% of the overall planned work in 2023.

The results achieved up to 2023 through analysis, lab and on-site testing will constitute a major input for the activities foreseen in the Europe’s Rail Programme.

TD2.5 On-board Train integrity

The TD was completed in 2022.

TD2.6: Zero on-site testing (control command in lab demonstrators)

The development of a new laboratory test framework comprises simulation tools and testing procedures for carrying out open test architecture with clear operational rules and simple certification of test results. It aims at minimising on-site testing (with the objective of Zero On-Site Testing - ZOST) by setting-up full laboratory test processes, even when systems comprise subcomponents of different suppliers. The test framework will also allow remote connection of different components/subsystems located in various testing labs.

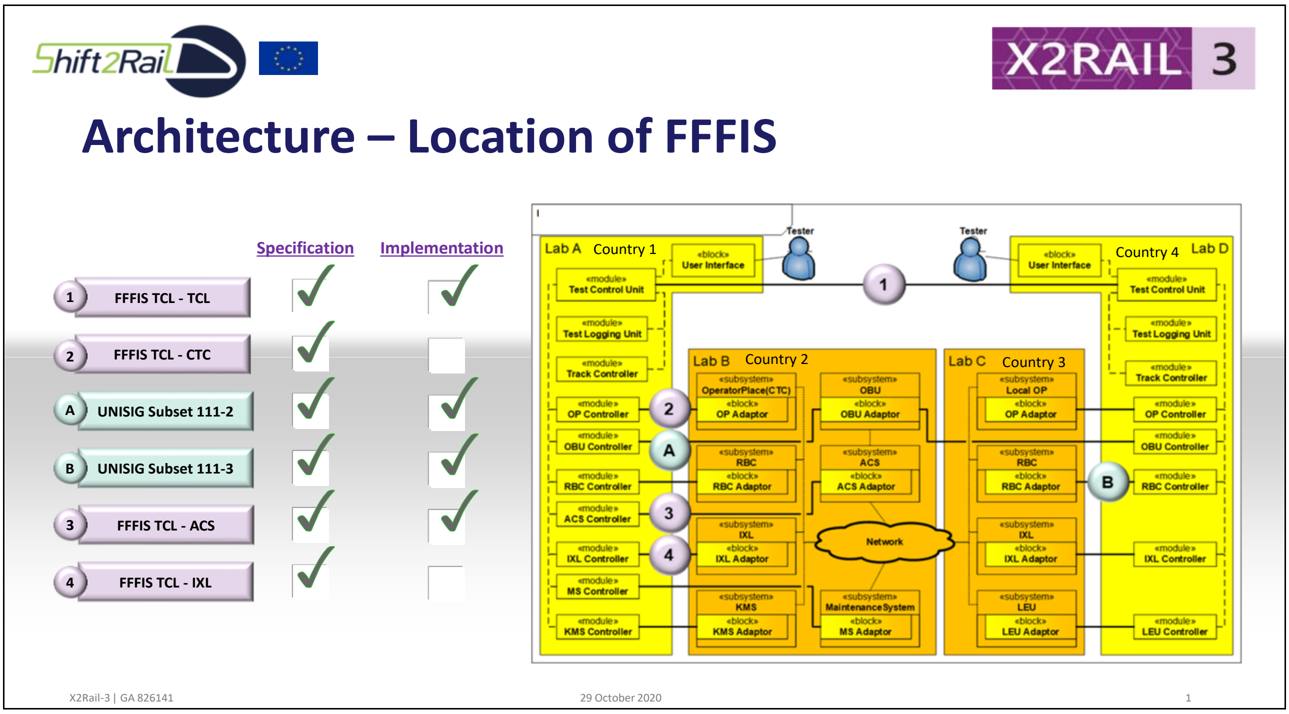
TD Progress

The activities related to this TD were started in X2RAIL-1 and the first results have been ready since December 2018. These results include a benchmarking analysis, the description of the test process and the definition of a full system test architecture for the necessary test environment to support shifting testing from the field to the lab. In this timeframe the results of the VITE open call have been jointly analysed and considered.

The TD continued the activities in 2019 as part of the X2Rail-3 and GATE4RAIL projects working on the following milestones finishing in 2020:

- definition of a generic communication model,
- data modelling for the test environment and
- validation of data with formal methods

In 2019, the generic communication model has been defined. In this generic communication model, several different interfaces and adapters are specified down to the level of FFFIS (Form Fit Functional Interface) specifications. They will make part of an important cornerstone for the implementation of the prototypes in 2020, the following picture shows which Interfaces had been specified and which of these specified interfaces are implemented and tested in 2020:



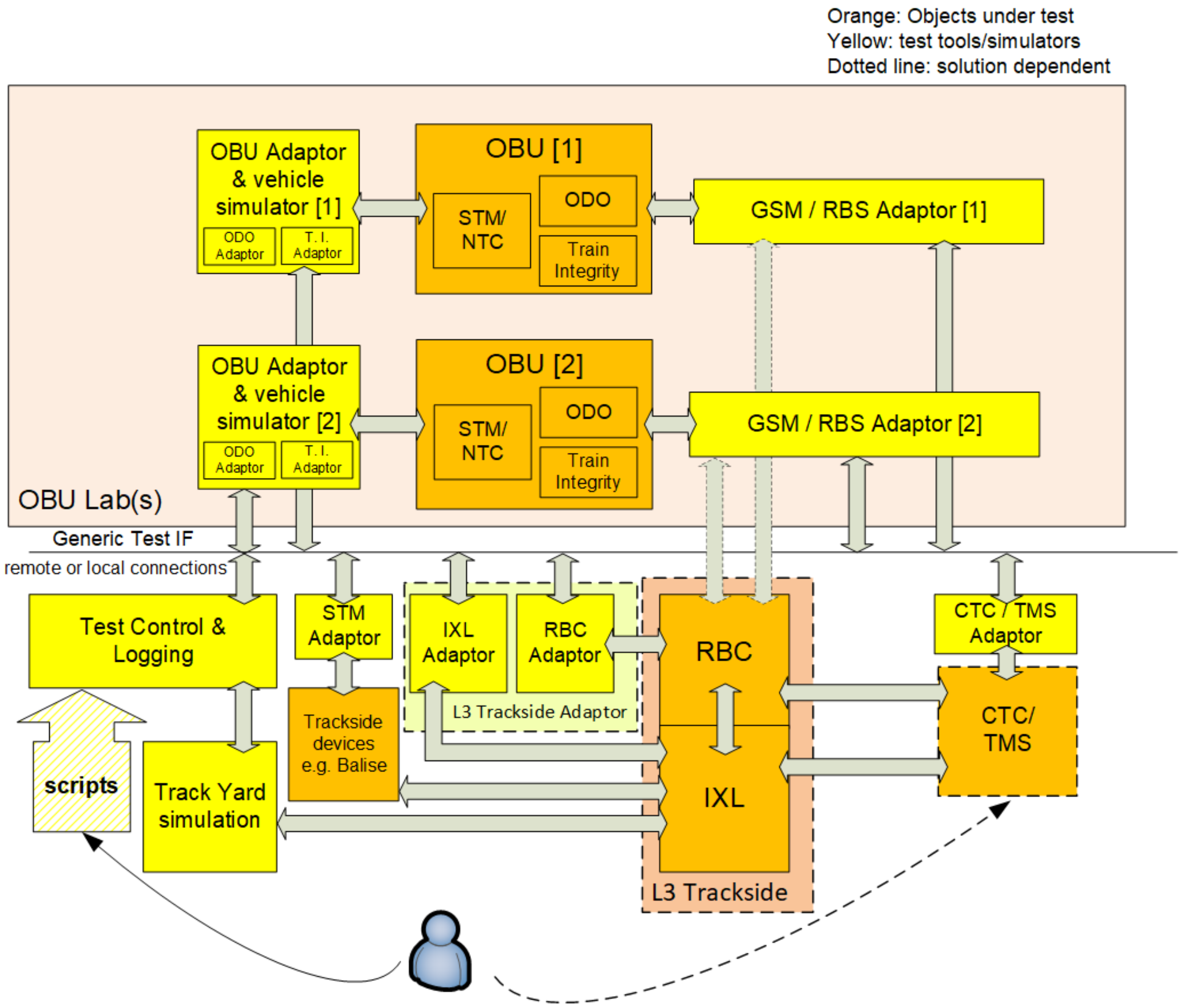
An initial data model to set up the common prototypes was finally agreed in 2020 and the analysis using formal modelling for verification of this data has been completed (D5.2).

For the above shown UNISIG and FFFIS interfaces various prototypes were implemented by the partners of TD2.6. In 4 different prototypes these interfaces were tested and a common verification report including the test results (D5.3) was delivered.

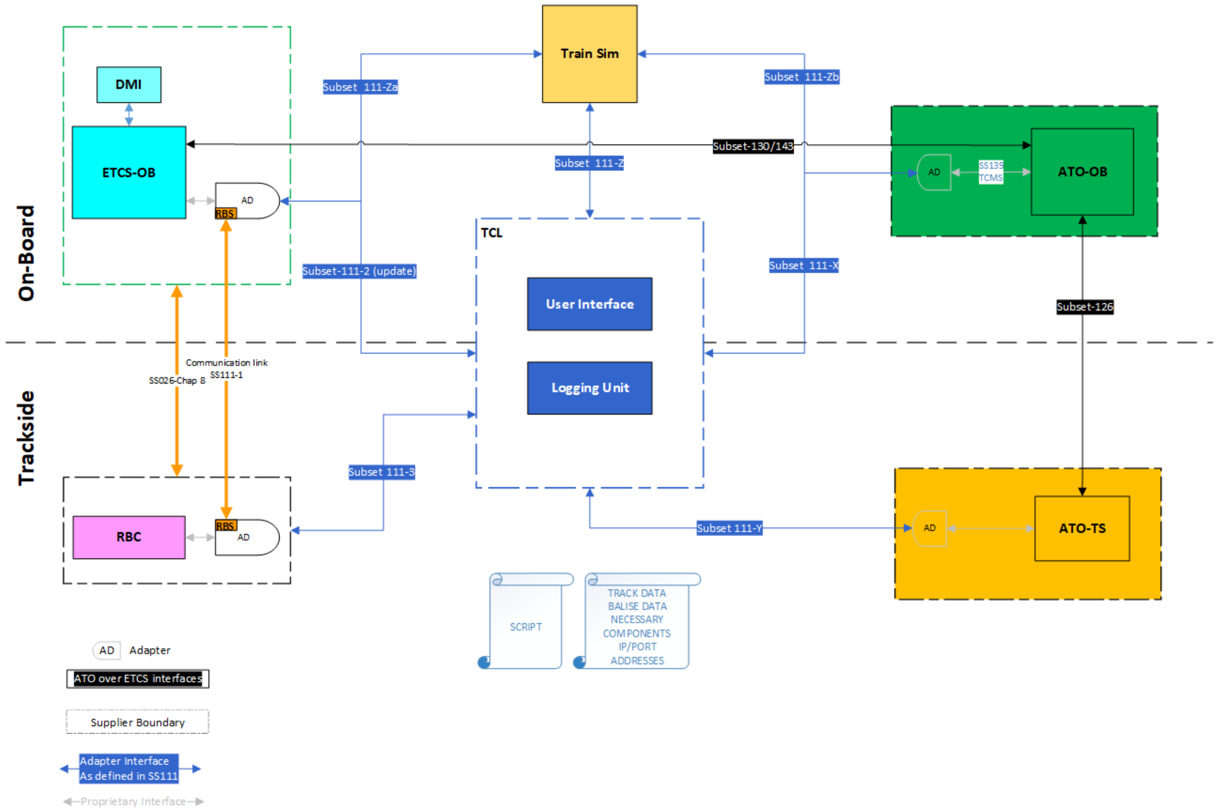
In 2021 – as part of the X2R-5 project in WP8 – the test architecture defined in X2R-3 has been rigorously analysed, to confirm that it is flexible enough to cover all the Zero On-Site Testing requirements. All of the new subsystems to be included in the testing architecture have been identified, according to the prototype development activities foreseen in X2R-5 WP9, together with the needs of other technical demonstrators. A series of workshops with all the representatives of the technical demonstrators were held to share with them the requirements of ZOST, the architecture and the testing model, and to take into account the suggestions and possible changes emerging from the current state of their work packages.

Based on these results, especially the Moving Block and ATO testing activities have been included within the Zero on Site Testing architecture, with the definition of the new interfaces and related specification(s). This was done as an update of the existing FFFIS/Subset 111 and by the creation of new documents:

- FFFIS for TCL - ATO-OBU adaptor
- FFFIS for TCL - ATO-TS adaptor
- FFFIS for TCL -Train Simulator, for Train Simulator – OBU Adaptor and for Train Simulator – ATO-OBU Adaptor



Use case "Environment for validation of Moving Block"

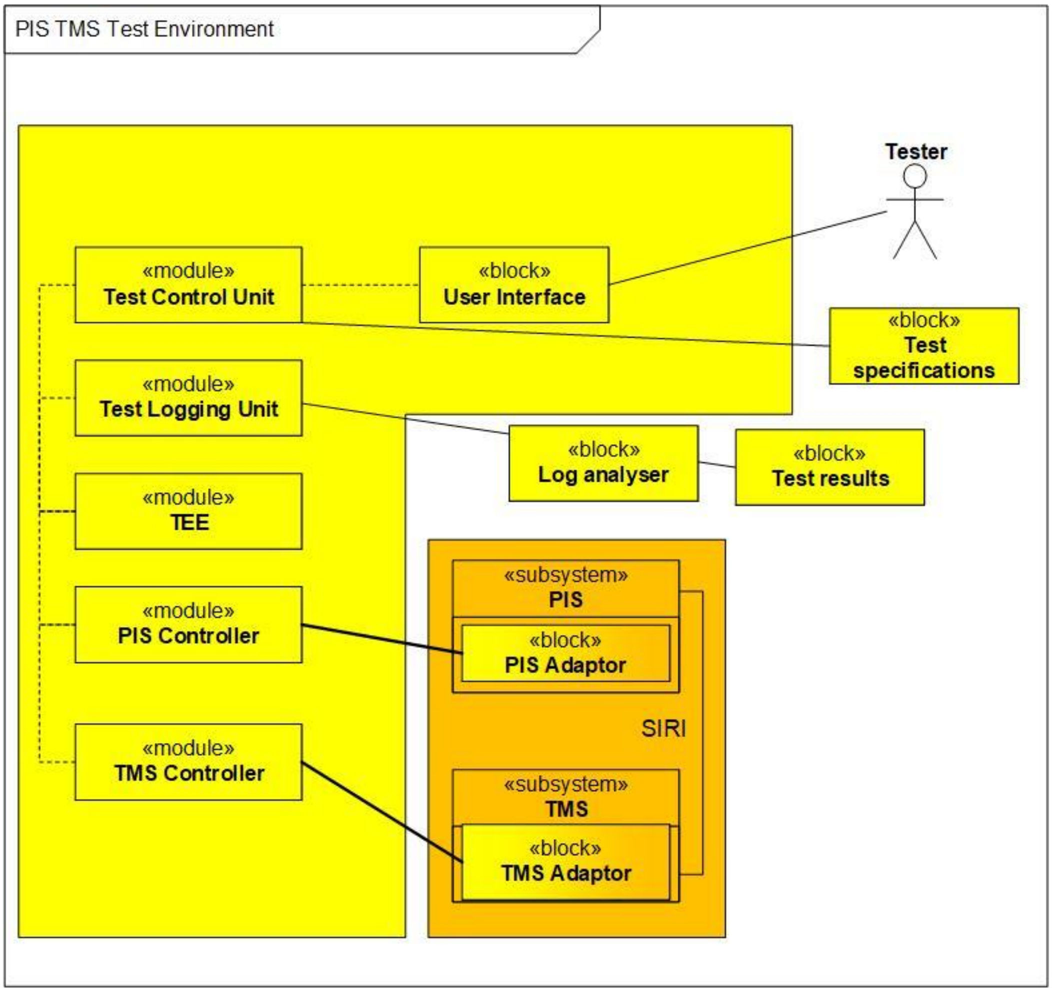


ATO Testing Architecture

According to the experience gained by all the partners involved in the prototype-development in X2Rail-3, the use of RailML as common data model has been analysed, and it was confirmed that not all information (such as information other than the description of the track data) can be represented in RailML. Consequently, it was deemed necessary to address the definition of the new data model. Alignment meetings with the LinX4Rail project representatives were held in order to discuss the use of the Common Data Model. While no final decision has been made, an opportunity has been created to fully address the issue in the future, specifically based on the needs of each testing activity.

Second activity in 2021 for TD2.6 was the update the test architecture defined in X2Rail-3 with the addition of a new set of standards related to the connection of TMS and PIS to exchange disruption management related information. This will complement the activities of X2Rail-3 to define standard data exchange inside the test environment.

The deliverable was prepared to cover the FFFIS standard to be used and the required automated test procedures for testing the connection of TMS and PIS based on the relevant (selected) test cases. By having undertaken an assessment of available communication standards for interfaces between TMS and PIS, it was decided to use the existing and well-established interface standard CEN/TS 15531 Service Interface for Real-time information (SIRI) [3] as the required FFFIS deliverable.



Third activity in 2021 was the analysis of system boundaries for the distributed Lab and a feasibility study for Digital Twin concepts in Zero On-Site Testing.

The boundary analysis compared these boundaries with the goals of Zero On-Site Testing and the potential business impact. A list of potential boundaries was created and analysed. Additionally, the impact of the distributed lab may have on the input data was analysed as well as finding solutions to mitigate against this impact.

Content of the Digital Twin Feasibility Study was the analysis of the applicability of different digital twin approaches for their usage in the railway sector for Zero On–Site Testing. Based on the very specific expectations from Zero On-Site Testing a definition was developed. In addition, possible Use Cases for implementing Digital Twin concepts in the existing test architecture were derived respectively Use Cases for expanding the test architecture were defined.

Based on the updated test architecture as well as the input coming from the feasibility study and further features within the context of game changers i.e., moving block or ATO, the focus of Zero On-Site Testing will be the completion of these requirements by providing additional simulation capabilities to the test environment focusing on interoperability tests between suppliers in a train handover scenario across borders with same supplier RBC or another supplier's RBC.

In 2022 the activities of the TD were focusing on the final definition and implementation of different prototypes. The prototypes are focusing on the following:

- Moving Block – will provide adapters to test the Moving Block System
  - The test-environments of the different Moving Block Technical Demonstrators (Urban / Suburban, Overlay, High Speed Lines and Low Traffic / Freight), developed in X2Rail-3 and continued X2Rail-5 are based on the Zero Onsight Testing architecture. Available

solutions for interfacing e.g. train- or RBC adaptors are combined with additional components/interfaces (e.g. interlockings) developed during X2Rail-3 and X2Rail-5. This enables a comfortable (and comparable) test execution done in different/distributed test labs.

- ATO – 2 different types of demonstrators focusing on the implementation of the adapters and the tuning of operational speed profiles within different segments
  - ATO interoperability will develop and validate a test environment for ATO interoperability tests based on the ZOST concept (adapter, ATO-OB, TCL, Train Sim and ETCS-OB). In addition, the test report resulting from this activity will be issued.
  - ATO Test Bench to optimize project implementations – focusing on developing and testing tools for segment design, run-time calculation and simulation of scenarios with the designed segments and timing points.
- ACS – Prototype Enhancement focusing on the transitioning from GSM-R to ACS
  - The target is to transition our test environment from a 2G set up to an FRMCS (5G) set up
  - IP based configuration but without Siemens this year which obliged Kontron and CEIT to rethink the complete environment
  - The time-consuming item is also to set up a brand new 5G environment in lab
  - The integration of the saboteur element is performed through a distant connection between lab in France and lab in Spain
  - Update of the saboteur according to the improvement of the prototype; additional faults implemented.
- Train Integrity – adding train integrity adapters
  - The focus on the Train Integrity Prototype Enhancement is to test that Train Integrity checks are executed correctly.
  - The prototype enhancement will be integrated with ETCS On Board Unit and tests will be carried out in order to verify the train integrity functionalities provided by the architecture defined in X2Rail-3 and X2Rail-5. Then a test report will be generated and released.
- TMS/PIS – demonstrator for auto testing of PIS/TMS using CDM
  - Test Demonstrator for automated lab testing of TMS/PIS interfaces to integrate TMS disruption management information to PIS based on standard protocol interfaces and the TMS Integration Layer (CDM).
- SWOC – prototype for online observation to mitigate outage
  - Using the possibilities of smart wayside objects opens a wide sphere of activities. One example: Based on data collected from real field elements a scientific approach is elaborated to prophesy with a high probability a malfunction. This can lead into better planning of maintenance and therefore will increase the level of safety. This approach also shows, which data should be collected online to enable a continuous observation.

The implementation of the prototypes has been finalized in 2023. Multiple test cases have been used to show the feasibility of the architecture and the demonstrator. The prototypes have been proving that the defined architecture is suitable to support the testing in the field also for the game changers defined.

In 2023, the TD has delivered the final reports on the implemented prototypes / demonstrators. In addition, the results have been summarized in a video and presented at the final event. The know-how has been shared with the follow up project in EU-Rail´s FA2. TD 2.6 has reported having accomplished 100 % of the planned work up to the end of 2023, which represents 100% of the overall TD.

TD2.7 Formal methods and standardisation for smart signalling systems

Formal methods (FMs) provide the means to establish correctness of a system model with respect to given properties, to improve verification, certification, and authorisation processes, while reducing the dependency on traditional and laborious V&V methods. The purpose of FMs use is to increase requirements quality, make it easier to implement and verify compliance, reduce dependency on manual judgement, and help achieve modularity. FMs enable these benefits by model building and rigorous model analysis before production. To verify safety is considered one of the most compelling use cases for FMs. FMs and standard interfaces aim to contribute to reduced life cycle cost and time-to-market, increased market competition and standardisation, and improved interoperability and reliability. While standard interfaces are orthogonal to formal methods (one can use one without the other), they help increase competition, and enable more efficient use (and reuse) of formal methods.

TD Progress

Throughout the S2R programme, this Technology Demonstrator (TD) was implemented via the following projects: X2Rail-2 and 4SECURAIL (both completed in 2021), PERFORMINGRAIL and X2RAIL-5 (both completed in 2023.

This TD created the FMs Guidebook due to interest from the Systems Pillar of Europe's Rail, and to pave the way for wider use of FMs in the rail sector. While considerable know-how about FMs exists, it is not generally widespread or available, and there is a lack of guidance on why, where, and how to employ FMs for railway signalling. There is also a lack of reference structure enabling to categorise projects applying FMs, to compare them and to better understand them. For these reasons, the FMs Guidebook describes the fundamentals of FMs, the generic process for FMs application, recommendations, and best practises in FMs use for the different life cycle phases, together with a handful of example purposes for FMs use.

This TD created the Proposed Methodologies based on FMs Guidebook describing methodology for creating tender requirements that are unambiguous and amenable to automated processing by suppliers and other stakeholders, e.g., towards automated authorisation procedures. This document provides a recommended process using semi-formal and formal requirements and models, for two application areas: EULYNX specifications, and interlocking logic.

This TD completed the FMs case study for ETCS trackside Level 3 (according to the old definition of ETCS level – currently, it would correspond to level 2) with moving block, using the Moving Block Specification by TD2.3 as main input. This case study applied FMs for the System Inception purpose described in the FMs Guidebook (early-stage V&V of requirements). Three reports describe the results, for the different steps in the generic FMs application process ranging over requirement analysis FMs application and verification results achieved.

This TD completed two toolchains for automated transformation of EULYNX SysML (Systems Modelling Language) models into formal models. Several examples such as the EULYNX subsystem point specification were used to test and validate the developed toolchains. This work continued and improved the Validation and Verification (V&V) approach begun in X2Rail-2. The main aim of the toolchains is to automate the transformation of EULYNX semi-formal models to formal models (to eliminate manual encoding steps). The objective of this transformation is to close the gap between semiformal SysML specifications and the applicability of formal methods to ensure high error detection already in early phases and thus enable more efficient and reliable system development.

The five expected deliverables have been delivered in 2023. TD2.7 accomplished 100% of planned work in 2023, which represents 100% of the overall TD.

TD2.8 Virtually – Coupled Train Sets (VCTS)

The TD was completed in 2021.

TD2.9 Traffic Management Evolution

The goals of a future Traffic Management System are to improve traffic management operations with new advanced applications, integrating real time data from different business services into automated decision-making processes.

TD Progress

This TD was completed in 2022.

TD2.10: Smart radio-connected all-in-all wayside objects

The objectives of this technology demonstrator are to develop an autonomous, intelligent, maintenance free smart equipment ("box") able to connect with any signalling wayside object and communicating device in the area (wireless), guaranteeing safety and security, by the definition of a common architecture and of requirements and interface specifications. The TD will develop concepts for locally derived power, for the overall reduction of power consumptions and required cabling as well as to specify interfaces with control, power, diagnostics and maintenance systems using both low- and high-capacity wireless links.

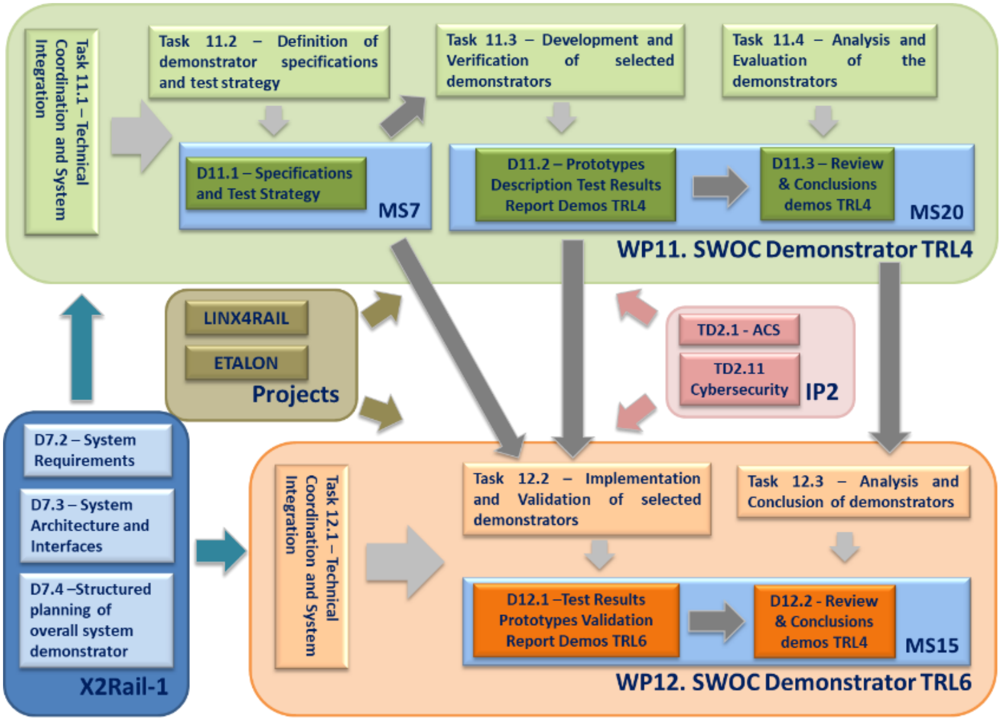
These "intelligent" objects - knowing and communicating their status conditions - would not only provide opportunities in terms of cost reduction and asset management improvement, but also establish new means for management and control of railway network information.

TD Progress

This TD currently builds on the following projects: X2RAIL-1, ETALON (both completed in 2019), and X2RAIL-4, launched in December 2019 and completed in December 2023.

In 2023, the TD focused in the Implementation and Validation of selected demonstrators at TRL6. The aim is to further enhance the demonstrators in operationally representative environment to reach Technology Readiness Level 6 (TRL6), evolving the demonstrators at TRL4 already implemented in the scope of WP11, till the end of X2Rail-4 in 2023.

In the following figure the methodology used to generate the corresponding deliverables is described:



The Implementation and Validation of selected demonstrators at TRL6 in the scope of WP12 uses as inputs the deliverables D7.2 System Requirements and D7.3 System Architecture and External Interfaces of X2Rail-1 and D11.1 Specification and Test Strategy of X2Rail-4 WP11 for the implementation of the demonstrator.

The main focus of the demonstrators was to develop and test them in a operationally representative environment (TRL 6) against the requirements to cover the uses cases described in the following table:

Use Case	Existing OCs	SWOC	Demonstrator
IXL control management	✓	✓(A)	✓(A)
OBU Interface with SWOC	✗	✓(O)	✓(P)
TMS interface with SWOC	✗	✓(O)	✓(P)
SWOC distributed Architecture	✗	✓	✓
Safety Conditions	✓	✓	✓
Power Management	✓	✓(A)	✓(A)
Management of SWOC deployment	✗	✓	✓
Communication Management	✓	✓(A)	✓(A)
Security	✓	✓(A)	✓(A)
Maintenance Management	✓	✓(A)	✓(A)
Diagnosis Management	✓	✓(A)	✓(A)
Asset Management	✓	✓(A)	✓(A)

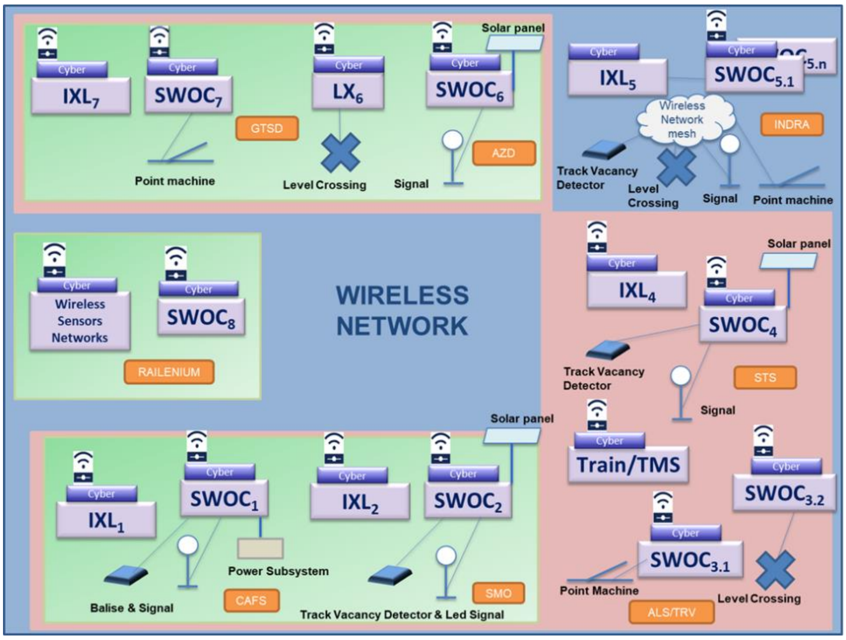
✓ OK: Available ✗ NOK: Not available ✓(A) OK (Advanced): available and improved ✓(O) OK (Optional): available only if desired ✓(P) OK (Partially): Partially available

Also, different operational scenarios, in terms of market segments, types of wayside element controlled, communication type, control entities, diagnosis &maintenance features and power management have been defined. At least one sub-demonstrator shall cover the use case of each type of wayside element.

For this purpose, eight different demonstrators have been defined in order to cover a large spectrum of suitable scenarios, with the intention of being able to test, in greater detail and precision, each of the functionality/features to be covered by the SWOC.

The demonstrators and the partners involved are:

1. Wireless Low Power Object Controller demonstrator, carried out by CAF Signalling
2. Track vacancy detection SWOC demonstrator, of Siemens Mobility.
3. Cable Less Railway Embankment Demonstrator, of Alstom/BTSE and Trafikverket
4. Multiple Networks Scalable SWOC, carried out by Hitachi Rail STS
5. Smart Wayside Object Controller, of Indra
6. Gate Signal Smart Wayside Object Controller, carried out by AZD Praha s.r.o
7. Wireless, Advanced Diagnosis, Intelligence distribution and Low Power Consumption carrying out by Thales
8. New generation of adaptable Wireless sensor Network for way side objects in railway environments by Railenium.



All the demonstrators have been developed and tested successfully.

For each demonstrator, the following information has been documented:

- Description of the demonstrator including use cases, functional architecture and test environment
- Production of test cases and assessment cases, including the traceability with requirements

- The results of the tests of each demonstrator

The final work of the TD, in the Analysis and Evaluation of the demonstrators, aims of performing a review analysis of the work done per each demonstrator at TRL 6 and draw conclusions from it.

In the overall SWOC demonstrator at TRL6 the coverage of requirements obtained is:
- 98,5% of mandatory requirements and
- 95,3% of recommended requirements

The conclusions from testing the SWOC overall demonstrator are positive in all the areas defined:

- Wireless communication: wireless has been successfully implemented, using Rasta or other protocols; even requirements on reliability, availability and latency of the used wireless technology could be needed to be adequate for the use cases.
- Power supply: local power supply systems have been demonstrated and reduction of power consumption, including power saving modes.
- Smart features as diagnosis and maintenance management: predictive enablers, remote update of SWOC (configuration data and applications), using OPC UA or other protocols.
- Cybersecurity concept according to IEC 62443-4-2 standard in order to reach Security Level 2.

In addition, the influence in Life Cycle Cost has been demonstrated with a qualitative reduction in CAPEX and OPEX. Energy savings can reach up to 50% for object controllers.

There are still a lot of potential for future works in various areas and in the scope of EU-Rail, it is foreseen to continue the work done in TD 2.10.

In 2023, the overall progress was in line with the plan. TD 2.10 reports having accomplished 100% of the planned work up to the end of 2023, which represents 100 % of the overall TD 2.10.

TD2.11 Cybersecurity

The interconnected digital railway network at European level is constantly growing and will keep on growing, which will increase the number of risks associated to security. There is therefore a growing need for handling these cyber-security threats in railway systems. This technology demonstrator aims at achieving the optimal level of protection against any significant threat to the signalling and telecom systems in the most economical way (e.g., protection from cyber-attacks and advanced persistent threats coming from outside).

TD Progress

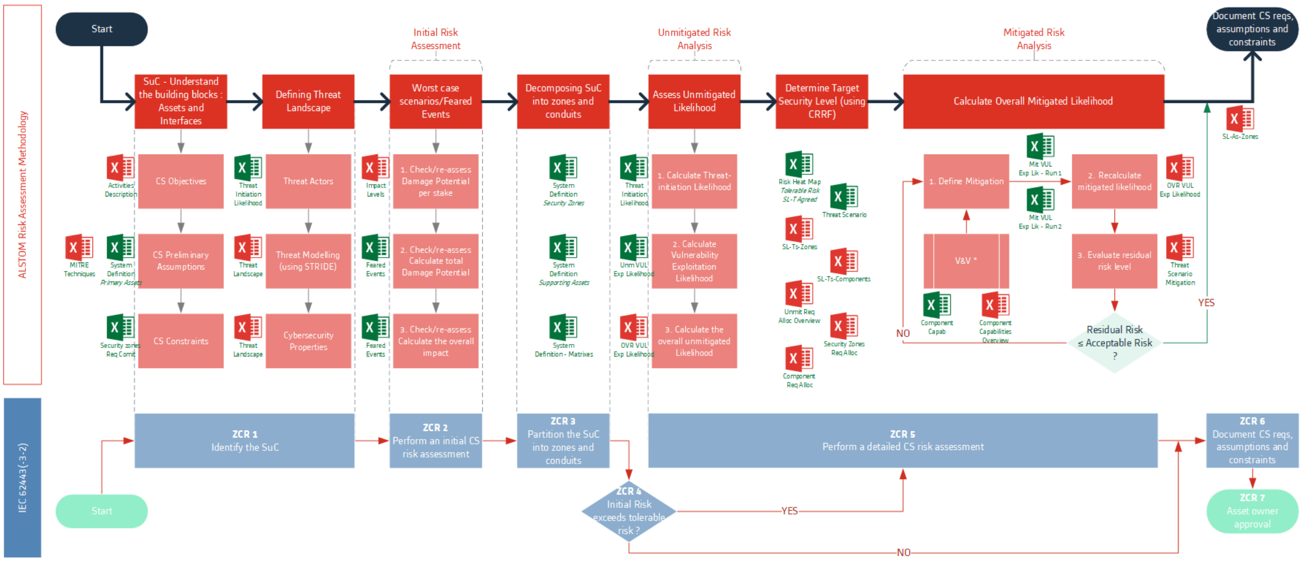
The activities of the TD were implemented via the projects X2Rail-1, X2RAIL-3, 4SECURAIL (all completed in 2021) and X2Rail-5 (completed in 2023). The following achievements have been reached in 2023:

- Completion of joint analysis and demonstrator with other TDs/Cybersecurity assessment of other TDs;
- Integrated technical demonstrator with adaptable communication TD: Security Assessment;
- Integrated technical demonstrator;
- Completion of the ISAC prototype and its validation and Operator Statement;
- Analysis of railway systems' cyber resilience.

Completion of joint analysis and demonstrator with other IP1 and IP2 TDs: Cybersecurity assessment of other TDs

In X2R-3, two demonstrators involving other TDs started. The first demonstrator consists in performing cybersecurity analyses of the architectures proposed by some other TDs and to provide them some recommendations for hardening. In X2R-5, the concerned TDs (ATO GoA2, ATO GoA3/4, and NG-TCN), the proposed potential mitigations, architecture changes and countermeasures to fulfil the cybersecurity recommendations were assessed.

In the course of 2023, risk assessments on the above TDs have been performed using the risk assessment methodology developed in 2022.



One of the key challenges that had to be addressed was to introduce in the scope of the methodology the management of attack paths (as part of the collaboration with the S2R TCMS activity, via the project CONNECTA-3), as well as to improve the impact and likelihood criteria defined in the previous Simplified Risk Assessment methodology, to match with the NG-TCN environment. For both TDs (ATO, NG-TCN), special attention was given to the management of Safety functions with respect to cybersecurity attacks, which was not covered by the previous analysis in X2R-3. The results of the risk assessments were included in the X2R-5/D11.1 report, delivered in June 2023. They were also presented in the 5th SmartRacon.

Integrated technical demonstrator with adaptable communication TD: Security Assessment

The goal was to validate and assess the TD2.1 (ACS) Technical Demonstrator based on the proposed Protection Profile. The results of the technology demonstrator lab and field test reports from X2R-5/WP3 have been analyzed and mapped to the security requirements of the protection profile defined in X2R-3 (19 requirements from the IEC 62443-4-2 standard were considered as applicable). The latter then mapped to mitigations and attack techniques of the MITRE Attack Framework for ICS. Each of the IEC 62443-4-2 requirement provided at least one mapped test case of the lab test or the field test. The following 4 common component security constraints (CCSC) were considered:

- CCSC 1: Support of essential functions
- CCSC 2: Compensating countermeasures
- CCSC 3: Least privilege
- CCSC 4: Software development process

With respect to the IEC Fundamental Security Requirements at component level (in the ACS Protection Profile), it has been demonstrated that:

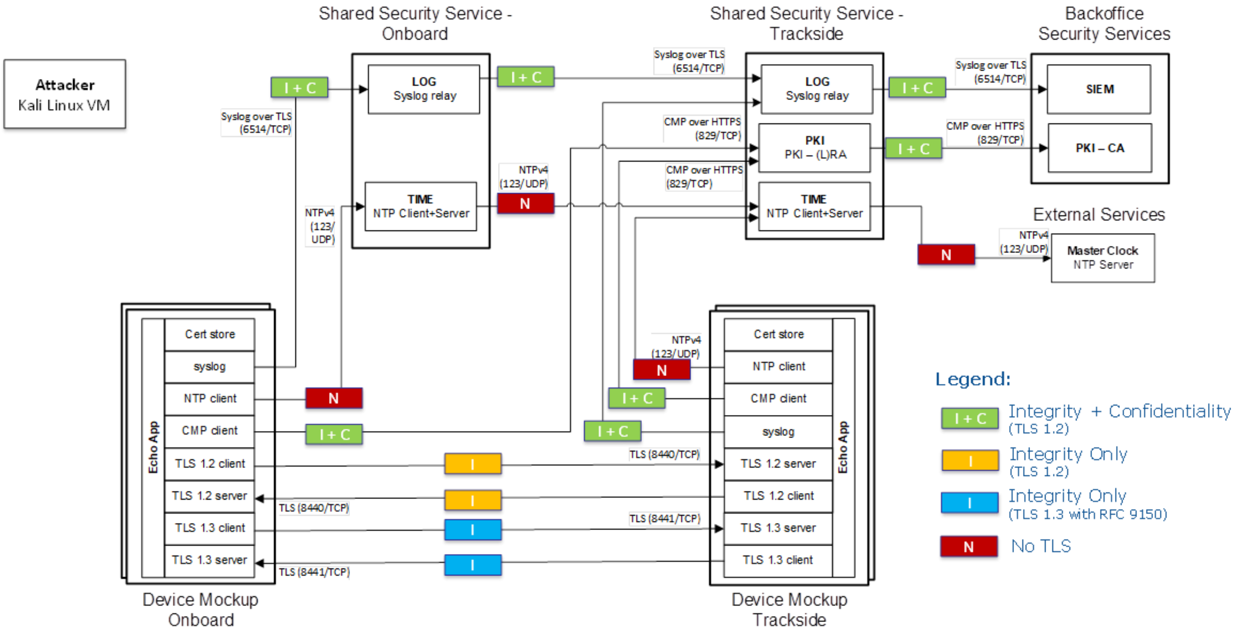
- FR1 - Identification and Authentication" and "FR7 - Resource Availability" are generally fulfilled
- FR 2 - Use Control" and "FR3 - System Integrity" are partially fulfilled

Integrated technical demonstrator

This new demonstrator aims to validate and assess the security requirements defined in the TSI CCS 2023 (a subset of the protection profiles defined during the TD).

In 2022, the demonstrator was set up as a cloud service which facilitated the collaboration between the TD members. It includes two onboard and trackside rail automation mock-ups which implement the new TSI CCS / UNISIG subset 146 security requirements, as well as the shared security services for onboard, trackside and back office required for the new TSI. Additionally, security and penetration tests were performed on the demonstrator to validate the security functions as well as the cyber resilience. The pen testing findings shown that although resilience can be achieved, it is necessary to standardize the process for software updates, as well as the process for backup and restore the system in a secure state.

A requirement tracing from the full protection profile was performed in 2023 identifying the missing requirements for future developments inside Europe's Rail (and specifically in the System Pillar).



Completion of the ISAC prototype and its validation and Operator Statement

ISAC prototype verification, validation and test Use-case is describing how DB implemented and tested a railway ISAC. Based on the experience of different ISAC projects, DB prepared an ISAC platform called prototype. This platform has been tested in 2022.

Summary Statement from the perspective of an operator was prepared with respect to the analysis of the ISA IEC 62443-2-1 part of the standard as well as the analysis of ISO 27001/2 and how to integrate both standards together. Processes, people, technical and regulatory requirements were considered to define what must be prepared for the different aspects by Operators and what must be delivered by the supply chain so that Operators can fulfil their responsibilities, utilizing the results of the Holistic Approach developed previously in the TD.

In 2023 the following activities were performed:

- Analysing impact for operation in applying SL 3 or SL 4 of IEC 62443.
- Analysing gaps and challenges for operation (regulatory, supply chain, cost of security).
- Finalizing preparation of summary exchange tables of what must be delivered by the supply chain.
- Summary of the main conclusion.

Key challenges for the Operator are summarized to the following:

- It is often under question, what is the root-cause of a failure: are safety damages due to safety failures or due to the lack of cybersecurity measures in place?
- The rising cost of cybersecurity during operation: lack of the needed cybersecurity solutions affects the whole supply chain.
- Operator dependency on supply chain - Technical challenges: on Operating systems, hardware, component/device, sub-systems.
- Contradictions identified in the standards – ISA IEC 62443 vs. EU cyber act: it is expected that responsibilities of the supply chain should be in line with EU regulatory requirements.

Analysis of railway systems' cyber resilience / Recommendations on railway systems' cyber resilience

The NIST SP 800-160 Vol.2r1 12/2021, the Mitre Attack Framework, the ENISA Threat Landscape, and the EU Cybers Resilience Act (draft) have been analysed to identify cyber resilience related concepts, and provide clarifications and recommendations upon the different cyber resiliency techniques:

- selected APT attacks to the railway reference system have been analysed to identify cyber resiliency implementation approaches when performing an Initial Risk Assessment according to IEC 62443-3-2: based on ATT&CK Framework ICS tactic Impact techniques, mitigations, and related risk effects.
- essential cybersecurity requirements for Vulnerability management have been identified.

In 2023, the main goal was to complete this analysis by analysing the IEC 62443 requirements for cyber resilience capabilities and to identify complementary recommendations for Cyber resilience of railway system.

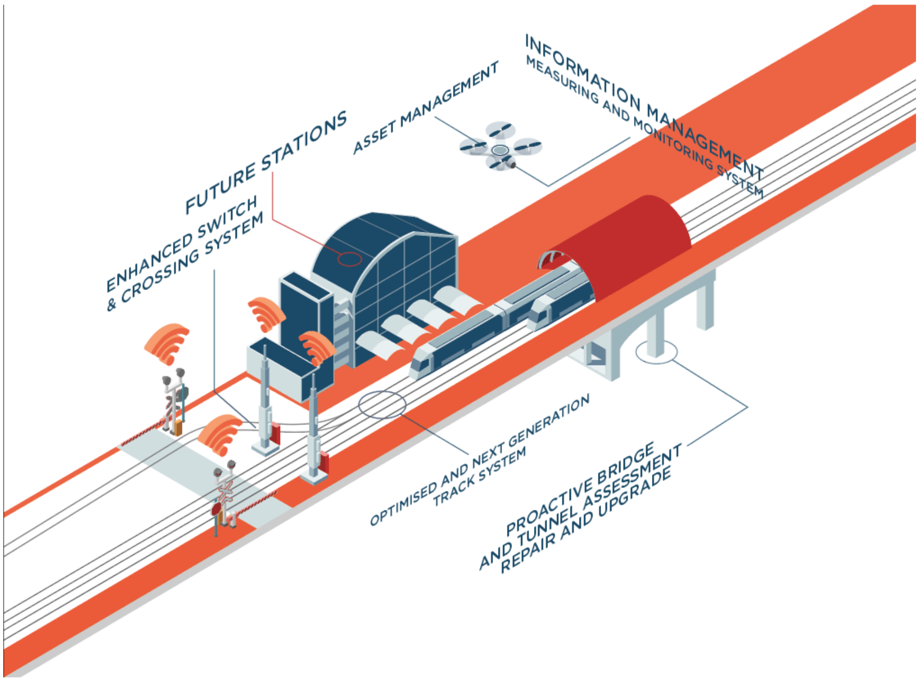
Key points are summarized below:

- EU-Rail system pillar cybersecurity team should identify cyber resiliency implementation approaches and techniques as part of their innovation pillar demonstrator requirements specification.
- Asset owners and product suppliers should define cyber resiliency requirements – or identify and map existing ones from ISA/IEC 62443 standards – applicable to the different phases of the ISA/IEC 62443 lifecycles.
- IEC TC9 PT 63452 members should address MITRE ATT&CK knowledge base in context of risk assessment and operations' cybersecurity threat intelligence in the deliverable IEC 63452 Railway Applications – Cybersecurity.
- ENISA should provide design guidance - including handling of conflicts and synergies - on cyber resiliency, cybersecurity and resiliency for critical infrastructure asset owners/operators, product suppliers, and service providers.
- IEC TC9 PT 63452 members as well as the EU-Rail system pillar cybersecurity team should review and adapt NIST SP 800-160v2r1 [12] strategic and structural cyber resiliency design principles in context of their deliverable(s) IEC 63452 Railway Applications – Cybersecurity.

In 2023, all expected deliverables for TD2.11 have been delivered. At the time of writing this report, some are still undergoing administrative review steps. The overall progress was in line with the planned activities, which corresponds to 100% of the overall activities of the TD.

1.2.3. IP3 Cost-Efficient and Reliable High-Capacity Infrastructure

The picture below provides a visual of the TDs where improvements are expected.

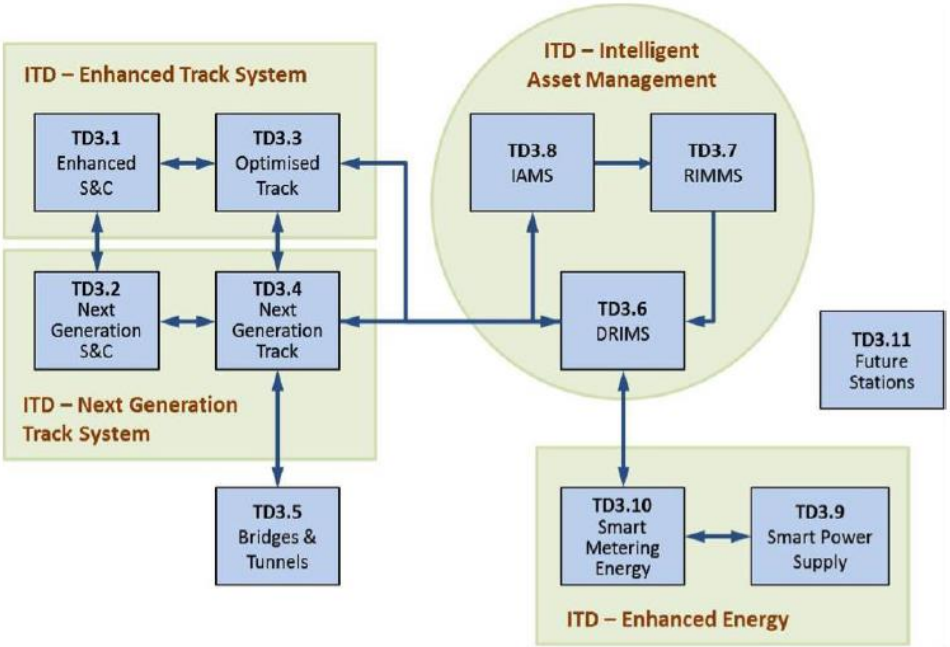


The design, construction, operation and maintenance of rail network infrastructure have to be safe, reliable, supportive of customer needs, cost-effective and sustainable. In order to deliver the benefits of market opening and interoperability and to reduce the life cycle costs of rolling stock and on-board signalling systems, the network diversity needs to be eliminated, notably through a migration towards common high-performing infrastructure system architecture.

Activities that can support the reduction of infrastructure maintenance costs, such as simplified procedures or automation, need to be led in priority. They should propose solutions that can be rapidly and efficiently deployed. Furthermore, the infrastructures have to be managed in a more holistic and intelligent way using lean operational practices and smart technologies that can ultimately contribute to improving the reliability and responsiveness of customer service, as well as the capacity and the whole economics of rail transportation.

In order to be competitive with other modes but also integrated with them, compatibility between different modal infrastructures (including multimodal hubs, changing points and stations) needs to be ensured and based on principles of interoperability and standardisation.

The picture below shows the interconnections and dependencies within the IP3.



TD3.1 Enhanced Switch & Crossing System Demonstrator

TD3.1 aims at improving the operational performance of existing Switches and Crossings (S&C) designs through the delivery of new S&C sub-systems with enhanced Reliability, Availability, Maintainability and Safety (RAMS), improved Life Cycle Cost (LCC), sensing and monitoring capabilities, self-adjustment, noise and vibration performance, interoperability and modularity.

TD Progress 2023

TD3.1 builds on the project's activities of IN2RAIL, IN2TRACK, IN2TRACK-2 and IN2TRACK-3 (all completed).

In 2023, several enhanced S&C demonstrators were installed in-field equipped with extensive measurement continuously generating data for technology evaluation to validate the solutions. Among the most significant results:

- The demonstrator of welded bainitic-steel components has been tested under operational environment since March 2022. Regular visual inspections and qualitative assessments of the welds, the geometry and the hardness were carried out. No defects have been identified to date.
- VARS enhanced switch & crossing, equipped with extended Data Acquisition System are continuously gathering data of both the S2R turnout and the reference turnout. The outcome demonstrates better results for the enhanced S&Cs, in some aspect beyond the initial requirements. The results show that the VARS demonstrator loads the ballast less than a standard turnout. The benefit of the full enhanced reliability and maintainability of the subsystem couldn't however have been fully validated within the programme timeframe (long lifespan).

The **whole system modelling approach** including hybrid testing approaches for virtual evaluation and design of S&C were developed and have been validated with data from real-world operations from the VARS enhanced S&C Systems. E.g., the developed crossing nose plasticity model can be used for the time-efficient rail surface damage prediction for crossings. The developed model will contribute to track damage prediction as well.

The **cladding process** in the transition area of a crossing has been successfully tested in field using mobile laser system on a crossing.

During 2023, 2 deliverables were planned and released. TD3.1 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.1.

TD 3.2 – Next Generations Switch & Crossing System Demonstrator

TD 3.2 aims to provide radically new system solutions that deliver novel methods for directing trains between tracks to unlock additional network capacity, while reducing maintenance needs, traffic disturbances and life cycle costs. Step-change solutions are prioritised over short-term incremental improvements. However, it must be recognised that incremental changes to the current switch and crossing design will need to be progressively introduced and a transitional approach adopted. This will enable a change from current design forms to a radical shift to a new approach in transferring trains between tracks in a +40-year horizon view.

TD3.2 builds on the project's activities of IN2RAIL, S-CODE, IN2TRACK-2 and IN2TRACK-3 (all completed).

TD Progress in 2023

In 2023, further development on the approximately 20 components/sub-systems in the scope of TD3.2 has been carried out. Below is an extract of some of the achievements and issues encountered:

Extensive design development of the Repoint concept drive system has continued focusing on the drive system and rail joint for the moveable switch. This has culminated in a full-scale drive bearer demonstrator being manufactured which will begin validation testing at the end of 2023. Extensive modelling of the rail joint for the Repoint concept has been undertaken with a scale model demonstrator being built to simulate the drive system and rail joint functionality including the redundancy capability of the concept.

The development of the next generation switch control system prototype has been successfully completed and demonstrated in a representative environment after extensive testing and evaluation of the system. Validation of the remote node simulator integrating the communications protocol has also been completed. The development of 3D printed/additively manufactured solutions for S&C components has been successfully completed reaching TRL 4. The design and shape of a small number of S&C components that are traditionally produced by casting, have been optimised using 'off the shelf' software. This has enabled the component shape to be enhanced, reducing the weight and material required to produce each component, without compromising the required performance. Physical 3D printed examples of the optimised baseplate and concrete bearer fastener housing have been successfully manufactured. Testing of these components is planned to current EN standards.

A full-scale demonstrator of the radical tramway crossing has been manufactured and assembled, reaching TRL6. Full FEM of the crossing components has been completed indicating the potential in service lifespan of the crossing system. Inservice testing is planned for future validation of the concept crossing out of the S2R programme.

The development of drone inspection of S&C has been successfully completed on live infrastructure with 2D orthographic and 3D point cloud images being taken of S&C units. On site processing of the images has drastically reduced the image processing time and enabled images to be available for assessment. Machine learning techniques have been incorporated to detect change in component status, comparing images from previous inspections. Dimensional parameters can also be checked utilising the images produced. An example portal has also been developed to present the data to end users. This project has successfully reached TRL 6 and could be deployed to augment and ultimately replace BVI (basic visual inspections) and Supervisor inspections of S&C.

Testing and validation of the Crossing Restoration machine (CRM) has been completed in a factory environment. Further developments included the capability of the machine to recognise the angle of the crossing to be repaired. Design work on the compatibility with the track lower sector track gauge has been completed to confirm the machine can be deployed anywhere on the UK network. The development of deployment method design for the machine has been mirrored with that of the plain line DDR machine, as a combined platform capable of being utilised by both machines.

During 2023, 5 deliverables were planned and released. TD3.2 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.2.

TD3.3 Optimised Track System

The TD challenges track construction assumptions, currently implicit in track design, and explore how innovative solutions in the form of products, processes and procedures can provide enhanced reliability, availability, sustainability, fewer capacity consumptions together with LCC savings. The aim is to derive medium-term solutions thus requiring harmonisation with current solutions and regulations. The TD pays also attention to the wheel/rail interaction that needs to work properly for a good performance of the entire railway system. The environmental aspect is also involved in his TD.

TD3.3 builds on the project's activities of IN2RAIL, IN2TRACK, IN2TRACK-2 and IN2TRACK-3 (all completed).

TD progress in 2023

In 2023, further development on the various TD3.3 demonstrators have been carried out. A summary of some of the key achievements can be found below:

The 3MB innovative slab-track solution has been installed (2022) with results taken forward to the final installation, with the inclusion of modifications to the initial assembly process (fastener bolt torque limitation, determination of optimal auxiliary means and best practices for vertical levelling). The system has been in real operation and exposed for 15 MGT in Northern Sweden under harsh climate conditions and exposed to 31 tons of axle load. The system has been instrumented, and the performance evaluated, concluding that the structural performance of the system elements is satisfactory.

A vehicle in commercial service has been equipped for demonstration on how defects in rails (rolling contact fatigue) can be identified thanks to onboard sensors. Data has been analysed during 2023 from the test runs and from the infrastructure to investigate the results. The correlation from the instrumentations has shown a high-quality conformity with the performed field inspections, thus demonstrating the suitability of the solution to replace manual inspection.

The work on wheel/rail system has established a new parameter for evaluation if the wheel or the rail in a good condition regarding passenger comfort (vehicle stability). Now this parameter called GIP has reach the EN 15302 technical report CEN/TR17792.:2022. as a new geometrical parameter for judging the stability on track. A wheel profile for passenger vehicles is now in service for assessment of the performance considering stability on track by an onboard monitoring system.

During 2023, 2 deliverables were planned and released. TD3.3 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.3.

TD3.4 Next Generation Track System

TD3.4 aims to provide solutions that improve the plain line track system substantially, targeting a time horizon of around forty years beyond the current state-of-the art. The improvements are planned for delivery through the development of novel sub-systems and components, combined with more efficient and targeted inspection and maintenance processes. Step-change solutions are prioritised over short-term incremental improvements and as such, a longer-term implementation timescale is envisaged for the majority of technologies developed.

TD3.4 builds on the project's activities of IN2RAIL, IN2TRACK, IN2TRACK-2, IN2TRACK-3 and IN2ZONE (all completed).

TD progress in 2023

In 2023, further development on the various TD3.4 demonstrators have been carried out. Below an extract of some of the achievements:

Innovative numerical tools have been further developed to assess the vibrations induced by the railway traffic, predicting the free-field response and simulating the building response. New methodology based on models has been developed using Machine Learning algorithms. To simulate the building response the proposed tool is based on an experimental (hammer test) and numerical (Soil Structure Interaction curves) approach. This allows the assessment of the dynamic response of a new building subjected to an external vibration source.

Development of a novel method of slab track repair, that enables the slab to be de-bonded has continued to make good progress. The principle is based on adding a layer of material between the Hydraulically Bounded Layer and the precast slab that can be easily melt. The work focussed on designing and testing the machine that can melt this layer and defining the material of the layer. This has been achieved through simulation and then manufacturing prototype machine. Lab testing has demonstrated the potential of this technology reaching TRL4. However, improvements are needed to increase the wave penetration and some optimization to address real size slab track module.

An improved method for the assessment of the critical speed of slab track solutions applied in soft soils has been developed and validated. The proposed numerical approach can be used in the design of ground improvement solutions, where a significant increase of the system’s critical speed is required. Given the complexity involved and the high computational resources needed for its application, the analytical approach proposed can be considered as a viable alternative solution. This work has reached TRL4.

The development of ‘Smart Materials’ that can be used to monitor the track structure has successfully advanced in the programme. The solution is based on the piezoresistive effect provided by conductive fillers, carbon nanotubes (CNT)/ graphene nanoplatelets (GNP). Lab test and simulation and software development have been completed with the development of the interface to connect the smart material to the data acquisition system. A better understanding of the behaviour of the electrodes is needed to improve the measurement accuracy as well as complementary research on impedance spectroscopy measurements to fully validate the applicability of the solution.

In 2023, the TD has also successfully demonstrated the feasibility of autonomous rail inspection to TRL7. A prototype autonomous rail inspection system was built by integrating an autonomous rail vehicle and a state-of-the-art UT system.

Regarding Track stiffness monitoring, the work on the method that uses in-service train Axle Box Accelerometer technology to assess track stiffness was validated in an industrially relevant environment (TRL5) by comparing the track stiffness evaluated using axle box accelerations data with that obtained from hammer tests.

Regarding Rail defect monitoring, a semi-autonomous motorised trolley has been designed and manufactured to use contactless Electro Magnetic Acoustic Transducers sensors that are able to detect rail surface defects which are difficult to monitor with current technologies. In-field tests were conducted to validate the trolley and to improve the sensors signal processing to enhance the defect detection.

Development of the ColdSpray technology for Rail defect repair which consists in spraying metal at high speed and low temperature without melting has progressed well. Laboratory testing of the technical feasibility has been successfully completed. This has been achieved by developing the required parameters that permit good powder adhesion and mechanical characteristics for a rail repair.

The Discrete Default Repair machine is able to repair rail with a fully automated process. The machine measures the rail profile, removes the required part of the rail, add the welding for repairing and mill according to the measured profile. It was validated in several industrial environments and is in the process of being used in service by Network Rail.

Finally, regarding transition zone monitoring, a condition monitoring system for transition zones was designed, based on three-dimensional vibration monitoring. The system was tested in a large-scale testing facility but couldn’t be installed in an operational environment due to delays in the track refurbishment site that was foreseen to host the demonstrator (out of programme scope).

During 2023, 5 deliverables were planned and released. TD3.4 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.4.

TD3.5 Proactive Bridge and Tunnel Assessment, Repair and Upgrade Demonstrator

The main objective of the TD is to improve inspection methods and repair techniques in view of reducing costs, improving quality and extending the service life of existing structures. One of the main objectives also consists of reducing the cost for new bridges regarding bridge dynamics.

TD 3.5 builds on the project's activities of IN2RAIL, IN2TRACK, ASSETS4RAIL, IN2TRACK-2 and IN2TRACK-3 (all completed).

TD Progress in 2023

In 2023, the TD has finalized its activities, notably the operational validation of the bridge strengthening technology for improving shear capacity. The strengthening technology was applied without disturbing train traffic and work procedures were successfully demonstrated. Developed strengthening system may increase service loads on the bridge with approximately 5 tons per axle depending on the individual structure to be strengthened, by enhancing the bridge structural ductility and fatigue capacity.

The other TD results were already reported in 2022.

During 2023, 5 deliverables were planned and released. TD3.5 has reported having accomplished 100% of the planned work up in 2023, which represent 100% of the overall TD3.5.

TD3.6: Dynamic Railway Information Management System (DRIMS) Demonstrator

The TD defines an innovative system for the management, processing and an analysis of railway infrastructure data obtained from TD3.7 (Railway Integrated Measuring and Monitoring System (RIMMS) Demonstrator). The aim is to provide high-quality input to TD3.8 Intelligent Asset Management Strategies (IAMS). The main goal of these three TDs is to create new and optimised strategies, frameworks, processes and methodologies, tools, products and systems for the implementation of a step change in risk based, prescriptive and holistic asset management in the rail sector.

TD3.6 builds on the project's activities of IN2RAIL, IN2SMART, IN2DREAMS, IN2SMART2 and DAYDREAMS (all completed).

TD Progress in 2023

While most of the activities were concluded in 2022, the TD has finalized in 2023 the development of all the Use Cases foreseen in the programme. More specifically, the asset management tool in a Dutch environment underwent enhancements across various research lines to develop a decision support tool for improving mid-to-long-term planning. The key results across different research lines are as follows:

- **Dynamic Data**: Significantly improving the model, the tool now accesses dynamic data, allowing visualizations to display up-to-date information with a daily scheduled refresh.
- **Machine Learning**: Exploring the integration of Python with Power BI, the study involved creating Python visual objects, conducting data modelling and transformations with Python in Power BI, and assessing the application of machine learning algorithms. A proof of concept was executed using a Decision Tree algorithm on the model.
- **GIS Approach**: Reports were generated to compare the use of Leaflet and ArcGIS for GIS visuals. Additionally, a direct connection was established between Power BI and Strukton's ArcGIS Pro API, enabling access to updated GIS information.
- **Fast Access and Key Insights**: Mobile layouts were designed, and datasets uploaded to Power BI Service were utilized to create user-specific, complementary reports focused on providing fast access to key insights.

These enhancements collectively resulted in a more advanced decision support tool, equipped to address long-term planning challenges, and leverage dynamic data, machine learning, GIS approaches, and user-specific insights.

Additionally, the Remote Condition Monitoring Maintenance Reduction Interventions and Decisions Use Case developed Machine Learning (ML) models to reduce the number of alarms raised and predict the insurgence of anomalies. Multiple and different ML approaches were implemented and have generally reached a satisfying level of accuracy, showing also potential for future application in the railway environment and scenarios for additional improvements.

These algorithms have been developed focusing on the integration with existing systems or interfaces to investigate the functionality and viability of industrialised use. This integration has been done using real, existing and available asset management systems, in this case the TIRIS platform.

The developments demonstrated a groundwork laid for industrialisation of the solutions in existing (tangible) internal products. The future prospects that are already in motion in the business include the continuous fine-tuning of the algorithms and complete integration with the User Experience (UX) aspect of the asset management system in conjunction with the interfaces designed for these algorithms.

Finally, the four following scenarios (Management of Track Circuits (TC) in a Metro Environment; Railway Infrastructure Maintenance Management in RFI; Monitoring of track geometry and location of rail defects; Joint optimization of track maintenance planning and multi-modal transport for service continuity) have reached a high level of maturity, bringing significant results in the specific use cases addressed and paving the way for future improvements. A great example of this is the first scenario that focused on the exploitation of all data coming from the TC system (e.g., TCs board parameters), together with maintenance data (e.g., past planned and actual maintenance), with the final goal of improving the entire TCs asset management process thanks to the use of Prescriptive Analytics.

The developments contributed to the following benefits:

- Improve the accuracy in the estimation of priority of the intervention and repair time by developing DDMs trained on historical data able to assess the status of TCs and predict their faults;
- Reduce service interruptions and line unavailability by scheduling a maintenance plan based as much as possible on CBM (Maintenance downtime reduction is reduced by 30%);
- Optimize the maintenance plans via PA and MOO and in turn reducing the related cost;
- Improve the (re)scheduling maintenance process by developing an automated tool (thanks to PA, MOO and HMI) able to support the operators during the entire procedure.

During 2023, 11 deliverables were planned, all of them released. TD3.6 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.6.

TD3.7: Railway Integrated Measuring and Monitoring System (RIMMS) Demonstrator

The TD aims at providing innovative tools and techniques to capture information on the current status of infrastructure assets in a non-intrusive and fully integrated manner. To this end, the TD focuses on infrastructure asset status data collection in close interaction with TD3.1 Enhanced Switch & Crossing System Demonstrator and TD3.5. Proactive Bridge and Tunnel Assessment, Repair and Upgrade Demonstrator.

TD3.7 builds on the project's activities of IN2RAIL, ASSETS4RAIL, IN2SMART and IN2SMART2 (all completed).

TD Progress in 2023

As the data collection activities are fully integrated in the developments in TD3.6 and TD3.8, the results reported in TD3.6 are integrating the last remaining specific activities of TD3.7.

During 2023, 15 deliverables were planned, all of them released. TD3.7 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.7.

TD3.8: Intelligent Asset Management Strategies (IAMS)

The vision of the TD is a holistic, whole-system approach of asset management employing collected and processed infrastructure data provided by TD3.7 Railway Integrated Measuring and Monitoring System (RIMMS) Demonstrator and TD3.6 Dynamic Railway Information Management System (DRIMS) Demonstrator. This includes translating long-term strategies into day-to-day execution of the maintenance and other short term maintenance activities. It also includes new and advanced working methods, tools and equipment and logistics solutions, supporting the LEAN execution of intelligent maintenance processes.

TD3.8 builds on the project's activities of IN2RAIL and IN2SMART, IN2SMART2, DAYDREAMS and STREAM (all completed).

TD Progress in 2023

As the decision-making aspects are fully integrated in the developments of TD3.6 and TD3.7, the results reported in TD3.6 are integrating the last remaining specific activities of TD3.8.

Regarding LEAN execution work in 2023:

In 2023, the TD finalized the validation of the exoskeleton designed for railway workers handling heavy tasks to alleviate muscular fatigue. The evaluation spanned a six-month experimental campaign at railway construction sites by RFI and MERMEC STE s.p.a, with a concluding phase near Milan.

Throughout the campaign, involving laboratory tests and on-site validation with railway workers, the StreamEXO demonstrated its effectiveness. In the final demonstration, 15 workers utilized StreamEXO for approximately 100 hours, engaging in real work activities, such as carrying and positioning concrete conduits weighing between 20kg and 30kg. The results indicated a noteworthy 50% reduction in ergonomic risks for the musculoskeletal system, particularly in the lumbar region. Fatigue levels were reduced by up to 30%, and muscle activity saw a decrease of 25%.

This comprehensive experimental campaign played a crucial role in advancing the technological maturity of the prototype, positioning it for future industrialization. The StreamEXO aims to provide a comfortable solution for workers in heavy-duty industries, particularly those in the construction sector, such as railways, during their work shifts.

During 2023, 15 deliverables were planned out, all released. TD3.8 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.8.

TD3.9: Smart Power Supply Demonstrator

The global objective of the Smart Power Supply Demonstrator (TD3.9) is to develop a railway power grid in an overall interconnected and communicating system. This will enable improvements and optimizations regarding train traffic capacity, energy losses and costs, energy supply security and availability for the railway system and environmental impact.

TD Progress

In 2023, the TD3.9 builds on the progress made by FUNDRES, IN2RAIL and IN2STEMPO (all completed).

The smart control and protection demonstrator has been finalized proofing the intended objectives. High interoperability, interchangeability and modularity of the developed demonstrator has led to a reduction of the engineering and maintenance effort. Assets management functions enable a targeted, preventive maintenance approach reducing further the needed effort. Protection and system tests as well as FAT have been conducted for the complete control and protection equipment leading to the achievement of a TRL5.

The application of the smart control and protection demonstrator in trial operation in an actual switchgear station was however not implemented due to missing specific cables. The trial operation will be conducted by DB Energie GmbH outside the S2R/EU-Rail programme.

During 2023, 1 deliverable was planned out and released. TD3.9 has reported having accomplished 100% of the planned work in 2023, which represent 100% of the overall TD3.9.

TD3.10: Smart Metering for Railway Distributed Energy Resource Management System Demonstrator

The objective of the Smart Metering Demonstrator (TD3.10) is to achieve a fine mapping of energy flows within the entire railway system, as a basis of any energy management strategy.

TD Progress in 2023

TD3.10 built on the project's activities of IN2RAIL, IN2DREAMS and IN2STEMPO and was completed in 2022.

TD3.11: Stations

The primary objective of the TD is improved customer experience at stations increasing thus the number of customers that will use rail as their preferred transport mode. The TD is organised around four identified key functional demands; two demands relate to improving capacity, safety and security in large stations, one demand relates to the design of small stations with the objective of reducing whole life costs and standardising design where possible and the final demand relates to platform to train accessibility.

TD3.11 builds on the project's activities of FAIRSTATIONS and IN2STEMPO (all completed).

TD Progress in 2023

The TD focused its effort in 2023 to the administrative closure of the TD and no additional results are reported to compare 2022.

During 2023, 3 delayed deliverables from 2022 were planned out and released. TD3.11 has reported having accomplished 100% of the planned work, which represent 100% of the overall TD3.11.

1.2.4. IP4 IT Solutions for Attractive Railways Services

In order to become more attractive, rail must respond to customer needs to support seamless door-to-door multimodal journeys encompassing different modes of transport. Rail must achieve interoperability with other transport modes and mobility services, within different regions, cities and across borders. In view of this objective, rail needs to take due advantage of the ever-growing connectivity of people and objects, the availability of European Global Navigation Satellite System (GNSS) based location and other means of localisation, the advances in cloud computing, Open Data and Big Data Analytics and the wide dissemination of Internet and social media. Multimodal integration will also take benefit from existing rail standards as FSM and TAP TSI.

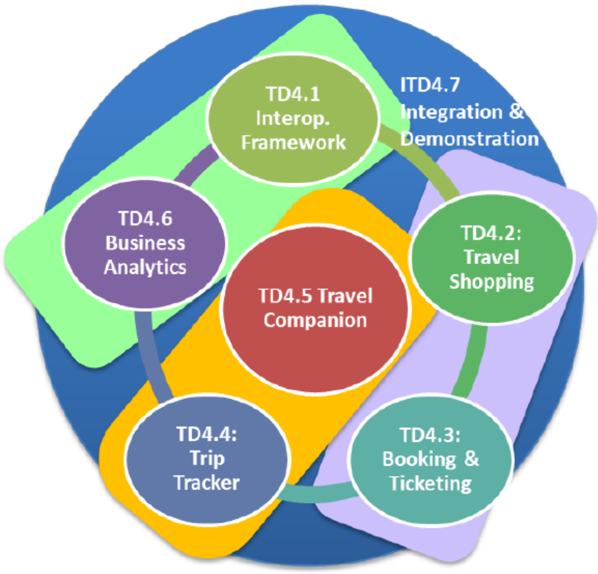
The picture below represents the areas where IP4 Technological Demonstrators will introduce improvements.

To achieve this, the IP4 ecosystem aimed to integrate and make interoperable all possible transport modes and travel services: rail, urban transport (metro, tram, and buses), airlines, private cars (such as the use of toll roads and parking, which have an associated price) and also shared modes (cars and bikes). Thus, multimodality and the use of public transport are being fostered, making it easier for travellers to connect with rail stations and airports, regardless of where and how they start their journey. For the future, Demand Responsive Transport and Ride Sharing was included in the ecosystem to ease the access to everyone to long distance trips, even to those living in not well- connected areas.

IP4 Ecosystem has also evolved to implement at European Level the new Mobility-as-a-Service (MaaS) paradigm, which considers the mobility system as a whole in order to achieve an optimal and sustainable transport scheme. This way, the IP4 ecosystems facilitates the task to create formal contracts that could involve the agreements, business rules and financial compensation that shall occur between the different stakeholders when combining their services into a joint product. In the future, this component will evolve to be used also to create MaaS Packages that integrate a variety of transport services that could include multiple Transport Service Providers.

IP4 is organised around 7 Technological Demonstrators within three priority research and innovation areas as shown in the graph below.

- Technical Framework: Interoperability Framework and Business Analytics
- Multimodal Travel Services: Travel Shopping and Booking and Ticketing
- Customer Experience Applications: Travel Companion and Trip Tracker



IP4 projects are contributing to developing innovations in each TD. All the outcomes of IP4 project will contribute to one single Integrated Technological Demonstrator (iTD4.7), which will merge all the developments.

TD4.1 Interoperability Framework

The primary goal of the TD is to streamline diverse modes of transportation within a complex environment that offers various means of travel. Semantic interoperability is achieved through the establishment of clear and formal models in the transportation domain, using an open, standardized, and machine-readable language. These models are automatically exchanged by computers, therefore allowing seamless access to all transport data and services in a multimodal and distributed environment. As a result, TD4.1 plays a crucial role as a technology enabler for a complete transformation of the European transportation ecosystem.

The TD covers different aspects of the Interoperability Framework (IF), including the definition of architectural principles, the implementation of components with basic capabilities and the development of a reference ontology. The Interoperability Framework have been used to allow end-to-end with test cases with the business applications developed in IP4 Projects interacting with the Transport Service Providers that are integrated with the S2R-IP4 ecosystem. TRL in these activities have reached 5-6.

TD Progress

In 2023, the activities have been focused on the finalisation of activities of the final release (F-REL) of the Interoperability Framework. The CONNECTIVE project has focused on the integration and support of travel services demonstrated for the OC pilots. CONNECTIVE is the main responsible of the integration as it is the responsible of developing the Service Implementations for each of the integrated services based on the documentation provided by the OC. During 2023, up to 31 services for the pilots that were located in Athens, Padua, Warsaw, Liberec, Osijek and Barcelona have been integrated and demonstrated.

Thanks to the CONNECTIVE IF components, it was possible to demonstrate some end-to-end test cases for the Ride2Rail and IP4MaaS projects, as the IF integrates the services provided by the TSPs that participate in the project and additional services that contributed to their pilots. Hence it obliges CONNECTIVE to have an active role supporting the requirements of the new functionalities of other projects during most of the project lifetime that is added to CONNECTIVE's scope.

This Final Release has demonstrated a major improvement in terms of performance that has been documented on the COHESIVE deliverable focused on the performance of the ecosystem. Improvement to the overall architecture have been developed and tested in the remainder part of the programme and overall increase of performance of 42% from the initial delivered system for the different aspects such as shopping orchestrator, Issuing Orchestrator.

TD4.1 Interoperability Framework									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
		Finished: IT2Rail, ATTRACkTIVE, MaaSive							
					Finished: CONNECTIVE				

During 2023, D1.6 and D1.9 were submitted covering the Interoperability Framework components (F-REL), gathering all the results obtained and giving an overview of the services integrated during the F-REL, accomplishing 100% of the objectives of the TD.

TD4.2 Travel Shopping

The concept of TD4.2 Travel Shopping is both to enable and to respond to an emerging single European multimodal transport marketplace within a Single European Transport Area (SETA). The IP4 approach will promote the integration of distributed travel operators’ data and services and the orchestration of services such as expert journey planning and offer building for all modes. It will benefit from the Interoperability Framework that enables applications based upon different interfaces, standards, or coding lists, to communicate meaningfully but without costly application adaptations with the existing legacy systems of all stakeholders. The TD4.2 contribution to IP4 System is to enhance the technical facilitation of a one-stop-shop capability, to enable comprehensive choice of itineraries and offers from modes/operators capable of responding to customer mobility requests, especially using existing services from all stakeholders by interfacing their legacy systems.

TD Progress

Within the project Extensive, the development of the general idea to plan a personalised Multimodal European wide Door to Door journey has been finished. It is based on the Interoperability Framework (TD4.1) that enables Service Providers to be connected to the IP4 ecosystem. With this idea multimodality is implemented by design. To further prove that this system fulfils the expected outcome additional Travel Service Providers within the Open Calls IP4MaaS and Ride2Rail have been successfully integrated during 2023.

It is obvious that having a pan European travel solution in mind hundreds of different Travel Service Providers needs to be attached to the ecosystem. It would take too much time to connect them manually. Within ExtenSive it was therefore decided to include a SaaS system into the ecosystem. This will enable specifically small providers to easily provide their services through the IP4 ecosystem. Development of this system was finished in 2023.

In regard to user-oriented functionality and user experience, several enhancements and improvements were developed within ExtenSive and completed in 2023:

- The travel shopping algorithm was extended to compute itineraries where a car (e.g. a rental car) is not only used for first/last mile but where it is used for the main part of the itinerary and complemented by public transport for the first/last mile.
- Furthermore, the travel shopping algorithm was extended to take an additional criterion into when searching for pareto-optimal trip options. So far, only the duration of a trip (shortest travel time) and the comfort of a trip (minimal number of transfers) were considered. The new version of the trip search algorithm can also find trips with minimum distance (shortest travel distance).

TD4.2 Travel Shopping									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
		Finished: IT2Rail, Co-Active, MaaSIVE							
						Finished: RIDE2RAIL, EXTENSIVE, IP4MaaS			

The deliverables expected for the period have been delivered. TD4.2 reports having accomplished 100% of the planned work during 2023, which represents 100% of the overall TD.

TD4.3 Booking & Ticketing

Nowadays, even within a specific mode of transportation (such as air, rail, urban, etc.), the ability to travel is, at best, characterized by restricted interoperability among different travel service operators. The objective of this Transportation Directive is to coordinate numerous yet parallel interactions with various booking, issuing, payment, and ticketing engines, encompassing crucial activities. The overarching aim is to significantly simplify the traveller’s experience by eliminating uncertainties and complexities tied to the intricate 'behind-the-scenes' procedures involved in multiple booking, issuing, payment, and ticketing processes.

TD Progress

This Technical Demonstrator is based on developments carried out in projects as IT2RAIL, Co-Active, MaaSive Ride2Rail and ExtenSive. Activities in 2023 have allowed finalizing the implementation and integration of all existing components in other IP4 TDs as well as of the new ones created during 2022.

In 2023, all the new use cases created in 2022 have been finalised and implemented, such as implementing the user registration by Digital Onboarding through fingerprint and the new authentication method with Gmail. Also, after sales functionality has been enhanced and the issuing flow has been improved by separating payment and delivery of the ticket, and the integration of the solution for the Best Price calculation for public transport has been finalised.

Following MaaS approaches, 2023 efforts have focused on the implementation of adding to the CMMP’s administrator the possibility of checking the record of actions done by the users, the online validation of tickets supported by a whitelist of tickets sold in the ecosystem, the validation without physical interaction and the reception of a ticket before the trip starts have been finalised and implemented.

In addition, CRM functionalities allowing the validation of new registered users by the administrator and the recording of transactions have been added. The interfacing of the CMMP with a Distributed Ledger has been finalised. This allows providing audit and traceability when mobility packages are created and shared between TSPs. Regarding ticketing delivery and improvement of the After Sales Orchestrator, the activities of implementing the enhancements of IP4 flows including ExtenSive functionalities has finished during 2023.

Moreover, an initial Proof of Concept has been developed of a contactless validation technique. For this purpose, BLE technology have been used and both the field equipment and travel companion needed to be improved.

In 2023, the development of an intermodal best price was completed. This best price covered public transit legs and also bike sharing and car sharing legs. If the costs for single trip tickets of a user exceed a threshold within a day, for example, a MaaS day pass is granted and invoiced that can be valid for different modes of transport. Compared to the previous prepaid and product-based best price in MaaSive, the best price in ExtenSive can be categorized as post paid and route-based.

TD4.3 Booking & Ticketing									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
Finished: IT2Rail, Co-Active, MaaSIVE									
				Finished: RIDE2RAIL, EXTENSIVE					

During 2023 deliverable D4.1 was submitted. This document reports implementation results, integration and testing activities for all components. Since the beginning, TD4.3 has accomplished 100% of the planned work in 2023, reaching the objectives of the TD.

TD4.4 Trip Tracker

The overall objective of the Trip Tracking system is to assist a traveller throughout his multimodal journey in respect to any obstacles that might occur during his trip. Technologies that accurately and timely notify the traveller of those unforeseen difficulties on individual trips will be used. In cases they arise alternative routes will be provided to limit any impacts on them. When a disruption occurs, Trip Tracker provides assistance by calculating with a multimodal approach both whole new itineraries door to door, and from the current position or even only single legs. It will analyse and correlate available static data (such as timetables), dynamic data (mainly real-time data) and passenger data (like preferences, locations). The architecture of Trip Tracking foresees not only to easily remove service providers and/or event sources but as well to add new and upcoming services is it a transport service provider or specific event sources bringing benefit to the travellers.

TD Progress

During the project phase of 2021 the projects CONNECTIVE and MaaSive contributed to the Trip Tracking system. Main objective was a more flexible solution by integrating the Interoperability Framework for both partial Trip Tracker and Event Sources.

Within 2022 some minor stabilisation in cooperation with the CONNECTIVE project in respect to the integration of TT into the Interoperability Framework took place. For instance, the configuration of new partial Trip Trackers at the Tracking Orchestrator was improved. Instead of manually adding the endpoints of pTTs to a list that is read by the Tracking Orchestrator, the Tracking Orchestrator applies a dynamic look-up to get the current endpoints from the Travel Service Registry.

In 2023, no development was done with regards to trip tracking. In 2023, the focus was put on supporting the Open Calls IP4MaaS and Ride2Rail. For example, the IP4MaaS pilot in Liberec included trip tracking for a TSP and the partial trip tracking service provided by the TSP was interfaced by the IF.

During 2023 there was no specific deliverable planned for TD4.4.

TD4.4 Trip Tracker									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
Finished: IT2Rail, ATTRACkTIVE, MaaSive									
			RIDE2RAIL, EXTENSIVE						

The Trip Tracking system has an overall target of TRL6/7. Since the beginning TD4.4 has accomplished 100% of the planned work up to 2022, which represents 95 % of the overall TD. A few final tests and checks were done in 2023 so that 100% of the overall TD were reached.

TD4.5 Travel Companion

The overall objective of the TD 4.5 Travel Companion is to research, implement and evaluate a seamless and interoperable platform offering new levels of interaction between travellers and transport stakeholders along with an innovative ubiquitous adaptive front-end to the global transportation service ecosystem. Allowing the direct communication between TSPs and travellers, and helping the PTOs to create and supervise their virtual stations.

Thanks to their own personal and secured ‘Travel Companion’ travellers will have access to all travel services needed for the journey (shopping, booking, ticketing, trip tracking, preferences, cancellation, ancillary services as well as novel forms of experiences) which will extend and transform the journey to a real door to door experience.

TD Progress

Based on the specification developed in 2021, implementation work was carried out during 2022 and 2023.

The collaborative space released in 2022 was tested, the new Collaborative Space functionality for travellers integrated on the Travel Companion app (map-based interface), working together with the previous reporting tool and feedback requests mechanisms. New advancements in code refactoring have been undertaken to optimize this functionality and improve its overall performance.

The initial version of the map interface was completed and incorporated to the TC PA, this module allows travellers to navigate within the map and get their interactions there, this module interacts as well with the rest of the functionalities available for the traveller (booking shopping, LBE…).

Activities were also performed on the web front end. Initially created in other S2R projects, this module allows users to access services using a web browser with a double identification factor for registration in a simple interface. ExtenSive has enhanced the registration of new users and authentication methods by including Google account, also allowing payment of both travel offers and Mobility Packages with different payment methods.

Finally, work on the orchestration tool was carried out and finalised. This desktop application dedicated to the TSPs for real time travellers' supervision and POI management allowing the display of travellers and network status interact with the TC PA and the Map interface to position POI and LBE on the displayed traveller Map.

The Orchestration tool handles the authoring of multi-user experiences, collecting data about each traveller and adjusting each of the orchestrated experiences, accordingly, thus enabling users to remotely interact. The two applications and related libraries dedicated to share information and meeting points were finalised. Now the operators can populate the Map with the POIs and can send messages to the travellers in specific location when there are using the TC PA. A specific meeting point can be established and shared between travellers. The guidance instructions are then proposed to the travellers.

Accordingly, MR S2R library was updated with the new also, the necessary blocks to allow the interaction and the data sharing based on the TSP tool were added.

Thanks to these achievements, a demonstration was performed at the Pomiechówek station in August 2023 with the travel companion personal application the HoloLens and the orchestration and supervision tool.

Based on the orchestration and supervision tool, and the work performed in WP10 (Geolocation work) guidance instructions were provided to the users guiding them through the station.

This demonstration concluded the interaction with IP3. The Information Reliability Evaluation System (IRES) was defined and IRES system served for the interaction with the TVM to allow the travellers to print their already booked ticket from the TC PA.

The IRES will allow the connection between the TC PA and the vending machine, to allow the travellers to print their already booked ticket.

In addition, particular attention was paid to the collaboration with the open call project Ride2Rail.

TD4.5 Travel Companion									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
	Finished: IT2Rail, ATTRACkTIVE, MaaSIVE, My-Track								
					Finished:_ RIDE2RAIL, EXTENSIVE				

During 2023, 4 deliverables were submitted covering the whole TD4.5planned out of which two were released. Since the beginning, TD4.5 has accomplished 100% of the planned work of the overall TD.

TD4.6 Business Analytics

The TD will provide a common business intelligence foundation for all products and services transport providers based on the access to open-ended web of transportation data offered by the Interoperability Framework (TD4.1).

Based on descriptive, predictive, and prescriptive analytics using multimodal data sets generated by the Travel Service Providers and by the services developed in IP4, the TD will help the passenger carriers to better adapt their level of service to the passengers' demand and to optimize their operations. TD4.6 will also provide interactive and dynamic visualization capabilities. The TD will adopt two approaches to develop Business Analytics. The first is a top-down approach: it aims to identify what information operators would value, regardless of any existing implementation and any data availability. This method is complemented with a bottom-up approach which aims at managing real data from real operators, to be able to build robust big data platforms and to propose rich algorithms.

TD4.6 cooperated with IP2 on specifying a solution on how to exchange data. The value of exchanging new data sets and information about passenger demand and transport supply capacity will be demonstrated in the Use Case. The objective is to implement vehicle occupancy predictive analytics and on dwell times at stations, impacted by fluctuating passenger flows. By exchanging in real-time the information within all subsystems, prescriptive analytics will be developed for example for Train Management Supervision Systems (TMS) for real-time timetable optimization based on the demand (demand-based operations).

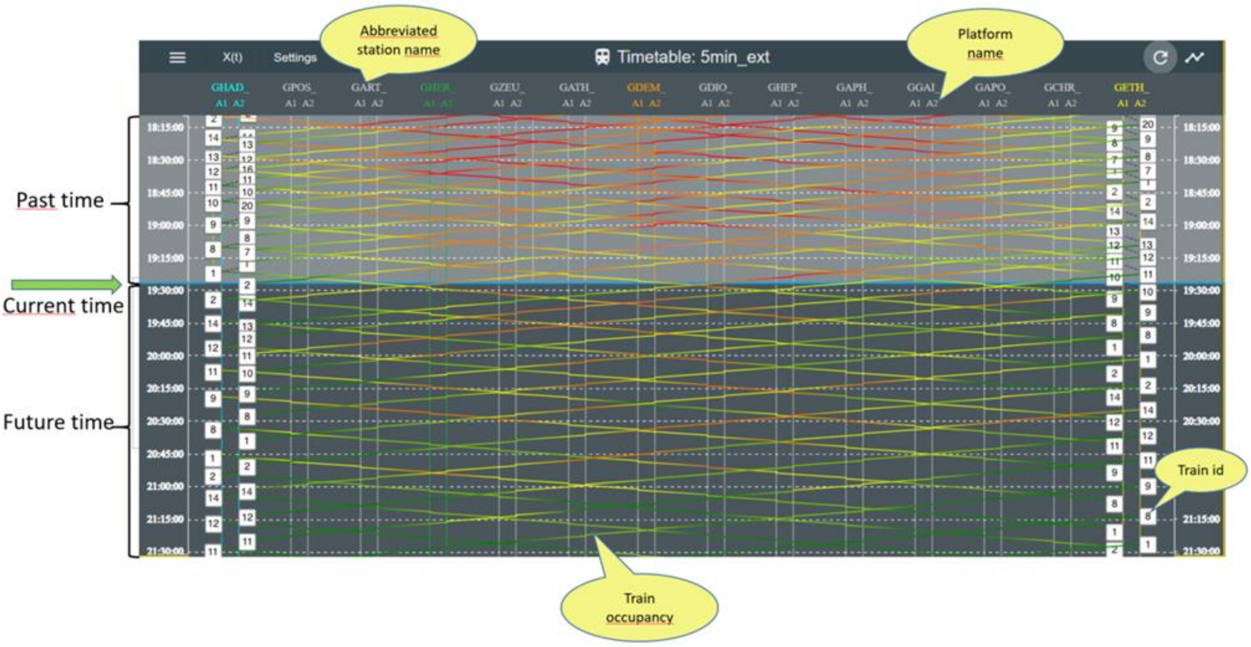
Data privacy is also an important issue in transportation: European GDPR – General Data Protection Regulation is effective since May 2018 and before GDPR adoption, other regulations were applied in the transportation context. To this end, anonymization services will be developed to guarantee privacy and confidentiality.

TD Progress

In 2023, the document 2.6 has been finalized by Network Rail, and reviewed by Indra; STS, and Thales. Two reports in conjunction with Indra, Hitachi and Thales which compare the top-down and bottom-up use case approaches, has been produced and NR has intended to provide some observations regarding the overlap (and therefore gaps) in these approaches. The reports also provide feedback on the visualisations generated by the top-down use cases. The insights and data delivered from this work have been incorporated notably in D2.6.

Analysis Train Services use case, which uses data set generated from Network Rail's own data source, has been finalized by Indra. After an Exploratory Data Analysis carried out during 2022, the works on the development of descriptive KPIs have continued during 2023, analysing the relationships between incidents at the route level, looking at the failures that happen based on the events both at the operator and manager level and their relationships, and also the temporal evolution of the incidents and their correlations, seeing times and impact of each incident.
In addition, work related to the development of predictive KPIs has also been completed, focused on prediction models for events and incidents. Event prediction work has been carried out for a transport operator, assessing daily aggregates and for the following hours, analysing the following 12, 8 and 4 hours. Regarding the prediction of incidents, both simple models (with the operators DB Cargo, Northern Trains Ltd, and Sussex) and a multi-Manager model have been analysed.

Visualisation of the scenario concerning medium term regulation adaptation has been finalized by Thales in 2023. This scenario targets the integration of continuous KPIs computations (using passenger flow simulations) during online operations based on ATS (Automatic Train Supervision) train movements and forecast demand predictions. The ATS Timetable widget representing the train missions in the form of space-time diagram (Train occupancy is indicated by line colour (green = empty, red = full)) has been added.



In 2023, All official deliverables has been finalized. Business Analytics has been presented at the UITP event in June.

Work in this TD has continued until oct-2023, supported by the activities of projects CONNECTIVE and EXTENSIVE.

TD4.6 Business Analytics									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
Finished: IT2Rail									
			Finished: CONNECTIVE, EXTENSIVE						

TD4.6 reports having accomplished 100% of the planned work up to Oct 2023, which represents approximately 100% of the overall TD objectives.

ITD4.7 Integrated Technical Demonstrator

At the core of the ITD lies the objective of opening the transportation ecosystem to new business actors, able to rejuvenate the transportation ecosystem technologies and business models, thus achieving the goals of European leadership in the market. The ITD will release, on a regular basis and for all TDs, successive versions of enriched deliverables, from early conceptual prototypes to the final version. It will act as the orchestrator of other TDs' developments and will ensure the systems approach to integrate the different TDs' results.

ITD Progress

In 2023, the ITD continued to address the coordination of IP4 activities and support internal technical discussions to guarantee consistency among projects. Another focus from the ITD was the coordination of the interface between the CFM projects and the Open Call projects aiming to have integrated and coherent demonstrations allowing projects' objectives to be fulfilled.

Activities in ITD 4.7 were mainly handled and managed by the project COHESIVE until the end of 2022 being from then onwards (2023) managed by the Extensive project – providing technology development) and by Open Calls (Ride2Rail and IP4MaaS – preparing and running pilots).

The ITD had several targets for the year 2023:

- Improve the performance of the ecosystem, providing a more pleasant experience with the Travel Companion;

- Integrate the last technical results from the ExtenSive project;
- Integrate the final technical results from the CONNECTIVE project;
- Maintain and coordinate deployments on the two technical environments (test and demonstration) to be used for integration activities, demonstrations, and pilots;
- Demonstrate the IP4 projects outcomes at UITP Global Public Transport Summit 2023 in Barcelona;
- Coordinate the execution of 5 pilots for Ride2Rail and IP4MaaS projects (Athens, Padova, Barcelona, Warsaw, Osijek, Liberec);
- Preparation and issue of the final documents.

In 2023, under the scope of Extensive, the final functionalities of this project were integrated with those from Connective. These integrations were centred on the preparation of pilot tests, aligned with the guidelines from Ride2Rail and IP4MaaS open calls.

Throughout the year, work activities focused on making travel easier, more connected, and better for passengers. The following points provide an overview of the key developments comprising each TD's activities.

- Improve existing services offered through the Travel Companion from previous releases, through better performance, user layouts or algorithms;
- Focus on finalizing the Interoperability Framework's final release, integrating several services for the pilots in cities including Athens, Padua, Warsaw, Liberec, Osijek, and Barcelona. The integration of the Interoperability Framework has also contributed to an enhanced Trip Tracking.
- Development of a system for planning personalized multimodal European journeys, integrating various Travel Service Providers;
- Implementation of a SaaS system for easier provider integration and enhanced travel algorithms;
- Completed integration of new booking and ticketing components, including user registration and authentication methods, as well as the introduction of a contactless validation technique and an intermodal best price system;
- Development of visualizations for medium-term regulation adaptations and presented at the UITP event.

Regarding pilot activities, in 2023, the second phase of Ride2Rail/IP4MaaS Demonstrations unfolded across six different demo sites: Athens, Padua, Warsaw, Liberec, Osijek, and Barcelona. This phase featured the integration of various TSP services, offering Operators in these cities the opportunity to participate in and engage with the available functionalities of the ecosystem.

The pilot in Athens started on 27th of March 2023 for 1-week period, using the following TSPs:

- OASA (Multimodal PTO)
- Taxiway (Taxi)
- Brainbox (Bike-Sharing)
- MIRAKLIO (PTO responsible for the buses operating within the Municipality of Iraklio, Attica)

The pilot in Padua was executed between 17th and 21st April 2023, using the following TSPs:

- Busitalia (Bus Operator)
- Trenitalia (Train Operator)

The pilot in Warsaw was executed between 15th and 19th May 2023, using the following TSPs:

- ZTM (Public Transport Authority representing MIASTO WARSZAWA – The City of Warsaw)
- MZA (Bus Operator)
- TW (Tram Operator)

The pilot in Liberec was executed between 15th and 19th May 2023, using the following TSPs:

- KORID (Public Transport Authority in the Liberec region)

The pilot in Osijek was executed between 29th May and 2nd June 2023, using the following TSPs:

- GPP PT (Tram and Bus Operator)
- GPP Sharing Mobility: Nextbike (Bike-Sharing)

The pilot in Barcelona was executed between 5th and 9th June 2023, using the following TSPs:

- TMB (Multimodal PTO)
- BusUp (Private Transport on Demand Bus Provider)
- Flexitransport Catalunya (mobility solution created by the AMTU (Association of Municipalities for Mobility and Urban Transport))
- SocialCar (Car Hiring and Car Sharing)

For all the pilots, the project provided the IP4 integrated technology, language support, user guides, bug fixing and coordination support. The ITD focused on the integration for the pilots running in 2023.

Pilot locations

Regarding the dissemination of the results, the following points cover the key activities for 2023:

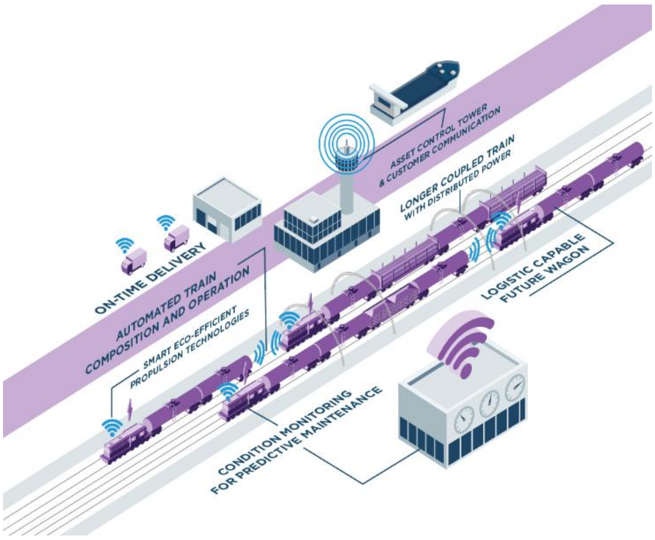
- In January 2023, the first results from the consortium's work in ExtenSive were communicated for the first time in the industry magazine Global Railway Review;
- In June 2023, IP4 had partners presence at UITP Global Public Transport Summit 2023 in Barcelona, promoting some demonstrations and presentations related to the IP4 technologies and solutions;
- In June 2023, Extensive/Connective/IP4MaaS Final Event took place in Barcelona, where IP4 partners had the chance to present the relevant outcomes and achievements of the corresponding projects;

ITD4.7 Integrated Technical Demonstrator									
2015	2016	2017	2018	2019	2020	2021	2022	2023	
Finished: IT2Rail, SPRINT, Shift2MaaS									
			Finished: COHESIVE, IP4MaaS, Extensive						

The ITD accomplished around 100% of the planned work up to the end of the extensive project closure in 2023.

1.2.5. IP5 Technology for Sustainable and Attractive European Rail Freight

The picture below gives a visual perception on where the TDs will introduce improvements.



This IP aims to improve the cost competitiveness and the reliability of freight services of the rail sector in order to meet the ambitious objectives of almost doubling the use of rail freight compared to 2005. This will allow achieving the White Paper objective of a shift of 30% of road freight over 300 km to modes such as rail or waterborne transport by 2030, and more than 50% by 2050. Rail freight must be in a position to offer a cost-effective, attractive service to shippers that helps to take freight away from the already-congested road network. Work focusses on different market segments with specific technical and operational characteristics and needs.

All outputs of the TDs in IP5 constitute an important input for the activities to be carried over in Flagship Area 5 of the EU-Rail programme.

TD5.1 Fleet Digitalisation and Automation

This TD targets the adoption of two global megatrends for freight rolling stock: Condition Based Maintenance and automation based on DAS/ATO and Digital Automatic Coupling for freight trains. DAC is an important boost in competitiveness of the rail freight market, not only delivering increased capacity in the system, but also enabling digitalisation of rail freight, which leads to smart, connected rail freight that offers the necessary information for improved services. The TD focuses on the following areas:

- Condition-based and predictive maintenance (CBM) of locomotives and wagons
- Automatic coupling
- Freight DAS and ATO, the latter is developed in close collaboration with IP2.

TD progress

Throughout the S2R programme, this TD has been implemented via the following projects: FR8RAIL III and FR8RAIL IV. Other projects also include ARCC, FR8RAIL, FR8HUB, FR8RAIL II, LOCATE, SMART, SMART II and INNOWAG were completed before 2023.

Condition Based Maintenance

In the area of CBM, the overall ambition can be summarized as followed:

- Development of a condition-based and predictive maintenance strategy and roadmap, as the umbrella for all asset intelligence projects in IP5;
- System engineering incl. data crunching, modelling, behavioural research & development of mass data infrastructure for live pattern recognition and recommendation of measures;
- Process conceptualization, testing, validation and change management in the implementation.

In 2023, the focus was put on completing the end-to-end solution including processes, data processing, analytics and dashboards for locomotives and wagons. The basis for the end-to-end solution is a well-functioning data path that transfers the data from the locomotive into the analysis systems. The below figure shows the complete data flow for the end-to-end solution build. The CBM end-to-end process starts with the collection of the locomotive data (1). To gather the necessary data e.g. live location, process data, etc., onboard telematic and sensor systems are installed on the locomotive. This data is the basis of all analysis. From the onboard telematic device the data will be transmitted using a mobile connection to the data lake (4) – the storage for all telematic data. After validation and pre-processing the data is transmitted into the Analytics Platform, in which all the data from different systems e.g. maintenance, infrastructure, etc. come together. In order to be able to analyse the individual use cases, the data is presented in user-friendly dashboards (6). Within the dashboards, it is shown how the data of different locomotive components are behaving. The Feedbackloop (7) can be used to check the thresholds defined for CBM-initiated maintenance measures. If a threshold value is exceeded and the locomotive is taken to the workshop, the actual condition of the component can be reported by the workshop using a feedback form in order to compare it with the condition assumed by the algorithm. Once a use case has been validated and the threshold values checked, the corresponding damage code can be automatically transmitted to the ERP system (9). The maintenance rules can be changed quickly and easily using the DM Cube (8).

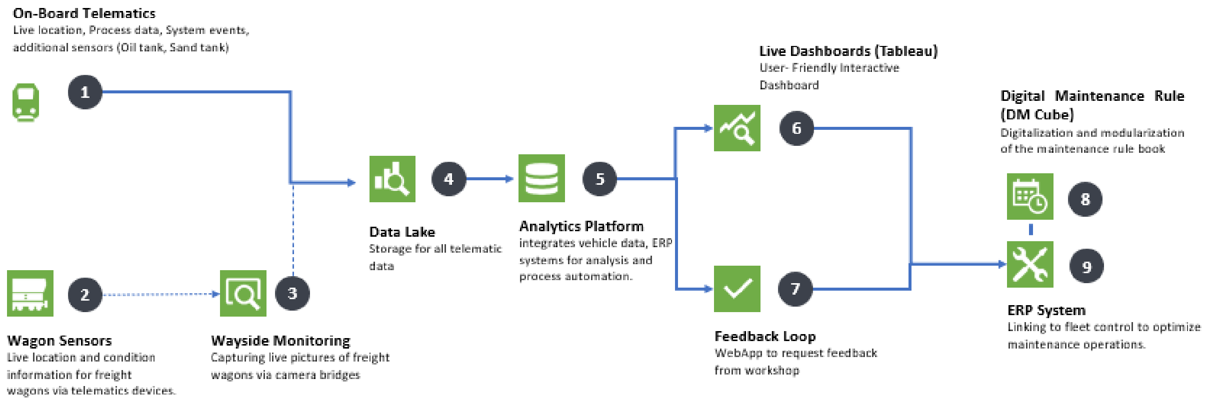


Figure: End to End Data Handling

In recent years, CBM has experimented extensively with new ways of working and systems. However, as CBM grew in maturity and scope and more and more data had to be analyzed and evaluated in order to derive appropriate CBM actions, it became necessary to define clear processes based on previous knowledge and experience. An end-to-end process was created.

The processes created as part of CBM were integrated into existing maintenance processes. They cover both the generation and implementation of new use cases as well as the monitoring of data quality across the entire data path. Along with the newly created processes, the roles of Fleet Management (ECM3), Target-state modifier (ECM2) and the Data Scientists were also revised. Depending on the process step and requirements, the roles were defined as responsible parties within the end-to-end solution. By creating specific processes, it was possible to increase the commitment of those involved and improve the quality of the work. This has made it easier for CBM to be more closely integrated into the processes of the line organization and the ECM organization.

The results from the Technical Demonstrator 5.1 for condition-based monitoring show that the basis for successful predictive maintenance measures is always a stable, efficient IT infrastructure. This makes it possible to develop use cases holistically and thus achieve savings in maintenance costs and increase availability of the fleet. Using the diesel particulate filter as an example, it was possible to prove in operational use that condition-based monitoring can lead to considerable savings. In this use case the temperature and pressure of the diesel particulate filter are measured using the installed sensors. If a threshold value defined by the analysis team is exceeded, an automatic damage code is generated, which is transferred directly to the ERP system via the data path created.

For CBM, two major strategies to gather data to assess locomotives and wagons are: 1. Sensors directly built in the asset and 2. Sensors that are installed close to the railway tracks, that measure specific parameters while a train is moving by . These systems are referred to as wayside monitoring systems.

Historically, wayside measurement systems for railway vehicles have been focusing on detecting critical states of the vehicles like failing axle-boxes or wheel flats. The systems have been designed in a reactive manner to examine the assets for conformity with respect to important characteristics which could lead to damages of the infrastructure or disturbance of the traffic. Hence, the systems are detecting wagons in a faulty state which has implications on both the railway capacity and the probability of inducing wear on the infrastructure.

The main objective of this work so far is to examine the possibility of moving from the existing reactive approaches to a more proactive approach and hence support a CBM strategy for the vehicle, with the aim of reducing the number of capacity consuming events and the probability of introducing failures or wear to the infrastructure. To improve the CBM strategy, a holistic view of the sensors currently installed on the railway is required to identify the gaps and possible improvements that will allow to transition towards a proactive approach.

C-DAS/ATO

As already described in the MAAP, TD5.1 consists primarily of the area of digitalisation and automation. The third main topic within TD5.1 are Connected-Driver Assistance-Systems (C-DAS) and Automated Train Operation (ATO). After the successful ATO tests in Switzerland in 2021, in 2023, as part of DAS, a strategic analysis was carried out to initially analyse the current status of technology and automation systems in the context of freight transport.

Based on this analysis, a qualitative data analysis was carried out within FR8RAIL IV to identify the driving and inhibiting factors in this area and whether scenarios of parallel operation for DAS/ATO are possible. Based on this, recommendations for ATO pilot lines and migration strategies were identified in order to be able to develop a standard within the European framework.

The start of the art so far has been Manual train operation whereby a train driver controls starting, stopping and handling of incidents. Activities within the framework of FR8RAIL IV pick up on this point and have built on previous test activities of the ARCC consortium. Use cases were defined based on these test drives. The focus was on the areas of remote control, running on a shunting yard, service the last mile and infrastructure independence.

The technical activities in the remaining open projects (FR8RAIL III and FR8RAIL IV) completed by end of 2023. It is expected that the demonstration activities are in line with the MAAP planning for this TD.

TD5.2 Digital Transport management

This TD is targeting the digitisation of processes to optimise service planning and operation thanks to real-time data gathering, steering, operation and coordination of intermodal transport at higher speed. This supports better utilisation of available capacity, by optimising access and operation of local hubs which are essential but cost-intensive subsystems for rail freight business. The TD is looking into improvement of effectiveness in marshalling yards and terminals with the introduction of innovations in real time information management (e.g., intelligent video gate). The key challenge is to improve the interaction between yards/terminals and the network, thus reducing the lack of information and adding new decision tools that will increase punctuality and capacity.

TD progress

This TD has progressed through the work performed in FR8RAIL II, FR8RAIL III and FR8RAIL IV. These projects were based on the initial work carried out in INNOWAG, SMART, ARCC, FR8RAIL and FR8HUB all closed by 2021.

The TD5.2 is built around the following building blocks:

- Intelligent Video Gate Terminals
- Improved methods for timetable planning & Real Time management
- Real-time yard management & SWL system

Intelligent Video Gates

In 2023 the work with the concept of IVG has continued within the framework of Europe's Rail FA5 (TRANS4M-R) "Standardised European Railway Checkpoints at borders and other operational stops". There, the concept is further elaborated and implemented across Europe.

Improved methods for timetable planning & Real time Management and Real-time yard management & SWL system

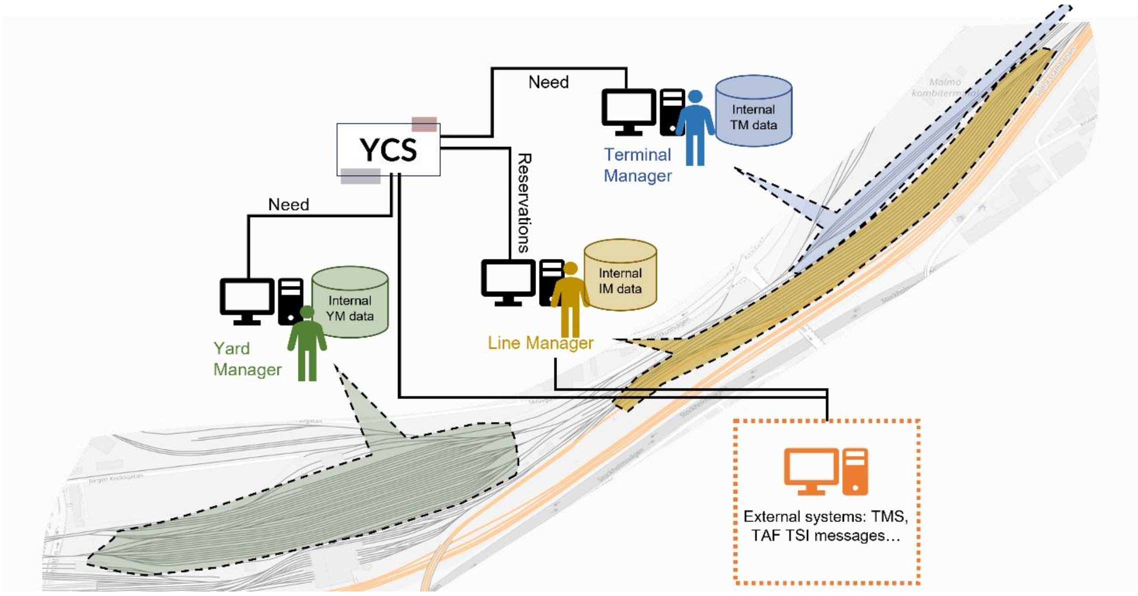
The TD's goal for improved methods for timetable planning & Real time Management Terminal and Yards was to move ahead on the development of the solutions identified for reducing the gap between planning and operation and developing methods for improving network management.

Progress continues by increasing TRL for the advanced real time network management for freight rail traffic. The focus has been on the coordination between traffic control, train drivers and yard management, three essential parts in the real time management of a rail freight network. Works on the final demonstrator started within FR8Rail III compiling scenarios for enhanced and integrated line- and yard planning. The proposed demonstrator had a focus on the interaction between different systems and between humans using these systems, but also on the rail freight system perspective by the inclusion of the connection between the line and the yard.

Main demonstrator demonstrates interaction freight node (yards) and the network. The Yard Coordination System demonstrator (YCS) was developed within FR8HUB and FR8Rail III.

Demonstrator YCS co-operative Planning Malmö Yard

D2.2 (2023-03-01) describes the demonstrator and the specifications of the integrated demonstration platform for planning at a marshalling yard. The specified and developed tool assists in producing coordinated plans for a combined arrival/departure yard. The actors and their roles are specified together with the shared data and the owner of different data. The conflicts that the tool detects and highlights are described as well as the calculation principles for default values which reduce the workload of the use. YCS connects Malmö yards to the network. Line manager control arrival/departure yard. This yard is connected to marshalling yard Yard manager, combiterminal Terminal manager and the rail network.



Yard Coordination System Concept at Malmö

The demonstration has shown that a tool like YCS can improve transparency and enable cooperative and pro-active planning. The demonstration has shown that a tool like YCS can improve transparency and enable cooperative and pro-active planning. The practitioners reckoned that the tool could prevent and alleviate departure delays, and they expressed a strong wish for continued development of such support. An extensive list of experiences, development suggestions, potentials and risks are reported.

User interface and Video

The user-interface is rather similar for the different actors (since they are interested in the same kind of information) but the functionality differs. Most notably, there is data integrity between the actors and an actor can only change data that he/she is responsible for. In the user interface, the trains and activities that are not connected to the actor (and that he/she cannot change) will be semi-transparent. A Video describing YCS is available on IP5 YouTube channel see https://youtu.be/LR_QJG3OvXU?feature=shared

D2.3 YCS architecture, demonstration and next step Europe Rail

In D2.3 chapter 3 there is an overview of the YCS architecture and plans for connecting to a TMS. The TRL6 demonstration with actors is presented in chapter 3.4 of the deliverable, including results and conclusions from the demonstration are also included. Experiments with automatic data updates are presented in chapter 3.5 of the deliverable. Finally, conclusions and next steps for YCS are outlined.

Europe Rail: In flagship 1 and flagship 5 there are common show case planned for the corridor Malmö – Oslo Alnabru. FP1 has a use case with decision support in Malmö Yard and how it connects Malmö – Oslo Alnabru. In FP5 use cases are data processes for collecting and sharing data.

Demonstrator for improved forecasts Malmö – Hallsberg, Estimated Time of Arrival

Further, a model framework for connecting yards and lines is proposed. This model framework incorporates a yard departure prediction model based on machine learning and a rail network macro-simulation model, Proton. The aim is to create a transparent interconnection between yards along the network lines, which will give both the infrastructure manager and the yard operator improved action flexibility by giving them higher prediction accuracy for arrivals and departures.

The combined model benefits and results are reported in D2.3 chapter 4.

The demonstrator integrates Planning Module M2 from Timo SW and the macro simulation SW Proton. Scenarios take as a reference Hallsberg – Malmö rail traffic taking into account planned and unplanned traffic disruptions due to infrastructure maintenance work and infrastructure errors. Progress has been achieved as simulation/rendering times have gone down from hours to the order of magnitude of minutes, becoming closer to expected TRLs regarding response time for a commercial use of this kind of tool.

TD 5.2 Digital Transport Management								
2015	2016	2017	2018	2019	2020	2021	2022	2023
	Finished: SMART, ARCC, FR8HUB, OPTIYARD, FR8RAIL II, FR8RAIL III							

The remaining open project FR8RAIL III within TD5.2 completed its activities at the end of the 2023. It is expected that the demonstration activities are in line with the MAAP planning for this TD and 100% of the TD is completed.

TD5.3 Smart freight wagon concepts

This TD has the objective of delivering technical demonstrations of next generation running gear and wagons for freight. The next generation freight wagons will improve the competitiveness of rail freight logistics by providing more flexible and reliable high-capacity assets at competitive costs. This will be achieved by means of the technological outputs delivered by this TD consisting of low-noise, lightweight, high speed & track friendly freight running gear, intelligent freight wagon for core market share increase & extended markets able to provide information such as wagon assets status and location.

TD progress

This TD is progressed during 2023 through the work performed in FR8RAIL IV. These projects build in the initial work carried out in FR8RAIL, INNOWAG, FR8HUB, FR8RAIL II and FR8RAIL III.

The TD5.3 is built around the following building blocks:

- Running gear and Core Market Wagon (CMW)
- Extended Market Wagon (EMW)
- Telematics and Electrification (T&E)

CMW

In 2023 the work related to Core Market Wagon (CMW) has been focused on:

1. Laboratory tests with Aluminium bogie
2. Field test - run of CMW and FR8RAIL bogie with aluminium frame

Laboratory tests with Aluminium bogie

Aluminium bogie laboratory tests consisted of:

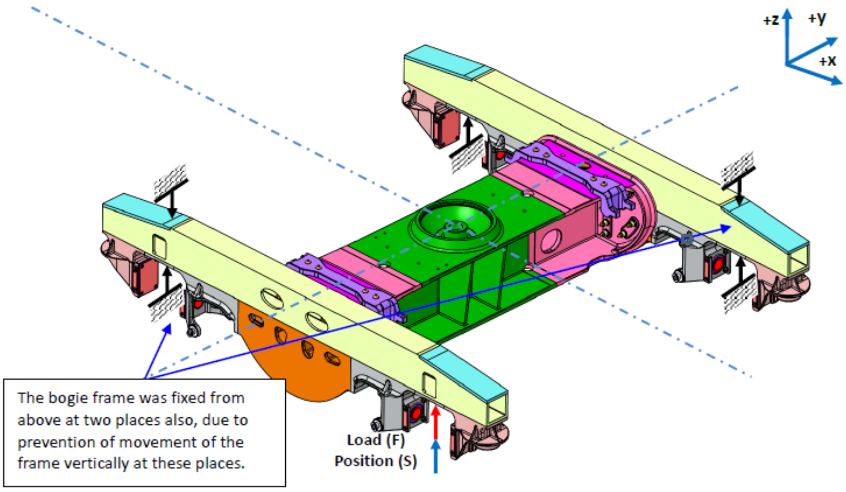
- Simulation of operational strength
- Measuring of bogie frame torsional stiffness
- Static test with normal service loads

Simulation of operational strength

In order to calculate the running strength of the aluminum frame of the bogie, a flexible model in the form of *.mnf was created in the Marc/Mentat 2022 program. The *.mnf file type contains information about the eigenvalue and eigenfrequencies of the structure. The bogie simulation model was created in MSC.ADAMS/View software.

Modeled bogie parts are designed from aluminum alloys EN AW 6082 and EN AC-43300.

The bogie frame torsional stiffness have been measured at the workshop with the aluminium frame as shown in the next figures.



Mechanical scheme of the torsional stiffness measurement


Realisation of torsion stiffness measurement

Static test with normal service loads

15 static normal loading conditions were performed, which the bogie frame was able to withstand without exceeding the permitted stress values. Two loading conditions were not carried out due to the need to rebuild the assembly, which was planned after the end of the exceptional loads.

In the accredited testing facility VÚŽ Praha on the dynamic bench, the bogie frame was equipped with strain gauges and the test stand was established for verification of strength characteristics of the frame in accordance with the applicable standard EN 13749. Measurements of torsional stiffness were performed and the frame was loaded with the first series of static normal operational loadings, which it passed.

During the tests, the values of stresses on the frame during the load with service loads were obtained. This opens up space for us to further analyze the structure and search for possible improvements to achieve sufficient static strength (for example, modification of frame production technology, use of other aluminum alloys...).

Field test - Run of CMW and FR8RAIL bogie with aluminium frame

Field test runs were performed on a siding track of the company Tatravagónka a.s. in Poprad. The plant in Poprad disposes of the overall area of 568,292 m2, built up area is 294,290 m2, and the overall length of rails is 6 km.

The FR8RAIL Y25Lsso(f)-D bogie with aluminium bogie frame was installed under the CMW wagon, see the following figure.

CMW with FR8RAIL bogie with aluminium bogie frame

EMW

In 2023, the work on the EMW was focused on the testing of the wagon under real world conditions and thus its achievement of TRL6 as a demonstrator. The final structural design of the demonstrator was developed over the course of the preceding years under consideration of the following factors:

1. Manufacturability
2. Availability of materials (influenced by supply chain disruptions in the course of the pandemic and the Russian invasion of Ukraine)
3. Structural and functional considerations
4. The available time leading up to the planned display of the demonstrator at the InnoTrans

Testing of the EMW

Following the InnoTrans and in the period leading from 2022 to 2023, a series of experiments were planned which were designed to test and verify various simulated results and the overall running safety and stability of the wagon under real-world conditions. A testing site and an experienced testing provider were selected, the final choice being VÚKV at the test facility operated by VUZ (Výzkumný Ústav Železniční, a. s.).

The tests planned out were as follows:

1. Test for safety against derailment (quasi-static torsion test in accordance with EN 14363 Method 2)
    - Wagons in five loading conditions, empty to 24 tonnes loaded
    - Measurement of wheel forces on a test stand
    - Measurement of the wheel-rail forces in a flat 150m curve
2. Driving test in an instrumented curve at low speed (R = approx. 150 m)
    - Unloaded and fully loaded with 24 tonnes
    - Forces measured using instrumented track in 3 measuring positions according to EN 14363
3. Driving test according to EN 15839 in S-curve with small radius (150 m)
    - Fully loaded with 24 tonnes
4. Driving test on a straight track and in curves with large radii (1400 m)
    - Unloaded and fully loaded with 24 tonnes
    - Checking driving stability/safety up to speeds of 140 km/h

The basic wheel-rail interaction forces (Y, Q) were measured in an instrumented track section as described above. The use of conventional measurement wheelsets was not practicable in view of the non-standardised wheelsets and the EMW's use of wheel brake discs. As sufficient information could be collected with the help of instrumented tracks and various displacement and acceleration sensors, the production of measuring wheelsets was considered an avoidable risk.

Many acceleration and displacement sensors were used to measure the driving characteristics. The following variables were measured during testing:

1. Wheelset yaw
2. Vertical primary suspension
3. Lateral primary suspension
4. Vertical secondary suspension
5. Lateral secondary suspension
6. Vehicle roll
7. Pitching of the bogie frame
8. Accelerations on the wagon frame and bogie

Two cameras were installed in addition to the existing sensors. The cameras filmed the wheel-rail contact of the leading wheelset on the one hand and the EMW from above and thus the overall behaviour on the other.

The tests were to include runs with both active and deactivated air suspension, but problems with the air suspension's sensor system became apparent after the period in which the wagon was parked outdoors over the winter of 2022/2023. Due to supply difficulties with spare parts, it was decided to carry out the tests with the air suspension switched off. As this condition (driving on emergency springs/empty air springs) represents the most unfavourable configuration with the lowest possible torsional flexibility and is usually the most critical case, the tests are still relevant for an evaluation of safe driving behaviour under certain conditions.

Testing results

The tests began in May 2023 with the derailment safety test. This two-part test consisted of a torsion test to determine the wheel-rail forces with a mobile test stand and on a section of instrumented track. In the test rig, a test rig is mounted under each wheel to lift the diagonally opposed wheels. In this way, the torsional flexibility is tested and thus the wagon's ability to drive through twisted tracks without unloading any of its wheels. This ability is a crucial test of safety against derailment.

The measurements were carried out with different loading scenarios. The unloaded condition and the loaded condition were tested. The loading was realized using steel frames with corner castings corresponding to the dimensions of 20-foot containers. Concrete slabs were placed in these frames until the target mass of 12 t was reached for each frame. After each increase in mass, the measurement was repeated to determine the Q/Q relation.

The test was carried out in the VÚKV test hall. The vehicle was lifted by workshop jacks ca. 1.2 m above the top of rails. Test rig was arranged under vehicle. All support - wheel contact points were set into the horizontal plane. The vehicle was positioned on the test rig. Wheel vertical displacements and vertical wheel forces were continuously measured at each train wheel.

All twist cases in all loading conditions were performed in separated tests. Twists (g*) were performed three times to investigate the repeatability.

The positive results of the previous tests enabled the vehicle to be trialled on the large test ring. The driving tests were initially carried out in an unloaded state. The tests were started at a speed of 30 km/h and the speed was gradually increased by 10 km/h to the target speed of vmax = 140 km/h. From a speed of 120 km/h, the increase was only 5 km/h for safety reasons. The unloaded tests were successful; the car remained stable and ran smoothly despite the air suspension being switched off. This was consistent with the simulation results from the multi-body simulation (MBS), which had shown stability up to 200 km/h under most loading conditions.

After the positive test results with the unloaded EMW, the EMW was loaded with 24 tonnes and testing continued. The tests also began at a speed of 30 km/h, with the aim of gradually increasing this up to vmax. However, an anomaly occurred on the rear wheelset during the test. At approx. 30 km/h in a curve with approx. 140 mm superelevation (i.e. under very high vertical and lateral loads due to the excess superelevation), this wheelset began to develop excessive resistance. The test was stopped in order to examine the affected parts, but the affected wheelset seized shortly before coming to a complete standstill. As an in-depth inspection or repair in the field was not possible in the limited time available and with the tools on hand, the fully loaded vehicle could not be tested up to vmax. Despite the cancelled test, it was observed that the EMW remained in a safe and stable condition during the incident.

Summary of testing results

In summary, the testing of the EMW was largely successful, especially considering the many innovative aspects incorporated into its design.

With the conclusion of the EMW's first extensive testing campaign, the vehicle and project have attained the level of maturity and technology readiness needed to prove its viability in the real world. The tests represent the culmination of the extensive work that went into preparing for them, but also the considerable effort by those involved to shepherd the wagon from its concept phase through the design, simulation and manufacturing processes, all the way to the testing grounds in Velim in Czechia.

Telematics & Electrification

The TD has also progressed in the activities related to telematics and electrification with the aim of building up the intelligent freight wagon. During 2023, activities were focused on the field tests of the **generic T&E for the intelligent freight wagon**.

The generic T&E solutions for the intelligent freight wagon have been tested on field in Sweden. The circular container commercial route between Nässjo and Goteborg Port has been selected for that purpose. The daily route starts from Nässjo traveling through Alvesta to Goteborg, and returns to Nässjo thrugh.

The solution of the intelligent wagon consists of different components:

- **wOBU**: the wagon On-Board Unit (wOBU) is a centralized system of the wagon that connects to the wOBUs and LOBU and collects all the information gathered by the sensors of the wagon. Moreover, it is responsible for the communications and the positioning of the wagon, for which the solution included in the field test in Sweden consists of a multi-sensor system with GNSS, IMU and UWB.
- **WMS**: the wagon monitoring system is responsible for monitoring tee assets of the wagon, in the field test in Sweden accelerometers to monitoring the springs of the bogies suspension have been deployed.

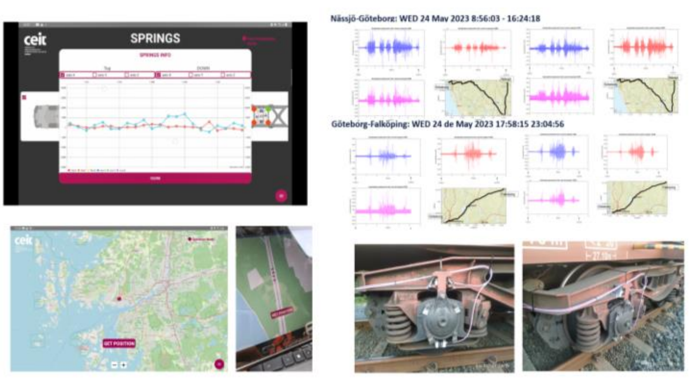
Moreover, the solution also includes components not integrated in the wagon:

- **LOBU**: the locomotive On-Board Unit (lOBU) is a centralized system that connects the wOBUS, the FTSMS and is able to send / receive data from vehicle to infrastructure / wayside equipment.
- **FTSMS**: the Driver Desk that provides information related to the train and the wagons to the driver and allows the driver to interact with the system through requests.

Generic T&E for the intelligent freight wagon

The functionalities tested in are summarized as follows:

- **Driver Desk**: application deployed in a tablet offering to the driver information of the train and wagons: and allowing to interact with the system. The functionalities tested in Sweden were train composition, train integrity, position, status monitor and springs.
- **Wagon Monitoring System**: the sensors installed on the bogies of the wagons allowed to obtained information of the different points where the sensors were located as shown in the picture below.



Wagon Monitoring System

- **Train Integrity and Positioning**: Train Integrity concepts class 1 and class 2 have been set in the Sweden tests and the results of the different runs have been gathered. Moreover, the multi-sensor positioning system with GNSS, IMU and UWB has been also tested.

TD 5.3 Smart Freight Wagon Concepts								
2015	2016	2017	2018	2019	2020	2021	2022	2023
	Finished: FR8RAIL, INNOWAG, FR8HUB, FR8RAIL II, FR8RAIL III, FR8RAIL IV							

The remaining open projects FR8RAIL III and FR8RAIL IV within TD5.3 completed their technical activities at the end of 2023. Full completion of the TD is expected in 2024 once the final deliverables will be approved. It is expected that the demonstration activities are in line with the MAAP planning for this TD.

TD5.4 New freight propulsion concepts

The target of this TD is to provide more attractive rail freight services to the final customer, with competitive rail solutions maximizing flexibility and efficiency while reducing the operating and maintenance costs. The focus of this TD is on improving the overall performance of today's locomotives by adding and integrating additional functionalities and technologies. Future locomotives will provide extreme flexibility for operation in non-electrified and in electrified lines, allowing private and public operators to offer broader rail freight services according to demand without the need of changing the locomotive or allowing the new production concepts. Future locomotives will feature remote control for distributed power, thus, allowing the increase of the train length up to 1500m and consequently improving the cost efficiency of rail transport. Moreover, other areas of work include reduced LCC, braking energy recuperation, operational efficiency increase by automating various activities such as train start-up, train preparation, start of mission, stabling and parking, generally shunting.

TD progress

This TD is progressed during 2023 through the work performed in FR8RAIL III and FR8RAIL IV. These projects build in the initial work carried out in FR8RAIL, INNOWAG, FR8HUB and FR8RAIL II.

Last Mile Propulsion systems

The main achievements for 2023 were finalization of development of Small-Scale Prototypes of improved traction chain with building and testing of the small-scale prototypes of the MF auxiliary converter and the SiC motor inverter to verify the theoretical study about efficiency improvements.

Long Trains up to 1500 m

In the topic area of over-long freight trains up to 1500 m with Distributed Power System (DPS), activities took place in 2023 focusing on a migration concept for the introduction of such trains into operation and on the analysis of signalling needs for over-long freight trains. The focus of the activities carried out and the most important results from the work package are summarised below. Detailed documentation of the status of work was provided in the two deliverables D8.1 and D8.3 of FR8RAIL IV.

Migration Concept

The work done for the migration concept focused on the following topics:

- vehicle-catenary interaction,
- operational concept,
- simulations of freight train longitudinal dynamics and
- the implementation of test runs

For long trains with DPS, the individual activities are briefly outlined below.

Regarding the interaction between vehicles and overhead catenary, the effect of the maximum current was investigated using dynamic simulations of freight trains with different masses and on different routes by DB Netz. The first step was to analyse relevant routes, which were selected based on their importance for rail freight transport and the respective gradient. The routes considered were mainly located in southern

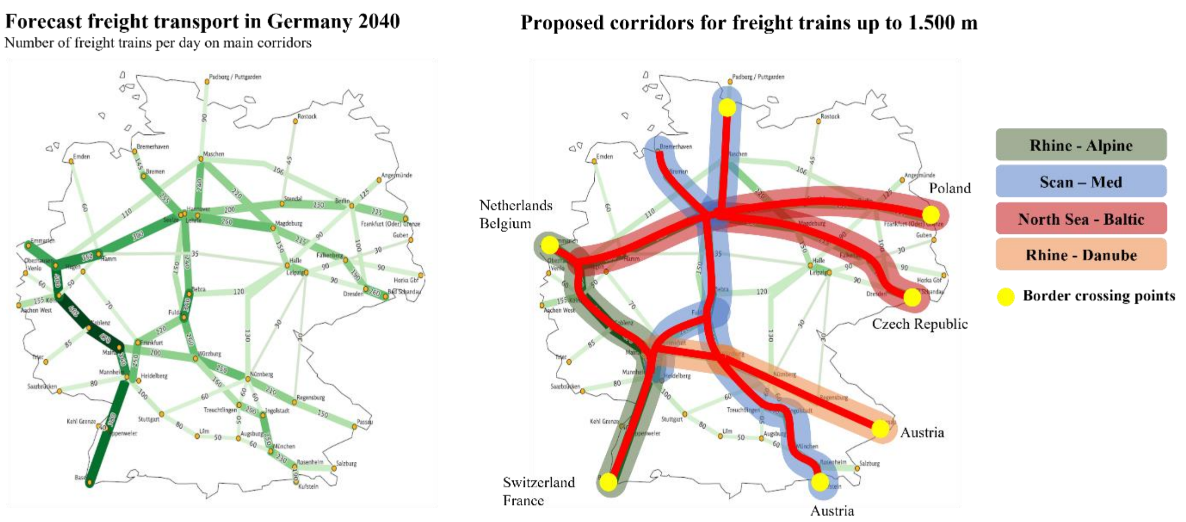
Germany. In this analysis, three different upper current limits were considered (600 A according to today's standard, 750 A and 900 A) and the train run was simulated with these values. In addition, a variant study was carried out in which stops to comply with operating requirements at various points along the route were included. The results show a clear impact of the current restriction on the train's overall running time. However, by intelligently upgrading the overhead line for higher currents, longer and thereby heavier trains with DPS can achieve the same journey times as today in double traction.

A second topic area related to the vehicle-catenary interaction of long trains with DPS was the operational handling of electrical section insulators which was analysed by DB Netz. If an electric traction unit with a raised pantograph comes to a standstill in an electric section insulator, this can result in a hazard due to excessive heating of the overhead catenary, so this situation must be prevented during operation. As DPS trains may have a significantly longer pantograph spacing than e.g., today's multiple units, this problem requires special consideration. Two pilot lines in Germany (Oberhausen - Munich; Oldenburg - Landshut) were selected to obtain an indication of the gravity of this challenge. On these routes, the distance to an electrical section insulator was analysed for all main signals (entry signals, exit signals, intermediate signals, block signals). The results show that critical cases for DPS trains (distance between signal and section insulator less than 800 m) occur at various points along both routes. DPS trains therefore require selective pantograph control which makes it possible to lower the pantograph of guided electric locomotives in electric section insulators.

In the operational concept for long trains with DPS, two main areas were analysed:

- corridors for over-long freight trains with DPS up to 1500 m (Germany and Sweden), and
- operational processes from the perspective of a railway undertaking for operations with DPS trains.

The development of a proposal for future long train corridors in Germany from an operator's point of view was based on traffic forecasts for rail freight transport in 2040 by DB Cargo. The introduction of over-long freight trains should be focused on certain corridor routes with high traffic volume. Due to the high number of trains, the potential of bundling two trains that are close to each other in terms of time and space is greatest. From the perspective of the railway companies, a target network for Germany was developed based on this forecast (see the figure below) which includes the most important rail freight corridors.



Forecast on rail freight transport in Germany 2040 and proposal for long-train corridors

Trafikverket has been working on enabling freight trains of up to 1050 m, looking at the Bothnian Corridor, the Kjuna intermodal terminal and the Malmö-Öresund Corridor. Along these routes, specific points were identified where passing loops could be extended for this train length and concrete planning was initiated.

The operational target processes for the journey of a DPS train was analysed and discussed including various operational experts and in part based on results of the other subtasks, e.g., the investigation concerning electrical section insulators or the simulation of the longitudinal dynamics by DB Cargo. The overall process is divided into four phases:

1. Planning and dispatching
2. DPS train preparation
3. DPS train ride
4. DPS train decomposition

In 2023, a demonstrator train with a length of 1050 me was planned by Trafikverket to run between Gothenburg and Sundsvall based on the experience gained from the previous tests. Due to operational problems with the new Swedish timetable system, this special train unfortunately had to be cancelled and could not be implemented as part of the project. This change to the scope is the subject of the second amendment. However, extensive preparations were made for this train, carried out by Trafikverket but also including, for example, the development of a measurement concept for measuring the braking behaviour during the journey by DB Systemtechnik.

Analysis of signalling needs for long trains

As part of this topic area aspects of the infrastructure and signalling for over-long freight trains with DPS were considered and analysed. Both Class B systems and ETCS were at the centre of the analysis. The results show that comprehensive equipment with ETCS offers opportunities to consider the issue of over-long freight trains from the outset in planning, but there are various hurdles and challenges that are to be discussed and further assessed in the future. In addition to the signalling systems, other aspects of the infrastructure were also highlighted, such as level crossings or track vacancy detection. The observations mainly related to the systems used in Germany. An outlook on other European countries, especially Sweden, is given regarding selected aspects.

TD 5.4 New Freight Propulsion Concepts								
2015	2016	2017	2018	2019	2020	2021	2022	2023
	Finished: FFL4E, DYNAFREIGHT, FR8HUB, M2O, FR8RAIL, FR8RAIL II, FR8RAIL III, FR8RAIL IV							

The remaining open projects FR8RAIL III and FR8RAIL IV completed their activities by the end of 2023. It is expected that the demonstration activities are in line with the MAAP planning for this TD once the final deliverables will be approved in 2024.

TD5.5 Business analytics and implementation strategies

This Technology Demonstrator was completed in 2021.

TD5.5 Business Analytics and Implementation Strategies									
2015	2016	2017	2018	2019	2020	2021	2022	2023	...
	Finished: SMART-RAIL, FR8RAIL, INNOWAG, FR8HUB								

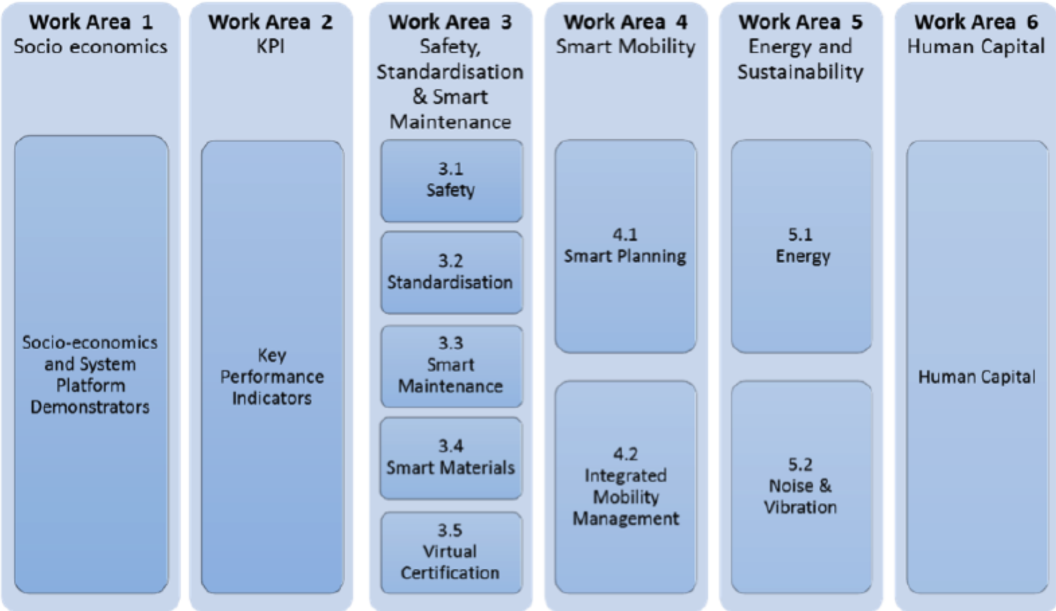
1.2.6. CCA Cross Cutting Activities

An overview of the various work areas in the CCAs is shown in the figure below.

Cross Cutting Activities are relevant to the different subsystems of the five IPs taking into account the interactions between them.

These Cross Cutting Activities ensure that the R&I activities within the different Innovation Programmes are closely aligned in terms of their objectives and their requirements, as well as the methodologies for evaluation and assessment of impacts. The Cross Cutting Activities facilitate a coordinated approach in order to avoid duplication and guarantee consistency.

CCA work is organised so as to achieve the objectives in the following areas:



Activities under WA 3.4 (Smart Materials) have not started; some activities on this subject will be carried out in the dedicated Innovation Programmes. Activities in the following WA have been accomplished in previous years: WA 1 (Soicial economics, WA 2 (KPIs), WA 3.1 (Safety), WA 3.2 (Standardisation) WA 3.3 (Smart Maintenance), WA 3.5 (Virtual Certification), WA 4.1 (Smart Planning), WA 4.2 (Integrated Mobility Management) and WA 6 (Human Capital). Below a summary of the activities performed in the CCA Work Areas (WA) in 2023 (Focused on WA5.2 - noise and vibration, the only remaining open activity).

WA5.2 – Noise and Vibration

The overall objective of this work area is to reduce the annoyance and exposure to noise and vibration (N&V) related to the railway sector in Europe and to provide the necessary system approach and leverage the results from all the IPs by applying effective noise control in the different technical demonstrators. The N&V work area further supports the development of simulation methodologies for exterior noise at standstill and pass-by, based on existing tools stemming from ongoing and past projects, as well as the prediction of ground-vibrations by passing trains. The outcomes will further improve the acoustic certification process for new trains e.g. during authorisation as well as for impact studies on vibration prediction during the Environmental Impact Assessment for new or upgrading railway lines.

The Noise and Vibration work area was covered in the previous CFM project FINE 1 and in the OC project DESTINATE, which were completed in 2019. Despite that the 2nd phase projects were heavily impacted by the COVID pandemic, the three projects, the CFM project, FINE 2, and two complementary Open Call projects TRANSIT and SILVARSTAR finalised their activities during 2023.

Regarding the **exterior noise prediction tools**, after all planned measurement campaigns within the framework of both the CFM and OC projects were completed in 2022, the focus of work in 2023 was put on analysing them and evaluating the outcomes. The focus of this activity on exterior noise simulation is to take into account the train integration effects (i.e. noise propagation when a source is integrated on the train). The train equipment has been measured standalone outside the train and again when installed on the train in standstill and pass-by modes. Two types of equipment are measured: an auxiliary converter and an HVAC system. From the standalone measurements of the equipment, equivalent monopole source data has been derived, including installation effects. The monopole source data is applied to predict the SPL (Sound Power Level) at the microphone positions used in the outdoor measurements and the prediction is compared to the measured SPL. The results were compared by the various commercially available or internally developed software simulation tools to carry out exterior noise propagation calculations used by rolling stock manufacturers and operators and finally evaluated by an uncertainty assessment.

The main conclusion of the exterior noise prediction tool is that the manufacturer's tools have similar accuracy as the advanced models developed in TRANSIT.

Pass-by noise is mainly driven by the vibrations generated at the contact between the rail and wheel, which is designated as rolling noise. Other contributions, such as traction noise (motor, gearbox) and aerodynamic noise (at high speeds) may also significantly contribute in some cases. To tackle the overall noise emissions of a train it is necessary to **separate** the different **noise sources** and to know their dedicated contributions to pass-by noise. The overall goal of this research was:

1. Separating the noise contributions (e.g., track noise from train noise) with the help of different selected techniques which rely on test methods.
2. Transposing noise emissions to a destination track by correcting the track contribution to a track with reference characteristics and recomposing the total pass-by noise.

The objective for the future is to use these separation techniques for the pass-by certification test which can partially replace the extensive and costly field measurements currently in use with virtual certification. This outcome could simplify the certification process as it is prescribed within TSI noise. Two aspects have been separately explored: separation of sources other than rolling noise and separation of wheels and track noise.

Two methods are explored for the separation of sources other than rolling noise (aerodynamic noise, traction noise, …): Beamforming (microphone array) and a PBA-based method. The following conclusions are drawn regarding the application of the two related methods:

> **Pass-by Analysis** (PBA) method provides a source identification in a single direction (longitudinal). Sources may be identified only if they significantly dominate the other sources at one precise location during pass-by. A process was described by TRANSIT but it is not yet conclusive to identify punctual sources power level and directivity, for the moment it can only describe power level for complete train vehicles, which is not the required input for simulations. For these reasons, it was not used to feed simulation models in this task. However, this method could be very useful to describe prominent sources in specific cases.
>
> The **beamforming method** enables a two-dimensional source identification (longitudinal/vertical plane). It was successfully demonstrated that the method can spatially identify sources within a 15 dB level range, which is confirmed relevant for pass-by separation applications. With additional manipulation (deconvolution technique), it is possible to identify individual source strength, but with significant uncertainty as the method failed to identify plausible directivity patterns.

Separation techniques tested aimed at taking a step forward to build a reliable identification of vehicle versus track noise. When using all available input data combinations, it was shown that pass-by simulations could deliver a satisfactory level of accuracy compared to the initial ambitions of work area.

During 2023, investigation of the challenge to determine the acoustic roughness of wheels from trains at pass-by measurements of running trains was carried out in case dedicated wheel roughness measurements of trains are not feasible or known. The results provide input to the revision of the CEN/TR 16891 including new data sets and recommendations.

During environmental impact studies by planning new or upgrading existing railway lines, not only noise impact studies but also extensive prediction of the ground vibration is necessary within the planning process. The first ground vibration prediction tool has been developed with a holistic approach capable of the assessment of vibration levels for large-scale studies and followed a hybrid approach, combining numerical prediction with experimental results. The database includes sets of data describing vehicles, tracks, unevenness, and soil and building transfer functions. The tool was integrated into noise mapping software with graphical user interfaces (GproIS level). The database includes sets of data describing vehicles, tracks, unevenness, and soil and building transfer functions.

In 2023, the software of this prediction tool was finalised and an extensive validation process was carried out comparing the data achieved by the simulation using a comparison with state-of-the-art numerical models for 18 case histories including measurements of urban traffic, mixed traffic and high-speed traffic with data by measurements. The results are promising, the vibration prediction tool is able to predict vibrations with high accuracy, especially when measuring data for the emission, the propagation transfer functions and the transfer functions to the building can be used.

The enhancement of the tools for **auralisation & visualisation** was finalised. More sophisticated virtual reality scenarios were developed for the demonstrator. Some examples are presented in YouTube videos, but the full realistic impression will be achieved by using VR glasses and headphones to cover the 3d effects. In 2023, an extensive validation process of the developed software was executed independently from the developers. Validation was performed by comparison of basic acoustic quantities and the psychoacoustical quantity loudness. Additionally, comparative listening tests have been carried out to validate the auditory impression. Two test cases were used for validation, a pass-by of a regional train without any mitigation measure (no mitigation measure) at velocities of 140 – 160 km/h and 2nd pass-by of a regional train with a standard barrier of 3 m height at velocities of 140 – 160 km/h. The validation of these two scenarios shows very good accordance for the acoustic quantities.

The WA objective to monitor and summarise the acoustic development status of the Shift2Rail Technical Demonstrators (TD) was carried out. However, the assessment in a holistic model to show the noise reduction of the trains on a system level couldn't be carried out due to a lack of validated and reliable results on environmental noise emissions from the projects, as they were not designed to carry out tests which could have provided the necessary data.

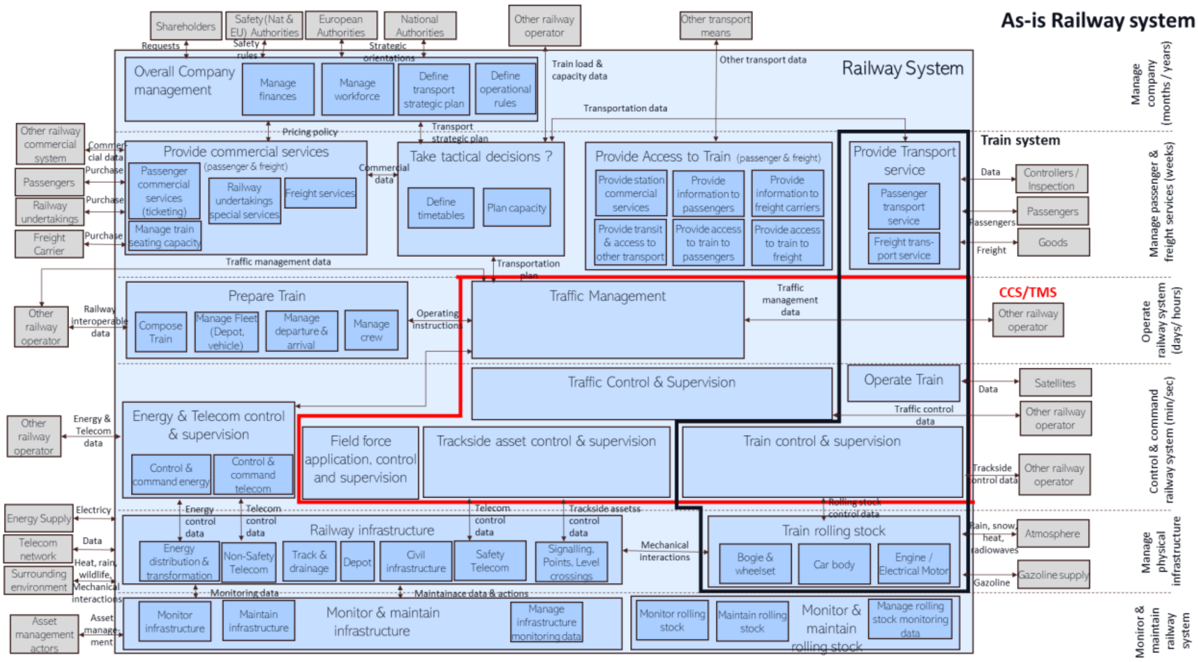
The work related to **new concepts** and approaches on **innovative materials** and design tools for improved interior sound control and acoustic comfort for passengers didn't bring the expected results. Two promising innovative solutions have been chosen to be further explored in subsequent tasks: the solution for the HVAC duct system and the design of the horn cover. Originally the final target of this work was to show the effect of this new approach with UTLF resonators installed on the train, but as the prototype did not have the proper acoustic performance and an estimation of the effect of the UTLF resonators was performed based on the calculated performance of the simulations and available interior noise data from vehicle measurements only.

1.2.7. IPx activities - Disruptive Innovation and Exploratory research

LinX4Rail and LinX4Rail-2 are IPx projects respectively launched in December 2019 and December 2020. Both are aiming at setting the grounds for a shared vision of the railway system architecture, as well as the development of the CDM (Conceptual Data Model) which will enable different simulation or operational subsystems to run together. This paves the way to building a shared and interoperable architecture. The work in this direction has now been taken by the Europe's Rail System Pillar.

The main results of the projects consist in:

- 2 consecutive releases of the System Functional Architecture. As an example, below is shown a proposed as-is overall railway system architecture,



Overall railway system as-is architecture

- The specification and the set-up of the formal definition of the Conceptual Data Model;
- The demonstration of the applicability of the CDM to concrete railway scenarios through four relevant use cases;
- Keeping up to date the ontology dictionary OntoRail by regularly uploading the newest versions of the source models & providing a short YouTube video giving an overview of the LinX4Rail project, focused on the main functionalities of the railway semantic dictionary built on top of the OntoRail knowledge engine.

In-order to get a broad acceptance for the technical concepts of the Europe's Rail CDM and System Architecture, three dedicated CDM workshops have been organized throughout the year 2022.

LINX4RAIL was completed in November 2022. LINX4RAIL-2 completed its activities in May 2023.

Artificial Intelligence (AI)

RAILS (Roadmaps for A.I. integration in the rail Sector) is a Ph.D. research project launched in December 2019. The project investigates aspects related to the adoption of Artificial Intelligence in rail automation, predictive maintenance and defect detection, traffic planning, and capacity optimization. Based on the work conducted during the first 2 years of the project, the research carried out in 2023 aimed at:

- Developing methodological and experimental proofs-of-concept;
- Developing Benchmarks, Models and Simulations as well as their key conclusions.

The goal of the proofs-of-concept is to support the definition of roadmaps, to answer research and development questions in application domains which are significant for the innovation of the railway sector, according to the analysis conducted in early stage of the project.

Proofs-of-concept have been established and are currently under development. They address the following issues specific to the railway operations:

- Railway Obstacle Detection and Collision Avoidance;
- Cooperative Driving for Virtual Coupling of Autonomous Trains;
- Predictive Maintenance for Rolling Stock;
- Smart Maintenance at Level Crossings;
- Graph Embedding for Primary Delay Prediction;
- Big Data on Incident Attribution Analysis.

The proofs-of-concept resulted in the definition of case studies that can be used as benchmarks in future research, and innovative approaches which exploit A.I. algorithms and techniques. The comparison among alternative solutions and the development of simulation tools and scenarios have also been addressed in carrying out the experiments. The main results are the following:

Railway Obstacle Detection and Collision Avoidance
An approach to effectively locating, identifying, and detecting any kind of obstacles on the railway track, by leveraging on lightweight equipment, such as a single camera mounted on front of the train. The approach uses computer vision and unsupervised learning. This proof-of-concept also allowed to underline the role played by scenario simulators and data augmentation techniques to build synthetic datasets. Recommendations are mainly oriented at highlighting the benefits that 3D editors could introduce when it comes to data collection for the fast realisation of PoCs, promoting the exploitation of domain- and task-specific characteristics which are peculiar to the rail sector, and underlining the potential of unsupervised anomaly detection approaches (integrated within a modular architecture) to detect any possible obstacle on rail tracks.

Cooperative Driving for Virtual Coupling of Autonomous Trains
An approach to virtually couple two or more trains in a single convoy through a Train-to-Train communication network to reduce the headway between them, thus enhancing line capacity. The approach, leveraging tools transferred from the automotive field, focused on the development of a controller based on Reinforcement Learning techniques. This proof-of-concept also allowed to underline the role played by the simulation platforms for training and validation purposes, since datasets would be inadequate to work in concrete operational scenarios. The recommendations are related to the potential of Reinforcement Learning methods to develop control strategies that could guarantee the Virtual Coupling objectives in a safe manner. The main criticalities concern the lack of explainability due to the inherent probabilistic nature of the proposed approach, the need for advanced simulators for virtual testing and validation, and the possible extension of the current European railway standards and regulations to account for the certification of safety-critical AI-based applications.

Smart Maintenance at Level Crossings (LCs):
An approach to monitor the health status of LCs systems (including a barrier and audio/video signals) with a specific focus on the usage of non-intrusive sensors. The approach is based on the definition of a modular architecture and exploits Convolutional Neural Network and Deep Learning object detectors. This proof-of-concept also allowed to underline the role played by videogames (such as GTA V) and Transfer Learning to cope with limited data availability. Recommendations are mainly oriented at: i) highlighting the benefits that 3D editors could introduce when it comes to data collection for the fast realisation of PoCs; ii) promoting the exploitation of task-specific characteristics which help to facilitate the tasks that AI model should face; iii) emphasising the contributions that AI and audio-video data can bring in the realisation of Digital Twins; iv) underlining the benefits of using modular approaches; and v) suggesting the possible dual-use of approaches leveraging audio-video data which could be exploited also for safety purposes.

Predictive Maintenance for Rolling Stock
An approach to continually monitor the health condition for train vehicle rolling stock with the particular purpose of reducing the overall cost of uniform rolling stock maintenance activities. This approach is represented as the job scheduling optimization problem based on a meta-heuristic algorithm that uses the particle swarm optimization method. This proof-of-concept also allowed to underline the role played by heuristic algorithms and predictive maintenance to fulfil the requirements from industrial practice needs. Recommendations encompass: i) investigating techniques for multi-objective optimisation to simultaneously handle multiple conflicting objectives; ii) integrating predictive maintenance models to improve the scheduling of maintenance activities; and iii) exploiting transfer learning and generalisation methods to reduce the training time and the resources required by Reinforcement Learning models.

Graph Embedding for Primary Delay Prediction
An approach incorporates the Structural Deep Network Embedding (SDNE) and Singular Value Decomposition (SVD) to understand and model the complex structure of the railway system from a network perspective and tries to capture a comprehensive collection of features including network topology, infrastructure, and train profile into a framework of train delay level prediction. This proof-of-concept also allowed to underline the role played by Graph Embedding and Matrix Decomposition to address traditional traffic management problem. Recommendations are mainly oriented at: i) introduce relevant AI or non-AI

techniques that enhance interpretability; ii) incorporate additional features into the learning process; iii) emphasise the ability of Customization and Adaptation of the model. On the other hand, regarding "Big Data on Incident Attribution Analysis", recommendations encompass: i) explore the feasibility of enhancing infrastructure planning and network optimization; ii) integrate the current framework into a Real-Time Response System; and iii) Collaborate with Domain Experts.

Big Data on Incident Attribution Analysis
An approach to interactively visualize historic train delay records and how delays were triggered by small disturbances. By deriving and learning how these disturbances lead to primary delays and their propagation along a specific route of the network, meaningful prediction insights of whether a delay will occur or cascade between particular locations, timepoints, and train services, would be generated. This proof-of-concept also allowed to underline the role played by Big Data and GNN-based techniques (such as Graph-SAGE) to construct potential propagation links between incidents. Recommendations are mainly oriented at: i) introduce relevant AI or non-AI techniques that enhance interpretability; ii) incorporate additional features into the learning process; iii) emphasise the ability of Customization and Adaptation of the model. On the other hand, regarding "Big Data on Incident Attribution Analysis", recommendations encompass: i) explore the feasibility of enhancing infrastructure planning and network optimization; ii) integrate the current framework into a Real-Time Response System; and iii) Collaborate with Domain Experts.

Autonomous Train Operation

TAURO completed successfully its activities in the first half of 2023.

In the last 5 months of the project, the focus was put on completing the final technical work and deliveries focusing on the following elements;

- Propose a novel certification concept when the artificial sense is used for safety related functions as deliverable;
- Define a common database for artificial sense training and to create one alpha instance of it;
- Analyse how visual landmarks and radar signatures could be used for enhancing the train location function;
- Collect and prioritize the requirements for indoor environment perception-oriented services, covering security aspects, operational, customer service oriented and/or maintenance services, define the system architecture, perform feasibility studies and develop a demonstrator;
- Develop the comprehensive specification and functional architecture of the remote driving and command, including input for the IEC/EN 61375-2-6 standard by proposing a new application profile (use case) for the remote driving and command;
- Development of the Application Profile for remote driving and command that will be used in FP2-R2DATO as baseline and it has been offered as a service to the IEC/EN 61375-2-6 standard;
- Automatic Status monitoring and diagnostic for autonomous trains, addressing enhanced safety features for automatic diagnostics.

Supporting X2Rail-4 activities by upgrading the GoA3/4 specifications based on semi-formal models and validating the interaction between ATO (up to GoA4) and the Traffic Management System.

Finally, the project has finalised the transfer of knowledge of its results to the EU-RAIL Flagship projects, especially the Flagship Area 2 project FP2-R2DATO.

1.3. Research & Innovation activities/achievements: the EU-Rail Programme

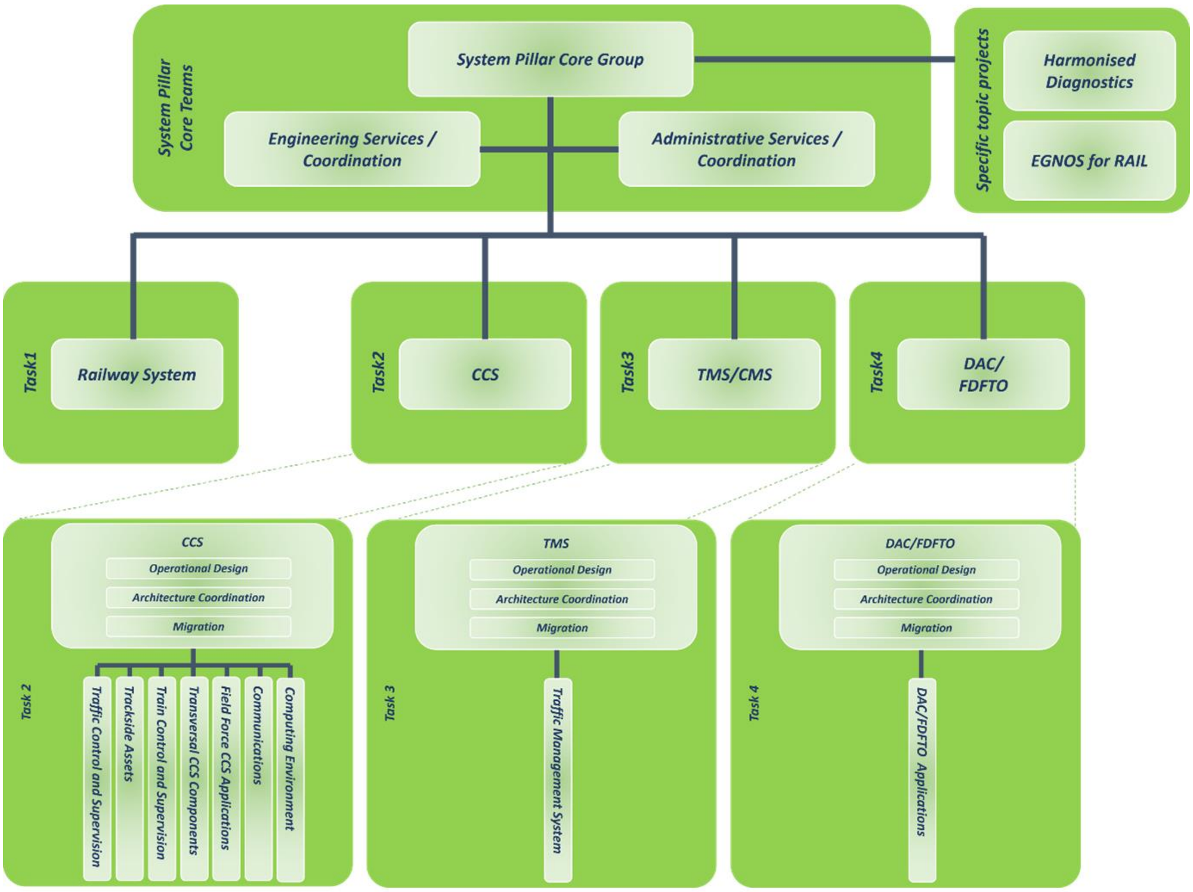
1.3.1. System Pillar

Organisation structure

The governance structure was set in 2022, with the System Pillar Core Group, under the supervision of the EU-Rail Executive Director and/or his delegated Head(s) of Units, leading the day-to-day work of the delivery of the System Pillar through the Tasks and with the support of Engineering and Administrative support services. It manages progress of and collaboration between the Tasks.

The overall activities accomplished during 2023 from the SP governance and organization point of view are:

- Governance in place (Core Group, Task and Domain teams, some mirror teams, Steering Group).
- Standardised system of systems approach introduced and adopted: System engineering management Plan (SEMP), Version 2.
- Supporting tools introduced: Polarion (platform for Requirements-, Quality-, and Application Lifecycle Management) and Capella (model-based system engineering (MBSE) tool).
- First inputs to Standardisation and TSI Input Plan (STIP) gathered. First STIP version sent out to sector for review.
- Process for interaction System Pillar and Innovation Pillar: Contributions to Maturity Check Points IP and alignment on DAC: EDDP, SP (task 4) and IP (FP5).
- Research to add new subjects: Harmonised European Railways Diagnostics (HERD) and Absolute Safe Train Positioning (ASTP).
- Alignment of SP with FRMCS programme.



EGNOS:	European Geostationary Navigation Overlay Service
CCS:	Control-Command and Signalling
FDFTO:	Full Digital Freight Train Operations
DAC:	Digital Automated Coupling
TMS:	Traffic Management System

Structure of the System Pillar

Together with the SP Core Group, the other SP horizontal teams are the Engineering Services / Coordination Team and the Administrative Services/Coordination Team.

The System Pillar **Engineering Services / Coordination Team** consist in:

- **Engineering Environment Team**: includes methods & tools definition and training for the whole System Pillar, monitoring of formal quality and allocation of work items and the consistency, traceability and integrity of the specification, active support to ensure quality and efficiency in the work of Tasks and Domains.
- **Standardisation and TSI Input planning**: structured along the catalogue of processes and interfaces/systems - describes the process of collecting and assessing IP and SP input to the harmonisation channels including regulation (TSI), standardisation (CEN/CENELC, ETSI) and System Pillar Industrial standards (SP documents).
- **Performance, Reliability, Availability, Maintainability and Safety (PRAMS)**: Coordination on the PRAMS requirements.
- **Security**: Coordination of the Security requirements.

The System Pillar **Administrative Services / Coordination Team** consist in:

- **Programme (Management) Office**: Support all the activities of the System Pillar, including management of:
  - Progress
  - Quality
  - Resources and administration
  - Communication
- **Economic Analysis**: economic analysis supporting the activities of the System Pillar (e.g. cost-benefit, enhancement change request, specific business cases, etc.).

<u>**Deliverables**</u>

The System Pillar **Tasks and domains** are:

- **Task 1: Railway System**
- **Task 2: CCS**, structured into:
  - The cross-cutting domain teams (comprising Operational Design, Architecture and Release Coordination and Migration and Roadmap).
  - The CCS System Design Teams (comprising Traffic control and supervision, Trackside assets control & supervision, Train control and supervision, Transversal CCS component, Field force CCS application, Communication team, Computing environment).
- **Task 3: CMS/TMS**
- **Task 4: DAC/FDFTO System design**
- **Specific Topic Projects:**
  - Harmonised diagnostics.
  - EGNOS for Rail.

In the following sections more information about the organisation structure bodies is detailed, together with their outcomes and activities progress during 2023.

<u>**Engineering Environment Team**</u>

The Engineering Environment team includes methods definition (System Engineering Management Plan (SEMP)) and tools provision and training (Polarion, Capella, SysML specification environment) for the whole System Pillar. It monitors the formal quality of the work items, their correct allocation to the tasks and domains, and the consistency, traceability and integrity of the specification. Its role is to actively support where needed and take care that the work of the Tasks and domain can be done in an efficient way and with the needed quality.

During 2023 the following achievements were accomplished (as Central Modelling Service):

- Release of System engineering management Plan (SEMP), Version 2.
- Input for STIP (Standardisation and TSI input planning).
- Integration of user interfaces (workbenches).
- Safety guideline for the SP work.

- Concept for configuration management.

Delivering the following deliverables:

- Training prepared and executed.
- Guide and support appropriate MBSE-training to contributors to the SP (Identification of users and readers of MBSE models and guide and support appropriate MBSE-training for users and readers).
- Define, train, continuously improve, and supervise a homogenous and integrated System Engineering Management Plan (SEMP) for SP level, tasks and domains. Design and describe the engineering process in the System Pillar (according to INCOSE/ISO15288) with roles, working steps and type of artefacts; processes change requests and proposals to the processes and methods.
- ALM Concept editing /content management.
- Requirements management platform (for all requirements) and methods and moderation of the creation, negotiation and CCM process for requirements.
- Existing functional models imported in the repository of domains models.
- Consolidated existing modelling rules.
- Choose, develop and provide the documentation, concept, architecting and modelling handbook (MBSE), the ontology, the architecting framework, and the Railway Dictionary.
- ALM tool established & administration.
- MBSE Collaboration tool established & administration.
- Document version/release management platform established.
- CDM consolidated for running SP domains.
- Manage relevant licenses and technical support for the necessary technical modelling software.
- Design, hosts and maintains the central tool platforms.
- Provide target tool platform.
- Work breakdown plan, assigned tasks and coordination for an integrated operational concept and process set (work assigned to the tasks).

Additionally, the Engineering Environment Team remit for 2023(Q3)-2024 was completed and the work on the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- SEMP (v3).
- Requirement Management (Set of Link Requirements).
- SP meta data (Glossary and References).
- Specification and model integration, quality assurance & import integration.
- Tool support.

<u>System Engineering Management Plan (SEMP)</u>

The SEMP defines the workflow rules and arrangements, methods, and tool usage for all specification related activities in the System Pillar.

It is essential that all SP tasks and domains, and linked work, follow the SEMP processes to enable the large and dispersed group of people working within the System Pillar to speak the same language and follow common processes.

Several critical points were identified in the SEMP V1 revision, and enhancement approaches were proposed. Additionally, a number of open points were identified in the SEMP V1 as well:

- The need for more clarity in the structure of the main document and annexes.
- The conditional acceptance of the chapter addressing the mirror groups.
- Tools need to be well understood and used by the experts.

Based on these open points and the feedback of some Domains the SEMP V2 was elaborated as an enhancement of SEMP V1.

During the SP-STG Meeting 7 in November 2023, the SP-STG:

- Endorsed the SEMP Version 2 main document and associated annexes.

PRAMS

The PRAMS team is in charge to define the strategy, policies, methods, and principles to be followed by the other Tasks and Domains during the design activities as well as to coach and support implementation. PRAMS team do not produce PRAMS Analysis, Hazard and Risk Analysis, for system components or system parts; these activities are delegated to the related Domain that have to include members with PRAMS skills. The PRAMS Functional team is in place to have a proper coordination and synchronization.

During 2023, the following deliverable from previous remit were delivered:

- Assure requirement implementation in the System Pillar Tasks (Active review of SEMP V2.0, granularity concept and Task4 Train Integrity and Train Length Specification).

Additionally, the PRAMS remit document for 2023(Q3)-2024 was completed and the work on the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- Refinement of Performance KPIs and definition of Performance Targets for a modular railway architecture.
- Analysis of RAM Performance to reach overall Performance Targets.
- Refinement of CBM RAMS rules.
- Update System Concept and PRAMS Plan.
- CENELEC changes proposal for harmonisation and modular approaches.
- Processes for Hazard and Risk Analysis and harmonized hazard lists for Operation and System level.
- Contribute to EGNOS Project.

Security

The Security team is in charge of centrally coordinating the Security requirements, including top-level design and assurance of the requirement implementation in the System Pillar Tasks and the specification of the subsystems for monitoring and the system control access.

During 2023, the following deliverables from previous remit (SC 2.1) were delivered (as PRAMSS Security team):

- As is Analysis (Analysis of 42 rail security documents).
- TSI input plan.
- System Analysis/Logical Architecture (Security Architecture).

Also, the Security remit document for 2023(Q3)-2024 was completed, and the following deliverable related to the remits for 2024 have been delivered during 2023:

- Draft security specifications for innovation pillar.
- Security specification development for TSI input.
- Cooperation with System Pillar Domains and Innovation Pillar for continuous support of the integration of the security requirements.

Task 1: Railway System

Task 1 consists in defining the Business Process Architecture and Operational Design (Organisational needs, Generic automation needs) for the Railway System, based on and reflecting the Common Business Objectives.

During 2023, the following achievements were accomplished:

- Business Process Architecture and Operational Design, version 1.
- Delivering the following deliverables (SC 2.1). Definition and prioritisation of uses cases of the full railway system (starting from input from Linx4Rail and Linx4Rail2) to be considered, where necessary, in further as-is analyses.
- Diagnosis of pain points and derivation of target performance Version 1.

Additionally, the Task 1 remit for 2023(Q3)-2024 was completed, and the work of the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- Capability prioritization based on identified pain points.
- As is (AI) Operational Architecture on the prioritized capabilities.

Task 2: CCS

Task 2 consists in developing the operational concept(s) and functional system architecture for a genuine integrated European CCS system, supported by a model-based systems architecting & engineering approach, beyond the current specifications in the CCS TSI, with much greater standardisation and much less variation than at present.

Task 2 is structured in Domain teams for cross-cutting activities and (Sub-)System Design activities that need to be managed and coordinated:

- Cross-cutting activities:
  - The Operational Design Team
  - The Architecture and Release Coordination Team
  - The Migration and Roadmap Team
- (Sub-)System Design activities:
  - The Traffic Control and Supervision Team
  - The Trackside Assets Control & Supervision Team
  - The Train Control and Supervision Team
  - The Transversal CCS Components Team
  - The Communications Team
  - The Computing Environment Team

During 2023, the following achievements were accomplished:

- Common business objectives and operational vision for CCS and TMS.
- Operational harmonisation principles and working methods.
- Harmonisation concepts for 12 of 31 areas of operational processes.
- Principles about the future harmonisation process, e.g., about harmonisation granularity.
- Logical architecture and modularity of the vehicle CCS onboard units.
- High level requirements and basic logical architecture of the advanced CCS trackside systems.
- Working hypothesis for the design of the future moving block approach.
- Potential harmonized API for decoupling of hardware, operating systems, and software.
- First educated draft for a harmonized CCS/TMS data model for interface exchange objects.
- Basic rules for secure component specification.
- Functional scope of driver assistance systems.
- Flexible aggregation of trackside and onboard sensor information for occupation detection.

Delivering the following deliverables:

- Operational design:
  - Collection of existing operational designs from Railways
  - Collection of operational improvement requirements
  - Operational design down to SEMP process 2.5
- Architecture:
  - Feature Development proposal – Describe how work is prioritized based upon the relevant importance, value and the agreed collaboration with OD (feature development).
  - Moderation Process – Describe and define how to resolve open points or issues and reach a mutually agreed position in an effective manner.
  - Granularity Concepts and Principles – Understand the problems and or issues with the existing standards and/or requirements and what is really necessary to be specified.
- Traffic CS:
  - Identification of necessary Traffic CS System capabilities and external actors
  - Analysis ETCS Concepts

        - Geometric safety logic
        - Train-centric track occupancy management
        - Enhanced backwards compatibility
        - C-DAS
        - Digital Maps and Digital Register
    - Functional allocation between Traffic CS and TMS
    - Interfaces to Trackside Assets
    - TIMS and Train Length
    - DAC
- Trackside Asset CS:
    - The Trackside Assets Data sharing Management/Maintenance
    - Interfaces between Traffic Control and Trackside Asset Control (Delivered as part of SP/EULYNX BL4 Release 2):
        - Structure of contained systems of the next system level
        - Logical Components Description
        - Physical architecture
        - Technical functional Requirements
        - Interface specification (system/user/physical interfaces)
        - Technical standardization specification
    - Layer with Trackside Assets and respective Object Controllers (Delivered as part of SP/EULYNX BL4 Release 2):
        - Structure of contained systems of the next system level
        - Logical Components Description
        - Physical architecture
        - Technical functional Requirements
        - Interface specification (system/user/physical interfaces)
        - Technical standardization specification
    - Application Specification To be clarified, partial configurations part of planned first release: Configuration 1(Delivered as part of SP/EULYNX BL4 Release 2)
    - Interfaces between Traffic Control and Trackside Asset Control
    - Layer with Trackside Assets and respective Object Controllers: Validation method, model proving, test cases
- Transversal
    - Provide integrated user interface
    - System specific Operational requirement Specification (ORS) / Engineering, asset and topology data:
        - As-Is Analysis
        - Common business objectives
        - Process Innovations
        - Application definition and categories
        - Operational Requirements
        - Operational Entities
        - Operational Capabilities
        - PRAMSS Targets and Breakdown
        - Operational Processes
        - Process hazards and risks
        - Operational standardization specification
    - System specific Operational requirement Specification (ORS) / Asset condition and intervention management (Integrated diagnostics protocols, analytics, event channelling, and smart/integrated event pattern recognition):
        - As-Is Analysis
        - Common business objectives
        - Process Innovations
        - Application definition and categories
        - Operational Requirements
        - Operational Entities
        - Operational Capabilities
        - Operational Processes
    - System Analysis (=FRS, Functional Requirement Specification) / Engineering, asset and topology data:

            - System Definition
            - Actor description and roles
            - System capabilities
    - System Analysis (=FRS, Functional Requirement Specification) / Asset condition and intervention management (Integrated diagnostics protocols, analytics, event channelling, and smart/integrated event pattern recognition)
        - System Definition Q3 2023
        - Actor description and roles
        - System capabilities
    - System Architecture (=SRS, System Requirement Specification or FFFIS for interfaces) / Engineering, asset and topology data:
        - Structure of contained systems of the next system level
    - Application Specification: configuration 1, 2, 3, n
- Communications
    - Description of the content of the V2 specifications and the rationale of the overall strategic orientations
    - Consideration of the completeness of the technical documents proposed.

Additionally, the Task 2 and domains remit documents for 2023(Q3)-2024 were completed, and the work on the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- Operational design:
    - Collected operational requirements from the sector.
    - Harmonized Processes.
    - Preliminary operational risk analysis
    - Contribute to the clarification Task of the T2MIG team concerning the need of special lineside signals.
- Architecture:
    - Amend system requirements, specify System Analysis and Logical Architecture.
    - Moderation and Coordination. ATO Action Plan.
    - Moderation and Coordination. Absolute Train Positioning Action Plan.
    - Moderation and Coordination. Architecture and Interface catalogue set up.
- Migration:
    - Consideration of CCS features packages indivisible for deployment.
    - Scope for System Pillar Reference Architecture Baseline 1 Release 1(B1R1).
    - Migration Requirements for Target System.
    - Special trackside signals (Lead of the workgroup with ARC, OD, TrafficCS, TACS).
    - Traffic CS:02-Traffic CS System capabilities, functions and system requirements - System Analysis (FRS).
- Traffic CS:
    - Traffic CS System capabilities, functions and system requirements - System Analysis
- Train CS:
    - Train CS logical architecture.
    - Update Train CS System capabilities.
    - Specification for Authorization, Integration and Upgradability of modular train CS system including train interface.
    - CCS Onboard Definition
- Trackside Asset CS:
    - Maintaining the specifications
    - Add basic Operational Analysis and System Analysis
- Transversal:
    - Digital Engineering, CCS/TMS exchange data.
    - CCS Diagnostics.
    - Configuration
    - User interface.

Task 3: Traffic management System/Capacity Management Design Team

Task 3 consists in developing the operational concept(s) and functional system architecture for the Traffic Management System/Capacity Management. Task 3 is structured around the Traffic Management Team, handling both cross-cutting activities and (Sub-) System Design activities.

During 2023, the following achievements were accomplished:

- Common business objectives and operational vision for CCS and TMS.
- Traffic Management System Concept.
- Functional allocation for the major CCS and TMS logical components.

Delivering the following deliverables:

- System specific Operational requirement Specification (ORS)
  - As-Is analysis
  - Problem analysis and derived process improvements
  - Application categories
  - Operational requirements (incl. non-functional and process requirements)
  - Operational entities and actor
  - Operational capabilities
  - Operational processes
  - TMS Variants
- Functional requirement specification (FRS)
  - System definition
  - Detailed system actor descriptions and roles
  - System capabilities
  - Functional chains and sequences per capability
  - Function specification
- Functional requirement specification (SRS)
  - Architecture of systems of the next level (if standardized)
  - Functional allocation to logical components
  - Technical and physical hazards and risks
  - Interface between Traffic Management and Traffic Control (operational plan)
  - System requirements and interface specification, incl. legacy adapters
  - Non-functional System requirements

Additionally, the Task 3 and domain remit document for 2023(Q3)-2024 was completed, and the work on the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- System Concept document.
- System Architecture Specification (and annexes).
- Interface between TMS and Traffic Control and Supervision system.
- System Analysis.
- Cross border TMS & CMS.

Task 4: Digital automated coupling (DAC), Full Digital Freight Train Operations (FTDFTO)

Task 4 consists in developing the operational concept(s) and functional system architecture for the Digital Automated Coupling (DAC)/ Full Digital Freight Train Operations (FTDFTO). Task 4 is structured around the Traffic Management Team, handling both cross-cutting activities and (Sub-) System Design activities.

During 2023, the following achievements were accomplished:

- High level requirements for digital coupling concerning integrity and train length.
- Analyses for Central Instance.
- Alignment with European DAC delivery Programme and FP5.

Additionally, the Task 4 and domain remit document for 2023(Q3)-2024 was completed, and the work on the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- EU Harmonised Operation Procedures (FDFTO Rule Book).
- Operations Architecture related to FDFTO interfaces.
- Train-internal DAC/FDFTO Interface Analysis.
- Central Instance Management of data & software (updates).

The following deliverable related to the remits for 2024 have been delivered during 2023:

- EU Harmonised Operation Procedures: second set of Ops Concepts.

Specific topic projects

Harmonised diagnostics

It has been identified that the lack of harmonization regarding the exchange of diagnostic data between the data users and the data providers, across Europe hinders development of the railway sector and blocks successful business cases. To overcome this issue, this specific project activity is aimed to generate a set of harmonized data formats for selected number of examples to prepare the concepts for European harmonization on the approach for exchanging diagnostic data, based on the SP Data Model and the associated Diagnostic Data Model.
During 2023, this specific topic project remit document for 2023(Q3)-2024 was completed. Later on, this specific topic project was re-defined as Task 5 Harmonised European Railways Diagnostics (HERD). Additionally, the work on the following deliverables related to the remits for 2024 have started in the last quarter of 2023:

- 01-Feasibility work.
- 02-Detailed use cases.

EGNOS for Rail

Current existing EGNOS service has been developed according to aviation requirements. As these requirements are different from railway ones, this service cannot be used in rail safety related applications without additional activities to ensure the compliance with railway standards and to support safety evidence and guarantees.

For the successful adoption of the use of EGNOS within ERTMS framework, it is necessary that both the system/service and the service provision are defined, and where appropriate, properly introduced in the regulations and certified/authorised according to the European Rail regulatory framework.

During 2023, this specific topic project was established to support this work.

System Pillar and Innovation Pillar interactions

In order to deliver a coherent output from EU-RAIL, the System Pillar and the Innovation Pillar will work together in the following way:

1. The System Pillar aims to provide the Innovation Pillar, where relevant, with a set of requirements aligned with the SP work, in order to ensure that research is targeted on commonly agreed and shared customer requirements and operational needs, compatible and aligned to the defined system architecture.
2. Reciprocally, the Innovation Pillar will impact the scope of the System Pillar where new technologies or processes mean that innovations can drive a change in approach, as well as delivering detailed specifications and requirements.
3. Accordingly, the SP considers results to be expected from the IP in its architectural works.

The main objectives of the IP-SP interaction are:

- Identify the main technical standardisation areas of collaboration between SP and IP, build in the projects the necessary details of the continuous process integration to reach together the EU-Rail outcomes that will achieve target system complying with the CBO.

- Include necessary provisions to achieve the Standardisation and TSI input plan together with all the necessary mature standards and regulation proposals.
- Revision that the inputs expected by the Flagship projects from the SP are foreseen to be achievable on time.

The current interactions between the SP domains and the IP FPs established during 2023 are in the table below:

Domain	Current Interactions with Innovation Pilar
Task 2 CCS: Operational Harmonization	Interactions with R2DATO in relation to a compared analysis between SP OD and R2DATO ATO methodologies for operational scenarios specification. Additionally, OD specified obstacle detection concept on R2DATO request.
Task 2 CCS: ARC	Involvement with FA2, specifically regarding ETCS (MB, ASTP, ATO). ARC is setting up coordination meetings with the IP related to ATO, ASTP and ETCS.
Task 2 CCS: Traffic CS	Traffic CS has interacted with IP in the last two months on the following topics: exchange and commenting of ATO red flags – identified in the review of ATO spec in 11/23 and Review of WP13 / MB spec Additionally, there are few members of Traffic CS employed in some IP WP.
Task 2 CCS: Transversal Systems	Close cooperation with FA Transversal Technology (FP1). Cooperation in FP1 WP26 and WP27 and in FP2 in WP26, 27, 36, 45. Contacted FP3 to stablish cooperation. April-Mid June it is planned to perform a dissemination CCS/TMS data model within the IP.
Task 2 CCS: Computing Environment	Ad hoc meetings with WP26 to collaborate on the modular platform architecture topics including architecture, interfaces and Glossary
Task 3 TMS & CMS	Biweekly meetings with FP1 about topics of interest shred: TMS - CDAS/ATO information exchange, Cross border related topics- (with RNE active involvement), Review of requirements specifications and Sharing of documents/specifications deemed relevant both teams' activities.

1.3.2. Innovation Pillar

The Innovation Pillar is structured in 7 Flagship Areas leading to large scale demonstration as defined in the SBA, complemented by Transversal Topics which ensure the engineering integration of the Programme.

In 2023, the 6 Flagship Projects responsible for undertaking the initial implementation of these Flagship Areas launched their activities. All projects started the preparatory steps and set up of their working structures, and reached the end of the year 2023 with already defined, in most cases, with key use cases and requirements for the main technical enablers part of their programme of work. All FPs have also established collaboration and working methods among themselves, but also with the EU-RAIL System Pillar.

The process of Maturity Checkpoint was further developed in 2023 and applied towards the end of the year in some FPs, assessing and validating the initial technical developments.

Flagship Area 1 (FA1): Network management planning and control & Mobility Management in a multimodal environment

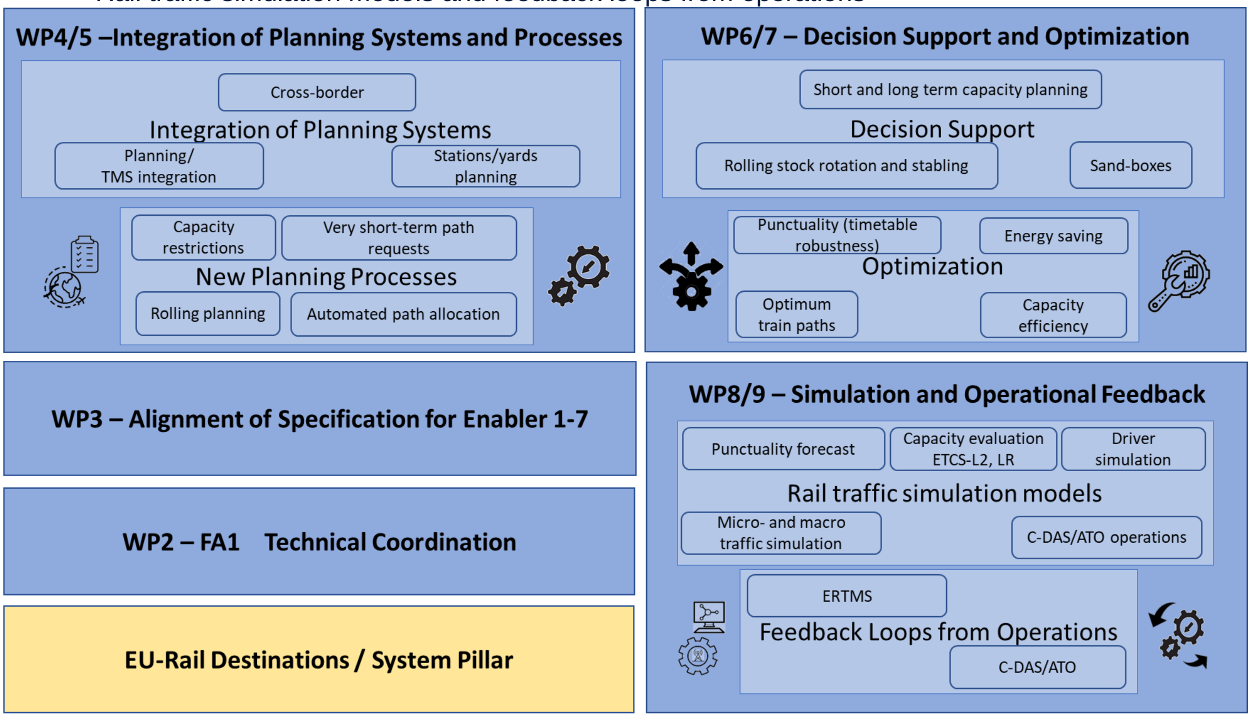
The main objective of Flagship Area 1 (FA1) is to provide solutions to dramatically improve flexibility, efficiency, resilience and capacity adaptation of the European rail network, and enabling the development and operation of a Single European Rail Area.

FP1-MOTIONAL project is the first project implementing FA1, and aims at contributing to this objective through the development of functional requirements, associated specifications, and operational and technological solutions to enable a future European Traffic Management System that will make rail the backbone of a multimodal transport system for passengers and freight. This project is being delivered in two Workstreams (WS): WS1, for the Planning and Operations of the European Traffic Management, and the Integration activities of the rail services with the door-to-door mobility; WS2 for the digital enablers (Transversal Topics) for all EU-Rail's destinations.

Workstream 1.1: Capacity Management (planning)

Main objective of Workstream 1.1 (WS1.1) is to improve the strategic and tactical planning of the rail network this covers (see figure below):

- Integration of planning systems and new planning processes
- Decision support and optimization
- Rail traffic simulation models and feedback loops from operations



Progress and results achieved in 2023:

- Alignment **with the System Pillar and Rail Net Europe (an association of European Rail Infrastructure Managers, supporting the coordination of international processes in Capacity management, Traffic management, Corridor management, IT, Sales and Legal matters)**, as well as with **Flagship Projects** 2, 3, 4, 5 and 6, when relevant (e.g., Collaboration has been established with relevant work packages in FP2 to be able to simulate the capacity effects of the planned digital technical developments.)
- Addressed topics related to **international planning, capacity allocation, integration between CMS and TMS, integration with yard/station capacity planning, long-term timetabling, short-term timetabling, rolling stock planning** that are linked to the following technical enablers to be developed within the programme:
  - Enabler 1: European cross-border scheduling with international train path planning
  - Enabler 2: Improved capacity allocation using rolling planning and Timetable Re-design (TTR)
  - Enabler 3: Decision support for short term planning
  - Enabler 4: Train path and schedule optimisation methods and strategies for capacity efficiency, punctuality and energy saving for different parts of the network and different traffic situations (level of punctuality)
  - Enabler 5: Improved rail traffic simulation models for selected Use Cases to forecast punctuality in the network
  - Enabler 6: Integration of planning systems and TMS with a) yard capacity planning and b) station capacity planning

- Enabler 7: New planning and operational processes using feedback loops from ERTMS ATO and C-DAS

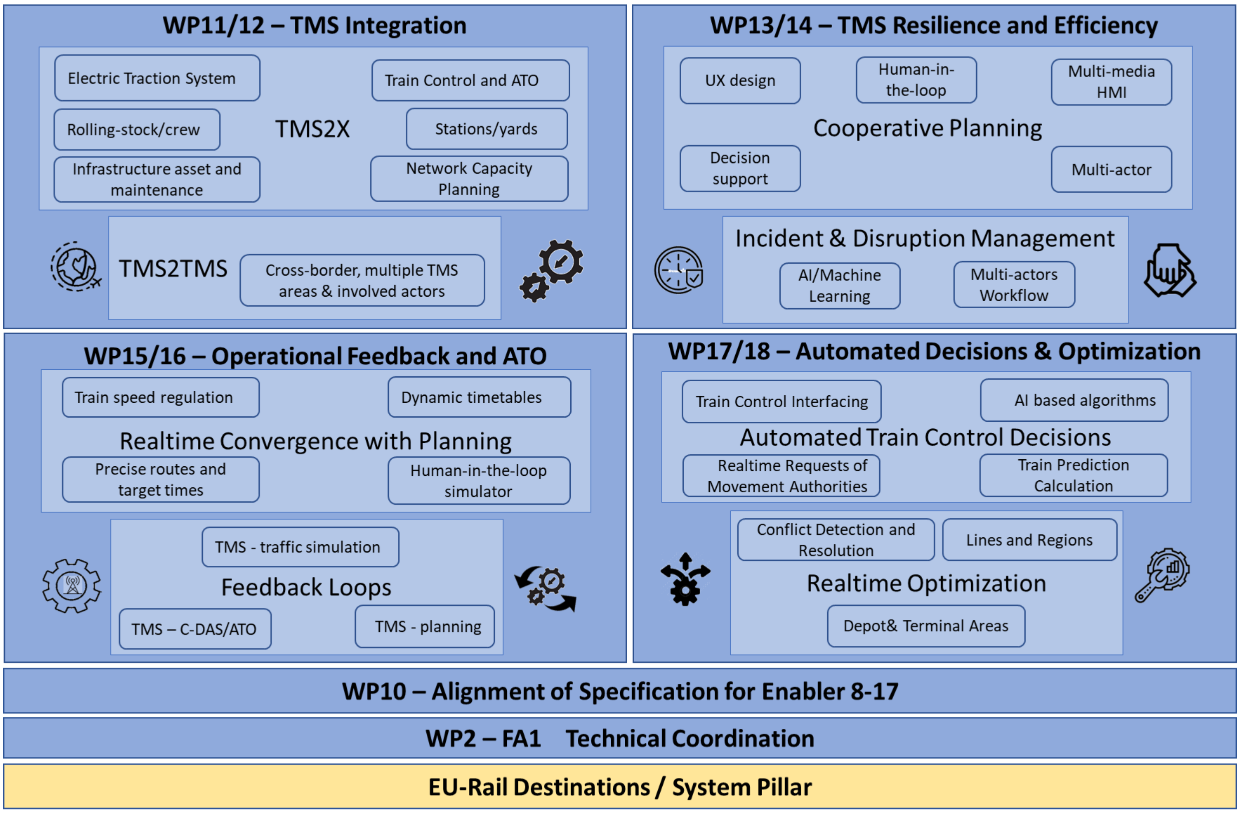
Progress made in terms of specific Deliverables:

The WS 1.1 progress in 2023 included the delivery of the high-level user cases, requirements and the identification and high level demonstrators required for the Capacity Planning, as well as simulation methods, models and feedback loops between Capacity planning and Traffic Management System (TMS), and TMS – Automatic Train Operation system (ATO)/Connected Driver Advisory System (C-DAS).

Workstream 1.2: Traffic Management (operations)

The main objective of Workstream 1.2 (WS1.2) is to achieve a more dynamic network and traffic management at European scale allowing agile, borderless and mixed-traffic operations based on a harmonised functional system architecture (see figure below):

- Integration of TMS and processes including cross-border traffic management
- Improved resilience and efficiency of disruption management
- Linking TMS to ATO / C-DAS for optimised operations
- Automated decisions and decision support for traffic management optimization



Progress and results achieved in 2023:

- The assessment of previous projects' results and the state-of-the-art lead **to specification of the Technical Enablers 8 to 17** including **high-level requirements and 63 use cases**: for the following enablers:
  - Enabler 8: Real-time connection of rail networks as managed by TMSs and involved actors.
  - Enabler 9: Modelling and decision support for cross-border traffic management.
  - Enabler 10: Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching.
  - Enabler 11: HMI for TMS based on User Experience (UX) Design and user input

    - Enabler 12: Real-time convergence between planning & feedback loop from operations.
    - Enabler 13: Cooperative planning multi-actors within rail
    - Enabler 14: Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management
    - Enabler 15: TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables
    - Enabler 16: Automation of very short-term train control decisions
    - Enabler 17: Real-time conflict detection & resolution for main line and optimization.
- **Initial functional requirements and use cases** have been specified for the **human-in-the-loop simulation environment** that focuses on TMS and ATO/C-DAS simulation with a train driver, signaler and dispatcher.
- The initiation of **the ATO-TMS integration platform** (Integration Layer) development. To communicate with this platform, systems need to exchange data using a Conceptual Data Model (CDM); therefore, we are **collecting from all involved partners the data needed** from their own systems to include them in the CDM.
- Start of **development of Algorithms providing decision support** covering Enabler 16 and 17.
- Activities were **aligned with the SP and RNE** as well as with **Flagship Projects 2, 3, 4, 5 and 6**.

Progress made in terms of specific Deliverables:

In summary, the progress and results of WS1.2 in 2023 included the development of the requirements and high-level Use cases and demonstrators for the Traffic Management System (TMS), taking into consideration the links of the latter with ATO/C-DAS. These deliverables also considered a Reference Control, Command and Signalling Architecture, a Conceptual Data model and an Integration Layer, as elements of the future architecture of the TMS supporting a Single European Railway Area.

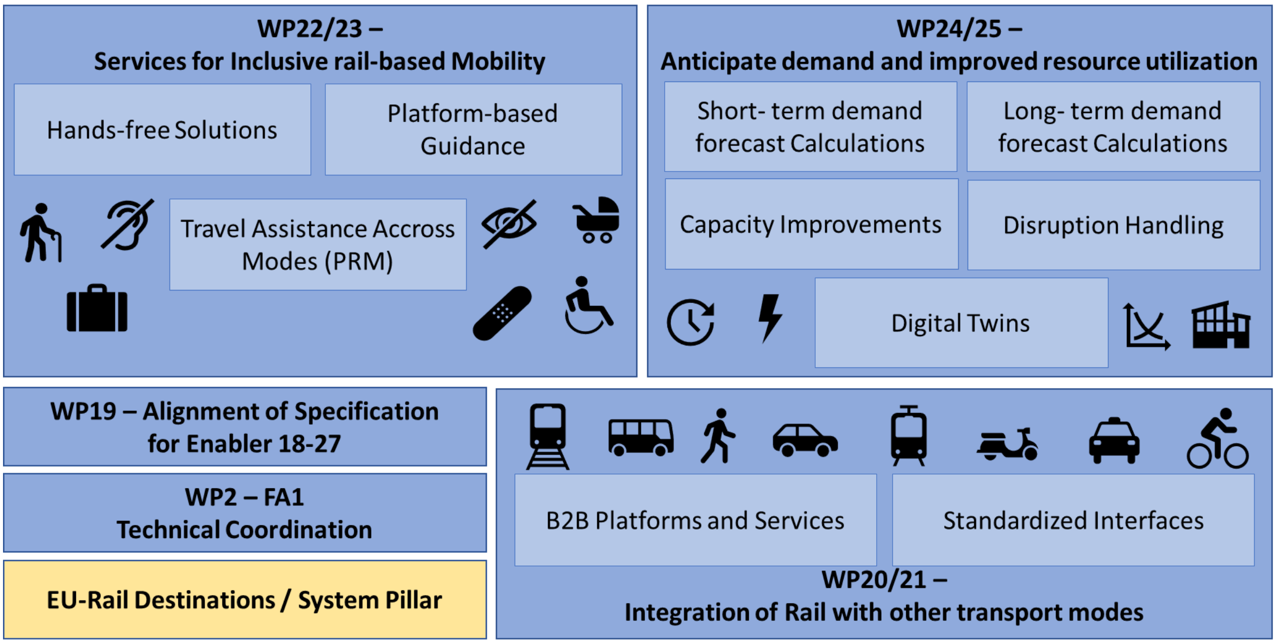
The following **Demonstrators have been identified for WS1.2**:

- 9 Demonstrators with a total of 17 high-level Use cases and for 3 Technical Enablers have been defined.

Workstream 1.3: Integration of rail traffic with door-to-door mobility

The main objective of Workstream 1.3 (WS1.3) is to increase rail attractiveness by integration with other modes to provide door-to-door mobility (see figure below):

- Integration of Rail with other transport modes
- Services for inclusive rail-based mobility
- Anticipate demand and improved resource utilization



Progress and results achieved in 2023:

- **Definition of the Technical Enablers 18-27 specifications** (D19.1) to give a complete overview of WS1.3 "Integration of rail traffic with door-to-door mobility".
    - Enabler 18 Improved rail integration using B2B intermodal services
    - Enabler 19: Harmonised interfaces between rail operators and other transport modes
    - Enabler 20: Services and solutions improving the quality of intermodal journeys and focusing on the support to PRM and passengers with special needs.
    - Enabler 21: Delivery of hands-free experience for travellers using rail services and transferring between rail operators, other mobility modes.
    - Enabler 22: Improvement of platform-based guidance in railway platforms and mobility hubs
    - Enabler 23: Short term demand forecast calculation using run time data
    - Enabler 24: Long term demand forecast with focus on data analytics based on a variety of sources
    - Enabler 25: Integrated traffic simulation and demand forecast in a Digital Twin to optimise offer, passenger occupancy, connection time and other service-related elements.
    - Enabler 26: Optimised rail capacity to better match the demand
    - Enabler 27: Disruption management across different mobility modes enabling operators to collaboratively solve the disruption and properly inform passengers.
- Taking into consideration the **reuse of methodologies and technologies** carried out in previous European research projects and innovation activities.
- General **description of the system through 54 Use Cases** as guidelines for the planned developments together with all actors and entities identified.
    - **System capabilities and requirements** which detail specific needs of the organizations or stakeholders that the system has to fulfil to achieve the Technical Enablers goals.
    - **Design of high-level architecture** through the logical architecture diagrams
    - **Description of the components** that will be developed in WS1.3
    - **Definition of the interactions between components** through sequence diagrams
- Relevant terminology has been defined in the **Glossary** Document providing the source of the relevant definitions.
- Activities were **aligned with the SP**, as well as with **Flagship Project 6**.
- Set of **standards defined** to be used for the **B2B services** that will be demonstrated:
    - **OJP** - Distributed Journey Planning: OJP will be used for cross platform Journey Planning queries allowing to test and evaluate the usage in various mobility contexts.
    - **OSDM** - Open Sales and Distribution Model: OSDM will be used for managing offers and booking from heterogeneous distribution system to retail channels.

  - **SIRI-SX**: SIRI-SX will be used to disseminate real-time information regarding disruptions and the mitigation strategies implemented by operators.
  - **NeTEx part 3**, Fare Information: NeTEx part 3 usage will be focused on data set related to sales transaction and their processing within the context of multimodal travels and associated financial/accounting processing.
  - **GTFS** - General Transit Feed Specification: GTFS data will be used to feed reference systems and simulators especially within the context of demand forecast.
- It was also defined that **platforms will be provide**d by different partners providing B2B interfaces.
- **Advanced development activities**, regarding implementations of the OSDM services.

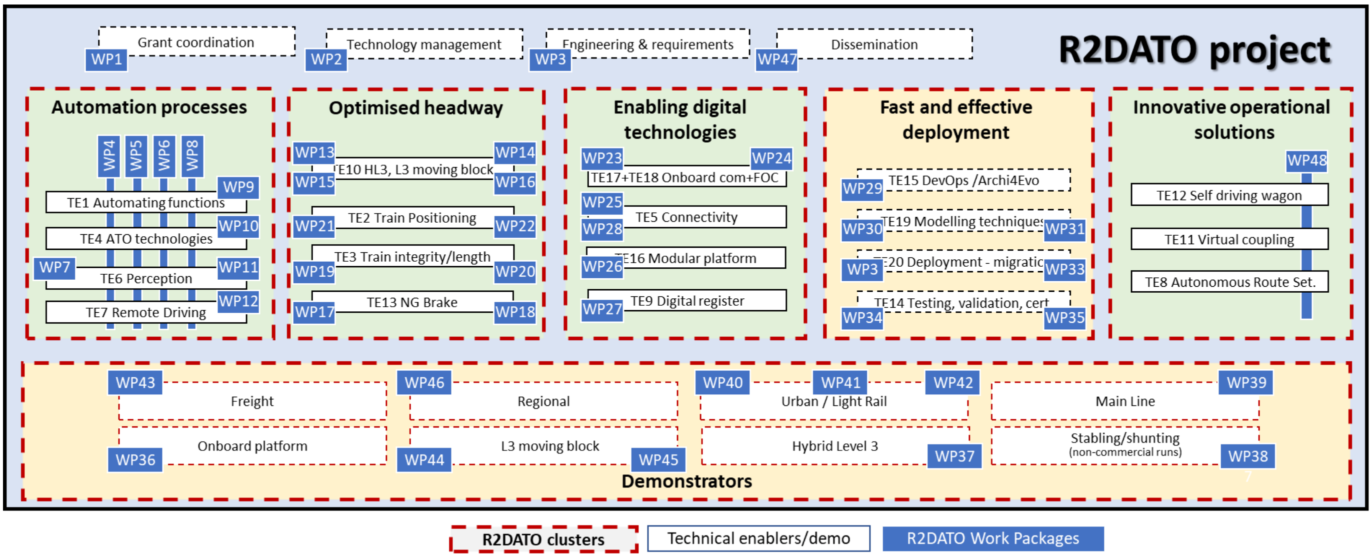
Progress made in terms of specific Deliverables:

The WS1.3 progress in 2023 includes the high-level architecture, requirements and identification of 54 use cases for the integration of rail traffic with the door-to-door mobility.

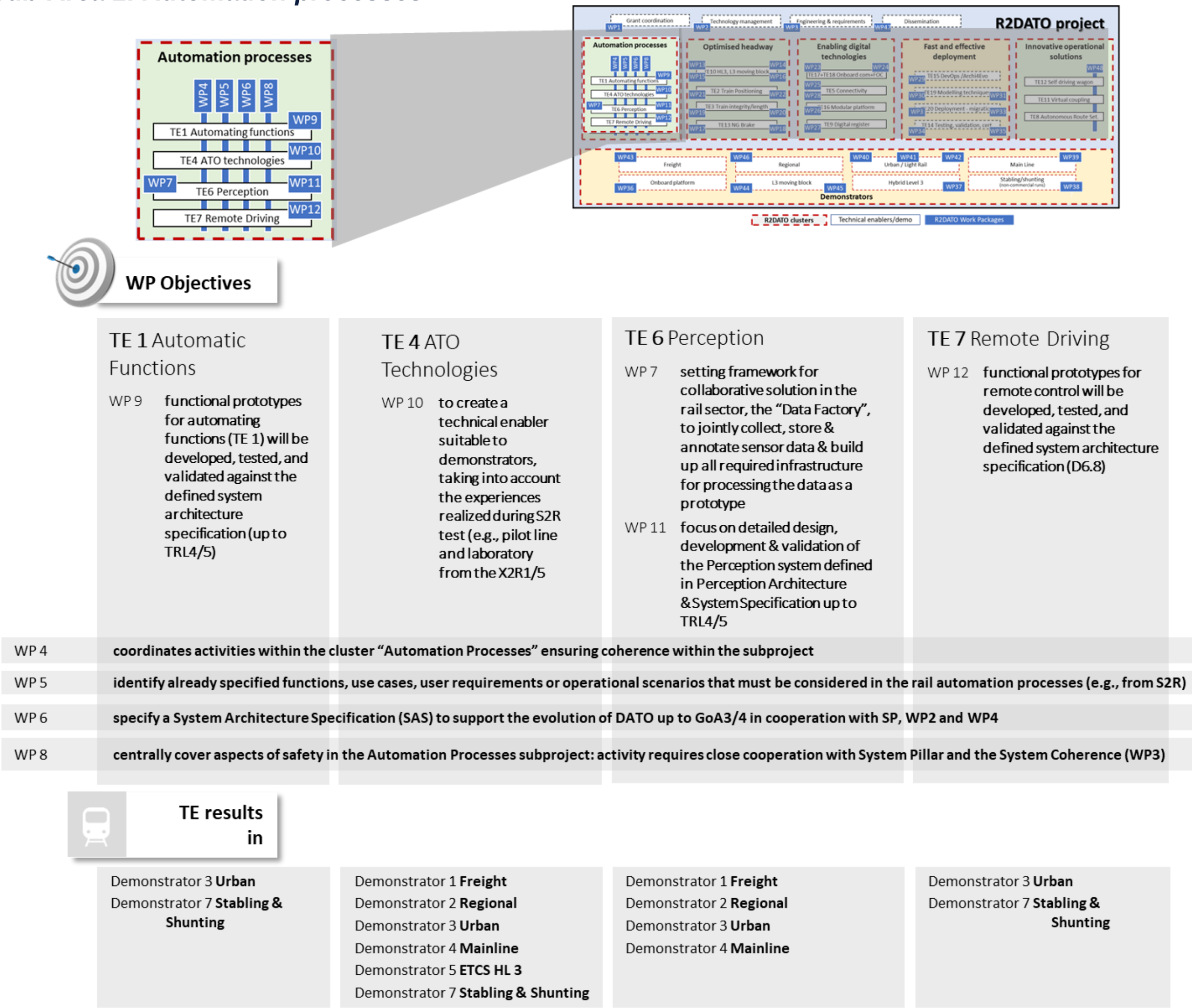
Flagship Area 2 (FA2): Digital & Automated up to Autonomous Train Operations

The targeted objective of Flagship Area 2 (FA2) is to take the major opportunity offered by digitalization and automation of rail operation and to develop the respective systems. This includes next generation Automatic Train Control (ATC), including Automated Train Operation (ATO) Grade of Automation (GoA) 4, building upon radio-based European Rail Traffic Management System (ERTMS) or above, representing the next evolution of the system, incorporating the latest technological advances, and with functionalities enabling full optimization of performance in line with the Traffic Management improvements developed in FA1. FA2 will aim at delivering scalable automation in train operations with fully unattended train operations including setting a train in motion, driving and stopping the train, opening and closing the doors, remote train control and recovery operations in the event of disruptions.

In the first phase of the programme, FA2 is implemented via the project FP2-R2DATO.



Sub-Area 1: Automation processes



Overview Sub-Area 1 – Automation Processes

General objectives of the Sub-Area 1 - Automation processes

The Automation Processes Cluster (APC) covers the Technical Enablers required to achieve the automated to autonomous train operation in Europe. As automation is one of the main pillars of the future rail system, it means that the APC activities have strong links with other tasks and initiatives such as the System Pillar as well as Flagship projects 5 and 6, while relying on the result of the Shift2Rail projects TAURO, X2Rail-4 and CONNECTA.

Automation Processes, integrates four Technical Enablers (TE1 – Automating Functions, TE4 – ATO Technology, TE6 – Perception, including the data factory, and TE7 – Remote Driving) which are core technologies required for the automatization of the railway operations.

These Technical Enablers (TEs) will be implemented to the level of laboratory validated prototypes (TRL4/5) ready for demonstration (TRL6/7) in the Demonstrators Cluster of the project.

Achievements in 2023

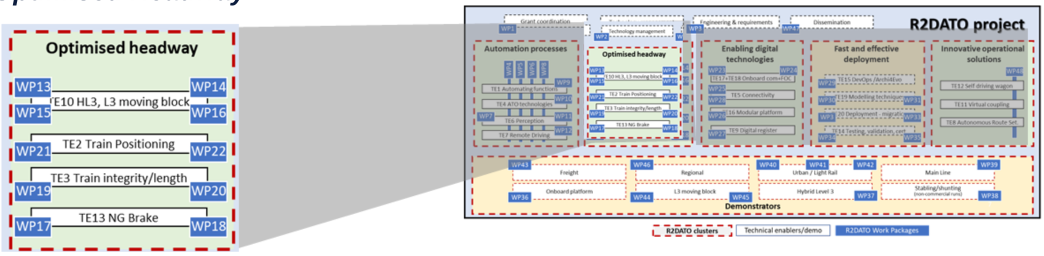
The Automation Processes Cluster (APC) activities were focusing on creating a stable basis for the upcoming implementation of the technical Enablers. Knowledge transfer with TAURO, CONNECTA and X2RAIL-4 has been organised in order to ensure the smooth transition and the reuse of available results from the Shift2Rail programme.

A major result has been achieved in taking over the specification and modelling baseline from X2RAIL-4 for GoA3/4 technologies. This baseline is also supported by the System Pillar with a roadmap for further development and improvements defined.

Use Cases creating the foundation for the demonstration in FP2, FP5 and FP6 have been defined, prioritized, aligned and approved. These use cases will also be used to support the activities of the Operational Domain of the System Pillar.

Safety Activities have been started in close collaboration with the requirements definition and for the data factory a first mature set of requirements is available.

Sub-area 2: Optimised Headway



WP Objectives

TE 10 HL3, L3 Moving Block	TE 2 Train Positioning	TE 3 Train Integrity/ Length	TE 13 NG Break
WP 13 define a high capacity, low cost, high reliability signalling system, based on a train-centric approach using Full Moving block principles WP 14 development and test of Moving Block prototypes of up to TRL 6 based on the specification of the Moving block Specification WP WP 15 align and integrate the Hybrid ERTMS/ETCS Level 3 (HL3) approach into the future Functional Railway System Architecture WP 16 development and test of Hybrid Level 3 prototypes of up to TRL 6 based on the specification of the Hybrid Level 3 Specification WP 15	WP 21 development of modular and scalable absolute safe train positioning (ASTP) system WP 22 (1) Definition of a ASTP system architecture (2) testing of the developped ASTP solutions (3) General assessment and evaluation of ASTP solutions, as well as the impact analysis of ASTP with regard to TSI gaps, need for TSI CSS modifications	WP 19 consolidation of requirements for the Train Integrity and Train Length Determination solutions and their insertion into the on-board architecture. WP 20 further consolidation of specs, the performance of a safety analysis and the realisation of demonstrators for the Train Integrity and/or Train Length Determination function	WP 17 New adhesion determination systems (ADS) and BAMS functions will be delivered and pre-validated test rigs, research trains, demonstrator WP 18 Related to testing/ realisation, the operational demonstration and validation of BAMS and the ADS use of a train demonstrator or a test rig will be prepared

TE results in

Demonstrator 2 Regional Demonstrator 4 Mainline Demonstrator 5 ETCS HL 3 Demonstrator 6 L3 MB	Demonstrator 1 Freight Demonstrator 3 Urban Demonstrator 7 Stabling & Shunting Demonstrator 8 Onboard Platform	Demonstrator 1 Freight Demonstrator 2 Regional Demonstrator 4 Mainline Demonstrator 5 ETCS HL 3 Demonstrator 6 L3 MB	Demonstrator 7 Stabling & Shunting

Overview Sub-Area 2 – Optimized Headway

General objectives of the Sub-Area 2 – Optimized Headway

Optimized Headway's main outcome is the validation of prototypes ready to demonstrate the ERTMS game changers in different operational environments, with mixed radio based ETCS levels with Hybrid Level 3, ETCS L3 moving block, absolute train position, train integrity and train length management, as well as optimized and reproducible braking performance under low adhesion conditions. To achieve this, intermediate results are required. Collection of use cases and requirements and completeness of the architecture in collaboration with the System Pillar are previous steps, leading to the development of building block prototypes and integrated demonstration.

Achievements in 2023

The Optimized Headway Cluster (OHW) was starting with consolidating results from Shift2Rail i.e. Shift2Rail IP2 (X2Rail-1 to X2Rail-5), PINTA, CONNECTA and PIVOT.

With respect to Train Positioning, the use cases and requirements have been collected and aligned. This activity will continue in cooperation with EUSPA[30] and ESA[31]. The different demonstrator solutions taken over from X2RAIL-5 are under analysis for further harmonization and to support the work for a common overall design and architecture of ASTP including RAMS activities. Furthermore, the integration of EUSPA and ESA in order to analyse the feasibility of EGNOS[32] for rail was launched and the necessary steps of work have been defined and officially kicked off.

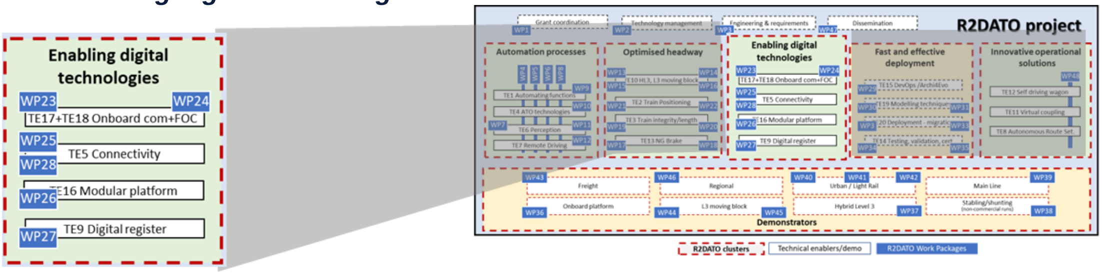
The work related to Train Integrity and Train Length has provided the requirements and architecture as continuation of X2Rail-2 and X2Rail-4. In alignment with the System Pillar, the requirements have been considered and aligned in order to pave the way for integration the solution in a later step.

Hybrid Level 3 and Moving Block were focusing on the requirements and the alignment with the respective demonstrators planned.

Next-Generation Brake was focusing on establishing close cooperation with the future users of the technical enabler and the exchange needed for the cooperation. NG Brake deals with brake and wheel/rail adhesion related solutions to be considered within ATO systems. FP1-MOTIONAL will support FP2-R2DATO in the simulation activities and a first set of use cases has already been exchanged.

[30] EUSPA: European Union Agency for the Space Programme (https://www.euspa.europa.eu/)
[31] ESA: European Space Agency (https://www.esa.int/)
[32] EGNOS: European Geostationary Navigation Overlay Service (EGNOS for Rail: https://egnos-user-support.essp-sas.eu/segments/rail)

Sub-area 3: Enabling digital technologies



WP Objectives

TE 17 Onboard COM Network / TE 18 Functional Open Coupling	TE 5 Connectivity	TE 16 Modular Platform	TE 9 Digital Register
WP 23 focusses on the communication functionality plus building up a lab environment for PoCs. WP 24 focusses mainly on the network management functionality and the CCS/TCMS interoperability	WP 25 Connectivity between train and trackside is obviously key for automated rail operations. WP 28 investigate how multiple radio bearers can be used concurrently to serve the needs of both the Gigabit train & future rail operations, & how the FRMCS architecture and specifications can potentially be expanded in this direction	WP 26 focuses on developing the architecture and specifications for the development, testing, and certification of modular and safe computing platforms for onboard and trackside systems which host safety-related and non-safety related functions, incl. standardized approaches for monitoring, diagnostics, and configuration management	WP 27 focuses on the specification, development, and implementation of the Digital Register in the sense of a database supporting assisted and automated train operations (including, e.g., traffic management systems) and optionally safe train positioning

TE results in

Demonstrator 8 Onboard Platform	Demonstrator 2 Regional Demonstrator 4 Mainline Demonstrator 8 Onboard Platform	(Demonstrator 7 Stabling & Shunting) Demonstrator 8 Onboard Platform	Demonstrator 1 Freight Demonstrator 6 L3MB Demonstrator 8 Onboard Platform

Overview Sub-Area 3 – Enabling digital technologies

General objectives of the Sub-Area 3 – Enabling digital technologies

The main and final results from Digital Enabling Technologies will be further evolved specifications and validated prototypes related to connectivity (both for train-to-ground communication and onboard communications), modular IT platforms, and the Digital Register as the single source of data truth for the railway system.

These results are complemented by studies and specific concepts of how the modular connectivity, IT and data platforms can be efficiently integrated, certified, and driven toward acceptance. Same as for other specific outcomes of the project, the basis of the work will be to consolidate prior work, further derive the requirements of future rail operation toward connectivity, IT and data platforms, and define related platform architectures in collaboration with the System Pillar.

The connectivity, IT and data platform solutions developed in the Enabling Digital Technologies cluster start from very different maturity levels. Beyond the development and validation of the individual technologies, a key challenge is still to integrate these among each other, and for instance to demonstrate how connectivity protocol stacks and common service functions can be efficiently implemented side-by-side with railway applications, leveraging common hardware pools and for instance common orchestration approaches. The main focus will be to provide the future-proof connectivity, IT and data platforms required for the automation of rail operations. Increase the cost efficiency will be a main focus leveraging off-the-shelve IT solutions by decoupling the life cycles of railway applications and connectivity.

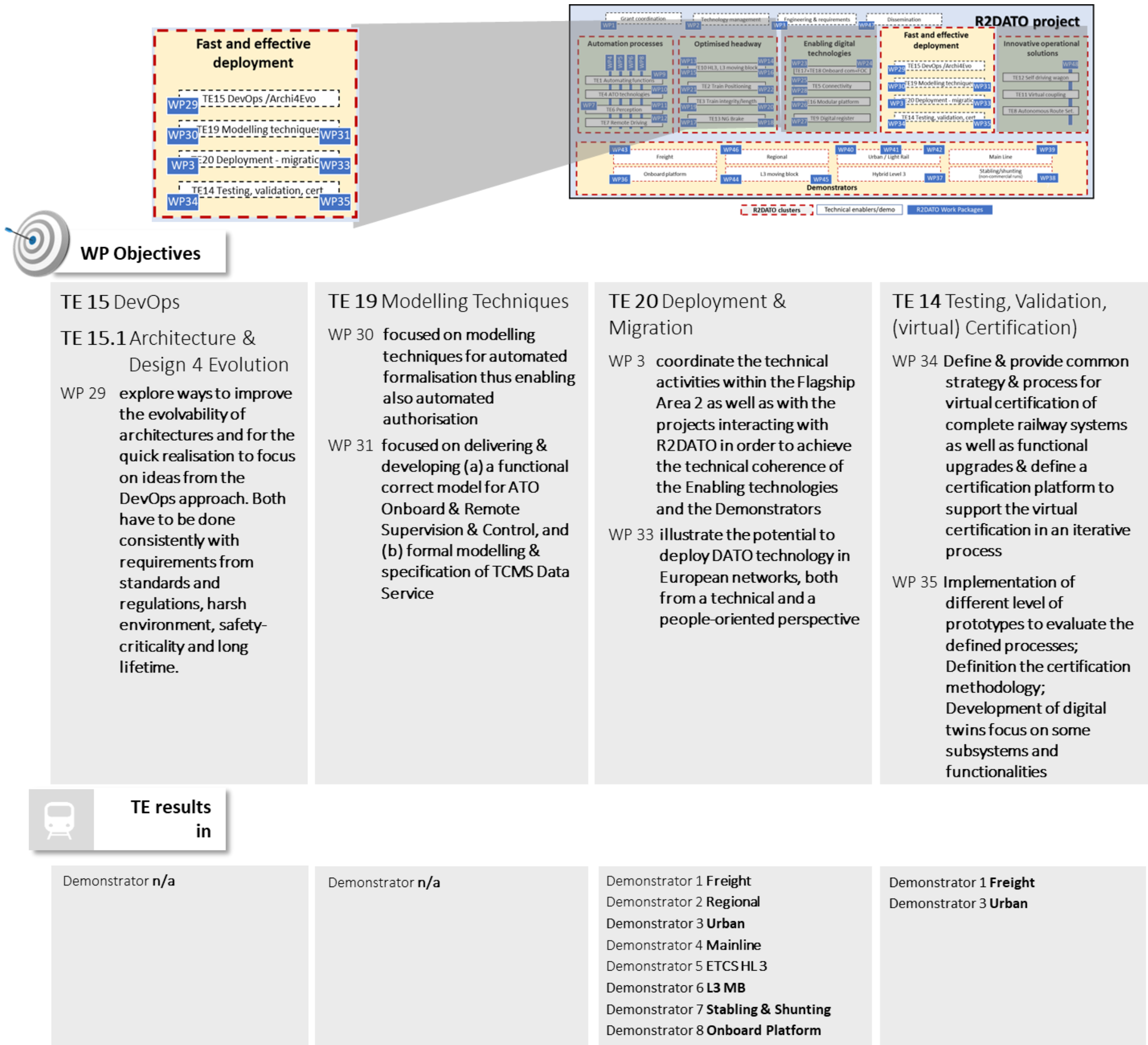
Achievements in 2023

The Digital Enabling Technologies started with the consolidation of the available results from past projects, and most notably from the Shift2Rail programme.

Use Cases and Requirements have been created for the Onboard Communication Network, the Modular Platform and the Digital Register.

Connections have been established with the future users of the Digital Enabling Technologies namely the System Pillar, the other Flagship Projects i.e. FP1 and FP6 and the demonstrators inside FP2-R2DATO.

Sub-area 4: Fast and effective deployment



Overview Sub-Area 4 – Fast and Efficient Deployment

General objectives of the Sub-Area 4 - Fast and efficient Deployment

Fast and Effective Deployment's main outcome will be the assessment of the technology for Digital automated up to autonomous train operation (DATO) which is implemented inside this project. The assessment will lead to the identification of potential for future application. Subsequently to the assessment guidelines for Migration and Deployment are written and reviewed. As a third element to reduce cost of deployment of innovations an approach for modelling techniques is developed and used for automatic approval and certification. Develop a concept for Rail-industrial DevOps and dedicated architecture for decoupling hardware and software development: Combining the advantages of agile processes with the ideas of continuous development, building, test and deployment, as a lot of learning possibilities for the rail sector from ordinary IT product development.

These innovative new modelling techniques such as Formal Methods, DevOps and Architecture Design4Evolution, will contribute to speed up the development processes and secure fast and effective impacts.

Achievements in 2023

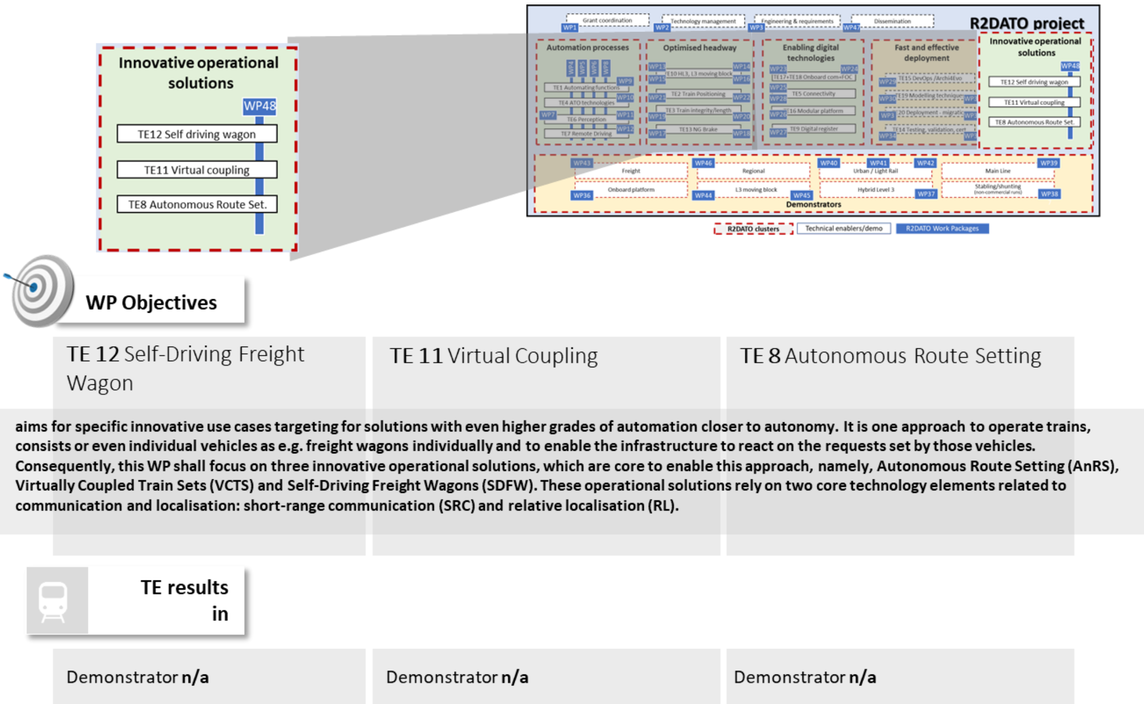
An outline of the business case for DATO has been defined. A close cooperation and information exchange is needed between different Technical Enablers in FP2-R2DATO as well as with FP1-MOTIONAL: A collaboration map has been laid out including the necessary exchange points.

For Testing and Validation, the Knowledge Transfer from Shift2Rail has been performed and the strategy for virtual certification is under definition. The implementation of two (2) test benches for the virtual certification has been started.

Modelling Techniques are continuing the work based on the achievements from Shift2Rail focusing on EULynX[33] and ETCS L3 Formalization.

Regarding DevOps and Architecture and Design4Evolution, a first set of user stories has been developed. DevOps processes and architectural patterns have been analysed for applicability.

Sub-area 5: Innovative operational solutions



Overview Sub-Area 5 – Innovative Operational Solutions

General objectives of the Sub-Area 5 – Innovative Operational Solutions

The objective from Innovative Operational Solutions is to identify, specific use cases where a further innovation beyond the GoA4 will bring additional value. The foreseen innovative concepts include the Autonomous Route Setting (AnRS), that will realize the autonomous path allocation on a technical level and help increasing the capacity on the network, the Virtually Coupled Train Set (VCTS), that is required for the steady state of operating virtually coupled train sets and the Self-Driving Freight Wagon, that will enable autonomous operations of single wagons. The technological element in focus will be short-range

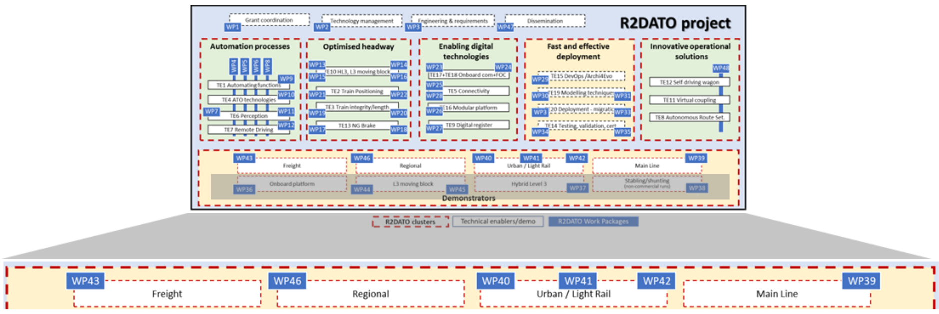
33 EULynX: EULYNX is a collective of railway Infrastructure Managers (https://eulynx.eu/)

communication (SRC), in order to reduce latencies down to the minimum in a train-to-train communication and relative localization (RL) e.g., between two consists or vehicles, to ensure the shortest possible dynamic distance between them.

Achievements in 2023

The activities of Innovative Operational Solutions were focusing on creating a stable basis for the activities to be performed in FP2-R2DATO. Results from previous projects such as Shift2Rail's X2Rail-3 have been taken over and analysed. The creation of Use Cases for the different Technologies has been started and for Self-Driving Freight Wagons a first version of the Use Cases is available.

Sub-area 6: Demonstrators

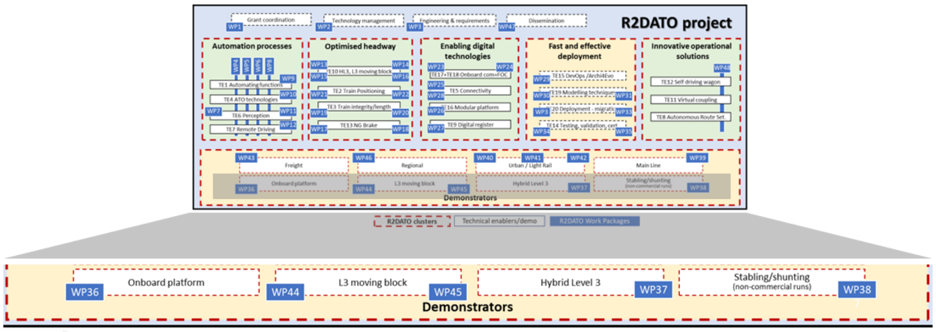


WP Objectives

DEMO 1 Freight	DEMO 2 Regional	DEMO 3 Urban	DEMO 4 Mainline
WP 43 To allow a smooth deployment of GoA 4 technology with different possible technological solutions, the systems need to be tested in real conditions in a demonstrator. The freight demonstrator will be equipped with sub-systems studied in the Technical Enablers. Tests will be performed, enhancing autonomous freight train operations.	WP 46 provide the bridge between R2DATO and FA6 demonstrations by supporting validation and testing of technical enablers in regional line environment, before they are handed over to FA6 for further adaptation and integration.	WP 40 make two trams ready for demonstration of different use cases and technologies along the project lifetime, which means to design, modify, and integrate appropriated systems which allows development of autonomous driving functions WP 41 **implement a REMOTE DRIVING AND TELECOMMAND demonstrator up to TRL7** WP 42 **implement an AUTONOMOUS MOVEMENTS demonstrator up to TRL6**	WP 39 (a) Prepare to demonstrate the solutions DATO over ERTMS technology can bring to relieve bottlenecks in main lines in high-density networks with heterogeneous traffic (b) Showing the relevant advantages deriving from the synergy between the digital automatic train operation up to GoA4 and the CCS evolution, increasing the capacity and punctuality of railway lines, by enabling ETCS L3 moving block with minimum infrastructure elements

DEMO Input from

DEMO 1 Freight	DEMO 2 Regional	DEMO 3 Urban	DEMO 4 Mainline
TE2 ASTP TE4 **ATO Technology** TE5.1 FRMCS TE6 **Perception** TE9 **Digital Register** TE14 **Testing, Validation, (Virtual) Certification** TE20 **Deployment & Migration**	TE2 ASTP TE3 Train Integrity TE4 **ATO Technology** TE5 Connectivity TE6 **Perception** TE6.1 **Data Factory** TE10 **HL3, L3 MVB** TE20 **Deployment & Migration**	TE1 Automatic Functions TE3 Train Integrity TE4 **ATO Technology** TE6 **Perception** TE6.1 **Data Factory** TE7 **Remote Driving** TE14 **Test., Val. & (virt.) Certif.** TE20 **Deployment & Migration**	TE3 Train Integrity TE4 **ATO Technology** TE5 Connectivity TE6 **Perception** TE10 **HL3, L3 MVB** TE20 **Deployment & Migration**



WP Objectives

DEMO 5 ETCS HL 3	DEMO 6 L3 MB	DEMO 7 Stabling & Shunting	DEMO 8 Onboard Platform
WP 37 develop migration and deployment strategies to accelerate the application of ETCS Hybrid Level 3, in order to reap the benefits as quickly as possible, thus avoiding costly investments in new infrastructure	WP 44 prepare the ground for a successful demonstrator: (a) identify relevant use cases/test cases to demonstrate (b) provide a demonstrator specific specification (architecture, functional requirements, interfaces) WP 45 **demonstrate a modular train-centric trackside protection system enabling moving block operations with generic safety core up to TRL6 in R2DATO**	WP 38 (a) Testing the performance of the technical enabler(s) incorporated in the demonstrator (b) Providing feedback to the TE-developer, in order to improve the functioning of the TE, or to enhance/improve/modify the specifications (c) Performing measurements to show the improvement of the new (sub)system over the existing system, so as to contribute to the realisation of the KPIs defined in the call.	WP 36 implement & validate a prototype & blueprint of the future-proof onboard connectivity & IT platforms that are required in a highly automated rail system, with the expectation that latest from EU-RAIL phase 2 on all larger-scale demonstrators would utilize these platforms; implement & validate in a lab environment (up to TRL 5/6) how railway application(s) can be hosted on a modular computing platform, making use of a safe Runtime Environment (RTE), standardized Platform Independent (PI) API, onboard FRMCS functions and a unified diagnostics service API

DEMO Input from

DEMO 5	DEMO 6	DEMO 7	DEMO 8
TE3 **Train Integrity** TE4 **ATO Technology** TE5.1 FRMCS TE10 **HL3, L3 MVB** TE20 **Deployment & Migration**	TE3 Train Integrity TE5.1 **FRMCS** TE9 Digital Register TE10 **HL3, L3 MVB** TE20 **Deployment & Migration**	TE1 Automatic Functions TE4 **ATO Technology** TE6 **Perception** TE7 **Remote Driving** TE13 **NG Brake** (TE16 **Modular Platform)** TE20 **Deployment & Migration**	(TE2 **ASTP)** TE5 Connectivity TE5.1 **FRMCS** TE9 **Digital Register** TE16 **Modular Platform** TE17 **onboard COM Networks** TE20 **Deployment & Migration**

Overview Sub-Area 6 – Demonstrators

General objectives of the Sub-Area 6 – Demonstrators

The objectives of the Demonstrator cluster are the [a] validation of the benefits of DATO technical enablers and [b] the validation of DATO technologies for specific target implementations.

The demonstrators will allow to validate the KPIs from AWP, uses cases and functional needs and Deployment and migration needs. Moreover, Technical Enablers can be employed in demos as support to validate other TEs. Depending on the required TRL, the demonstration will be performed either in a simulated or lab environment, or in a controlled real-world environment. Pre-deployment activities will be undertaken by demonstrating the performance of the system in a controlled environment and/or in a lab or simulated environment and preparing verification, validation, and certification evidence. These results can then be used as input during the full system level demonstration in the next phases of the programme. First steps in the development of the new functions and technical enablers will be completed, leading to prototypes and/or validation in laboratory (TRL5) and field (TRL6). The project will also allow to progress towards modularization, and first validation of the next generation ATC system in close collaboration with the System Pillar.

Achievements in 2023

All demonstrators foreseen in FP2-R2DATO have started the activities with a focus on aligning with the technical enablers needed for the demonstration. First prioritization of the use cases with the Automation Processes Cluster was performed in order to ensure the right priorities for the implementation of the TEs required.

With respect to Moving Block demonstration, a release plan for the demonstrator has been released describing the stepwise demonstration of the new technology and the goals to be achieved with the demonstration.

Demo 3 Urban has delivered the necessary use cases, the tramway modification report and summarized the lessons learned on the approval process for automated tramways.

The Onboard Platform demonstrator has been specified in close collaboration with the Enabling Digital Technologies Cluster.

Flagship Area 3 (FA3): Intelligent & Integrated asset management

The main objective of Flagship Area 3 (FA3) is to provide new innovative technical requirements, methods, solutions and services – including technical requirements and standards for future developments – based on the latest leading-edge technologies to minimise asset life-cycle costs or extend life cycles while meeting the safety and improving the reliability and availability and capacity of the railway system, addressing both infrastructure and rolling stock.

In the first phase of the programme, FA3 is implemented via the project FP3-IAM4RAIL.

Sub-Area 1: Wayside Monitoring and TMS link

Sub-Area 1 aims to transform asset management by incorporating predictive maintenance and intelligent system integration. Within the current railway infrastructure, different assets are controlled by separate systems, resulting in restricted data sharing and diagnostic capabilities. Maintenance is typically reactive or scheduled, causing operational disruptions and heightened expenses. For example, critical components like level crossings and switches require meticulous monitoring. The current methods rely on basic inspections and corrective measures only upon detecting malfunctions, proving costly, inefficient, and prone to service interruptions. To overcome these challenges, an **Intelligent Asset Management System** for **wayside assets** will be designed, deployed and validated. This includes securely collecting, storing, and analyzing data from wayside assets and sharing information with the **Traffic Management System (TMS)**. The information gathered will be analyzed to obtain information on asset status and detection of possible anomalies. These inputs will be used to optimize the maintenance process as well as the scheduling of the traffic.

Achievements in 2023

During 2023, the focus of Sub-Area1 activities was centered on delineating the architecture, the requirement for data platform and KPIs for validation process. Starting with the definition of functionalities aligned with the Infrastructure Manager's objectives, the general requirements for IAMS application have been defined. Validation rules for use cases were instituted, followed by the development of a cohesive approach for architecture design, data interoperability, and storage. Guidelines for analytic methodologies were established, and a preliminary design, informed by collected data, was initiated. The IAMS architecture, structured into Business, Application, and Technology Layers, was introduced as a standardized visual language, aligning seamlessly with the requirements of FA3.

This architecture was defined not only with Sub-Area1 objectives in mind, but also to be available for all FP3-IAM4RAIL Sub-Areas and it distinctly targets wayside and on-board systems, to ensure that the common architecture baseline for all FA3 Uses Cases remains aligned, focusing on the architecture for data interoperability and data sharing.

The forthcoming outcomes will be showcased through two pivotal Use Cases, demonstrating the implementation of intelligent asset management in Italy (Wayside and Infrastructure IAMS for TMS Optimization) and Spain (Wayside Monitoring in Conventional and High-Speed Lines for TMS Optimization) at TRL6.

Finally, alignment activities with FA1 have been initiated and will continue during the course of the project with the main objective to define common methodologies and best practices regarding the interconnected topics of Traffic Management System as well as Decision Support System.

Sub-area 2: Rolling Stock Asset Management

Sub-area 2 is focused on rolling stock asset management addressing on-board and wayside technologies developing new monitoring and inspections systems. Data on asset health collected will be used to perform data analysis and to develop predictive algorithms to support decision and planning of interventions. This aspect is very crucial considering that railway operators in Europe face constant pressure to control operating costs while maintaining high levels of reliability and efficiency. Maintenance costs and increasing expectations present many challenges. The primary goal for any railway operator is to maintain their fleets well, requiring regular inspections and repairs. To address these challenges, railway operators must shift from the old maintenance paradigm, based solely on preventive and corrective maintenance strategies, to a new one that integrates new strategies such as condition-based maintenance. To pave the way for this shift, a set of maintenance algorithms should be developed to enable the transition to the new paradigm.

Achievements in 2023

In 2023, the activities related to the description of the vision of future European Railway Checkpoints from a holistic point of view in alignment with FA5, including the mapping of possible technologies for infrastructure assets and on-board systems related to checkpoints and the evaluation of functional and operational objectives requested for railway checkpoints.

An important agreement has been reached between the industry partners and the railway operators about the data from different existing sources (sensors) of rolling stocks that will be exploited for the foreseen inspections and monitoring systems. This information will be used also for the development of algorithms for anomaly detection for subsystems like Bogie and Traction.

Regarding FA5 collaboration on the potential exploitation of the CBM algorithms and methodologies for freight developed in FA3, no final alignment was reached between parties for FA3 to receive from FA5 the expected data from previous maintenance activities, asset information, sensors, etc. – prerequisites for the development of FA5 tailor-made development in FA3.

Other activities aligned to FA5 are ongoing with the main objective to define common uses cases and the Standard concept of European Railway Checkpoints.

Sub-area 3: Infrastructure Asset Management

Strategic railway infrastructure asset management, particularly in maintenance, is crucial for safety, asset longevity, and operational reliability. It enhances customer satisfaction, minimizes costs, ensures regulatory compliance, and contributes to a sustainable and efficient transportation system by optimizing resources and minimizing environmental impact.

Sub-area 3 addresses various aspects of infrastructure asset management through demonstration in 13 use cases, with two main objectives:

- Long term asset management: developing decision and support systems for asset management and life cycle costing optimization;
- Enhancement of asset management and infrastructure via new monitoring and inspection system. These systems integrate Big Data from on-field and on-board sources, facilitating information sharing across the supply chain and Traffic Management System.

Achievements in 2023

In 2023, FP3 has conducted thorough research to establish the current state of the art within defined use cases, considering technological advancements and industry trends. This understanding serves as a foundation for defining Key Performance Indicators (KPIs) to effectively measure the proposed methodologies, algorithms, and technologies' effectiveness.

Furthermore, experimental work, field tests, sensor installations in the field, and other activities have been carried out in demonstration campaigns across multiple countries, including Germany, Sweden, Spain, The Netherlands, and France. A suite of applications utilizing diverse technologies to exploit the prototype platform's high-level architecture across use cases is currently under development. Lastly, interaction with FA4 has been initiated, focusing on the use of optic fibers for railway infrastructure monitoring.

Sub-area 4: Railway Digital Twins

Demonstrations in this subarea will focus on implementing railway Digital Twins (DT) to optimize processes, maintenance planning, and logistics related to the design, maintenance, upgrade, and renewal of railway assets.

DT implementations would address challenges which are common in the Flagship Area (asset modelling, secured data acquisition and exchange, data fusion, data presentation and behavioral simulation), therefore constituting a reference best practice for Digital Twin deployment. Main objectives of the sub-area 4 are:

- to develop methods to implement Building Information Modelling (BIM) replicas for asset management,
- to develop methods to link survey and diagnostic data to DT,
- to develop methods to presents and process DT asset data,
- to develop methods to enrich DT with behaviour for simulation and certification.

Achievements in 2023

In the course of 2023, initiatives were undertaken, encompassing the establishment of technical management within designated areas, accompanied by the facilitation of administrative support for partners.

Proactive measures were also implemented to establish and exploit connections with other FPs, ensuring technical. Regarding the development of methods to exploit the Digital Twin of a station, the BIM model of the Malaga Zambrano station has been made available. In order to develop the required services based on real world data, first sources of station monitoring data (e.g. video streams from station CCTV) have been identified to be later related to the Zambrano model and in a station in the city of Łódź (Poland).

Regarding the methods to use Digital Twin as integral part of a Virtual Certification Framework of the railway infrastructure, the overall conceptual framework and the related technical enabler have been defined. Use case requirements for the Common Data Environment have been shared with the Transversal Activity (TT). Synergies with FA4 have been investigated to support material tracing and passport management with the same technical solution (blockchain) envisioned to trace infrastructure certifications in the Virtual Certification Framework.

Sub-area 5: Environment, User and Worker Friendly Railway Assets

Sub-area 5 has the objective of creating environment, user and worker friendly railway assets addressing environmental and cost-effective lines, new additive manufacturing repair processes, robotic platforms for railway interventions and Augmented Reality and exoskeletons to support railway maintenance.

In the first year of the programme, this sub-area has been mainly focused in three general activities:

1. Definition of the use cases that cover the demonstration activities of the sub-area, describing the proposed technical activities and their potential for innovation, including specific technical KPIs to assess their validation.
2. Definition of user needs, specifications, requirements, etc., as the basis of all technical developments within the different UCs.
3. Initial works in the different technical activities across the WPs of the sub-area.

Six out of the 16 defined use cases aim to showcase eco-friendly design, production, and repair of resilient assets supported by advanced fabrication techniques like additive manufacturing. These case studies include sustainable and cost-efficient eco-design for rail assets, optimizing track and turnout designs to reduce environmental impact as well as creating train-track-bridge interaction models for realistic estimates of dynamic effects on bridges with ballasted tracks under dynamic loading. Scientific method descriptions for sustainable and cost-efficient eco-design are being defined, encompassing background, solution description, approach, and selected research methods. Additionally, several use cases focus on repairing metallic assets and spare parts for vehicles using additive manufacturing technologies like laser or WAAM, and novel materials such as flame-retardant. Specifications for these use cases have been defined in the first year.

The remaining 10 use cases will highlight high-tech automated solutions for construction and execution of interventions supported by robotics and wearables, creating a safer and more automated railway environment. Detailed solutions for automating operations like disinfection, ERTMS balises and axle counters installation, as well as data collection for maintenance purposes, will be developed. Robots are designed to meet diverse business needs, including accommodating transport offer growth without expanding maintenance facilities, accelerating equipment deployment programs, reducing costs, and improving information collection quality. Additionally, solutions to support operators, such as upper-body exoskeletons and augmented reality tools for railway workers in maintenance operations, will be developed.

Achievements in 2023

In 2023, FP3 has collectively defined main guidelines, common tools, and methodologies for ecosystem development. These efforts are instrumental in setting the trajectory for subsequent innovations, aligning with the overarching objective of creating a sustainable, user-friendly, and technologically advanced railway.

More specifically, final requirements and specifications list to successfully develop Augmented Reality (AR) and Exoskeleton solutions for railways maintenance operations have been issued. Additionally, regarding the development of the major common components, agreement has been reached on the use of ROS2 as middleware after a 2-stage study (literature review + technical and non-technical selection criteria assessment).

Flagship Area 4 (FA4): A sustainable and green rail system

The main objective of Flagship Area 4 (FA4) is to provide new innovative products and services based on leading edge technologies to minimize the overall energy consumption and environmental impact of the railway system, to make this transportation mode healthier, more attractive and to provide resiliency against climate change at a reduced total cost of ownership.

In the first phase of the programme, FA4 is implemented via the project FP4-Rail4EARTH.

Sub-Area 1: Alternative (to Diesel) energy solutions for the rolling stock

The main objectives of sub-area 1 are the demonstration of high-performance Batteries Electric Multi-Unit (BEMU) trains, hydrogen hybrid trains with testing of heavy-duty inspection vehicles and locomotives for freight and passengers, sub-urban catenary trains with on board Energy Storage Systems (ESS) and auto-adaptive train energy consumption to various service situations.

This will be enabled by increasing the energy density stored on-board the train, by extending the range accessible to the BEMU in catenary-free mode from 80 (present state-of-the-art) to 200 km and by improving the efficiency of the hydrogen traction system and standardizing its' refuelling interface.

The demonstrations planned as outcomes for this sub-area are the following:

- High performance battery-powered regional trains (200km), TRL6-7 in 2026;
- Hydrogen hybrid locomotive, TRL 5-6 in 2026;
- Hydrogen power plant for inspection vehicle, TRL 5 in 2026.

Achievements in 2023

During 2023, significant progress has been made and valuable results have been achieved on the different topics, ranging from the finalization of the general requirements for the next generation of European BEMUs, to the definition of almost all the requirements for the ESS and the external power supply.

Moreover, the charging power has been agreed among all the consortium partners and substantial work on traction chain requirements and the design of components has been achieved, including the analysis of the integration in a train (location and interfaces). The technology of the cells has been chosen and the first cell tests have started. At the same time, the potential candidate lines have been identified and their corresponding profiles were provided. Simulation methodologies have been developed for the traction and the complete system architecture was defined and modelled in a real-time software simulation environment.

The technical teams have developed and detailed two applications for semiconductor devices and battery cells and the usage of machine learning for the creation of a thermal model will be further explored in the future. A complete system modelling, including the configuration of the infrastructure installation, was detailed to guarantee the battery performance over a line and a test specification on a semiconductor device with internal condensation was performed and the related results of the pre-tests on the absorption mechanism of moisture in the silicone gel were evaluated. In an artificial test setup, the saturation effect of the moisture uptake of the pure silicone gel is in the range of approximately 10 specific condensation cycles. The failure mechanism itself is triggered after 80 condensation test cycles. One must consider that the severity levels of the condensation during test is different. This might have an impact on the numbers of cycles, but there is no final evidence of this issue. Ongoing investigations are focused on the clarification of this phenomena. Until now the generic test procedure is precisely defined; what is missing is the definition of the right condensation test cycle numbers, which shall be applied according to the requirements for Railway Traction Applications.

Regarding the hydrogen technology, different systems for improving the efficiency of a hydrogen power plant were identified and the complete characterization of a hydrogen power plant is currently on-going. The partners have also convened that the hydrogen refuelling interfaces for the railway environment do not have specific needs diverging from those of land vehicles.

Sub-Area 2: Energy in rail infrastructure and stations

The main objectives of sub-area 2 are the improvement of hydrogen refuelling stations for the railway sector by standardization, the development and integration of innovative solutions into the legacy railway system to improve and enhance the infrastructure traction power supply and the definition of the requirements and preliminary developments for the use cases of innovative solutions to manage and minimize energy consumption by optimizing the usage of needed resources and by reducing the total cost of ownership. The sub-area also targets the development of a new way of powering railway grids using renewable energy sources and local energy balancing solutions, such as energy storage systems and regenerative braking.

Achievements in 2023

During 2023, in relation to hydrogen refuelling stations, an analysis of the state-of-the-art for the use of hydrogen in railways has been conducted, ranging from the technical model and its verification to the analysis of the safety aspects linked with its usage, to the hydrogen refuelling station supply market. Use cases for the double-sided feeding of 50 Hz AC traction substations using a flexible alternating current transmission system have been defined and a first version of the Railway Interline Power Flow Converter requirements was consolidated. Regarding the energy storage solution for the AC railway grid, an analysis of the potential feasibility for different ESSs was conducted for this use case and converter topologies have been compared to allow the access of multiple ESSs to the railway traction system. Such converter topologies have been reviewed to integrate the energy storage and a new control strategy for the integration of the ESS has been developed. In particular, the parameters of a model of a transformer-less cascaded multilevel converter, as well as the type and capacity of the battery energy storage system, have been designed.

With reference to the optimization and management tools for the AC and DC railway grids, requirements for the former were received and reviewed, while for the latter a model was validated. For the introduction of energy hubs in specific traction conditions, different use cases were simulated, and the demonstrator locations were confirmed. The first draft requirements for the battery ESS were prepared and an architect designed an ad hoc container for the battery system. The first simulations and calculations with a limited scope on the location of the demonstrator were performed and a theoretical analysis to assess the validity of the designed models during normal operation was carried out, as well as a brief description of the energy management. Based on the performed analysis, the most suitable technology for the OESS to be developed for the large range BEMU demonstrator is the Lithium Ferrum Phosphate (battery). Progressing further towards introducing the energy hubs as advanced elements of the railway system, various models based on the integration of the ESS and the RES (Renewable Energy Sources) to the railway grid have been defined and additional improvements to the line model are still ongoing. Ad hoc simulations have started with the aim of fully understanding the potential applications of the ESS and of the photovoltaic technology in the identified substations. Test methods and testing scenarios for the demonstrators have been produced, as well as an algorithm for estimating electricity generation from renewable energy sources.

Finally, regarding the building of a modular low-emission station, the consortium has worked on the specifications and the use cases definition for the railway station energy digital twins, Building Information Model (BIM) data requirements, and validation plan. Different BIM use cases have been identified and potential use cases for Digital Twins have been mapped. The first 3D models of architectural concepts have been prepared, followed by the structural models required for conducting the static analysis and the dimensioning in various material and construction variants. These are completed by some tests and research on potential HVAC and lighting performance models.

Sub-area 3: Sustainability and resilience of the rail system

The main objectives of sub-area 3 deal with the sustainability and resilience of the rail system. This sub-area performs research, develops models, and will demonstrate solutions to better adapt the rail system to climate change and to reduce the impact of vibrations and noise on the surrounding environment.

Achievements in 2023

During 2023, several technical topics were tackled in different knowledge areas, including alternative drive systems, energy management, noise and vibrations, and wider topics like adaptation to climate change.

In relation to alternative drive systems, the project has studied the state-of-the-art related to hydrogen usage in railways and interfaces at battery level. In addition, the list of parameters to be exchanged between the traction system and the train driver desk, as well as the traffic management system, have been set. A more global view on smart energy management was considered, where various partial electrification scenarios have been simulated to evaluate the performances of alternative drive trains and the lifetime of energy storage systems. The optimization of the energy efficiency at railway system level have been modelled for the planned simulations.

The studies on the noise and vibrations topic have progressed by adapting the Railway Track Vibration Emission model (STEM model) for ground-borne vibration calculation in the time domain. This model was also used to assess the impact of the previously developed alternative ballast aggregate neoballast on the vibration emission of railway tracks. This modelling theoretical approach was completed by more practical results: the compiling of data from various inputs to establish a ground-borne vibration mitigation measures catalogue and, the creation of an overview of existing gabion walls within Deutsche Bahn's area of competence with the clarification of the installation conditions of gabion noise barriers or other masses close to the tracks in Germany. The latter study permitted to determine the relevant influencing variables for the effect of masses next to the track. Along with the vibration modelling, a pilot study was carried out related to the annoyance responses gathered at residents' homes, for which methodologies have been defined, both for studying high-train annoyance and tonalities.

Adaptation to climate change plays a key role in the future of the railway domain. Within the framework of FP4-Rail4EARTH Sub-Area 3, a worldwide bibliography analysis of more than 120 documents was conducted. Complementary to this work and with the aim of bringing together the widest possible range of skills, an operator part of the consortium implemented an internal Datathon competition to study the impact of the meteorological situation on the rolling stock maintenance.

Sub-area 4: Electro-mechanical components and sub-systems for the rolling stock

The main objective of sub-area 4 is to develop and to optimize key sub-systems of the rolling stock. This involves developing and introducing to the market (air-less) Electro-Mechanical Braking (EMB) system, pantograph and suspensions while targeting energy savings on the involved subsystems and reducing associated maintenance costs. A parallel objective is optimizing motors, gearboxes, high performance bogies and suspensions with regards to energy consumption and weight, thanks to the introduction of new materials following circular economy principles. In the scope of new usage, one key objective is to deliver alternative technologies to replace hydrofluorocarbon refrigerants in Heating, Ventilation and Air-Conditioning (HVAC) systems using green refrigerants or new cooling technologies with reduced energy consumption. An additional more global objective for the rolling stock is to introduce enhanced experimental and numerical methods on aerodynamics, with the aim of reaching certifications by 2025.

Achievements in 2023

During 2023, the electromechanical subsystems were studied in terms of existing maturity of the subsystems. First, the impact of the very new EMB systems on interoperability and EU standards was deeply analysed; as a result, new proposals of interpretation or elements of context about EMB have been provided for future EN revision working groups. Besides this, two air-less actuator types have been tested at a static and a dynamic test bench and the information gathered justifies the achievement of TRL4 and TRL6.Their interfaces to train demonstrators are being evaluated for their future integration and RAMS aspects are also being considered to ensure a design which will be compatible with a future authorization and homologation process Within the perimeter of new electromechanical subsystems, the obstacles to the introduction of electromechanical pantographs have been identified. The concept has been validated along with the related technology. The initial set-up for the simulation model of the dynamic interaction between the electro-mechanical pantograph and the flexible catenary structure has been shown. The current concepts of the third proposal of airless subsystem - the airless active suspensions - have been evaluated in relation to the current regulation. This concept led to initiate two related activities: the activity dealing with a simulation model to further study it, as well as sharing the concept of "single axle running gear with one air-free suspension step". To complete the suspension topic, basic principles of the secondary suspension were outlined and addressed to later depict the potential concept.

First studies addressing the theme of optimized motors and gearboxes, high performance bogies, suspensions, and new materials have also been addressed during 2023. The relevant results led to the first conclusions regarding the architecture of the bogies, the state-of-the-art survey for new materials and lightweight axle test results. A permanent magnet synchronous motor was mechanically simulated and tested, and the active steering simulation was prepared.

The third objective dealing with the HVAC topics was analysed by listing the possible alternative cooling technologies considering comparability criteria (KPIs) for technological assessment which were determined in 2023. These were implemented in an assessment table with rules (comprising, therefore, of a proper assessment tool) allowing to compare different cooling technologies.

Finally, aerodynamics numerical methods were enhanced by firstly designing a generic reference model train for the assessment of aerodynamic performances and by then listing the different methodologies to analyse the aerodynamics and the requirements and clarifying for each the relevant pros and cons. During 2023, the preparation of wind tunnel tests with the generic model have been completed.

Sub-area 5: Healthier and safer rail system

Sub-Area 5 is designed to achieve two main objectives: developing technologies and methodologies ensuring a reduced health risk for rail passengers and staff and building a better understanding on non-exhaust emissions emitted by wear particles from brakes, wheels-rail contact, pantograph-catenary line contact and assess the related risks.

Achievements in 2023

During 2023, substantial progress has been made on both topics.

Even though this sub-area is not directly contributing to the five project KPIs (Physical energy consumption, Physical CO2 equivalent emissions, Life Cycle Costs reduction, Autonomy of BEMU, Noise emitted per component), some local KPIs were defined in 2023, in order to be able to evaluate the progress done. They comprise, among others, of the mean and the local peak aerosol particles concentration in the breathing zone of all passengers, evaluated for locally exhaled particles, the mean spreading lengths of aerosol particles in the occupied zone of the passenger car, the mean particle lifetime in the occupied zone of the passenger car as well as the fraction of settled/removed particles, the virus, bacteria and Particulate Matter (PM) reduction, and also other points like space and weight requirement and life-cycle costs.

The passenger zone was the subject of different investigations. Firstly, the aerosol particle spreading inside the passenger zone of the train was investigated for different ventilation concepts. First intermediate results highlight the influence of the ventilation system, e.g., of the positioning of the supply and exhaust air openings, on the local aerosol particle spreading. Then, experimental procedures were applied to evaluate different air flow configurations and furthermore, the cabin geometry was prepared for computational fluid dynamics investigations. Being the evaluation of air quality improvement technologies a key point of this sub-area, a survey of the existing standards was done in parallel with the determination of the best evaluation criteria for the selection of novel air purification technologies which might be installed into the HVAC unit. This evaluation was also supported by the collection of different existing air purification technologies for which a pre-evaluation based on a literature survey was started. To complete the evaluation of the new technologies, the first test protocols for laboratory level tests were proposed and the discussion for the other levels (i.e., mock-up level and train level) has started.

With reference to the equally important topic of air quality on covered platforms and tunnels, three measurement scenarios (long-term, punctual, experiments to measure the efficiency of the air treatment devices) have been defined. The first experiments in an underground station to assess an air treatment technology have begun. As sub-area 5 is also responsible for evaluating the use of Low-Cost Sensors (LCS) for air quality measurements, the project partners compiled an inventory of LCS with their characteristics. After describing their calibration process, the use of these LCS in real conditions was begun in 2023, by measuring air quality in a mixed traffic situation at Arlanda Central Station, the railway station on the Arlanda Line serving Stockholm-Arlanda Airport in Sweden (still in progress).

Sub-area 6: Trains Attractiveness (Interiors)

The sub-area 6 is dedicated to the train attractiveness through the enhancement of various interior elements and aims to develop the technologies and design by facilitating:

- The adaptation of rolling stock with refurbishment and regular evolving layouts (summer/winter for example), and innovative concepts to support the increase of capacity of the rolling stock targeting TRL6 in 2025 and prepare for later evolutions.
- The reduction of the environmental impact by using interiors designed for circular economy with specific materials, shapes or assemblies done for the re-use or for very low impact during the life of the train.
- On-demand comfort for users such as modular seats, toilets "anywhere", touchless controls, fully hygienic designs, accessories, lighting, and acoustic conditions as well as new architectures to increase passenger capacity (target: TRL6 in 2025).

Achievements in 2023

The activities carried out in 2023 were based on state-of-the-art studies and on the application of the problem-solving "5 Why" method. The "5 Why" is a brainstorming technique consisting of repeatedly asking the question "why?" until the root cause of a problem is determined and is, therefore, an established method for finding the right path to reach innovative solutions in a given domain, while deeply analysing the related problems.

Concerning the modularity topic, the state-of-the-art review introduced the notions of modularity in production, modularity in design, and modularity of use. This allowed the partners to agree on modularity in design to be the context of work in this sub-area. A wider survey was then carried out, including existing and inspiring projects: Shift2Rail projects PIVOT, IdeenZug (from DB) and Mecanoo (NS). To move beyond the state-of-the-art, the current issues against the generalisation of modularity for interiors have been analysed by using the "5 Why" method. Following this analysis, six main issues were identified: design of new parts - no carry over, adjustments and reworks needed, validation process, complex supply chain, perceived quality and customization, short obsolescence time of new technologies. Based on these results, opportunities and challenges for modularity were identified, including the challenge of time to market, the challenge of the design for second life, the challenge of the carry over, the challenge of the validation process, the challenge of forgetting the tailored design and the challenge of the just viable technology.

The same methodology was applied for the circularity topic. As a result, six main issues were identified for this topic: railway's design not adapted, market not ready for railway, validation process, complex supply chain, perceived quality and customization, short obsolescence time of new technologies or functions. Data collection among the partners enabled to show the key points for circularity which include the challenge of new materials and the validation process, the challenge of creating a new market of the re use and the challenge of the supply chain.

As a complementary item, a preliminary literature study on the possibilities of biomimicry for circular and modular train interiors revealed the biomimicry potential of each challenge related to this sub-area.

Flagship Area 5 (FA5): Sustainable Competitive Digital Green Rail Freight Services

The objective of FA5 is to make rail freight more attractive through increased capacity, e.g., with Digital Automatic Coupler (DAC), which is enabling more functionalities in freight to increase network capacity in a smart way for all types of rail freight transport, as well as significantly improved cross border operations and multimodal customer services. Increased capacity is the key factor to enable a shift of transport volumes to rail, reducing substantially the related greenhouse gases emissions. FA5 tackles the challenges by having two clusters which are interlinked. The first one is "Full digital rail freight operations", focused on increasing substantially the productivity, quality and capacity of rail freight by applying digitalisation and automation to all possible operational functions and processes including innovative freight assets. The second one, "Seamless rail freight", is focused on important aspects to increase the efficiency of the immaterial (information/data) layer of transport and to gain time and save costs by ensuring a seamless environment (between different actors/countries/modes for planning/execution/management) in the long term, but also via short/medium-term achievements and quick wins.

In the first phase of the programme, FA5 is implemented via the project FP5-TRANS4M-R.

WS1 Full digital Freight Train Operations with DAC as enabler for full digital freight train operation

Since the beginning of the activities, the project has made significant strides in advancing the Future Digital Freight Train Operation (FDFTO) within the European rail freight sector. As a first step, target operational procedures for FDFTO have been developed and aligned within FP5-TRANS4M-R and with the System Pillar. Several Sounding Boards with further stakeholders from European DAC Delivery Program (EDDP) have been held in 2023 to ensure acceptance throughout the European rail freight sector.

Based on the target operational procedures, a Risk Assessment, through a pivotal deliverable, has been a cornerstone in defining safety requirements for the development of DAC and FDFTO components and solutions. Aligned with the EN 50126-1 standard, this comprehensive approach ensures a systematic apportionment of system requirements at the level 5 of the V-cycle.

Target Operational Procedures have been instrumental in outlining the initial target operational procedures for rail freight across Europe. The document describes both physical and digital layers, providing a foundation for specifying technical enabler requirements in digital-rail-based logistic systems.

The opening of the Train Test Lab in September 2023 represented a major step forward, marking a fourfold action plan that focuses on accelerating the development process through trial and error, deciding on component types, conducting approval-relevant tests, and implementing demonstrations. This approach not only facilitates rapid decision-making but also ensures the robustness and safety of the developed technologies. The developed Test Plan provides a holistic overview and planning for tests on vehicle and train levels, specifically targeting the FDFT components of the EU-Rail JU Flagship Project 5 TRANS4M-R. The document also emphasizes collaboration with other areas of the project and outlines the methodology, quality management, and system integration plan, contributing to a comprehensive testing framework.

In 2023 several tests have been carried out in the Train Test Lab:

- Installation tests of DACs from all four suppliers to analyse the installation suitability of the component.
- Test campaign for electrical coupler (e-coupler) design with e-couplers from two Knorr-Bremse and Voith. The test campaign was supervised by an expert group of operators that gave a recommendation for the favoured electrical coupler design.
- Early testing of prototype components such as decoupling actuators by interested industrial partners.

During 2023 there has been progress in the FP5-TRANS4M-R demo trains. The Swiss Demo Train testing the in train-communication system based on the physical layer “Powerline Plus” has started its activity and is collecting data. The Swedish Demo Train has been equipped with DACs and will start running in 2024. For the Austrian and the Italian Demo Trains the main part of the development is to be carried out in the next phase of the project.

In 2023, FP5-TRANS4M-R finalised the functional testing of the DAC prototypes in the manufacturers’ laboratories according to the test specification for the DAC. The successful passing of the laboratory tests serves as precondition to install the DAC on vehicles and further test those in railway environment in the FP5-TRANS4M-R train test lab. Additionally, FP5-TRANS4M-R executed interoperability tests for the DAC by 2023-year end. For the execution of the tests, all DAC-suppliers delivered prototypes to a laboratory in Budapest, where the interoperability tests have been executed according to the DAC test specifications.

The Authorisation Strategy, another critical delivery of the project, outlines the pathway for authorising the implementation of the DAC/FDFTO component and operational procedures into existing vehicles within the legal framework of the 4th railway package. This strategy aligns with the ERA document "Ensuring interoperability and safety in massive retrofitting of vehicles," ensuring compliance and safety. The actual implementation of the authorisation strategy e.g., for realising the pre-deployment trains is currently under alignment with ERA and other responsible national bodies.

The ongoing work, such as User Requirement Specification and Freight and FDFTO System Architecture, underscore the project's commitment to meeting user requirements and establishing a robust system architecture, which is open to further developments (upgradeability of the FDFTO system).

Technical Specifications and Architecture Development:

Based on the target operational procedures, risk assessment and system architecture, the technical specifications for the DAC subsystems, hybrid coupler and yard automation have been finalised:

- System Requirement Specification for Full Digital Freight Train defined.
- Technical specifications of Wagon and Locomotive DAC up to level 5, including hybrid coupler have been defined.
- Validation/Test Procedures of Wagon and Locomotive DAC up to level 5 have been started.
- Requirements specification for yard automation have been defined.

According to the FDFT System Requirement Specification the development of a physical reference system architecture and a digital/data reference system architecture for FDFT were started in 2023 and will be finalised in 2024.

The alignment with industry stakeholders and the result of collaborative efforts have been key to prepare the specifications for energy data and train safety concept for automatic uncoupling, electrical coupler selection and personal protection at 400V AC. These are some of the ongoing activities in relevant areas of the Project.

WS2 Seamless Freight: with easy access and reliable (intermodal) transport service offering digital solutions.

In 2023, significant progress has been made in initiating work related to the Seamless Freight cluster. Specifically, the focus has been on delivering the essential functional and technical specifications required for the realisation of the technical enablers of Seamless Freight.

A comprehensive report detailing the fundamental functional and technical specifications necessary to bring about the technical enablers of Seamless Freight has been delivered. This serves as a pivotal step towards aligning with the market requirements and sets the stage for future development efforts. Another report specifically addressing the basic functional and technical specifications essential for Seamless Planning, Dynamic Dispatching was also issued, and Intermodal Prediction. These specifications are intended to serve as relevant inputs for the ongoing efforts in FP1.

The overarching objective of the first year within this work stream was to meet market demands by establishing the functional and technical specifications required for the seamless freight cluster envisioned in this project. The concrete development work will take place from 2024 onwards while there is an important alignment with work areas of FP1-MOTIONAL and FP3-IAM4RAIL. These projects focus on mainline network planning and management, as well as the development of CBM (Condition-Based Maintenance).

Furthermore, the efforts within Seamless Freight in 2023 also include the definition and preparation of use cases which will result in showcases at the end of the project.

For Seamless Freight, the efforts in 2023 revolved around the specification phase according to the overall timeline:

- 2023: Specification Phase, building a foundation for the subsequent development and demonstration efforts.
- 2024 – 2025: Development Phase, planning, realizing, testing and deploying the planned developments of systems and interfaces
- 2026: Demonstration Phase, showing the achievement of the objectives set out in the Grant Agreement, including the mandatory TRLs, with the help of pre-defined KPIs

The specification phase included the definition of relevant requirements, the identification of use-cases as well as a description of relevant systems, data types, processes and challenges. As the basis for identifying the specific needs and use-cases, the status quo was considered in a first step. Specifically, the developments from the S2R project and other innovation projects, developments and studies as well as the current challenges and barriers for Seamless Freight from an operator's perspective played a crucial role.

One prominent example of Seamless Freight building on current initiatives is the harmonized Seamless Freight Process List. This list indicates the timestamps and milestones for terminal, yard and main-line processes and is a fundamental building block for intermodal prediction systems and connected use-cases for planning and dispatching activities. This process list is based on the Rail-CDM initiative as well as several European and national initiatives (ELETA, ProMI, EDICT) and considered the requirements from shippers, intermodal operators, railway undertakings and infrastructure managers.

Throughout 2023, there was a continuous and close alignment process between FP1 and FP5, specifically regarding the definition of requirements (FP5 to FP1) and the resulting system developments of TMS interfaces and Yard Coordination and Management Systems (FP1 to FP5). Additional milestones were defined for the pre-deployment and testing of FP1 systems in an FP5 demonstration environment. Additionally, the requirements towards general principles of data sharing were used to include and adapt a Common Data Model. This heavily supports the standardisation activities of the European Checkpoints (including Intelligent Video Gate). On this basis, the alignment process between FP1 and FP5 will be continued throughout the rest of the project lifecycle.

Based on the centralised specification efforts, the various system and interface developments are now starting in 2024. The overall framework, which was established in 2023, will be streamlined and adapted to serve as a common Seamless Freight Development and Deployment Plan to ensure that all activities fit into the Seamless Freight and are adequately aligned. This effort includes the allocation of KPI reference values to the various demonstrators, which in turn are directly linked to the realisation of the already defined use-cases.

The time savings within the processes depend on the functional capabilities of the technical enablers (e.g., the DAC type). Procedural improvements can be assessed via assumptions on time savings for the single tasks that will be improved or made obsolete by the different technical enablers. Tests within the project scope will verify the assumptions on time savings.

In 2023, the process for measuring them was defined as an important step in establishing the reference state against which progress can be measured. The measurement process links the KPIs to the technical enablers and to the target operational procedures. In addition, with a view to a harmonised approach within the sector, a synchronisation with other related activities, such as the cost-benefit analysis carried out within the EDDP, has been made.

Regarding performance indicators, the development of the DAC and yard automation contribute to their achievement. The outcomes of the project in 2023, especially the decision for an E-coupler design, the start of operational tests in the train test lab as well as the test results of functional and interoperability tests are important in this context.

Flagship Area 6 (FA6): Regional rail services/Innovative rail services to revitalize capillary lines

The overall objective of Flagship Area 6 (FA6) is to ensure long term viability of regional railways by decreasing the total cost of ownership (TCO), in other words, cost per passenger/ton kilometre both in terms of operational expenditure and capital expenditure, while offering a high quality of service and operational safety. In addition, the aspired results aim to increase customer satisfaction and to make rail an attractive and preferred choice of transport mode. These goals are expected to be achieved through a concept tailored to regional railways that includes digitalization, automation and utilization of mainstream and emerging technologies for signalling and trackside components, rolling stock and customer information.

In the first phase of the programme, FA6 is implemented via the project FP6-FutuRe.

Sub-Area 1: Regional Rail System Solutions/Architecture

The objectives of this Sub-Area are the following:

- Identify a harmonised and integrated railway scheme suitable for all kind of regional lines according to the overall objective to optimise the operational and capital costs.
- Verification of the achievement of the KPIs expected for the developed demonstrators.
- Evaluate the safety principle and the migration strategy applicable to these lines. These activities haven't started yet.

Achievements in 2023

In 2023, the focus was put on identifying and designing the overall Regional Architecture and the Operational and Functional requirements. The technology areas covered are aligned with the sub-area 2 to 5. The work covers both considerations, the Group 1 lines (lines covered in the Interoperability Directive 2016/797/EU) and the Group 2 lines which are not functionally/operationally connected to the mainline network. The first release of the requirements and architecture was shared with the relevant Flagship Projects and the System Pillar in to ensure a commonly accepted architecture and provide input to the prototype development.

In addition, the Key Performance Indicators defined for the project have been linked to the technology enablers, the baseline scenario with parameters have been defined together with a measurable criterion for each KPI.

In this sub-Area, are also managed the technical interaction with the other Flagship Projects and the System Pillar for the regional lines purpose.

Sub-Area 2: Regional Rail Command, Control and Signalling CCS & Operations

The Regional Rail CCS & Operations sub-area focuses on finding suitable Command, Control and Signalling (CCS) solutions and defining preparatory demonstration activities by using existing and potential interoperable standards applicable on European G1 lines (i.e., lines or network of lines that are connected to the mainline railway system, forming together the Single European Railway Area (SERA) in accordance with the Directive 2016/797/EU) to ensure their long-term viability by reducing the total cost of ownership while taking into consideration regional lines specificities. More specifically, the abovementioned CCS solutions cover:

- Automatic Train Operation (ATO), up to Grade of Automation 4 (GoA4)
- European Train Control System (ETCS) Level 2
- Traffic Management System (TMS)
- Absolute Safe Train Positioning (ASTP)
- Train Integrity and Length

Achievements in 2023:

As one of the important topics of this sub-area, relevant steps have been taken throughout 2023 with respect to the identification and development of multiple use cases (UC) which shall be further developed in future stages of the project and demonstrated. Deriving from this preliminary list of use cases, a series of requirements have been elicited to assist the technical team in the definition of a common European regional rail development management framework characterized by green, digital, safe and cost-efficient solutions where the CCS system plays a crucial role. Similarly, future achievements shall enable the Regional Rail CCS & Operation sub-area to make a significant impact on the establishment of such framework by providing a complete list of CCS requirements derived from fully developed use cases and demonstration activities.

Some of the topics discussed so far deal with:

- ATO adhesion management system: Special circumstances (e.g., extreme weather events) can have an impact on the ATO Operational Speed Profile as a consequence of low-adhesion conditions being present on the track. In managing low-adhesion areas it is possible to achieve a more precise traffic regulation and thus a more efficient traffic management system.
- Remote Driving: Demonstration of trustworthy back-up systems in case of ETCS failure. This technology will consider the following aspects:
  - investigation of network capacity and quality requirements for video support,
  - to showcase the possibility of using public networks on regional lines without the support of dedicated wireless connection
  - to gain early experiences from remote driving on regional lines.
- Preliminary analysis of possible measures for the simplification of infrastructure deployment in the context of ETCS L2 is ongoing, mainly in terms of possible reduction of signalling trackside assets and reduction of the operational and functional complexity.
- Preliminary evaluation of Conflict Resolution (including as main added value the use of AI algorithms), Mixed Regulation, and Mixed Planning functionalities performed by TMS. Mixed Regulation enables the TMS to regulate traffic depending on both timetable and the track area. Mixed Planning enables the TMS to plan based on a range of inputs (e.g., number and type of trains, topology, timetable, etc.)
- ASTP: regional railways are characterized by stricter funding constrains, limited infrastructure typically single-track configuration, lower demand on transport in remote areas and often remote localisation. Train to track communication options is typically limited (no or little radio signal coverage with radio holes leads to higher single train track occupancy as there are less chances to confirm track area release). Locomotives are typically low performance ones in regards of maximum acceleration and maximum achievable operational speed characteristics. This leads to less dense railway traffic (bigger headways between trains). Since the traffic is less densely packed, the demands on infrastructure are also lower including specific solutions where there is lower possibility of deploying human operators and service of the devices. This creates a need for innovative adaptation to specific conditions and demands of the railway managers in these lines. The activities performed so far focus on a preliminary assessment of a more accurate ETCS odometry and use of alternative virtual/physical reference points different from physical Eurobalises, among others.
- Studies for the introduction of Train Integrity and Train Length for the use of new signalling systems that go beyond ETCS L2 is carried out. These will be systems that will detect train integrity and train length automatically without the intervention of the driver. There is also attention to cost containment.

Sub-Area 3: Regional Rail Infrastructure Assets

Assets are a major cost driver in regional railways. Reducing the cost of assets in terms of both CAPEX and OPEX is an essential element of reducing the overall costs. The focus of sub-area 3 is to develop cost efficient assets tailored to regional railways by different means such as reducing complexity and removing cablings required for data transmission and power supply.

In addition, this sub-area provides a 5G communication concept and prototype for energy self-sufficient wireless assets and further develops Smart Wayside Object Controllers (SWOC). Wayside Object Controllers (WOCs) are devices used in railway systems to manage and control various wayside objects such as signals, switches, and other trackside equipment. Smart Wayside Object Controllers refer to advanced or intelligent versions of these devices that incorporate modern technologies to enhance functionality, efficiency, and safety. The first half of the project is dedicated to requirement specifications in a collaboration between industry, Infrastructure Managers, as well as scientific institutions.

Achievements in 2023:

In 2023, the efforts have been focused towards in the development of the specifications with its innovative approach in developing new solutions. This sub-area releases the results of the requirements specification phase in three milestones. The work builds on previous results of S2R as well as other R&I projects. Furthermore, workshops for alignment and exchange of knowledge with other European Projects such as C-Roads have been organized. This joint initiative of European member states will enable wireless data exchange between moving vehicles and infrastructure. For regional railways, which often cross remote areas, this future technology will be an opportunity to save costs and make railway crossings safer. A table with all the analysis of all the relevant projects have been created to further assess the innovation potential and will be developed during the demonstration phase.

In the area of assets, high level requirements, architecture, use cases as well as interfaces have been defined. The upcoming releases provide a more detailed requirements catalogue including wireless technology, power management, maintenance as well as benchmarking. In the area of communication, the work during the first year provides architecture, functional requirements and use cases. The future work in this area will continue including upper and lower open systems interconnection layer requirements and track to track communication. The work on SWOC provides the use cases, the first draft of architecture and interfaces as well as life cycle cost studies and exploitation model. The upcoming focus of this area includes multi-modality, national regulation, alarms and notifications.

The forthcoming work is focused on finishing the specifications in order to start building the prototypes as well as the concrete definition of the demonstrators to be implemented at the end of 2025.

Sub-Area 4: Regional Rail Rolling Stock

This sub-area aims to develop cost efficient vehicle concepts for G1 and G2 lines.

A novel lightweight regional emission free vehicle with significant weight reduction, flexible, modular solutions for vehicle interior for passenger vehicle is under the consideration. The sub-area also includes a development of efficient and sustainable vehicle-centric CCS for G2 lines.

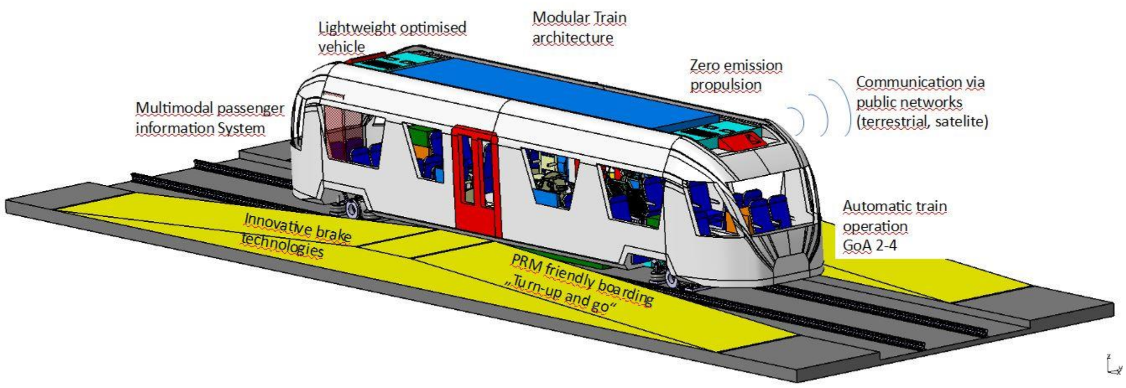


Illustration of a possible regional vehicle

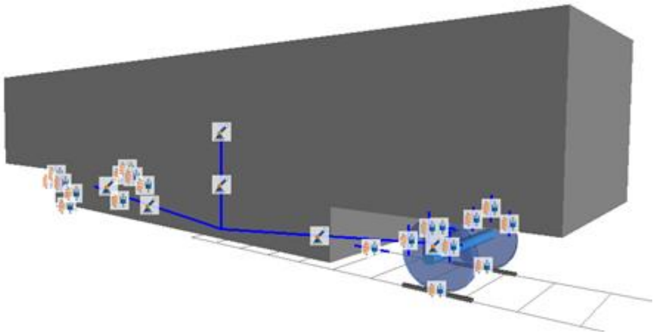
Achievements in 2023:

In 2023, the sub-area has collected information about existing regional vehicles and gathered this information in a rolling stock data base containing 29 vehicle types with a maximum capacity of 100 seats.

The high-level vehicle requirements and input to the technical KPIs have been provided to Sub-Area 1. It has also agreed internally on a more detailed set of draft requirements based on the target given: lightweight low-capacity vehicle with a zero-emission propulsion while significantly reducing CAPEX and OPEX.

The objective of the draft requirements is to proceed with further project activities related to the design of the vehicle and its components. Some of these requirements are subject for deeper studies within this sub-area as described below.

It has created a model of the regional train to enable vehicle dynamic simulations and modelled the entire car-body in a topology optimization task supported by a material selection study.



Multibody model of a possible regional vehicle

Further, a vehicle model of the propulsion chain has been created to allow comparing different propulsion options to select the optimal solution.

The work on Fuelling station is carried out in collaboration with FP4-Rail4ERATH, the Sub-area 4 started to define the most relevant set of data on hydrogen refilling stations which will be used by FP4 in their software tool to come to a best choice for pressures, flow rate etc.

In addition, the requirements for the vehicle centric CCS for G2 has been drafted and provided to Sub-Area 1. In the next year, additional studies will be performed to detail the requirements that currently are in draft version.

Sub-Area 5: Regional Rail Customer Services

The focus of Sub-area 5 is to provide customer services concentrated on development and consequent demonstrations of highly accurate multimodal travel solutions. The objectives comprise provision of multimodal solutions including first and last mile -- for passenger and freight transportation. This initiative is supported by a consideration of evolving travel behaviours characteristic of the "new normal." In tandem, the Sub-area is working towards a seamless and reliable integration of Traffic Management Systems (TMS) and Passenger Information Systems (PIS). Furthermore, to support the developments and demonstrations, assessment of suitable databases for completeness, and for the systems, conformity with standards is being undertaken.

in 2023, the sub-area has made progress defining specifications for the solutions. A report delineating the first compilation of user stories, use cases and requirements has been issued. Further, the report elaborated on the scope of collaboration with FP1-MOTIONAL focused on short- and long-term travel demand prediction analysis and Traffic Management System – Passenger Information System (TMS-PIS) interface. Moreover, progress within the tasks included derivation of use cases on various topics, including:

- integration of Demand Responsive Transport (DRT) with journey planning systems,
- inclusion of demand related information for passengers with reduced mobility (PRM),
- integration of TMS-PIS interface,
- travel demand prediction, and
- passenger congestion monitoring.

Moreover, identification of user personas and stories from a user's perspective was done. Requirements were derived from the use cases, along with acceptance criteria for them. In addition to that, development of a testing strategy and test cases for the identified requirements were elaborated.

Additionally, the Sub-area has explored potential interactions between FP6-FutuRe and the System Pillar, encompassing the extension of the Open API for distributed Journey Planning (OJP) protocol to encompass DRT, use of GTFS (General Transit Feed Specification) Flex to exchange DRT data and the TMS-PIS interface.

While the Sub-area remains in the specification phase with tangible results pending, the anticipated impact on the Overall Reduction of Operational Expenditure (OPEX) and Capital Expenditure (CAPEX) and Optimized Punctuality have been identified which contributes to the technical KPIs defined for the project.

Flagship Area 7: Innovation on new approaches for guided transport modes

The objectives of FA7 is to explore non-traditional and emerging flexible and/or high-speed guided transport systems, as well as to create opportunities for innovators to bring forward ideas for shaping those future systems via a scientific approach into an existing rail system. This shall provide socio-economically efficient and long-term sustainable transport for citizens and businesses throughout Europe.

MaDe4Rail

The MaDe4Rail project aims to explore non-traditional and emerging maglev-derived systems (MDS) and to evaluate the technical feasibility and effectiveness to introduce MDS in Europe under safety aspects and technical-economic performance. The project started on the 1st of July 2023 and is expected to end on the 30th of June 2024.

Benchmarking of the different existing traditional magnetic levitation systems and innovative maglev-derived technologies for transportation systems and their state of development was carried out. Definition of a common architecture and specification of the subsystems and technologies needed for its commercialization have been performed during the first half of the project. Such results have been necessary to define the vehicle subsystem, identify the different interfaces between the vehicle and infrastructure, and provide a list of requirements and technical specifications for the different configurations of MDS which will be the basis for the upcoming activities.

Furthermore, the first results also supported the definition of the different use cases considering the different configurations identified and analysed through the Technology Readiness Assessment and Multi-Criteria Analysis. Three categories have been analysed rail vehicle upgraded MDS, hybrid MDS based on air levitation and hybrid MDS based on magnetic levitation. In addition, a SWOT analysis has been performed for the three configurations taking into consideration passenger and freight applications.

Considering the one-year duration of the project, 19 deliverables are expected to be documented and submitted. On the first half of the project, 8 deliverables have already been delivered, which include both project management-related reports and technical documents.

POD4Rail

On the 1st of September 2023, the PODs4Rail project was launched. Gathering 15 partners from 7 different countries, the project aims at developing a concept for pods and pods carriers on railway in to adapt rail transport better to the users demand by providing higher flexibility and efficiency as well as realising on-demand transport. Pod-carriers are serving as a moving infrastructure, a digitalised and autonomous mobility service with multimodal interfaces to different transport modes, with rail as a backbone to offer a door-to-door transport service.

The railway-based intermodal pod system should be operating autonomously, electrically driven vehicle, and the authorised transport units should be designed for people or goods respectively and separated from a specific carrier unit. Together with a pods coordination and mobility management system for operations and logistics as well as all aspects of a mobility-on-demand offer across diverse transport modes, this represents a completely new form of mobility experience.

In 2023, the project laid down the basis for the development of such a concept by setting set a common understanding of the system and the main components as well as describing the technical and operational requirements. A benchmarking exercise on existing Pod systems was carried out with a particular focus on rail-compatible solutions together with an assessment of these systems, based on a set of characterisation parameters defined by the partners. In addition, analysis on user acceptance aspects of a potential future Pod system as well as on the normative and legal framework were conducted.

Transversal Topic (TT): Digital Enablers

The main objective of 'Digital Enablers' is to deliver new digitalisation capabilities across all the destinations of the EU-RAIL Work Program to support the operational processes and activities for the railway industry actors. through means such as:

- Digital Twins (DT) support by using reusable, blackbox, compiled, digital interoperable model units of components, subsystems, executing in a federated simulation runtime environment the DT to provide suitable analysis tools (e.g., root-cause analysis).
- Development of a Digital Twins Design toolbox (design-time) to model development tools for design as well as for validation, verification and test; to model registry and discovery services and to model Interoperability validation tools.
- a Federated Rail dataspace sandpit to enable the exchange of data using a common Ontology, Identity and Trust management, Federation Services, Data Assets registry and discovery services, Data Distribution Services, Data stream management, cyber security etc.

The Transversal Topic is implemented, in the first phase of the programme, via the project FP1-MOTIONAL (WS2).

TT.1 - Federated data space

The objective is to deliver a sandbox environment for a trusted, reliable, cybersecure Federated Rail data space to enable the sharing of digital resources across Rail operators, Infrastructure Managers and Suppliers, as a component of the future Common European Mobility Data Spaceand in compliance with the European Data Strategy.

Progress and results achieved in 2023:

A fully functional Rail Data Space sandbox environment (minimal viable data space) compliant with the International Data Spaces Association (IDSA) standards has been developed. This sandbox environment will enable the testing of different use cases for sharing data securely and in a sovereign way. During 2023, 35 use cases have been identified, assessed, validated and prioritized.

The Federated Rail Data Space Sandbox has been developed from existing "building blocks" with built-in cyber-security provisions. The IDSA compliance, covering the "Rule book" and "Reference Architecture Model" of this standard, will be demonstrated by a certificate of compliance from the IDSA's Certification Body. The latter will ensure that the delivered Rail Data Space can be included in the wider Common European mobility data space currently under development. The Rail Data Space will allow a fully distributed digital resource exchange, without the need for a centralized data storage, while guaranteeing full control by their owners. The environment will not be dependent on the type of the digital resources, allowing data sharing between a wide range of applications including, but not limited to Digital Twins.

This workstream is also expected to provide input into the System Pillar deliverables regarding the elements and architecture of the Rail Data Space, the governance and operational model, data exchange and communication requirements.

Common Domain Ontology

The objective is to deliver a Rail System's Common Domain Ontology/ Conceptual Data Model (CDM) as a common standardised machine-readable model of the rail system domain, leveraging from the results of Shift2Rail's LinX4Rail project. The Conceptual Data Model adheres to a semantic approach, in line and in synergy with the European Union Agency for Railways (ERA) Standards (in particular around the Registers of Infrastructure) and the European Commission.

Progress and results achieved in 2023:

In 2023, the work has progressed well on the following key topics:

- The collection of use cases, which required interactions with other Flagship Projects, leading to the identification of the first areas of interest for CDM (such as digital modelling of rolling stock, rolling stock and infrastructure maintenance, …); identification of data modelling requirements from those projects with possible impact / extension to the CDM in FP1-MOTIONAL. The identification and analysis of Use Cases for CDM will continue in 2024, and will be treated as a key aspect of this area of work.
- A thorough assessment of the CDM essential concepts regarding the Topology, Positioning, Localization and Geometry has been undertaken, with areas of improvement identified following an internal review. Similarly, some key modelling notions that span multiple use cases have been explored, such as the measuring units, uncertainties and tolerances, which have enabled the project to support the work of other stakeholders, notably of the System Pillar. The workstream also contributed to various ERA Topical Working Groups related to the Registers of Infrastructure, and has identified possible extensions to the underlying topological model to accompany evolution requirements of the ERA Vocabulary.
- A working paper highlighting modelling hints and guidelines as well as drawing some guidance from European Commission's support centre initiative, SEMIC which was created to support its Interoperable Europe Policy. The technical teams also supported ERA's efforts to accompany the ongoing transformation of the System Pillar CCS/TMS Data Model to embrace a semantic approach, in line with the European Commission guidance.
- Several **serialization approaches are being investigated**, covering the **production of semantic linked data** (including but not limited to practical leads on how to transform proprietary data into CDM-compatible data) and some experimentation around the **semantic transformation toolchain** based on the Chimera[34] framework previously investigated in European projects like SPRINT[35], SNAP[36] or TANGENT.[37]

Digital Assets Engineering

The objective of this WS is to deliver Digital Assets, an Engineering methodology and a toolbox to support the harmonization of digital processes for the end-to-end design of physical railway assets. The outputs of this work have contributed to the specifications of the Common Domain Models (Data model), software components (validation tool), and recommendation on their application across Europe (Guidelines and Engineering rules) to foster the Single European Railway Area (SERA).

This work also focuses on collecting digital assets data from all Flagship Projects in order to describe and create an inventory of the digital assets in the form of use cases.

Progress and results achieved in 2023:

The main progress and results in 2023 included the identification of the interactions within FP1-MOTIONAL as well as with the other Flagship projects and the synchronization with the System Pillar, the description of the general process for the collection of User cases and the development of a Use case repository. The latter has already been populated with the Use Cases identified by FP1-MOTIONAL, as well as FP2-R2DATO, FP3-IAM4RAIL, FP5-TRANS4M, FP6-FutuRe and FP7-2-MaDe4Rail.

Digital Twin support, development and run-time environment

The scope of this area of work is to deliver a common Digital Twin design and simulation environment to allow the virtual representation of digital models of physical systems to allow the replication of the behaviour of the railway system, its multiple heterogeneous subsystems and interactions during their lifetime.

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[34] Chimera is a software suit supporting a better connection between big data and semantic technologies.
[35] SPRINT: Sustainable Plant Protection Transition project (https://sprint-h2020.eu/).
[36] SNAP is an innovative tool for converting transportation data from various sources in a quick and easy way. The tool is provided by EIT Digital and it is supported by the European Union.
[37] TANGENT is a project funded by the European Commission for the development of new complementary tools for optimising multi-modal traffic operations (https://tangent-h2020.eu/).

Progress and results achieved in 2023:

The progress recorded in 2023 included extensive communication and exchange within FP1-MOTIONAL and the other Flagship Projects.

This also included the identification and analysis of a number of use cases provided by all FPs. Examples of complex use cases identified during this process can be found below:

- ETCS Digital Twin together with Balise and axle counter use case,
- Braking and Traction use case as a prominent Virtual Certification task,
- Driver cabin HVAC digital twin,
- Fault detection and diagnosis in Rail infrastructure,
- Station use cases.

As a major result of this process, a pilot Functional Mock-Up (FMU) of the rail infrastructure has been implemented, since this is a basis for almost all other digital twin applications. The infrastructure data was provided by the System Pillar as an *.xml file. A pilot simulation on the web-based digital twin runtime environment using a Multi-Agent-Simulator has been set up, representing a train running along a track and collecting Balise messages.

Exploratory Research

Academics4Rail

The Academics4Rail project, launched on the 1st of September 2023 (for a duration of 42 months), aims to build a stable and durable community of railway scientific researchers and academia to share and exchange scientific knowledge with Europe's Rail, as well as to enable a network of PhDs (with the academia teaming up with the industry) on the following topics:

- PhD1: Aerodynamics of freight trains.
- PhD2: Electromagnetic compatibility.
- PhD3: Additive Manufacturing in wheel re-profiling.
- PhD4: Digital communications for virtual coupling.
- PhD: Prognostics and health management approach for railway asset maintenance.
- PhD6: AI-based Driving Assistance.

Achievements in 2023

In 2023, all the 6 PhD positions have been filled in and the students have advanced positively through the state of the art on their respective areas. Moreover, the foundations for the establishment of a scientific community have been set and the project partners have drafted a document that gathers all their statutes. A screening activity for the funding for railway research in Europe has also been performed and information on current railway projects has been gathered in a database with the view of establishing an observatory for the development of rail research in Europe. Finally, the first steps towards the development of an overarching framework and methodology for the qualitative and quantitative assessment of Europe's Rail societal KPIs have been covered, thanks to a thorough review of the state of the art and the first discussions for the model foundations.

InBridge4EU

Railways play a crucial role to help make Europe the first climate neutral continent by 2050. In this regard, but it is essential to enhance the current resilience and capacity of the network, in particular from lifeline structures, such as bridges. Within this regard, several open points affecting the current Infrastructure Technical Specification for Interoperability (INF TSI) are yet to be closed, namely those related to the Dynamic Train Categories previously specified in EN15228:2015 and the limits of validity of the static compatibility checks currently stipulated EN15228:2021, the accuracy of the current dynamic amplification factors and damping values for railway bridges proposed in EN1991 2 (2003) and the validity of the deck acceleration limits imposed by EN1990-Annex A2 (2005) in both new and existing bridges.

The InBridge4EU project, which was launched on the 1st of September 2023, aims to answer these points through the formulation of an enhanced and harmonized method to assess the European dynamic interface between railway bridges and rolling stock.

Achievements in 2023

During 2023, the project has acquired from different sources information on passenger train data to build a database of vehicle parameters and train configurations and eventually evaluate if some of the trains are more prone to deliver inaccurate results with the spectral methods. At the same time, the project has selected 9 railway lines from 5 EU countries (3 lines with a maximum speed of 160 km/h, 3 lines with a maximum speed of 200 km/h and 4 High-Speed lines located across Spain, Portugal, Germany, France and Sweden) from which representative bridges will be analysed. The consortium laid the grounds for the study of the dynamic factors φ' and φ'' and experimental data from different bridges in Europe has been collected to estimate damping coefficients from the respective free vibration periods, thanks to the development of an artificial time-series generator to test and validate the damping estimation algorithms, namely the Multivariable Optimisation Method and the SSI-COV. A thorough review of previous research in ballast behaviour has been conducted and a questionnaire has been sent to other research teams and infrastructure managers to gather detailed insights, ideas, and questions, specifically on the topic of dynamically excited ballasted tracks bridges. This procedure will allow the consortium to have a broader insight of the issues related with this topic. Finally, FEM models of the case study non-ballasted bridges have been partially developed and the train-bridge interaction analysis already started, from which the preliminary results point to a lack of correlation between the deck acceleration and the train's stability.

RAIL4CITIES

The RAIL4CITIES ("RAILway stations for green and socially inclusive CITIES") project aims to trigger the transition of railway stations in Europe into real promoters of sustainable cities, by developing a new operational, readily available, and highly applicable model of stations (SCP model), combined with a common European methodology and tools for its effective implementation. The project will be put into practice through five living labs, each tailored to specific station transformations. The goal is to create a blueprint for transforming stations into engines of urban sustainability and integrated service hubs.

The RAIL4CITIES project, launched in July 2023, is organized along the following approach:

(a) Developing the RAIL4CITIES methodological foundation through research on railway station classification, creating the SCP model and tool for impact analysis based on sustainable return on investment (S-ROI) framework;
(b) Deploying the methodology on 5 living labs from 5 European countries addressing the railway stations' transformation into: hub of green and active mobility (FR - Toulouse), energy hub (IT - Milano), Transit Oriented Development (DE - Dorfen), socially inclusive services hub and the use of Nature Based Solutions (PL - Tomaszów Mazowiecki), services hub enabling 15-minute city & circular economy (BE - Ottignies);
(c) Consolidating the RAIL4CITIES methodology based on the lessons learnt from the deployment in the different living labs and following the recommendations from the International Advisory Board, and publication of the proposed methodology as basis for a common EU-wide methodology.

After 6 months of operation, the project has successfully setup its activities and has submitted a first deliverable (D2.1) introducing a new operational model for stations as sustainable city promoters (SCP), including the underlying theoretical considerations that led to its development. The model consists of three core components (Appraisal, Fields of action, Methodological toolkit).

Furthermore, an outlook is provided on how this proposed model will later be corroborated with data from the five living labs situated in France, Italy, Germany, Poland, Belgium, and three additional case studies in Portugal, testing specifically how railway stations can play a substantial role in sustainable urban development. While the process and results of the living labs are not part of this report, as they will be introduced at a later point in the research project, specific challenges and implications of the model application in the living labs have already been addressed. The updated station model will integrate the data gathered in the living labs and will be documented together with an EU-wide methodology by the end of the project.

ESEP4FREIGHT

Since launched on 1st September 2023, the main activities have been carried out on Data collection, innovation assessments and analysis of freight flows. The project has been working on identifying the stakeholder group is expected to validate the final set of KPIs. A work plan and the draft framework for the evaluation of innovative technologies were developed, and the results of the evaluation of the digital automatic coupler (DAC) and intelligent video gates (IVGs) showed that the time required for train handling in the terminals is lower. A work plan was developed for analysis of the freight market trends and freight flows and the collection of the required data was started. The methodology for the analysis has been developed and will be implemented as soon as the data collection is completed. A data collection plan and data sources for operational and infrastructure data have been formulated and will be finalised together with the Stakeholders' Group. Communication with Rail Net Europe has been developed and a data exchange agreement is planned.

In addition, the project also focused on analysing the contractual framework of various key intermodal contractual relationships. A literature review has been conducted and a plan for direct interviews with pre-selected operators has been set up. A draft conceptual framework and potential architecture for intermodal transport using blockchain technologies and smart contracts was developed.

Furthermore, a first draft of the functional requirements for the web platform and its modules has been prepared. The core of these activities is expected in 2024.

LEADER2030

The LEADER 2030 (Learnings for European Autonomy to Deliver Europe's Rail in 2030) aims at providing answer to the following key question: will there be enough raw materials and components to bring to the market in 2030 all the Railway innovations EU-RAIL is delivering?".

it aims at providing an answer to the following key question: will there be enough raw materials and components to bring to the market in 2030 all the Railway innovations EU-RAIL is delivering? The project has presented at the end of 2023 the results of the survey that was conducted through a multilanguage online European Consultation addressed to companies of the Rail Value Chain. The main outcome is that key supplies for digitalising, greening and innovating European Railways will require raw materials and components whose supply is already disrupted and whose demand is expected to at least double by 2030: it is the case for chips, expected to double between 2022 and 2030, with significant increases in future demand for leading-edge semiconductor technologies; it is the case for aluminium, expected to multiply more than 4 times by 2030, and copper, expected to multiply 8 times by 2030.

DACcord

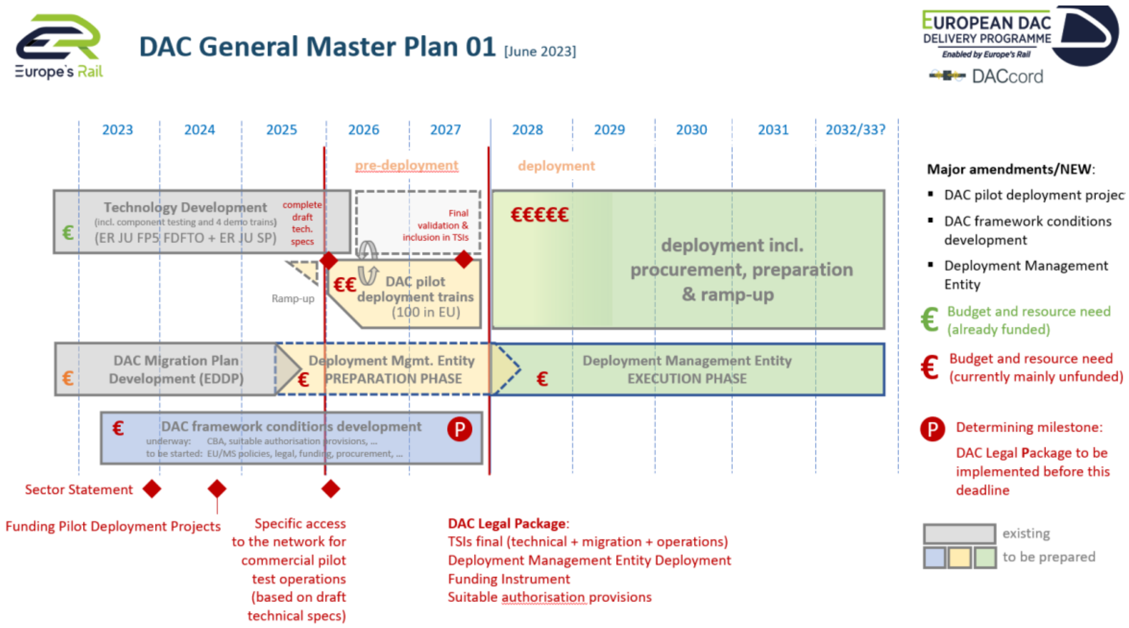
The DACcord as a Coordination and Support Action, supported the running of EDDP in 2023. It further worked on the DAC migration roadmap and on a EDDP Stakeholder Management.

A main achievement was the development of the revised **DAC General Master Plan 01**, taking into account all recent evolutions/insights and incorporating a large-scale testing phase of around 100 trains before embarking on a fully fledged DAC roll-out. An updated DAC Cost-Benefit Analysis (CBA) was coordinated in EDDP and led by the European Commission, followed by the installation of a Task Force on Intermodal Traffic with stakeholders from Intermodal and EDDP to better reflect Intermodal aspects in the CBA. This WP permanently interacted with all other DACCord WPs and with FP5-TRANS4RM-R. A regular cross-coordination of the works of the EDDP, FP5 and EU-Rail System Pillar (Task 4) was implemented.

Furthermore, the project supported the work of the migration roadmap update, especially on the collection of the European vehicle fleet data. A major milestone was the coordination and decision on the so called "**DAC basic package**" in September and November 2023. This package defines the DAC and DAC applications that the FP5-TRANS4M-R project will deliver by 2025/2026, for test in the pre-deployment trains and later for the full deployment.

In addition, the project coordinated in the first half of 2023 a "**DAC Sector Statement**" (taking into account the new Master Plan), which was signed by 50 companies and associations from the European rail freight sector and handed over from the Sector to the European Commission) in July 2023.

The project also worked together with FP5 TRANS4M-R project for setting-up and broadcasting of three so called EU-Rail "sounding boards". The results of these sounding boards were reported to the EDDP programme board and used for evaluation by the FP5 TRANS4M-R project.



DAC General Master Plan 01

1.4. Calls for proposals, grant information and other funded actions

1.4.1. Grants

Considering the annual budget availabilities and the EU-Rail Multi-Annual Work Programme and Work Programme 2023-2024, the EU-Rail R&I activities are implemented through combined and interdependent multi-annual Projects. This structured interdependence of the EU-Rail Projects is based on the mutually integrated System and Innovation Pillars, complemented by the work of the Deployment Group.

In 2023, the Europe's Rail Joint Undertaking launched one call for proposals, but first carried out the evaluation of the second call launched still in 2022. This second call (HORIZON-ER-JU-2022-02) was launched on 13 September 2022 following the adoption of the JU's Multi-Annual Work Programme[38] and Work Programme 2022-2024[39] by the Governing Board on 1 March 2022. This call for proposals covered two destinations (Flagship Areas) in accordance with Annex VIII of the WP 2022-2024. It was open to all eligible entities in accordance with the eligibility criteria set out in the Horizon Europe General Annexes, in particular General Annex B[40].

The respective Decision of the JU GB approving the results of the call was adopted on 15 March 2023[41]. One redress procedure was launched and the JU re-evaluated one proposal. The JU GB approved the results of the redress on 23 June 2023.

The following tables summarise the amounts and topics related to the call:

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38 https://rail-research.europa.eu/wp-content/uploads/2022/03/EURAIL_MAWP_final.pdf.
39 https://rail-research.europa.eu/wp-content/uploads/2022/03/AWP_2022_2024_Final_Published.pdf
40 https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-13-general-annexes_horizon-2021-2022_en.pdf.
41 Decision N°3/2021 of the Governing Board of the S2R JU of 22 June 2021 approving the ranked lists of actions selected for funding, reserve list and the list of rejected proposals under the Shift2Rail JU call for proposals H2020-S2RJU-2021

Call	Topic	Type of Action	Expected EU contribution per project (EUR million)
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-FA7-01	RIA	3
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-FA7-02	RIA	1.5
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-FA7-03	IA	2.3
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-01	RIA	0.7
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-02	IA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-03	RIA	1.3
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-04	RIA	2
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-05	RIA	0.7
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-06	RIA	0.7
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-07	CSA	1.5

Topic Code	Topic Description	Type of Action
HORIZON-ER-JU-2022-FA7-01	Conceptual development of Automated Multi-Modal Mobility-Systems ("Moving Infrastructures")	RIA
HORIZON-ER-JU-2022-FA7-02	Technological development of Maglev-derived Systems	RIA
HORIZON-ER-JU-2022-FA7-03	Hyperloop Industrial Roadmap and pilots	IA
HORIZON-ER-JU-2022-ExplR-01	New railway station concept for green and socially inclusive smart cities	RIA
HORIZON-ER-JU-2022-ExplR-02	Bridge Dynamics	IA
HORIZON-ER-JU-2022-ExplR-03	Standardised offer/contract management for agile access to Rail Freight and multimodal services in EU	RIA
HORIZON-ER-JU-2022-ExplR-04	Building a community of scientific research and and enabling a network of PhD (academia teaming with industry)	RIA
HORIZON-ER-JU-2022-ExplR-05	Digitalisation and automation enabling new railway services for passengers and freight	RIA
HORIZON-ER-JU-2022-ExplR-06	European value chains for rail supply	RIA
HORIZON-ER-JU-2022-ExplR-07	DAC Migration Roadmap towards Deployment	CSA

The total number of proposals received in response to the call for proposals was 16:

Call	Topic	Type of Action	Number of proposals received
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-FA7-01	RIA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-FA7-02	RIA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-FA7-03	IA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-01	RIA	2
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-02	IA	4
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-03	RIA	2
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-04	RIA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-05	RIA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-06	RIA	1
HORIZON-ER-JU-2022-02	HORIZON-ER-JU-2022-ExplR-07	CSA	2

A total of 116 participants were involved in the 13 eligible proposals submitted to this call, reflecting respectively on the ten topics open to them. Following the evaluation, 76 participants (66%) are involved in the 8 proposals considered for funding.

The total EU-Rail contribution requested by all the submitted proposals amounted to EUR 418,76 million compared to EUR 14,7 million available for funding:

Call	Grant Requested	Expected EU contribution
HORIZON-ER-JU-2022-02	18.0	14.7

Following the GB Decision N°5/2023 of 15 March 2023, grants were proposed to be awarded resulting in the amounts provided below:

Call	Total Project Cost	EU-Rail Funding	IKOP	Other contribution to R&I
HORIZON-ER-JU-2022-02	13.1	11.7	NA	NA

Following the GAP phase, the value of activities resulting from this call to be performed in the coming period in respect to the signed grants corresponds to EUR 11,4 million of eligible costs, and EUR 14,1 million of total project value, that will be funded by EU-Rail up to EUR 11,4 million.

On 4 October 2023, the JU launched the third call for proposals (HORIZON-JU-ER-2023-01). The number of proposals submitted where 24, the number of evaluated proposals was 21 and the number of proposals retained for funding was 7. Since the grants resulting from this call were evaluated and awarded at a later stage in 2024, the detailed funding figures related thereto will be presented in the 2024 CAAR.

1.4.2. Operational tenders and contracts

With regard to the implementation of procurement activities, the JU has complied with the principles of the EU Financial Regulation and the guidance provided in the European Commission Procurement Vademecum. This resulted in the implementation of activities obtaining the best value for money.

The values established for the different procurement procedures, which are below any materiality level considering the total value of the R&I activities and the Programme, result from the collective knowledge of involved staff and their experience in previous private and public organizations.[42]

In 2023, the JU conducted the following open tender procedure:

- Passengers and Railway Workers Perspective in Rail Transformation. As indicated in the Amended Work Programme 2022-2024, the JU published on 12/07/2023 a call for tenders divided in two lots: LOT 1 Passenger Perspective in Rail Transformation and LOT 2 Railway Workers' Perspective in Rail Transformation. The purpose was to avail the JU with the expertise in rail passenger aspects and human resources – railway workers perspective to complement the ongoing R&I activities and provide them with the relevant inputs that will help to shape the developed technological solution. After the outcome of the procedure, for LOT 1 a framework contract for services was awarded and concluded on 18/12/2023 with the European Passengers' Federation for a total value of the contract of 189 600,00 EUR. For LOT 2 no admissible tenders were received therefore no framework contract for services was awarded.

In accordance with Article 43(4) of the EU-Rail Financial Rules and as announced in the Europe's Rail Work Programme 2022-2024, in 2023 EU-Rail awarded six direct contracts for services with EU-Rail private Founding Members to avail EU-Rail with the services of Flagship Project Managers with a total value of EUR 600.000 per contract. The EU-Rail Financial Rules allow to conclude direct contracts with EU-Rail private Founding Members "*without having recourse to a public procurement procedure*". To preserve the principle of sound financial management and the legality and regularity of the procedure, EU-Rail

[42] Also in answer to point 15 of Discharge 2016 of EP, reference P8_TA-PROV(2018)0173.

implemented a light "negotiated procedure" with the EU-Rail private Founding Members and applied by analogy the procurement negotiated procedure for very low value contract (Point 14 FR Annex 1 of the EU Financial Regulation).

In accordance with the Amended Work Programme 2023-2024, the implementation of the following framework contracts continued in 2023:

- Europe's Rail System Pillar. Implementation of framework services contracts concluded on 12/07/2022 with "System Pillar Consortium" (for the 3 lots) for the provision of services to EU-Rail in the fields of System Pillar core group (lot 1), System Pillar expertise (lot 2) and CCS TSI maintenance activities (lot 3).
- Strategic support to the EU-Rail and other impact assessments, evaluations, foresight, analyses and studies. Implementation of framework services contracts concluded on 03/02/2021 for the provision of services to the EU-RAIL in the fields of strategy advice (LOT1), support to programme management (LOT 2) and legal assistance (LOT3) with companies Ernst&Young, Deloitte Consulting and consortium Daldewolf/Privanot respectivelly[43].

In accordance with Article 15 (Principle of transparency) of the EU-Rail Financial Rules the JU shall make available on its internet site no later than 30 June of the following financial year information on the recipients of funds deriving from its budget, including procurement contracts. In addition, as stated in point 3.3 of Annex I to the Financial Regulation 2018/1046 (which applies to the JU), EU-Rail, as a contracting authority, shall publish a list of contracts on its website no later than 30 June of the following financial year for specific contracts and order forms implementing a framework contract. The EU-Rail recipients of Funds and Annual List of Specific Contracts are published at https://rail-research.europa.eu/participate/recipients-eu-rail-funds/.

1.5. Evaluation procedures and outcomes

EU-Rail launched 1 call for proposals in 2023.

The evaluation of the call was carried out between 9 February and 14 March 2024. The evaluation procedure was performed remotely, making use of digital web-conferencing tools. However, this represented no issue to the proper performance of the evaluation process.

The evaluation of proposals was carried out with the assistance of 18 independent technical experts (4 of them financial experts), and 4 additional experts contracted as recorders. Evaluations were conducted in four panels, with the representatives from the Commission (DG MOVE, DG RTD), from ERA and SESAR JU having been invited to be present at the panel's meetings as observers. An independent observer was also appointed in accordance with the procedures laid down in the Guide for proposal submission and evaluation of the Horizon Europe grants. The independent observer's role was to observe and offer independent advice on the conduct and fairness of the evaluation sessions, on the application of the evaluation criteria and on ways to improve processes.

In selecting the independent external experts, the primary objective was to ensure a high level of skills, experience, and knowledge in the areas of the call (including project management, innovation, exploitation, dissemination and communication). Under these conditions, special attention was given to achieve an appropriate balance composition of the panel in terms of various skills, experience, and knowledge, geographical diversity and gender. The composition was the following:

- Gender balance: 9 men (43%), 12 women (57%);
- Regional balance: representatives from 12 different countries.

The consensus meetings of the experts were organised remotely during the period 8 – 14 March 2024. A briefing was held on 9 February 2024, in which the EU-Rail representative provided relevant information related to the consensus phase to the independent experts, such as the specificities of the EU-Rail calls

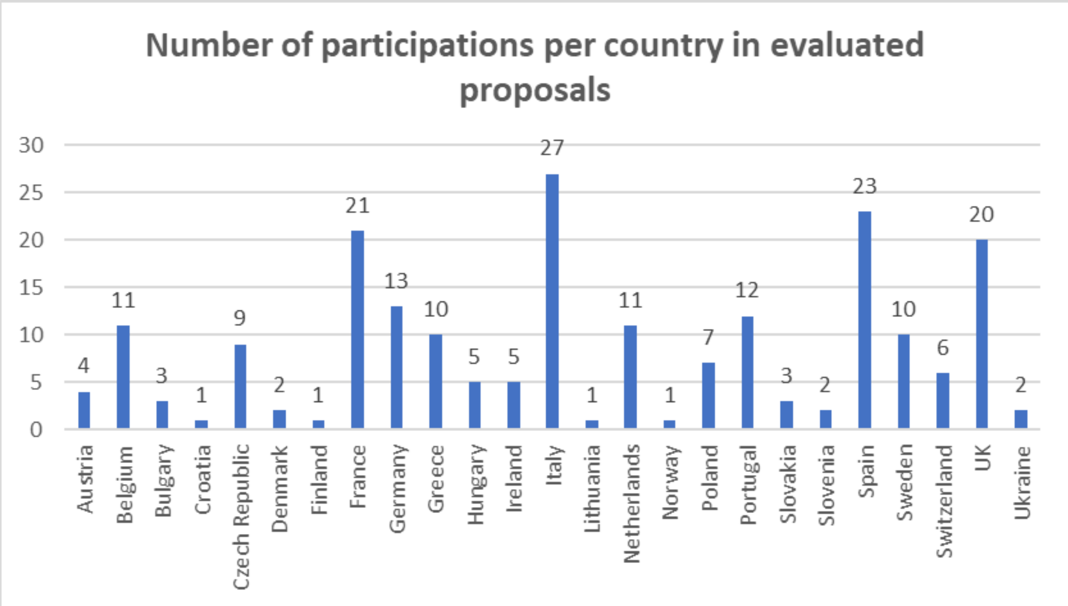
[43] Taken into consideration the nature of the services covered by LOT 2 and LOT 3, the implementation of those Framework contracts is covered by the administrative expenditure (see section 2.5- Administrative Procurement and contracts).

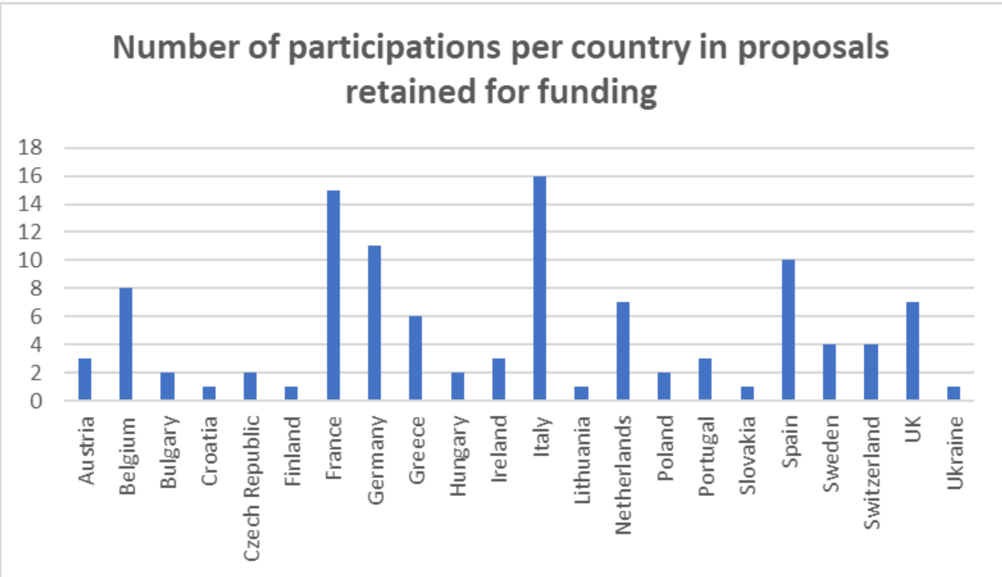
for proposals, the confidentiality requirements, or the experts' obligations regarding potential conflicts of interests.

The total number of proposals submitted was twenty four, twenty one of them were evaluated. Seven proposals were retained for funding representing a success rate of 63,3% out of the admissible and eligible proposals.

There were 41 SMEs participating in the call with a success rate of 51%, 21 of them having their proposal retained for funding. Participations of SMEs represented 19% within the overall proposals evaluated and 19,1% within the proposals retained for funding.

From a geographical perspective, there were participants to the call coming from 25 countries, there were participants from 21 EU Member States, 2 participants from Associated Countries, UK and one from a third country. Among the 110 participations in proposals retained for funding, 19 EU Member States, 1 participant from an Associated Country, UK and 1 from a third country are represented.

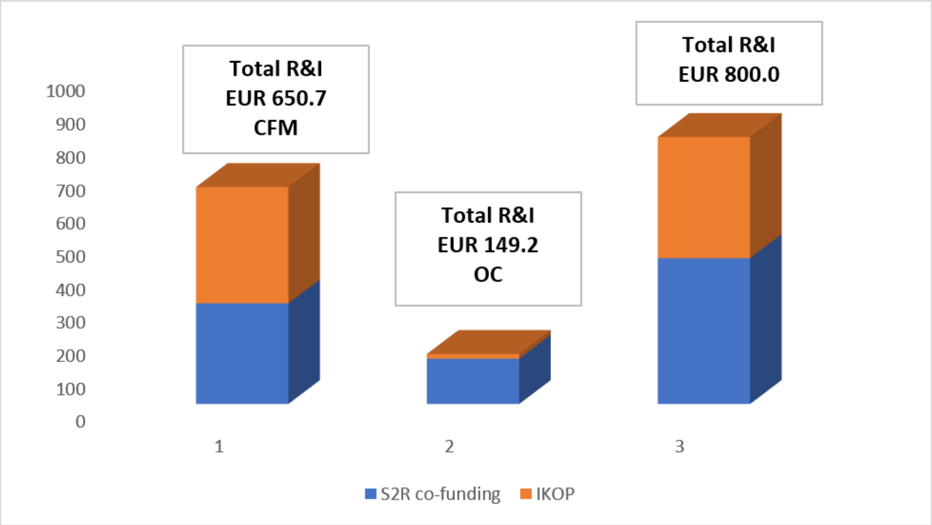




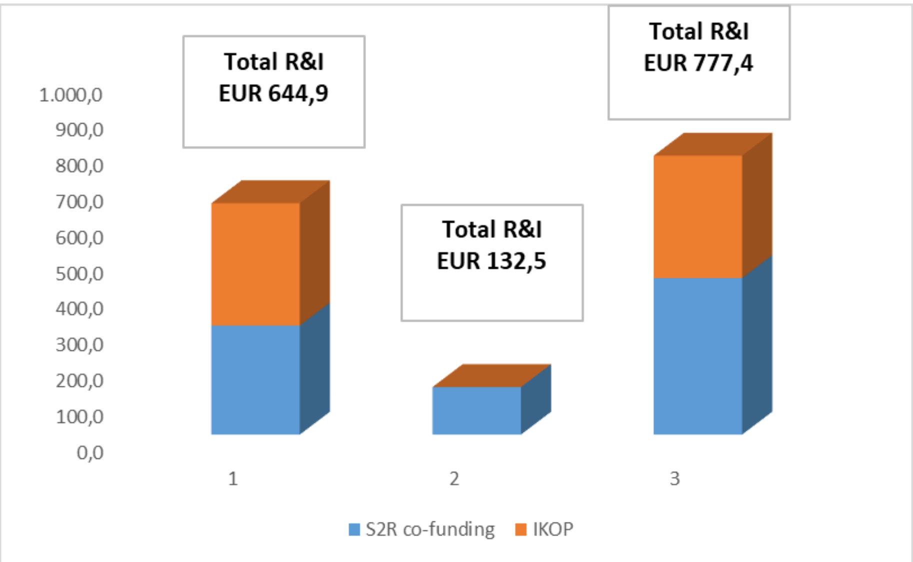
1.6. Follow-up activities linked to past calls

For the Shift2Rail Programme, the year 2023 mainly consisted in ensuring the proper execution of ongoing activities. As by the end of 2021, the JU had signed a total of 101 grant agreements since its autonomy in 2016. The R&I activities performed in the Programme will reach EUR 800 million (including Lighthouse Projects as part of the S2R initiative), of which EUR 650,7 million performed by the S2R Other Members with a funding made available by the JU up to a maximum of EUR 303,3 million.

While in accordance with the respective Membership Agreements the S2R Other Members agreed to limit their request for funding to 44,44% of the Total Project Costs, the OC topics are co-funded at the rates established in the H2020 Rules of participation.



S2R JU R&I running activities all calls included



S2R JU R&I activities Programme expected objectives at Programme level

It is therefore important to mention that the S2R R&I activities are expected to exceed the objectives as described in the JU Council Regulations. This will be further confirmed during in 2023 and with the Programme closure in 2024.

On 31 December 2023, taking into consideration activities reaching their completion, 33[44] projects which have finalised their operational activities by year end, have to be closed administratively with a last payment

[44] Four Lighthouse projects (2015) not included.

pending verification and confirmation of the last activities and costs, of which 17 Call for Members (CFM) and 16 Open Call (OC) projects. 31 projects were distributed on the 5 Innovation Programmes, 2 projects on the Cross Cutting Activities and no more projects in IPX, as follows:

IP1: Cost-efficient and Reliable Trains, including high-capacity trains and high-speed trains

Project Title	Call Reference	Period[45]	Project Value (signed GA)
CARBODIN	S2R-OC-IP1-01-2019	01/12/2019 - 28/02/2022	€ 3 334 368
CONNECTA-3	S2R-CFM-IP1-02-2020	01/12/2020- 30/11/2023	€ 8 973 663
GEARBODIES	S2R-OC-IP1-03-2020	01/12/2020- 30/16/2023	€ 2 419 969
PINTA-3	S2R-CFM-IP1-01-2020	01/12/2020- 31/05/2023	€ 19 446 251
PIVOT2	S2R-CFM-IP1-01-2019	01/10/2019 - 31/03/2023	€ 40 975 405
RECET4Rail	S2R-OC-IP1-01-2020	01/12/2020- 31/05/2023	€ 2 300 036
SAFE4RAIL-3	S2R-OC-IP1-02-2020	01/12/2020- 31/07/2023	€ 4 585 831

IP2: Advanced Traffic Management & Control System

Project Title	Call Reference	Period	Project Value (signed GA)
4SECURAIL	S2R-OC-IP2-01-2019	01/12/2019 - 30/11/2021	€ 549 875
AB4Rail	S2R-OC-IP2-02-2020	01/01/2021- 31/12/2022	€ 349 926
OPTIMA	S2R-OC-IP2-02-2019	01/12/2019 - 30/04/2023	€ 2 235 999
PERFORMINGRAIL	S2R-OC-IP2-01-2020	01/12/2020 - 30/06/2023	€ 1 335 359
X2Rail-1	S2R-CFM-IP2-01-2015	01/09/2016 - 30/06/2021	€ 42 905 588
X2Rail-2	S2R-CFM-IP2-01-2017	01/09/2017 - 30/04/2021	€ 28 833 202
X2Rail-4	S2R-CFM-IP2-01-2019	01/12/2019 - 31/12/2023	€ 41 109 700
X2Rail-5	S2R-CFM-IP2-01-2020	01/12/2020- 31/05/2023	€ 33 890 375

[45] When the period end date is before the 31/12/2022, this means that the project is ended but that the final payment is still ongoing (suspended, technical and financial review ongoing, etc.).

IP3: Cost-efficient, Sustainable and Reliable High-Capacity Infrastructure

Project Title	Call Reference	Period	Project Value (signed GA)
DAYDREAMS	S2R-OC-IP3-02-2020	01/12/2020-31/05/2023	€ 1 709 875
IN2SMART2	S2R-CFM-IP3-01-2019	01/12/2019 - 30/11/2022	€ 23 091 203
In2Stempo	S2R-CFM-IP3-01-2017	01/09/2017 - 31/03/2023	€ 13 439 977
In2Track2	S2R-CFM-IP3-01-2018	01/11/2018 - 28/02/2022	€29 676 015
In2Track3	S2R-CFM-IP3-01-2020	12/05/2021- 30/12/2023	€ 27 329 170
IN2ZONE	S2R-OC-IP3-01-2020	01/12/2020-31/05/2023	€ 1 349 974

IP4: IT Solution for Attractive Railways Services

Project Title	Call Reference	Period	Project Value
CONNECTIVE	SR2-CFM-IP4-01-2017	01/09/2017 - 30/06/2023	€ 7 906 243
ExtenSive	S2R-CFM-IP4-01-2020	01/12/2020-30/06/2023	€ 11 308 530
IP4MaaS	S2R-OC-IP4-01-2020	01/12/2020-30/06/2023	€ 2 507 081
RIDE2RAIL	S2R-OC-IP4-01-2019	01/12/2019 - 30/04/2023	€ 2 999 993

IP5: Technologies for Sustainable & Attractive European Freight

Project Title	Call Reference	Period	Project Value
DACcelerate	H2020-S2RJU-2021	01/06/2021 - 31/01/2023	€ 2 171 998
FR8RAIL II	S2R-CFM-IP5-01-2018	01/05/2018 - 31/12/2022	€ 12 450 390
FR8RAILIII	S2R-CFM-IP5-01-2019	01/09/2019 - 30/06/2023	€ 13 061 601
FR8RailIV	S2R-CFM-IP5-01-2020	01/07/2020-30/06/2023	€ 17 604 534
LOCATE	S2R-OC-IP5-01-2019	01/11/2019 - 30/04/2022	€ 1 499 072
SMART2	S2R-OC-IP5-02-2019	01/12/2019 - 30/11/2022	€ 1 708 737

CCA: Cross Cutting Activities

Project Title	Call Reference	Period	Project Value
FINE2	S2R-CFM-CCA-01-2019	01/12/2019 - 31/05/2023	€ 8 179 973
SILVARSTAR	S2R-OC-CCA-01-2020	01/11/2020 28/02/2023	€ 949 999

On 31 December 2023, 66 projects were closed with final payment executed in 2023 for all the projects listed above (closure date may refer to some administrative reopening after final payment):

Closed Projects related to Call for member topics for S2R JU Members

TOPIC	ACRONYM	TITLE	PROJECT VALUE	GRANT	START DATE	CLOSURE DATE
H2020-S2RJU-CFM-2015-01-1	ARCC	Automated Rail Cargo Consortium: Rail freight automation research activities to boost levels of quality, efficiency, and cost effectiveness in all areas of rail freight operations	5.3	1.5	18/04/2023	15/03/2024
H2020-S2RJU-CFM-2015-01-1	ATTRACKTIVE	Advanced Travel Companion and Tracking Services	5.4	2.2	01/09/2016	21/10/2020
H2020-S2RJU-CFM-2015-01-1	CO-ACTIVE	Co-modal journey re-Accommodation on associated Travel services	7.7	3.4	01/09/2016	18/01/2023
H2020-S2RJU-CFM-2017	COHESIVE	Coherent Setup and Demonstration of Integrated Travel Services	3.8	1.5	26/09/2023	20/10/2023
H2020-S2RJU-CFM-2016-01-1	CONNECTA	Contributing to Shift2Rail's next generation of high Capable and safe TCMS and brakes. Phase 1.	11.5	5	01/09/2016	25/03/2020
H2020-S2RJU-CFM-2018	CONNECTA-2	Contributing to Shift2Rail's next generation of high Capable and safe TCMS. Phase 2.	9.9	4.3	01/10/2018	31/07/2021
H2020-S2RJU-CFM-2015-01-1	FFL4E	Future Freight Loco for Europe	3.5	1.4	01/09/2016	25/03/2020
H2020-S2RJU-CFM-2015-01-1	FINE1	Future Freight Loco for Europe	3.2	1.3	01/09/2016	12/04/2021
H2020-S2RJU-CFM-2017	FR8HUB	Real time information applications and energy	9	4.2	27/10/2023	08/12/2023

		efficient solutions for rail freight				
H2020-S2RJU-CFM-2015-01-1	FR8RAIL	Development of Functional Requirements for Sustainable and Attractive European Rail Freight	10.9	3.3	01/09/2016	14/12/2021
H2020-S2RJU-CFM-2015-01-1	IMPACT-1	Indicator Monitoring for a new railway Paradigm in seamlessly integrated Cross modal Transport chains – Phase 1	1.2	0.3	01/09/2016	05/07/2021
H2020-S2RJU-CFM-2017	IMPACT-2	Indicator Monitoring for a new railway Paradigm in seamlessly integrated Cross modal Transport chains – Phase 2	7.5	3.1	07/08/2023	14/11/2023
H2020-S2RJU-CFM-2016-01-1	IN2SMART	Intelligent Innovative Smart Maintenance of Assets by integrated Technologies	15.7	7	01/09/2016	26/04/2021
H2020-S2RJU-CFM-2016-01-1	In2Track	Research into enhanced tracks, switches, and structures	5.3	2.3	01/09/2016	03/10/2022
H2020-S2RJU-CFM-2019	LINX4RAIL	System architecture and Conceptual Data Model for railway, common data dictionary and global system modelling specifications	4.3	2	14/11/2023	17/12/2023
H2020-S2RJU-CFM-2020	LINX4RAIL2	System architecture and conceptual data model for railway, common data dictionary and global system modelling specifications	2.7	1.2	01/12/2020	30/01/2024
H2020-S2RJU-CFM-2018	MaaSive	Passenger service platform specifications for an enhanced multi-modal transport eco-system including Mobility as a Service (MaaS)	9.3	5.1	01/11/2018	18/01/2023
H2020-S2RJU-CFM-2016-01-1	PINTA	IP1 Traction TD1 and Brakes TD5 – Phase 1	28.8	12.6	01/09/2016	14/09/2020
H2020-S2RJU-CFM-2018	PINTA-2	IP1 Traction TD1 and Brakes TD5 – Phase 2	31	12.7	01/09/2018	07/03/2022
H2020-S2RJU-CFM-2017	PIVOT	Performance improvement for vehicles on track	15.4	7.6	01/10/2017	17/03/2021

H2020-S2RJU-CFM-2015-01-1	PLASA	Smart Planning and Safety for a safer and more robust European railway sector	1.1	0.3	01/09/2016	16/07/2019
H2020-S2RJU-CFM-2018	PLASA-2	Smart Planning and Virtual Certification	1.8	0.8	01/09/2018	21/03/2022
H2020-S2RJU-CFM-2018	X2Rail-3	Advanced Signalling, Automation and Communication System (IP2 and IP5) – Prototyping the future by means of capacity increase, autonomy and flexible communication	33.8	17.2	01/12/2018	21/02/2023

Closed Projects related to Open call topics for S2R JU non-Members

TOPIC	ACRONYM	TITLE	PROJECT VALUE	GRANT	START DATE	CLOSURE DATE
H2020-S2RJU-OC-2018	ASSETS4 RAIL	Measuring, monitoring and data handling for railway assets; bridges, tunnels, tracks and safety systems	5.5	4.5	01/12/2018	09/03/2023
H2020-S2RJU-OC-2017	ASTRail	Satellite-based Signalling and Automation Systems on Railways along with Formal Method and Moving Block validation	1.8	1.8	01/09/2017	29/04/2020
H2020-S2RJU-OC-2018	B4CM	Blockchains as a Distributed Ledger for Attribution of RCM Data in Rail	0.4	0.4	01/12/2018	01/03/2024
H2020-S2RJU-2021	Ben[at]rail	Benefits at rail, top-down holistic approach of impact and benefits to make rail attractive for stakeholders	0.1	0.1	27/06/2023	22/07/2023
S2R-OC-IP2-01-2015	CYRAIL	Cybersecurity in the Railway sector	1.5	1.5	01/10/2016	28/01/2020
S2R-OC-CCA-03-2015	DESTINATE	Decision supporting tools for implementation of cost-efficient railway noise abatement measures	1	1	01/11/2016	14/08/2019
S2R-OC-IP5-02-2015	Dynafreight	Innovative technical solutions for improved train Dynamics and operation of longer Freight Trains	0.9	0.9	01/11/2016	24/01/2019

H2020-S2RJU-OC-2018	EMULRA DIO4RAIL	Emulation of radio access technologies for railway communications	0.7	0.7	01/12/2018	26/11/2021
H2020-S2RJU-OC-2017	ETALON	Energy harvesting for signalling and communication systems	1.7	1.7	01/09/2017	09/12/2020
H2020-S2RJU-OC-2017	FAIR Stations	Future Secure and Accessible Rail Stations	1.2	1.2	01/09/2017	10/02/2021
H2020-S2RJU-OC-2018	FLEX-RAIL	Paradigm shifts for railway – Technology uptake strategies for a lean, integrated and flexible railway system	1	1	01/12/2018	14/12/2021
H2020-S2RJU-OC-2019	FUNDRE S	Future unified DC Railway Electrification System	0.7	0.7	01/12/2019	03/10/2022
H2020-S2RJU-OC-2018	GATE4R AIL	GNSS Automated Virtualized Test Environment for Rail	1	1	01/12/2018	07/02/2022
S2R-OC-IP4-01-2016	GoF4R	Governance of the Interoperability Framework for Rail and Intermodal Mobility	1.8	1.8	01/11/2016	08/11/2019
H2020-S2RJU-OC-2015-01-2	GoSAFE RAIL	GoSAFE RAIL- Global Safety Management Framework for Rail Operations	1.3	1.3	01/10/2016	24/07/2020
H2020-S2RJU-OC-2020	HYPERN EX	Hypernex: Ignition of the European Hyperloop Ecosystem	0.3	0.3	01/12/2020	24/07/2020
H2020-S2RJU-OC-2017	IN2DREA MS	Intelligent solutions 2wards the Development of Railway Energy and Asset Management Systems in Europe	2.1	2.1	01/09/2017	21/02/2023
H2020-S2RJU-OC-2015-01-2	INNOWA G	Innovative monitoring and predictive maintenance solutions on lightweight Wagon	1.4	1.4	01/11/2016	03/08/2020
H2020-S2RJU-OC-2018	M2O	Make Rail the hope for protecting nature 2 future operation	0.6	0.6	01/12/2018	16/06/2021
H2020-S2RJU-OC-2017	Mat4Rail	Designing the railway of the future: Fire resistant composite materials and smart modular design	3.5	3.5	01/10/2017	06/06/2020
S2R-OC-IP2-03-2015	MISTRAL	Communication Systems for Next-generation Railways	0.5	0.5	01/11/2016	08/08/2019

H2020-S2RJU-OC-2017	MOMIT	Multi-scale Observation and Monitoring of railway Infrastructure Threats	0.6	0.6	01/09/2017	27/10/2020
H2020-S2RJU-OC-2018	MOVING RAIL	Moving block and Virtual coupling New Generations of Rail signalling	1.2	1.2	01/12/2018	28/06/2021
H2020-S2RJU-OC-2018	MVDC-ERS	Flexible medium voltage DC electric railway systems	0.1	0.1	01/12/2018	12/03/2023
H2020-S2RJU-OC-2017	My-TRAC	My-TRAC	3.5	3.5	01/09/2017	03/11/2021
S2R-OC-CCA-01-2015	NEAR2050	NEAR2050 - future challenges for the rail sector	0.4	0.4	01/10/2016	18/10/2019
H2020-S2RJU-OC-2019	NEXTGEAR	Next generation methods, concepts and solutions for the design of robust and sustainable running Gear	2.6	2.6	01/12/2019	21/02/2023
H2020-S2RJU-OC-2015-01-2	OPEUS	Modelling and strategies for the assessment and Optimisation of Energy Usage aspects of rail innovation	0.7	0.7	01/11/2016	08/09/2020
H2020-S2RJU-OC-2017	OPTIYARD	Optimised Real-time Yard and Network Management	1.4	1.4	01/10/2017	09/12/2020
H2020-S2RJU-OC-2019	RAILS	Roadmaps for A.I. integration in the rail sector	0.1	0.1	01/12/2019	01/03/2024
H2020-S2RJU-OC-2017	RUN2Rail	Innovative Running gear solutions for new dependable, sustainable, intelligent and comfortable rail vehicles	2.5	2.5	01/09/2017	03/08/2020
H2020-S2RJU-OC-2016-01-2	SAFE4RAIL	Safe architecture for Robust distributed Application Integration in rolling stock	6.7	6.7	01/10/2016	15/07/2020
H2020-S2RJU-OC-2018	SAFE4RAIL-2	Smart Planning and Virtual Certification	4	4	01/10/2018	04/04/2022
H2020-S2RJU-OC-2016-01-2	S-CODE	Switch and Crossing Optimal Design and Evaluation	4.4	4.4	01/11/2016	28/11/2021
H2020-S2RJU-OC-2018	SHIFT2MAAS	Shift2Rail IP4 enabling Mobility as a Service	1.4	1.4	01/12/2018	16/01/2022

		and seamless passenger experience				
H2020-S2RJU-OC-2015-01-2	SMART	Smart Automation of Rail Transport	1	1	01/10/2016	02/02/2021
H2020-S2RJU-OC-2017	SMaRTE	Smart Maintenance and the Rail Traveller Experience	0.7	0.7	01/09/2016	02/07/2020
H2020-S2RJU-OC-2018	SPRINT	Semantics for Performant and scalable Interoperability of multimodal Transport – SPRINT	2	2	01/12/2018	21/10/2021
S2R-OC-IP4-02-2016	ST4RT	Semantic Transformations for Rail Transportation	1	1	01/11/2016	21/06/2019
H2020-S2RJU-OC-2020	STREAM	Smart Tools for Railway work safety and performance improvement		1.1	01/12/2020	01/03/2024
H2020-S2RJU-OC-2018	TER4RAI L	Transversal Exploratory Research Activities for Railway	0.5	0.5	01/12/2018	28/05/2021
H2020-S2RJU-OC-2019	Transit	Train pass-by noise source characterization and separation tools for cost-effective vehicle certification	1.3	1.3	01/12/2019	16/02/2024
H2020-S2RJU-OC-2019	Translate 4Rail	Translation for breaking language barriers in the railway field	0.2	0.2	01/12/2019	09/08/2022
H2020-S2RJU-OC-2015-01-2	VITE	Virtualisation of the testing environment	0.9	0.9	01/11/2016	22/06/2020

1.7. Openness, cooperation, synergies and cross-cutting themes and activities

In terms of national funded R&I activities in the Railway sector, the JU invites the relevant Member States to present their programmes and projects in the context of the meetings of the SRG. This allows discussion on ways to interconnect the different activities and ensure that resources are leveraged to achieve the best results. This is an ongoing process, which becomes increasingly relevant in view of standardisation processes and market uptake.

During 2023, the JU also continued its efforts to increase cooperation with Member States, through the Spanish Presidency by organising a joint 'Satellite for Rail' conference in collaboration with the European Union Agency for Railways and the European Union Agency for the Space Programme, supported by the Spanish Transport Ministry.

Cooperation was also enhanced with the Swedish Presidency where EU-Rail organised a joint event with the European Commission, Trafikverket and RailNetEurope (RNE) entitled 'Rail Transport Day'. An MoU was signed during the 'Rail Transport Day' event between EU-Rail and RNE. The collaboration facilitated by this MoU covers traffic management and capacity allocation, exchange and communication of railway related data, infrastructure, and services, aiming to achieve higher railway sector efficiency, faster uptake and deployment of projects and innovations, and leverage the huge potential of digitalisation and automation to reduce rail's costs, increase its capacity and enhance its flexibility and reliability.

In addition, the JU also further explored synergies with other JUs and partnerships. 2023 was also marked for the first ever (across JUs) definition of synergy topics calls, with SESAR3 JU under the EU-Rail call 2023-1 launched in October 2023 and with the Smart Network Services (SNS) JU under the EU-Rail call 2024-1 launched in January 2024. As a result, EUR 2.5 million coming from SESAR3 JU and EUR 1 million from SNS JU are enlarging the EU-Rail Programme field of action, respectively for the Traffic Management and the next EU rail communication system, where rail cooperates and works with other modes to ensure attractive, innovative and tailor-made rail services.

Synergies within the "Climate, Energy and Mobility" cluster: EU-Rail has reach out to other mobility JUs with the aim to build, where possible, consistent projects and demonstrators for climate neutral mobility solutions. This may also address shared areas of intervention such as multi-modal transport, automation in vehicles and other assets, decarbonisation, use of alternative fuels, etc. In particular, specific coordination with the European Partnership Sesar 3, Clean Hydrogen, as well as with the Battery co-programmed partnership appear to be of key relevance. This resulted in publishing in 2023 the first synergy topic call HORIZON-ER-JU-2023-FA1-SESAR: EU-RAIL – SESAR SYNERGY: INTEGRATED AIR AND RAIL NETWORK BACKBONE FOR A SUSTAINABLE AND ENERGY - EFFICIENT MULTIMODAL TRANSPORT SYSTEM.

Synergies with the "Digital, Industry and Space" cluster: Considering the key challenges related to the digital transformation of rail, this cluster collaboration has also been critical. Artificial intelligence, cyber-security and high-performance computing are cross sectoral issues that require deep coordination especially for the development of use cases and the application of European standards. In addition, European space policy appears to be of key relevance, considering the ambition to introduce more and more satellite-based solutions for localization or data transmission. Here also synergies with EUSPA (and ESA) and SNS will be continued building upon the past experience. This resulted in building up in 2023 a first synergy topic call HORIZON-ER-JU-2024-FA2-SNS: EU-RAIL – SNS SYNERGY: DIGITAL & AUTOMATED TESTING AND OPERATIONAL VALIDATION OF THE NEXT EU RAIL COMMUNICATION SYSTEM. Additionally, following the successful Space for Innovation in Rail event in 2023 under the Spanish Presidency of the Council of the European Union, EU-Rail has set up in 2023 the elements for a concrete project on EGNOS for rail in cooperation with the EU Agency for the Space Programme (EUSPA), and with the European Space Agency (ESA), under the strategic leadership of the Commission and in full coordination with ERA, for delivering through R&I the technical and operational elements to reach competitive and resilient satellite-based rail services.

Coherence and synergies in relation to major national (sectoral) policies, programmes and activities: It is estimated that around 15% of the EU stimulus package called Recovery and Resilience Facility -RRF- will be invested in different areas of rail national systems. There is a need to ensure maximum levels of complementarity and impact, including focusing on future-proof investments. This will require to leverage local, regional and national investments to complement the research and innovation activities performed at EU-Rail level and vice versa. In this respect, the States Representatives Group has delivered for the first time in 2023 countries report describing the national or regional policies in the scope of the Europe's Rail joint undertaking and identified specific national projects where cooperation could be sought with the actions funded by EU-Rail.

EU-Rail also continued the cooperation with a number of key international partners, such as FRA, APTA, FTA in the US and CUTRIC (CA).

The collaboration with the EU neighbouring countries, in particular Western Balkans and the Transport Community has been reactivated in 2023.

The JU continued also its participation to the Digital PRIME working group, promoted by the European Commission together with rail infrastructure managers around traffic planning/management improvements mainly.

In terms of synergies with other Union Programmes, the JU works closely with the other Joint Undertakings sharing the same building, infrastructure, etc. maximising the opportunity for collaboration in terms of administrative and operational activities.

Beyond the operational activities, 2023 was the second year of implementation of Article 13 SBA, where EU-Rail took over the responsibility for the coordination of the Back Office Arrangement (BOA) Accounting Services. Other 3 BOAs were established led by other JUs where EU-Rail took also a supporting role, please refer to the section 2.7.2 "Efficiency gains and synergies", of the present document.

1.8. Progress against Key Impact Pathways and JU's Key Performance Indicators

1.8.1. Progress against H2020 legacy Key Performance Indicators

The H2020 Key performance Indicator results for the year 2023 are presented in Annex E. The JU has taken into its scoreboard all Horizon 2020 indicators, which have been established for the entire Research family by the Commission, to the extent they can be applied to the JU in view of providing meaningful results.

Comments to some indicators are provided in the tables in Annex E or in the related section of this CAAR, to which the indicators refer.

Within the context of the CCA activities, during 2023 the JU continued the work to maintain the 'S2R 2030 Impact Forecast Model' ensuring the next Release, resulting from the update of the data input from the different projects and TDs. The latest figures (Release 5) are provided in Annex E Table IV of the present CAAR.

1.8.2. Progress against General Horizon Europe Key Impact Pathways Indicators (KIPs)

The HE Key Performance Indicator results for the year 2023 are presented in Annex F. Given that the programme only started with projects at the end of 2022, several indicators cannot be reported for 2023.

1.8.3. Progress against HE Common JUs Key Performance Indicators

The HE Key Performance Indicator results for the year 2023 are presented in Annex F. Given that the programme only started with projects at the end of 2022, several indicators cannot be reported for 2023.

1.8.4. Progress against JU-specific Key Performance Indicators

The EU-Rail specific Key Performance Indicator results for the year 2023 are presented in Annex F. Given that the programme only started with projects at the end of 2022, several indicators cannot be reported for 2023.

1.9. Dissemination and information about project results

The JU disseminates the project results at the heart of its R&I programme. Dissemination activities mainly target the European scientific and academic community working in the mobility field, and specifically rail, but not exclusively. Dissemination therefore plays an essential role within the EU-Rail Programme, being a core ingredient of its success. In 2023 many in-person communication and dissemination activities took place. Namely, UIC World Congress on High-Speed Rail, SIFER 2023, UITP Global Public Transport Summit, Space for Innovation in Rail, Rail Live, and other events, were an opportunity to bring S2R innovations, present the Europe's Rail programme and introduce the new EU-Rail projects to the railway, transport and research industries, as well as decision and policy makers.

All JU dissemination activities are designed to consolidate the JU as the key European platform for R&I in the railway sector, with the System Pillar bringing the sector together, where all interested parties, including manufacturers, infrastructure managers, rail operators, regulators, research centres, SMEs and other stakeholders can exchange to ensure rail becomes the everyday mobility in Europe. The JU website hosts Shift2Rail and Europe's Rail projects' websites and dissemination activities (See also section 2.1).

In 2023, EU-Rail further elaborated a set of communication and dissemination guidelines specifically targeted towards the Europe's Rail Flagship Projects, but also the Other Activities and Exploratory Research Projects. The guidelines provide information and best practices on how to develop a successful and thorough communication and dissemination strategy, provides a timeline for implementations and explains how EU-Rail can support in disseminating their news and results. The guidelines also include a set of templates the projects are requested to use to ensure outputs follow EU-Rail brand guidelines, in addition to communication plan templates that the projects are requested to fill in on a monthly basis. A dedicated Teams environment was set-up to facilitate seamless exchange of information and to encourage the projects to fill it the communication plans.

In 2023, dissemination was further enhanced via dedicated project websites developed in collaboration with the EU-Rail Communication and Programme Units. The websites serve as a single point of entry and database for project deliverables, news and events. The websites summarise the information about the projects and set the timeline for major milestones and demonstrations. Projects were also provided a set of guidelines and suggestions with regard to the production and design of the project logos. All projects were requested to ensure the colours and fonts used are in line with the EU-Rail brand graphic guidelines to achieve a unified look and showcase that the projects belong to the EU-Rail programme.

Furthermore, to ensure seamless communication between the EU-Rail Communication Unit and the EU-Rail projects, joint meetings with the Project Coordinators, the Flagship Project Managers, and the Communication Work Package Leaders were organised to discuss to progress made with the Communication and Dissemination Strategies, as well as to exchange on best practices and align on targets, milestones and ensure synergies are created not just between the EU-Rail corporate communication office and the projects, but also among the projects themselves. Flagship Projects' Communication and Dissemination Strategies were thoroughly reviewed by the EU-Rail Communication Unit to ensure they feed into the overarching corporate communication strategy of the Europe's Rail Joint Undertaking. Projects were advised on best practices and given guidelines for future planning of their events and communication outputs, including relations with the press and production of scientific articles.

A set of in-depth feature articles, summarising the main objectives and expected outcomes of the Flagship Projects, was produced by the EU-Rail Communication Unit and published on the corporate EU-Rail website on a monthly basis. The articles were further disseminated in the EU-Rail newsletter. Emphasis was also placed on the finishing Shift2Rail projects. Articles and videos of project demos were collected and promoted on the EU-Rail website, social media and in the monthly newsletter.

Dissemination of project results was a prominent element of various EU-Rail and external events during 2023, especially during the Europe's Rail General Assembly on 5-6 December in Brussels and online, Space for Innovation in Rail – Towards a Satellite based ERTMS on 13-14 September in Madrid, Spain, SIFER 2023 on 28-30 March in Lille, France, as well as the UITP Global Public Transport Summit on 4-7 June in Barcelona, Spain.

The EU-Rail General Assembly was open to all the participants to Europe's Rail Joint Undertaking research and innovation activities. It was an opportunity to reflect on the overall direction of the JU's activities, while conducting an open and transparent discussion on the progress of the Master Plan and the Multi-Annual Work Programme implementation. The event was divides into two days, where Day 1 focused on strategic reports from EU-Rail, including an update on the state of play, presentations from the advisory bodies, as well as the European DAC Delivery Programme, and sessions on synergies and cooperation. While Day 2, on the other hand, was dedicated to operational reports, including an update on the ongoing activities in the Innovation and System Pillars. It was an opportunity to present the progress of the Flagship Projects, while presenting a clear timeline for expected milestones and demonstrations. Furthermore, success stories from the Shift2Rail programme were presented during the event. Namely, C-DAS Leader upgrade development, Intelligent Video Gate, GoA-2 solutions, Commercialisation of Ticket Vending Machine, Traction Silicone Carbide technology, IAMS platform equipped with decision support methodologies and algorithms for anomaly detection.

The JU organised The Space for Innovation in Rail – Towards Satellite Based ERTMS event against the backdrop of the Spanish Presidency of the Council of the European Union, together with the European

Commission, the European Union Agency for the Space Programme (EUSPA), and the European Union Agency for Railways (ERA). The event gathered Europe's major transport stakeholders, including key decision makers and the railway sector representatives across the entire value chain, debating the introduction of the European Union's Space Programme assets in the railway domain. The main focus of the event was on the European Global Navigation Satellite Systems (GNSS) utilisation for fail-safe train localisation within the European Rail Traffic Management System (ERTMS) evolution. It was an opportunity to discuss the work achieved in EU-Rail Flagship Projects 2 and 6, as well as the major achievements on the System Pillar with regard to train positioning.

The UITP Global Public Transport Summit was a key event in which EU-Rail disseminated its project results. EU-Rail was present with a 36sqm stand, showcasing several innovations, including the Travel Companion, the Ultralight Seats and the Virtual Reality Tool on Noise Abatement Technologies. The objectives of the EU-Rail Flagship Project 4 Rail4Earth, specifically related to energy efficiency, were presented during a Spotlight Forum Session on 'Managing Energy in Public Transport Operations: From Renewable Supply to Intelligent Management.' The event was also an opportunity to present the final results of our Innovation Programme 4 projects IP4MaaS, Connective, ExtenSive. The projects showcased the culmination of several years of activity in the areas of multimodal services integration, developments in passenger experience, results of European pilots, route to market and exploitation. Furthermore, the Innovation Programme 4 project IP4MaaS kicked-off its demonstration activities for a set of digital tools aimed at improving mobility during the Innovation in the Spotlight session.

Furthermore, SIFER 2023 was an opportunity to present the project results to the French stakeholders. More precisely, video material from S2R and EU-Rail projects was showcased during the event. Additionally, EU-Rail took the opportunity to lead a masterclass specifically dedicated to energy efficiency in the rail sector.

Moreover, project results were also presented and discussed at a number of other external events where JU staff, Founding Members and project partners participated. More details on these events are available in Annex C.

2023 also saw a use of shared dissemination information among projects coordinated by the JU Communication Team. Throughout 2023 the webpage on Project Results launched in 2021 in collaboration with the JU Programme Unit was a key communication and dissemination priority. Each month a number of selected results and deliverables coming from Shift2Rail and also the EU-Rail projects are highlighted in this section of the website to ensure continuous communication about their achieved progress. The webpage includes a short description of each deliverable, giving a brief of account on how it brings us closer to achieving better rail for Europe. This approach has resulted in a multiplier effect as we have used this content for further promotion on our corporate social media channels and newsletter.

In 2023 we also continued to populate the section in the JU newsletter specifically dedicated to EU-Rail and Shift2Rail project news. This section benefits from an increased click-through rate from our viewers. Additionally, in 2023, EU-Rail has continued to promote projects final and mid-term conferences on social media channels, news section of the JU website and newsletter. The cross-projects collaboration of communication activities pushed by the JU, has allowed for a more efficient promotion of this increased activity and a global overview of all project dissemination, ensuring we are able to promote results in a timely and effective manner. It also has enabled monitoring and the possibility to advise projects in the dissemination of their work in order to ensure they support the programme approach and contribute to the overarching JU communication strategy.

Project Final Conferences in 2023:

- 17 January – COHESIVE Final Event, Toulouse, France
- 15 February – Transit and Silvarstar Final Event, Brussels, Belgium
- 16 February – OPTIMA Final Conference, Brussels, Belgium
- 27 April – Ride2Rail Final Event, Brussels, Belgium
- 23 May – LinX4Rail & LINX4RAIL-2 Final Joint Event, Paris, France
- 23-24 May – TAURO, X2Rail-4 & X2Rail-5 Final Event, Berlin, Germany

- 24 May – DAYDREAMS Final Conference, Brussels, Belgium
- 31 May – IN2ZONE Final Event, Budapest, Hungary
- 6 June – IP4MaaS, ExtenSive, Connective Final Event, Barcelona, Spain
- 8 June – STREAM Final Event, Port of Tarragona, Spain
- 13 June – Pivot 2 Final Event, Brussels, Belgium
- 15 June – FR8RAIL IV Final Event, Frankfurt, Germany
- 15 June – PERFORMINGRAIL Final Event, Birmingham, United Kingdom
- 21 June – GEARBODIES Final Conference, Brussels, Belgium
- 27 September – RECET4RAIL Final Event, Brussels, Belgium
- 27 September – FINE-2 - Noise & Vibration Final Event, Berlin, Germany
- 7 November – CONNECTA-3 and Safe4RAIL-3 Final Conference, San Sebastian, Spain
- 30 November – In2Track3 Final Event, Stockholm, Sweden

2. SUPPORT TO OPERATIONS

2.1. Communication activities

The JU continued to promote the activities of the Programme during 2023. The JU communication activities in 2023 were focused on the continued promotion of the S2R Programme and bringing as much visibility as possible to the results of its R&I activities, while also raising awareness of the Europe's Rail Programme, its mission and vision, its Calls for Proposals and the new System and Innovation Pillars, while taking into consideration the upcoming Deployment Group.

The second General Assembly[46] of EU-Rail was organised on 5-6 December 2023, supporting the operational activities of the JU and gathering all participants to the research and innovation activities of the Europe's Rail Joint Undertaking in accordance with Article 93(5) of the Single Basic Act. The primary objective of the assembly was to stimulate reflection on the overall direction of the activities of the Europe's Rail Joint Undertaking, while conducting an open and transparent discussion on the progress of the Master Plan implementation.

Most communication activities in 2023 revolved around organisation and participation to events, as well as raising awareness of the new EU-Rail projects, with a particular focus on the Flagship Projects, as described is section 1.9. Furthermore, EU-Rail launched a campaign on the European Year of Skills. At the heart of the campaign was video series on the EU-Rail YouTube channel, sharing personal experiences of the EU-Rail Founding Members, partners, and staff encouraging young people to build their careers in rail. Viewers had the opportunity to learn from the people in the industry what are the skills that can be developed while working in rail, what skills are necessary to have and what skills are used daily. The purpose of the campaign was to put skills centre-stage and promote a mindset of reskilling and upskilling, as well as bringing organisations and people together to share their experiences and insights.

Promotion of the 2023 Calls for Proposals was as usually a focus of the yearly communication activities. In 2023 one Call for Proposals was launched and widely promoted through website, newsletter, social media channels and through events and this promotional content was successfully re-shared by EU-Rail Founding Members, the European Commission and partners as well as reported in the press (see Annex C). Additionally, the Info Day was further promoted by the Horizon Europe National Contact Points Network, including organisation of regional Info Days. To ensure hight participation rate to the Call, a paid LinkedIn campaign was launched, and an advertisement was placed in the International Railway Journal. A particularity of this Call was the joint topic on 'Integrated Air and Rail Network Backbone for a Sustainable and Energy Efficient Multimodal Transport System' with the SESAR 3 Joint Undertaking. To further

46 https://rail-research.europa.eu/about-europes-rail/europes-rail-structure-of-governance/europes-rail-governing-board/general-assembly/

leverage on the synergies offered by the collaboration, a joint communication campaign was launched, including a press release, a social media campaign and visual materials. Furthermore, a novelty is this Call, was the launch of a dedicated long-term matchmaking platform encouraging interested applicants to find like-minded experts, exchange ideas and schedule meetings. The platform was open up until Call closure.

In 2023, the JU Communications successfully organised two meetings with the Communication Officers of Founding Members' companies to align the key priorities and communication expectations, as well as agree on best practices on information exchange. The meetings were used as an opportunity to involve Founding Members in events organised by the JU. These meetings have deemed successful as Founding Members have placed a much stronger emphasis in incorporating communication about Europe's Rail in their Corporate Communication Strategies and Action Plans.

As described in section 1.9., in 2023 the JU Communications organised two meetings with the Flagship Projects to align on the Communication and Dissemination Strategies and inform the projects on potential synergies and collaboration with the Corporate Communications of the JU, especially in terms of event participation.

In parallel to the key events organised and participated in by the JU during 2023 (see Annex C), the JU continued to build its audience and continued to improve its stakeholder mailing list in order to ensure that news is reaching the correct audiences. For instance, a list of the new projects was fully developed. Furthermore, mailing lists were reviewed and updated on a regular basis. In addition, with EU-Rail's increased presence as a key actor in rail, new stakeholders in other areas of interest (climate, growth, other transport areas) are increasingly reaching out to the JU. In 2023, EU-Rail began expanding on relationships with the Transport Ministries of the Member States of the Union and received a visit of the Latvian Minister of Transport.

Europe's Rail co-organised the Rail Transport Day under the Swedish Presidency, involving the European Commission, Trafikverket and RailNetEurope. Europe's Rail also continued to build networks via the Spanish Presidency by organising an event on Space for Innovation Rail – Towards a Satellite based ERTMS Conference in Madrid. The event was joint organised with the Spanish Transport Ministry, the European Commission, the European Union Agency for the Railways, the European Union Agency for the Space Programme and Adif. It is also worth mentioning that the network with the Communication Officers of the other Joint Undertakings was utilised too in 2023 to ensure coherent information exchange, as well as regular exchanges with HCIN.

Relations with the European Parliament are regular and the JU's expertise is searched to contribute to a number of working activities from the TRAN Committee in particular. The exchanges with the Chair of the TRAN Committee were further strengthened via the European Startup Prize for Mobility, an EU startup acceleration programme supported by EU-Rail.

Furthermore, press relations in 2023 were also strengthened, increasing media presence not just in specialised rail press (particularly in the Railway Gazette, International Railway Journal, Global Railway Review, Rail Target, and Railway Pro – all press articles are listed in Annex C), but also in more mainstream press outlets, such as EURACTIV and the Brussels Times. In 2023, the JU continued to implement ongoing media partnerships with BtoB Magazine and signed a new partnership with the European Files Magazine. The JU also had a collaboration agreement with Rail Live and SIFER organisers.

In terms of website, the JU continued revamping its website based on the new visual identity guidelines by introducing new features, sections and improving user friendliness. The website was further enhanced with new content, especially the News section was populated with articles and features on a weekly basis to engage with the readers. EU-Rail continued placing increased efforts on its social media channels, which resulted in a major follower growth on LinkedIn, where a milestone of 10,000 followers was reached At the end of 2023, EU-Rail's LinkedIn account had more than 12,000 followers The overall impressions reached on Europe's Rail LinkedIn channel was over one million, compared to only 700k in 2023, showcasing that there is strong interest to follow content produced by the JU. Moreover, the JU also kept increasing its presence on its YouTube channel. Efforts have been made to publish videos showing our innovations as well as recordings of our online events to ensure that even those who were unable to join can access the content. In 2023 the videos were further divided into dedicated playlists to improve user friendliness. Just like in previous years, in 2023, JU also had at the heart of its strategy the promotion of the JU project results through its social media channels. Thanks to the collection tool developed by the JU, projects are able to directly propose content for organic or re-shared posts. The projects are encouraged to send content directly to the Communication Team to ensure it is promoted across the social media channels in a timely manner. In 2023 the Communication Team launched the pilot phase of the dedicated Microsoft 365 Teams environment which is being used for collecting content from the projects for publication via social media.

New webpages on EU-Rail projects were created in 2023. Additionally, a contract on website UX analysis was signed at the end of 2023 – the work will be carried out in 2024, including a larger revamping project.

During 2023, the JU published five different publications: Smart and affordable rail services in the EU: a socio-economic and environmental study for High-Speed in 2030 and 2050, The European DAC Investment Plan, Final Report: Work to support with a cost-benefit analysis the definition of migration paths for the implementation of S2R selected innovations on the European network, Definition of the KPI Model for the EU-Rail Programme: KPI Cards, Annual Activity Report 2022: Executive View. The publications incorporated the new visual identity and were promoted during various events in presence, most prominently, SIFER, Rail Live, UITP Global Public Transport Summit

The JU participated to nearly 62 different events across Europe and beyond, strongly showcasing the Partnership's importance within the rail and transport communities globally. One example is Europe's Rail participation to the UITP Global Public Transport Summit. Europe's Rail participated with a 36sqm stand, showcasing various demonstrations developed in the Shift2Rail Programme and promoting the new EU-Rail projects. A full list of events organised and participated in by the JU to ensure stakeholder engagement is available in Annex C of this CAAR.

A close collaboration with the European Union Agency for Railways (ERA) in different areas, with the European Union Agency for the Space Programme and with the European Railway Research Advisory Council (ERRAC), as well as with the different International and European organisations and associations was maintained. A continuous and constructive exchange took place with other Union bodies and agencies. In terms of collaboration for instance, and as mentioned above, ERA, EUSPA and EU-Rail organised a joint event under the Spanish Presidency.

In 2023, journalists have also been targeted by the JU on social media which has proved effective as well. The fact that the Programme continues to become better known and the interest in its results progressively increases is reflected in a broader media coverage of EU-Rail compared to previous years.

Communication statistics can also be found in Annex C.

Data protection

In cooperation with the ICT Officer, the Chief Legal Officer, who also acts as the JU's Data Protection Officer, and two contractors managing the rail-research.europa.eu and projects.shift2rail.org domains, EU-Rail Communication team continued to work on making the website compliant with the data protection regulation based on the instructions provided by the European Data Protection Supervisor. It was ensured that the website platform and applications are compliant with the GDPR and EUDPR Regulations. In particular, our contractor ensured that full website maintenance procedures are carried out on a daily basis. For instance, in 2023 newsletter subscription form was linked to a dedicated Mailchimp account, staging environment was updated and plugins renewed/updated on a regular basis.

In 2023, the contractor placed an increased emphasis on managing server security, protection from denial-of-service attacks, timely application of security patches, anti-virus to ensure protection from documents coming from users, private data, human error reduction, storage of online consent in the context of EUDPR regulation, website cookies.

As a result of this work, JU's website is considered compliant with the data protection regulation that also helped the domain to substantially improve its position in the EU Privacy Score Tool.

2.2. Legal and financial framework

In accordance with Council Regulation (EU) 2021/2085 (the "SBA"), EU-Rail is the legal and universal successor of the S2R JU, which it replaced and succeeded as from 30 November 2021.

To ensure the business continuity of the operations, in the first Governing Board meeting of EU-Rail a list was approved containing Decisions[47] adopted still under the S2R JU which continue to apply for EU-Rail in accordance with Article 174(12) of the SBA. This list includes Decisions concerning aspects related to governance, human resources, finance, audit and internal controls and compliance, and in particular the Financial Rules of the JU. The Executive Director also approved the list of ED Decisions adopted under the S2R Ju that will continue to apply to EU-Rail.

Thus, as indicated in our web site[48], any references to S2R JU in the internal legal framework shall be construed as references to EU-Rail (e.g.: the JU Financial Rules adopted by S2R JU).

In 2023, the EU-Rail legal framework refers predominantly to:

- Treaty on the Functioning of the European Union (TFEU), and in particular Article 187 and the first subparagraph of Article 188 thereof.
- Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC) No 219/2007, (EU) No 557/2014, (EU) No 558/2014, (EU) No 559/2014, (EU) No 560/2014, (EU) No 561/2014 and (EU) No 642/2014 ("the Single Basic Act")[49] as amended by Council Regulation (EU) 2023/1782 of 25 July 2023 as regards the Chips Joint Undertaking[50] This Regulation sets up nine joint undertakings – including EU-Rail - within the meaning of Article 187 TFEU for the implementation of institutionalised European partnerships referred to in Article 10(1), point (c), of the Horizon Europe Regulation. It determines their objectives and tasks, membership, organisation and other operating rules.
- The General Financial Regulation (EU, Euratom) 2018/1046[51], subject to any specific provisions of the Financial Rules of EU-Rail and the Single Basic Act,
- The Financial Rules of EU-Rail[52], adopted by the Governing Board Decision N° 11/2019 of 20 December 2019[53] and entering into force on 1 January 2020.
- The EU-Rail Governing Board (GB) Decisions adopted since its establishment, which frame the functioning of EU-Rail, within the boundaries of the Single Basic Act and the EU-Rail Financial Rules, in particular the Europe's Rail Work Programme 2023-2024 and its amendments[54] approved by the GB (draft budget, Staff Establishment Plan, Scientific Priorities, calls, tenders, etc.). As indicated in the EU-Rail GB Rules of Procedure, once adopted, the GB decisions are published on the EU-Rail website[55].

In addition:

- Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013[56]. This regulation) establishes the policy and legal framework for European

47 EU-Rail GB Decision n° 02/2021. The list is available at: https://rail-research.europa.eu/about-europes-rail/europes-rail-structure-of-governance/europes-rail-governing-board/
48 https://rail-research.europa.eu/about-europes-rail/europes-rail-reference-documents/europes-rail-key-documents/
49 OJ L 427, 30.11.2021, p. 17–119.
50 OJ L 229, 18.9.2023, p. 55–62. Consolidated text available in https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02021R2085-20230921&qid=1710346003599

51 Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council of 18 July 2018 on the financial rules applicable to the general budget of the Union, amending Regulations (EU) No 1296/2013, (EU) No 1301/2013, (EU) No 1303/2013, (EU) No 1304/2013, (EU) No 1309/2013, (EU) No 1316/2013, (EU) No 223/2014, (EU) No 283/2014, and Decision No 541/2014/EU and repealing Regulation (EU, Euratom) No 966/2012. OJ L 193, 30.7.2018, p.1.
52 By Delegated Regulation (EU) 2019/887, the Commission adopted the model financial regulation for public-private partnership bodies to ensure sound financial management of Union funds and to enable public-private partnership bodies like S2R JU to adopt their own financial rules. The model financial regulation should be consistent with the provisions of Regulation (EU, Euratom) 2018/1046. The S2R JU shall adopt its financial rules in accordance with this model financial regulation.
53 https://rail-research.europa.eu/wp-content/uploads/2020/01/S2R-JU-Financial-Rules.pdf
54 https://rail-research.europa.eu/about-europes-rail/europes-rail-reference-documents/europes-rail-annual-work-plan-and-budget/
55 https://rail-research.europa.eu/about-europes-rail/europes-rail-structure-of-governance/europes-rail-governing-board/
56 OJ L 170, 12.5.2021, p. 1–68

partnerships with private or public sector partners. European partnerships are a key element of the policy approach of Horizon Europe – the Framework Programme for Research and Innovation ('Horizon Europe').

- The Staff Regulations of officials and the conditions of employment of other servants of the European Union are applicable to the staff of the JU.

Additional reference documents can be found on the JU's dedicated webpage: https://rail-research.europa.eu/about-europes-rail/europes-rail-reference-documents/

2.3. Budgetary and financial management

STATEMENT OF REVENUE	Voted Budget 2023 - A2		Budget 2023 as finally adopted	
Heading	*Commitment appropriations (in EUR)*	*Payment appropriations (in EUR)*	*Commitment appropriations (in EUR)*	*Payment appropriations (in EUR)*
EU contribution excl. EFTA	***94.234.167***	***83.767.283***	***94.234.167***	***83.767.283***
of which Administrative	*2.346.053*	*3.578.712*	*2.346.053*	*3.578.712*
of which Operational	*91.888.114*	*80.188.571*	*91.888.114*	*80.188.571*
Third countries contribution including EFTA	***2.651.117***	***2.370.050***	***2.651.117***	***2.370.050***
of which Administrative	*67.801*	*98.001*	*67.801*	*98.001*
of which Operational	*2.583.316*	*2.272.049*	*2.583.316*	*2.272.049*
Industry financial contribution	***3.676.713***	***3.676.713***	***3.676.713***	***3.676.713***
of which Administrative	*3.676.713*	*3.676.713*	*3.676.713*	*3.676.713*
Interest generated	-	-	-	-
Unused appropriations from previous years	***1.920.790***	***30.357.172,47***	***2.059.390***	***30.495.772***
Of which administrative	*1.795.440*	*3.652.661,42*	*1.810.680*	*3.667.901*
Of which operational	*125.350*	*26.704.511,05*	*248.710*	*26.827.871*
TOTAL ESTIMATE REVENUE	***102.482.787***	***120.171.218***	***102.621.387***	***120.309.818***

STATEMENT OF EXPENDITURE (Commitment appropriations)	*[Amended - A2] budget 2023 (AWP)*	*[Amended] budget 2023 after transfers*	*Executed Budget 2023*	*%*	*Available for future use (N+3 rule)*
Title 1 - Staff expenditure	***3.575.460,00***	***3.590.700,00***	***3.590.700,00***	***100,0%***	***-***
Salaries & allowances	*3.010.360,00*	*2.825.640,02*	*2.825.640,02*	*100,0%*	*-*
Mission expenses	*153.000,00*	*153.000,00*	*153.000,00*	*100,0%*	*-*
Training	*51.000,00*	*22.965,01*	*22.965,01*	*100,0%*	*-*
Other Staff related expenditure	*361.100,00*	*589.094,97*	*589.094,97*	*100,0%*	*-*
Title 2 - Infrastructure and operating expenditure	***1.426.900***	***1.426.900***	***1.424.463,75***	***99,8%***	***2.436,25***
Rental of buildings and associated costs	*401.900*	*401.900*	*401.900,00*	*100,0%*	*-*
Information, communication technology and data processing	*195.000*	*238.040*	*238.039,81*	*100,0%*	*-*
Movable property and associated costs	*10.000*	*1.630*	*1.630,00*	*100,0%*	*-*
Current administrative expenditure	*15.000*	*14.000*	*14.000,00*	*100,0%*	*-*
Postage / Telecommunications	*15.000*	*9.574*	*9.574,10*	*100,0%*	*-*
Meeting expenses	*50.000*	*20.241*	*20.241,42*	*100,0%*	*-*
Running costs in connection with operational activities	*140.000*	*120.600*	*118.163,75*	*98,0%*	*2.436,25*
Information and publishing	*450.000*	*436.241*	*436.241,06*	*100,0%*	*-*
Other infrastructure and operating expenditure	*150.000*	*184.674*	*184.673,61*	*100,0%*	*-*
Title 3 - 4 - Operational expenditure	***94.596.780***	***94.720.140***	***94.623.458,94***	***99,9%***	***96.680,81***
S2R Programme	*125.350*	*178.710*	*82.028,94*	*45,9%*	*96.680,81*
EU-Rail Programme	*94.471.430*	*94.541.430*	*94.541.430,00*	*100,0%*	*-*

Title 5 - Unused appropriations not required in current year	*2.883.647*	*2.883.647*	*-*	*0,0%*	*2.883.646,84*
TOTAL	***102.482.787***	***102.621.387***	***99.638.622,69***	***97,1%***	***2.982.763,90***

STATEMENT OF EXPENDITURE (Payment appropriations)	***[Amended - A3] budget 2023 (AWP)***	***[Amended] budget 2023 after transfers***	***Executed Budget 2023***	***%***	***Available for future use (N+3 rule)***
Title 1 - Staff expenditure	***3.148.460,00***	***3.163.700,00***	***3.044.475,93***	***96,2%***	***119.224,07***
Salaries & allowances	*2.730.360,00*	*2.780.360,00*	*2.716.626,47*	*97,7%*	*63.733,53*
Mission expenses	*100.000,00*	*100.000,00*	*80.835,47*	*80,8%*	*19.164,53*
Training	*34.000,00*	*34.000,00*	*26.120,35*	*76,8%*	*7.879,65*
Other Staff related expenditure	*284.100,00*	*249.340,00*	*220.893,64*	*88,6%*	*28.446,36*
Title 2 - Infrastructure and operating expenditure	***1.444.200,00***	***1.444.200,00***	***1.318.756,57***	***91,3%***	***125.443,43***
Rental of buildings and associated costs	*351.900,00*	*351.900,00*	*348.730,50*	*99,1%*	*3.169,50*
Information, communication technology and data processing	*261.000,00*	*261.000,00*	*225.035,05*	*86,2%*	*35.964,95*
Movable property and associated costs	*10.000,00*	*10.000,00*	*1.630,00*	*16,3%*	*8.370,00*
Current administrative expenditure	*15.300,00*	*15.300,00*	*13.777,69*	*90,1%*	*1.522,31*
Postage / Telecommunications	*15.000,00*	*15.000,00*	*3.916,88*	*26,1%*	*11.083,12*
Meeting expenses	*21.000,00*	*21.000,00*	*16.401,27*	*78,1%*	*4.598,73*
Running costs in connection with operational activities	*360.000,00*	*360.000,00*	*340.874,99*	*94,7%*	*19.125,01*
Information and publishing	*300.000,00*	*300.000,00*	*260.576,19*	*86,9%*	*39.423,81*

Other infrastructure and operating expenditure	*110.000,00*	*110.000,00*	*107.814,00*	*98,0%*	*2.186,00*
Title 3 - 4 - Operational expenditure	***111.669.638,94***	***111.792.998,79***	***94.754.879,32***	***84,8%***	***17.038.119,47***
S2R Programme	*39.780.183,94*	*39.833.543,79*	*26.555.504,55*	*66,7%*	*13.278.039,24*
EU-Rail Programme	*71.889.455,00*	*71.959.455,00*	*68.199.374,77*	*94,8%*	*3.760.080,23*
Title 5 - Unused appropriations not required in current year	***3.908.919,53***	***3.908.919,53***	***-***	***0,0%***	***3.908.919,53***
TOTAL	***120.171.218,47***	***120.309.818,32***	***99.118.111,82***	***82,4%***	***21.191.706,50***

At the year-end 2023, the JU had implemented 100% of its commitment appropriations made available in its active budget (Titles 1 to 4). The payment appropriations were implemented up to 85.2% (79.1% in 2022) of the active funds (or 82.4% of implementation when compared to the full JU budget (including Title 5)).

In GB Decision 14/2022 on 30 November, the EU-Rail Governing Board adopted the initial Annual Work Plan and Budget for 2023-2024.

There were two amendments adopted to this document during 2023 with budget impact.

- **Amendment number 1**

The Executive Director ad interim proposed to the Governing Board adaptation of the Budget as per following:

Statement of Revenue

This amendment recognised and balanced (Revenue and Expenditure) unused appropriations on S2R Programme operational expenditure due in relation to the previous budgetary years, in accordance with EU-Rail Financial Rules Article 6.5.

Were entered in addition to the estimate of revenue:

- EUR 0.08 million EUR in commitment and payment appropriations recovered from S2R Programme project that had to be re-paid through the EC Guarantee Fund.
- EUR 26.1 million EUR in payment appropriations due in relation to the unused appropriations of previous budgetary years that are required in 2023 in order to pay S2R Programme grants interim and final payments, following an action plan of "REPA 2023" discussed and agreed with the EU-Rail SIPB and project coordinators between January and May 2023.

In accordance with the SBA (recitals 10 and 12 and Article 5(2) c)), to achieve maximum impact, the joint undertakings should develop close synergies with other Horizon Europe initiatives and other Union programmes and funding instruments, particularly with those supporting the deployment of innovative solutions. Following the identification of synergies between them, joint undertakings should aim to determine budget shares which should be used for complementary or joint activities between joint undertakings, including by dedicating, where appropriate, a part of the joint undertaking's budget to joint topic calls. EU-Rail and SESAR3 Joint Undertakings launched a joint call as indicated in the section above. EUR 2.5 million was increased in the section "EU Contribution" in accordance with the structure of the EU-Rail budget but was coming from SESAR 3 JU and not from the Union.

In accordance with the SBA Article 10.4, the EUR 2.5 million new revenue in 2023 are considered as additional Union funds complementing the contribution allocated to the EU-Rail Programme implementing

Horizon Europe. In this respect, and in accordance with SBA Article 10.6, this additional contributions from Union programmes corresponding to additional tasks entrusted to EU-Rail shall not be accounted for in the calculation of the Union maximum financial contribution to the EU-Rail Programme.

Statement of Expenditure

Title I and II: minor adaptation of the Budget appropriation per line was proposed considering the evolution of budget needs identified since the estimates made in October 2022.

The increase of payment appropriations in Title 2 was to ensure the implementation via interim and final payments of JU activities agreed with the GB in 2022, mainly about the support of the initial activities of the System Pillar – on the transition to the full System Pillar running, on the setting up of the System Pillar programme and project management plan, and on the drafting of the Standardisation and TSI input plan.

This increase was covered by the administrative unused appropriations coming from the Title 5 "Unused".
Title III (Operational S2R Programme): increase of the S2R Programme operational payment appropriations of 26.2m EUR, in order to pay the S2R Programme grants interim and final payments expected for the year 2023.

This increase is covered by the entering in addition to the estimate of revenue, the unused payment appropriations from the previous budgetary years.

Title IV (Operational EU-Rail Programme): the commitment appropriations are increased by EUR 2.5 million for the joint topic call between EU-Rail and SESAR 3 JU.

- **Amendment number 2**

The Executive Director ad interim proposed to the Governing Board adaptation of the Budget as per following:

Statement of Revenue

Compared to Work Programme 2023-2024 and Budget Amendment nr1, this amendment recognised the inscription of new assigned revenue (recovery from projects or administrative expenditure).

Statement of Expenditure

Title I and II: adaptation of the Budget appropriation (mainly in payment appropriations) per line was proposed considering the evolution of budget needs and payment budget forecast expected until year-end, lower than planned, in particular for staff expenditure and associated costs (turnover in 2023).

Title III (Operational S2R Programme): increase of the S2R Programme operational appropriations of EUR 43k, in order to re-inscribe the assigned revenue collected from projects.

Title IV (Operational EU-Rail Programme): the payment appropriations were increased by EUR 795k for unused administrative expenditure.

Implementation of the Budget

Administrative costs (Title 1 Staff Expenditure and Infrastructure and Title 2 Operating Expenditure)

Title 1 and Title 2 of the Budget were executed up to 100% in commitment appropriations, demonstrating a reliable budgetary planning.

Title 1 – Staff Expenditure was mainly used for the salaries of the JU staff. During the year, the JU also made use of external support, to fill the gaps during the recruitment process on staff turnover and to cope with the important workload on JU activities.

Title 2 – the administrative expenditure was mainly used to ensure the JU activities – in particular to cover the high number of communication events and the commitment for InnoTrans 2024.

The implementation rate of the payment appropriations was 95% (84% in 2022), showing an increase in implementation of payment appropriation in relation to the previous budgetary year.

Title 3 and Title 4 Operational Expenditure

Title 3 of the Budget constitutes the JU's Operational Budget for implementation of the S2R Programme activities.

Title 4 of the budget constitutes the JU's Operational Budget for the implementation of the new EU-Rail Programme activities.

The majority of the JU's budget falls under this category representing 95% of the active (Titles 1 to 4) and 92% of overall budget (including Title 5). The proportion has stabilized compared to 2022 (97% in 2022) since EUR 94.7 million was available to be allocated to EU-Rail operational commitment appropriations this year, being the second year of the launch of activities under the EU-Rail Programme.

The budget category Title 3 covers the interim and final payments implementing the remaining grant agreements, operational procurement and expert fees incurred as part of the evaluation for the S2R Programme.

The budget category Title 4 covers the second instalment of the first Call for proposal of the JU for a total funding of EUR 234 million and launched with multi-annual instalment (EUR 135.7 million EUR of Commitment Appropriations (CA) used in 2022 and EUR 55.9 million used in 2023), a third Call for Proposal for Exploratory Research (for 21.2m EUR) and tenders for System Pillar activities and other tenders and studies.

The implementation rate of the operational budget in both commitment and payment appropriations was respectively 100% (99.9%) and 85% (79% in 2022). This year, a major portion of payment appropriations were used for the second pre-financing of the grants resulting from the 2022 first call for proposal.

The reported implementation also includes payments to the Expert Evaluators which is managed by the European Research Executive Agency (REA) Services.

Title 5 Unused appropriations not required in current Year

The amount included under Title 5 – Unused appropriations not required in current year has been established to support a transparent implementation of JU Financial Rules Art.6.5, the so called n+3 rule. In accordance with the Financial Rules and the general practice of the JU, these appropriations will be reactivated in the future year budget(s) of the following year and used first.

The 2023 as finally adopted budget presents EUR 2.9 million of unused administrative commitment appropriations, and EUR 3.9 million of unused payment appropriations (for EU-Rail Programmes administrative budget) that will be re-inscribed in revenue and expenditure in the following years.

2.4. Financial and in-kind contributions from Members other than the Union

As not all the contributions included in the Single Basic Act as funding options for the activities caried out on various programs, are reflected in the financial statements of the Joint Undertaking, the below information aims to provide a comprehensive overview of the funding for the on-going programmes used.

The information provided combines contributions validated and estimated in an effort to breach the timing gap in the validation of the cash and in-kind contributions. In addition to the information on cash and IKOP presented the notes related to the net assets and liabilities, the below overview also includes information on the IKAA contributions which are not presented in the financial statements.

	Members' contributions (as per Funding regulation)				
Programme	EU cash (a)	Private members cash (b)	Private members IKOP (c)	Private members IKAA (d)	**Total (e)=(a)+(b)+(c)+(d)**
H2020	*450.000.000,00*[57]	*13.500.000,00*	*336.500.000,00*	*120.000.000,00*	***920.000.000,00***
Horizon Europe	*600.000.000,00*	*24.000.000,00*	*576.000.000,00*		***1.200.000.000,00***

	Members contributions as of 31.12.2023							
Programme	EU cash validated	EU cash not validated (PF)	Private members cash validated	Private members IKOP validated	Private members IKOP estimated	Private members IKAA certified	Private members IKAA estimated	**Total**	**Achievement rate**
H2020	*447.682.873,41*	*0,00*	*12.964.995,26*	*315.424.297,90*	*44.681.263,11*	*266.794.243,22*	*0,00*	***1.087.547.672,90***	***118%***
Horizon Europe	*178.605.203,99*	*8.863.027,01*	*5.934.491,10*	*0,00*	*47.304.629,73*	*69.944.329,59*	*23.040.213,91*	***333.691.895,32***	***28%***

[57] The SBA target for the Union includes 52M which have been provided and implemented before the autonomy of the Joint Undertaking for the LightHouse projects.

Horizon 2020 programme

The information presented for Horizon 2020 is in line with the expected financing for a programme which is in the sunset phase. The Joint Undertaking is foreseeing that the last financial operations on this programme will be concluded in 2024. The achievement rate above 118% at programme level is mostly due to the IKAA contributions from the Private members. While if we consider, the targets of 470M of Private Members’ expected contributions as per the Shift2Rail Council Regulation, the Private members validated contributions have already exceeded the target reaching approx. 127%.

The Union’s contribution stands at 99% from the objective as per the Shift2Rail Council Regulation.

The last cash contributions from the Union and the Private members are planned to be received in 2024. It is expected that in 2024 the last certification of in-kind contributions will also take place.

Horizon Europe programme

The information presented for Horizon Europe is in line with the financing expectations from a programme that started in 2022.

While looking at the contribution targets per member category as indicated in the Single Basic act, the total contribution of the Union stands at 31% against the 600M target and the Private Members contribution is estimated at 24% against the 600M target. The difference in the pace of contributions between members in the beginning of the programme is expected as the Union’s financing in the form of cash is required for the prefinancing of activities and must be provided before any other type of contribution.

The in-kind contributions result from the activities carried out by the JU’s members other than the Union, funded by the JU when in relation of awarded actions (IKOP) and/or not funded by the JU (usually Additional Activities and/or IKAA). They are not revenues in accordance with the budgetary accounting, hence they are not reported in the Budgetary tables and shall be excluded from any other purposes than the achievement of the SBA objectives.

Nevertheless, they constitute the essential component of the “partnership” nature of the Joint Undertaking.

2.4.1. Europe's Rail in-kind Contributions

As the EU-Rail started official on 30 November 2021, the operational activities performed in December 2021 and in 2022 in relation to EU-Rail are already summarized in Annex G. EU-Rail agreed with its Private Founding Members that the certification for the year 2022 would be done on voluntary basis, while all Private Founding Members shall report about the Amount of certified IKAA for the years 2022 and 2023 by 31 May 2024.

Values of certified IKAA – Evolution (in EUR)	
Year	**Amount of certified IKAA (in €)**
2021	*N/A*
2022	*16.093.788,68*
2023	*53.850.540,90*
TOTAL since 2021	*69.944.329,59*

2.4.2. S2R in-kind Contributions

In accordance with Article 174 of the Single Basic Act, Europe's Rail JU (hereinafter EU-Rail) is the legal and universal successor of the Shift2Rail JU (S2R JU). The rights and obligations in relation to the Shift2Rail Programme, hence, remain applicable under the current legal framework.

In this respect, in accordance with article 4(3) of the S2R Regulation, "the members of the S2R Joint Undertaking other than the Union shall report by 31 January each year to the Governing Board of the S2R JU on the value of the contributions referred to in paragraph 2 made in each of the previous financial years".

Article 4(2) of the S2R Regulation establishes that the total contribution to be provided by the Other Members[58] and totalling EUR 470 million shall consist of:

IKOP[59] (in-kind contribution to operational activities): at least EUR 350 million, including at least EUR 200 million from the founding members other than the Union and their affiliated entities, and at least EUR 150 million from associated members and their affiliated entities. In accordance with Article 16(3)b of the S2R Statutes, IKOP consists "of the costs incurred by them [the S2R Other Members] in implementing indirect actions less the contribution of the S2RJU and any other Union contribution to those costs".

IKAA (in-kind contribution to other activities): of at least EUR 120 million, of which at least EUR 70 million from the founding members other than the Union and their affiliated entities, and at least EUR 50 million from associated members and their affiliated entities. These contributions shall consist of the costs incurred by them in implementing additional activities outside the work plan of the S2R Joint Undertaking, which are complementary to this work plan and contribute to the objectives of the S2R Master Plan. Other Union funding programmes may support those costs in compliance with the applicable rules and procedures. In such cases, Union financing shall not substitute for the in-kind contributions from the Members other than the Union or their affiliated entities.

The aforementioned in-kind contributions, which consist of financial expenditure executed by the Members – salaries, assets, operations, etc. – to achieve the S2R Programme and its Projects, are in addition to the cash contribution of the S2R Other Members to the 50% of the running costs of the JU.

S2R Other Members' reporting for 2023

58 The "Other Members" consist of the Founding Members of S2R, with the exclusion of the Union, and the Associated Members.
59 As laid down in Article 16(2) and Article 16(3)(b) of the S2R Statutes.

The Other Members of S2R submitted their reporting on IKOP and IKAA to the JU by 31 January 2024.

The Lighthouse projects are excluded from this reporting as assimilated to open calls and within the administrative management of the European Commission. This report covers IKOP related R&I activities as from Sept 2016 till Dec 2023, which is the end period for the S2R Programme operational activities; in terms of IKAA the activities are considered eligible as from the date of acceptance by the Other Members of the S2R JU Statutes, by means of their respective letters of endorsement.

In accordance with Article 4(4) of the S2R Regulation, the Other Members shall have the costs related to IKOP and IKAA certified by an independent external auditor appointed by the entity concerned.

IKOP and IKAA Certification

By 30 April 2023, the S2R Other Members have provided the JU with audit certificates on the IKOP and IKAA costs declared for the year 2022. After due examination of the relevant certification and, in particular, the audit standards applied to the issuance of the "audit certificates", the acceptable corresponding IKOP contributions have been "validated" by the Executive Director and will therefore be accounted towards the obligation set in Article 4(2) of S2R Regulation to the S2R Other Members.

By the deadline of 31 January 2024, none of the S2R Other Members was in the position to have its costs related to 2023 IKOP and IKAA certified. Nonetheless, this is in line with Commission position communicated officially in July 2016, which clarifies that the certification of costs (based on which IKOP is calculated) should be annual and it should be transmitted to the relevant JU by its members by 30 April. This is also essential for the preparation of the Final Annual Accounts of the JU to avoid an external auditor's qualified opinion on them.

With regard to the Final Accounts of EU-Rail:

- considering the reported values of the total project costs and the certificates already submitted by the end of April, an estimated value of approx. EUR 44.7 million was recorded in the annual accounts as IKOP to be validated; The validation of the full amount during the course of 2024 could bring the value of the total validated IKOP to approx. EUR 360 million.
- the validation of IKOP by the JU will be performed in conjunction with the financial closure of the programme and is highly dependent on the timely submission of the certificates.

Additional information

IKOP

The progress is in line with a Programme Management S-Curve (with 88% of linear time consumed since September 2016 and with 105% of the IKOP objective reported).

As indicated under the definition of IKOP, these costs represent the difference between the Total Project Value of S2R projects and the EU-Rail co-funding (or estimated).

The 2023 IKOP is the cumulative result of the activities awarded by EU-Rail to the Other Members:

EUR million	R&I activities			%
	awarded and signed	realized		
	Sept 16 - Dec 21	2023	Sept 16 - Dec 23	
Total Value	**618,1**	**60,1**	**627,1**	*101,5%*
S2R co-funding	271,9	20,7	267,0	*98,2%*
IKOP	**346,2**	**39,4**	**360,1**	***104,0%***

In order to allow EU-Rail to be in the position to sign the relevant grant agreements, the Union provided the necessary Commitment Appropriations to match the S2R Programme co-funding of EUR 271.9 million above (excluding OC), against the S2R Other Members' commitment of EUR 619.4 million. In terms of Union Payment Appropriations, they were used to provide the pre-financing up to 45% till 2019 and 55% for the call 2020 (to maintain cash flow in the current economic negative situation created by the C-19 pandemic) of the estimated funding in accordance with the relevant provisions of the grant agreements. In 2021, only two projects were signed following the call 2021 with limited contribution and impact from the S2R Other Members'.

It should be noted that the estimated requested co-funding included in the 2021 Other Members' declarations is within the limits of the provision of the relevant Membership Agreements. In fact, Article 2.2 of each Other Member's Membership Agreement signed with EU-Rail establishes that "the Member agrees to limit its reimbursement request in indirect actions funded under Article 3(1)(a) of the S2R JU Regulation to an amount not exceeding 44.44% of the Member's total eligible costs in implementing indirect actions. In case of research and innovation activities delivering the expected results through a series of intertwined actions throughout successive S2R JU Annual Work Plans, and without prejudice to the provisions concerning co-funding rates established in the S2R JU Annual Work Plans, this 44,44% threshold shall be applied cumulatively taking into account the final amount of reimbursement requested at the end of the last action implementing the specific intertwined research and innovation activities".

The percentage resulting from the cumulative reimbursement requests in all indirect actions for S2R Other Members in 2023 is 42.58%, within the maximum level of 44.44%.

However, it is to be noted that the intermediary reports of the following Members show the most important deviation with respect to an IKOP rate below 55.56% event if overall, it is to be noted that the collaboration of all Members during the reconciliation exercise 2023 has allowed to show important improvement compared to last year reporting and percentages. Here below are reported the Members with the biggest deviation still to be resolved with a reconciliation exercise in 2024.

Associated Members:

- CFW 46.74%
- SmartRacon 45.45%
- SNCF 44.72%
- Switracken 45.78%

While some are still slightly above but also have significantly improved their position since last year reporting (e.g., Indra, Kontron).

This will be brought to the attention of the Governing Board for any remedial action to be taken and followed up by the EU-Rail in 2024 and in any case will result in a grant final payment which will correspond in a cumulative rate not exceeding[60] 44.44% rate by the end of June 2024, when it is expected that all final payments for S2R Programme would be executed.

[60] In this respect, the Governing Board adopted Decision 16/2018 amending the Other Members' model Membership Agreement.

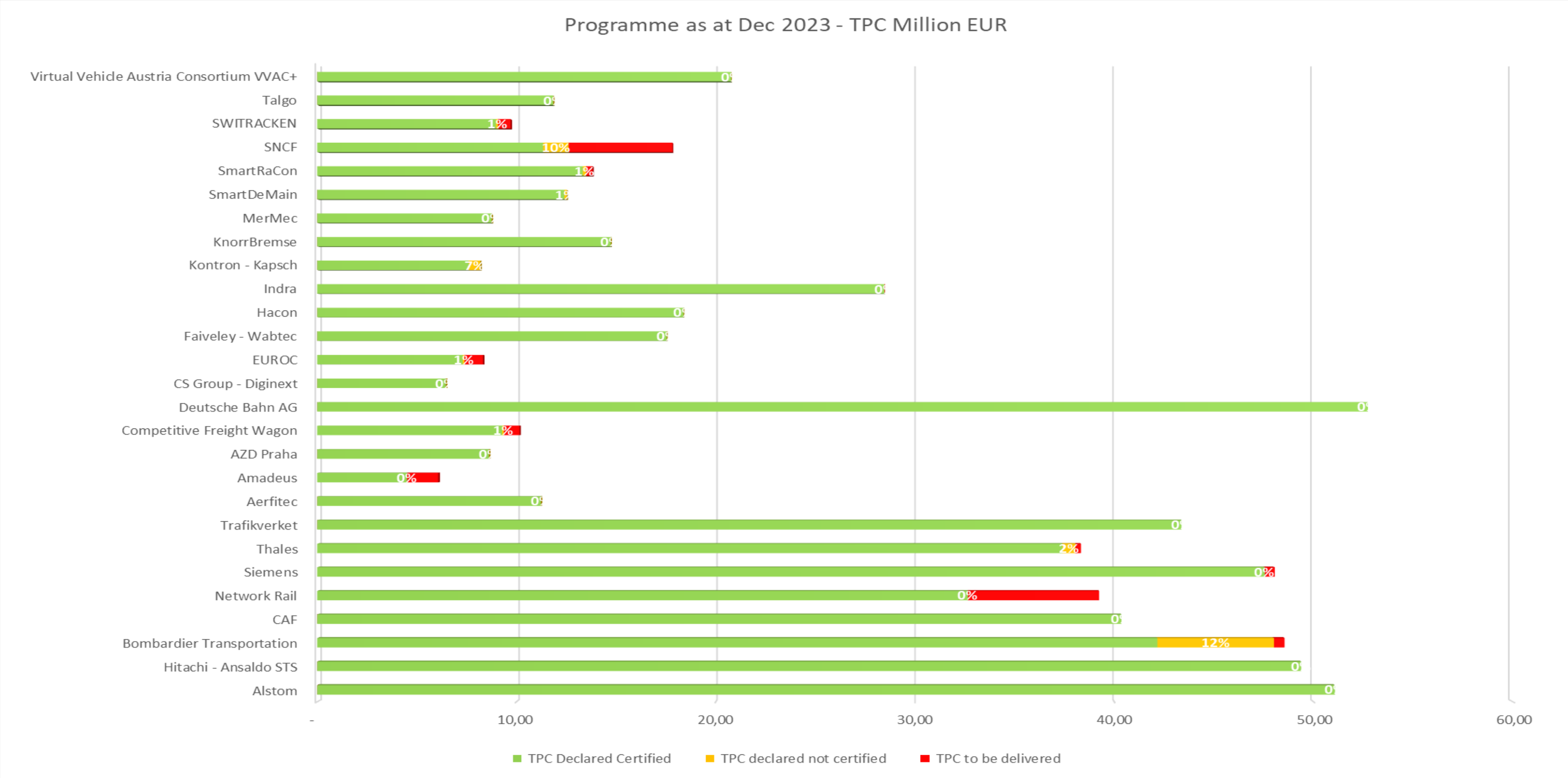
IKAA

In terms of IKAA, the total contribution for the S2R Programme has now reached EUR 266.8 million, 122% above the regulatory obligation of minimum EUR 120 million.

On 30 April, based on the declarations and the Projects' cost statements, the situation of IKOP and IKAA was the following:

	TPC/IKOP REPORTING												
	TOTAL PROJECT COST				CO-FUNDING			IKOP					
Other Members	AAR 2016 - AAR 2022	AAR 2023	TOTAL	of which CERTIFIED	AAR 2016 - AAR 2022	AAR 2023	TOTAL	AAR 2016 - AAR 2022	AAR 2023	TOTAL	*Validated as Net Assets*	*To be validated*	*Deviance as per MA Art 2(2)*
Alstom	49.906.187	1.167.024	51.073.211	***51.073.211***	21.032.930	440.548	**21.473.478**	28.873.256	726.476	**29.599.732**	*28.701.262*	*898.471*	*42,04%*
Hitachi / Ansaldo STS	44.931.598	4.451.569	49.383.167	***49.383.167***	20.204.956	1.619.113	**21.824.069**	24.726.642	2.832.456	**27.559.098**	*24.257.895*	*3.301.202*	*44,19%*
Bombardier Transportation	42.259.887	5.753.627	48.013.514	***42.163.898***	17.712.691	3.035.403	**20.748.094**	24.547.196	2.718.224	**27.265.420**	*22.966.399*	*4.299.021*	*43,21%*
CAF	38.663.871	1.697.448	40.361.319	***40.361.319***	16.565.908	811.637	**17.377.544**	22.097.964	885.811	**22.983.775**	*21.889.533*	*1.094.242*	*43,05%*
Network Rail	24.692.469	7.962.315	32.654.784	***32.654.784***	13.530.922	839.203	**14.370.125**	11.161.547	7.123.112	**18.284.659**	*10.014.308*	*8.270.351*	*44,01%*
Siemens	44.993.181	2.562.093	47.555.274	***47.555.274***	19.950.090	2.089.071	**22.039.161**	25.043.091	473.022	**25.516.113**	*24.478.874*	*1.037.239*	*46,34%*
Thales	34.031.815	4.020.775	38.052.590	***37.392.235***	14.726.529	1.949.249	**16.675.777**	19.305.286	2.071.526	**21.376.812**	*18.892.279*	*2.484.533*	*43,82%*
Trafikverket	40.020.950	3.351.877	43.372.828	***43.372.828***	16.325.435	1.557.562	**17.882.998**	23.695.515	1.794.315	**25.489.830**	*22.907.472*	*2.582.358*	*41,23%*
Founding Members	**319.499.958**	**30.966.729**	**350.466.687**	**343.956.715**	**140.049.462**	**12.341.785**	**152.391.247**	**179.450.496**	**18.624.943**	**198.075.440**	**174.108.023**	**23.967.417**	
Aerfitec	10.843.327	382.159	11.225.486	***11.225.486***	4.865.690	30.706	**4.896.396**	5.977.638	351.453	**6.329.090**	*4.357.826*	*1.971.264*	*43,62%*
Amadeus	4.514.883	-6.395	4.508.487	***4.508.487***	2.382.149	-35.522	**2.346.626**	2.132.734	29.127	**2.161.861**	*2.126.339*	*35.522*	*52,05%*
AZD Praha	7.944.705	673.137	8.617.842	***8.617.842***	3.487.427	71.234	**3.558.660**	4.457.278	601.904	**5.059.182**	*4.430.785*	*628.396*	*41,29%*
Competitive Freight Wagon	7.040.419	2.325.597	9.366.017	***9.279.870***	3.079.013	1.298.435	**4.377.448**	3.961.406	1.027.162	**4.988.568**	*4.808.910*	*179.659*	*46,74%*
Deutsche Bahn AG	49.107.438	3.624.740	52.732.178	***52.732.178***	18.228.306	1.927.851	**20.156.157**	30.879.132	1.696.889	**32.576.021**	*29.929.852*	*2.646.169*	*38,22%*
Diginext	5.966.672	483.027	6.449.699	***6.449.699***	2.608.288	203.282	**2.811.570**	3.358.384	279.745	**3.638.129**	*3.352.207*	*285.922*	*43,59%*
EUROC	4.791.468	2.598.719	7.390.187	***7.295.903***	2.225.185	522.340	**2.747.525**	2.566.283	2.076.379	**4.642.662**	*2.263.831*	*2.378.831*	*37,18%*
Faiveley - Wabtec	17.626.407	-84.465	17.541.942	***17.541.942***	6.766.935	-119.173	**6.647.763**	10.859.471	34.708	**10.894.179**	*10.804.561*	*89.618*	*37,90%*
Hacon	17.767.595	612.293	18.379.888	***18.379.888***	7.983.657	-363.715	**7.619.943**	9.783.938	976.007	**10.759.945**	*10.160.568*	*599.377*	*41,46%*
Indra	23.979.188	4.490.261	28.469.450	***28.469.450***	11.534.953	1.130.657	**12.665.609**	12.444.236	3.359.604	**15.803.840**	*12.141.285*	*3.662.555*	*44,49%*
Kontron - Kapsch	7.600.368	579.318	8.179.686	***7.597.270***	3.435.178	174.139	**3.609.317**	4.165.190	405.179	**4.570.369**	*4.102.996*	*467.373*	*44,13%*
KnorrBremse	14.068.647	664.813	14.733.459	***14.733.459***	4.352.061	456.439	**4.808.500**	9.716.586	208.373	**9.924.959**	*9.394.970*	*529.989*	*32,64%*
MerMec	8.255.588	495.224	8.750.813	***8.750.813***	3.504.038	351.371	**3.855.409**	4.751.550	143.853	**4.895.403**	*4.633.198*	*262.206*	*44,06%*
SmartDeMain	8.998.225	3.522.468	12.520.693	***12.399.823***	4.974.880	479.963	**5.454.843**	4.023.344	3.042.505	**7.065.850**	*6.067.079*	*998.770*	*43,57%*
SmartRaCon	11.343.955	2.148.882	13.492.837	***13.326.834***	5.237.133	894.874	**6.132.008**	6.106.821	1.254.008	**7.360.829**	*7.016.937*	*343.892*	*45,45%*
SNCF	11.397.825	1.219.888	12.617.712	***11.332.718***	5.839.772	-196.816	**5.642.956**	5.558.053	1.416.703	**6.974.756**	*5.956.199*	*1.018.558*	*44,72%*
SWITRACKEN	7.444.378	1.629.442	9.073.819	***8.966.623***	3.380.729	773.609	**4.154.338**	4.063.649	855.833	**4.919.482**	*3.507.535*	*1.411.947*	*45,78%*
Talgo	10.450.480	1.388.336	11.838.816	***11.838.816***	4.803.042	61.577	**4.864.619**	5.647.438	1.326.759	**6.974.197**	*5.589.629*	*1.384.568*	*41,09%*
Virtual Vehicle Austria Consortium VVAC+	18.369.450	2.404.313	20.773.763	***20.773.763***	7.606.800	676.165	**8.282.965**	10.762.650	1.728.149	**12.490.798**	*10.671.570*	*1.819.229*	*39,87%*
Associated Members	**247.511.016**	**29.151.758**	**276.662.774**	**274.220.864**	**106.295.235**	**8.337.418**	**114.632.653**	**141.215.781**	**20.814.341**	**162.030.121**	**141.316.275**	**20.713.846**	
Total	**567.010.974**	**60.118.487**	**627.129.461**	**618.177.579**	**246.344.697**	**20.679.203**	**267.023.900**	**320.666.277**	**39.439.284**	**360.105.561**	**315.424.298**	**44.681.263**	**42,58%**

Other Members	IKAA REPORTING In-Kind Additional Activities as at 31 December 2023	In-Kind Additional Activities as at 30 April 2024	TOTAL	*of which Certified as at 1 June 2024*
Alstom	11.912.418	-	**11.912.418**	*11.912.418*
Hitachi / Ansaldo STS	9.854.167		**9.854.167**	*9.854.167*
Bombardier Transportation	15.688.168		**15.688.168**	*15.688.168*
CAF	20.432.481		**20.432.481**	*8.946.296*
Network Rail	2.220.203	21.027.798	**23.248.000**	*23.248.000*
Siemens	10.950.000		**10.950.000**	*10.950.000*
Thales	26.936.033	-	**26.936.033**	*26.936.033*
Trafikverket	25.159.312	-	**25.159.312**	*17.302.291*
Founding Members	123.152.782	21.027.798	144.180.580	***124.837.373***
Aerfitec	2.050.291	229.381	**2.279.671**	*2.279.671*
Amadeus	17.496.678		**17.496.678**	*17.496.678*
AZD Praha	3.627.880	1.175.792	**4.803.673**	*4.803.672*
Competitive Freight Wagon	1.311.596		**1.311.596**	*1.039.853*
Deutsche Bahn AG	29.084.129	151.090	**29.235.220**	*29.235.220*
Diginext	1.977.115	101.686	**2.078.801**	*2.078.801*
EUROC	9.777.478	4.386.412	**14.163.890**	*14.163.890*
Faiveley - Wabtec	3.303.537	166.264	**3.469.801**	*3.469.801*
Hacon	18.872.992		**18.872.992**	*18.872.992*
Indra	5.426.000		**5.426.000**	*5.426.000*
Kontron - Kapsch	3.980.835		**3.980.835**	*3.980.835*
KnorrBremse	9.551.294		**9.551.294**	*9.372.373*
MerMec	2.667.014		**2.667.014**	*2.667.013*
SmartDeMain	5.224.492		**5.224.492**	*5.054.040*
SmartRaCon	1.094.299	2.496.163	**3.590.462**	*3.590.462*
SNCF	5.333.903		**5.333.903**	*4.845.155*
SWITRACKEN	26.892	29.365	**56.257**	*2.569.446*
Talgo	2.906.321		**2.906.321**	*2.906.321*
Virtual Vehicle Austria Consortium VVAC+	7.132.484	972.163	**8.104.648**	*8.104.648*
Associated Members	130.845.230	9.708.317	140.553.546	***141.956.870***
Total	253.998.012	30.736.114	284.734.126	266.794.243


Programme as at Dec 2023 - TPC Million EUR
Virtual Vehicle Austria Consortium VVAC+
Talgo
SWITRACKEN
SNCF
SmartRaCon
SmartDeMain
MerMec
KnorrBremse
Kontron - Kapsch
Indra
Hacon
Faiveley - Wabtec
EUROC
CS Group - Diginext
Deutsche Bahn AG
Competitive Freight Wagon
AZD Praha
Amadeus
Aerfitec
Trafikverket
Thales
Siemens
Network Rail
CAF
Bombardier Transportation
Hitachi - Ansaldo STS
Alstom
10%
7%
2%
12%
-
10,00
20,00
30,00
40,00
50,00
60,00
TPC Declared Certified
TPC declared not certified
TPC to be delivered

2.5. Administrative Procurement and contracts

In order to reach its objectives and adequately support its operations and infrastructures, the JU continued in 2023 to allocate funds by procuring the necessary services and supplies. In the interest of sound financial management the JU made, to the possible extent, use of Service Level Agreements (SLAs) with relevant Commission services and EU Agencies (such as in the field of ICT, training, payroll, mission, experts reimbursements, interim staff, etc.).

As it was the case in 2022 for the SLA implementing the back office arrangements for the accounting services with other JUs, in 2023 EU-Rail signed an SLA implementing the back office arrangements for procurement with other JUs. In addition, EU-Rail signed an SLA with European Union Agency for Law Enforcement Training (CEPOL) in order to provide them accounting services for a shorten period.

EU-Rail did not sign in 2023 any new SLAs with European Commission services, only amendments to the existing ones to include additional services or to remove services that became obsolete.

In 2023 EU-Rail continued to participate in inter-institutional framework contracts (e.g.: IT, audit, office furniture, insurance, human resources services) by signing Memoranda of Understanding. In particular, to ensure synergies between the JUs, in 2023 EU-Rail continues to implement a Multiple Framework Service Contract in cascade (4 lots) for communication services between Clean Aviation (lead JU), SESAR and EU-Rail Undertakings. As indicated in section 1.4.2, EU-Rail continues to implement its framework contract for services related to support to programme management and legal assistance. At this regard, in order to ensure synergies between the JUs, EU-Rail – as the sole contracting authority- managed, signed and implemented specific contracts for other JUs, with the prior signature of SLA with those JUs to formalise the process and the transfers of amounts from the other parties to EU-Rail for the payment provided for in the specific contract (via "debit notes"). This approach was validated by the European Court of Auditors during the Audit of the annual accounts of the EU-Rail concerning the financial year 2022 and EU-Rail complied with the transparency requirements by publishing such specific contracts in the EU-Rail recipients of funds (see below).

In 2023 EU-Rail awarded a negotiated procedure without prior publication of a contract notice[61] to build-up a stand for the 2023 UITP Summit (4-7 June 2023). The event organiser confirmed that company FIRA INTERNACIONAL DE BARCELONA was the sole economic operator which centralised the stand's build. Therefore, this company had a monopolistic position in the market for the provision of those services. EU-Rail awarded the contract (purchase order) to this company for an amount of EUR 49.946. The contract resulting from this negotiated procedure will be published in the EU-Rail recipient of funds 2023 to meet the ex-post publicity obligations.

Where SLAs or a FWCs were not available for specific services or supplies, the JU resorted to middle and low-value contracts. As indicated in the Amended Work Programme 2022-2024, in 2023 EU-Rail launched several very-low value procedures (i.e.: below EUR 15.000) for e.g.: team building, subscriptions to journals and periodicals, catering services.

In accordance with Article 15 (Principle of transparency) of the EU-Rail Financial Rules the JU shall make available on its internet site no later than 30 June of the following financial year information on the recipients of funds deriving from its budget, including procurement contracts. In addition, as stated in point 3.3 of Annex I to the Financial Regulation 2018/1046 (which applies to the JU), EU-Rail, as a contracting authority, shall publish a list of contracts on its website no later than 30 June of the following financial year for specific contracts and order forms implementing a framework contract. The EU-Rail recipients of Funds and Annual List of Specific Contracts for 2022 are published at https://rail-research.europa.eu/participate/recipients-eu-rail-funds/.

In order to establish the maximum values of procurement contracts, where necessary, the JU makes use of the collective experience of its involved staff, its Members and experts, as necessary, driven by the principle of sound financial management. Although this was not formally documented in formal acts, audit trails are available also in the exchanges between the staff and the procurement sector to finalize the call for tenders before the approval by the Executive Director.

[61] Point 11(b) Annex 1 EU Financial Regulation - monopolistic situation.

In 2023, for open procedures, the JU continued using the e-tendering and the e-submission platforms available from the TED e-Tendering website and accessible on the Funding and Tenders Opportunities portal[62]. In the context of the eProcurement strategy, in 2022 EU-Rail started the on-boarding process of the Public Procurement Management Tool (PPMT), the tool that will replace TED e-notices and e-tendering. The on-boarding process finalised in April 2023. New open tender procedures that EU-Rail intend to launch in 2024 will be published using the PPMT tool.

During 2023 several guidance documents and templates for procurement procedures continued to be updated by the Chief Legal Officer (i.e.: calendar, tender specifications, opening and evaluation of tenders, award procedures for low value contracts, etc.) to adapt them to JU needs and to the DG BUDG recommendations, in particular to the e-submission and PPMT procedures. In addition, the register of framework contracts, SLAs and Memoranda of Understanding has been regularly updated to ensure a proper follow-up of the SLAs and FWCs in force.

In 2023, the register of procurement contracts built from ABAC legal commitment (LCK) continued to be updated. The "e-contract register" contains records of all JU's legal commitments (i.e.: "procurement contracts and grant agreements") and thus serves also as the source of data for publication of the "EU-Rail Annual Recipient of Funds, including all specific contracts implementing framework contracts" information on its website. The register also allows the monitoring of the JU's consumption of framework contracts.

2.6. IT and logistics

The JU's focus was on the core activities: since its creation, the JU has been one of the most active promoters of a single approach for all the JUs to the ICT environment, reducing costs, outsourcing, and increasing performance.

In this respect:

a. Use of European Commission applications and framework contracts

The JU has implemented common ICT tools designed and made available by the EC for the financial and call management. These tools are updated and maintained on regular basis by the EC; they require continuous input from the side of the JU, on the one hand, to correct the multiple and repetitive mistakes and, on the other hand, in terms of future developments to meet the expectations of the partnership. The follow-up of these processes absorbs multiple resources of the JU.

In order to ensure the correct usage and implementation of these applications, JU makes use of the training services offered by the EC on these applications.

For the execution of the calls for proposals, the IT systems were used throughout the entire process: for the publication of the call, for the submission and evaluation of the proposals as well as for grant preparation. The EC IT systems "e-submission/e-tendering" have also been used since 2020 by the JU for operational tender procedures.

In addition to the extended use of the Commission financial applications, the JU adopted the EC's ICT systems for HR (Sysper) and daily document management (ARES) to leverage the EC's proven working technology solutions already in place, but also to streamline and further harmonize the processes, workflows, procedures of record management, document archiving and electronic document cataloguing, secure storage and document access.

The JU continued to make use of the Commission's ICT framework contracts to procure all ICT services required to run its activities.

b. Use of European Agencies' framework contracts, including with or on behalf of other JUs

[62] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home

In addition, EU-Rail participates to the joint strategic ICT plan of the JUs located in the White Atrium building. Since 2018, EU-Rail shares its virtual IT infrastructure that is hosted by a private cloud computing provider and also shares the ICT managed services performed by a private company, in synergy with the other JUs. In 2020, the connectivity to the EC tools has also been migrated to this private cloud, which provides a full mobility and independence from the EU-Rail premises, and which proved to be very efficient during the Covid-19 pandemic. In 2020 and 2021, EU-Rail has also further integrated other agencies to benefit from these services, such as ERA, ELA, BEREC, etc., building upon a unique know-how of synergies' service model.

In 2020, on behalf of all the JUs, the JU commissioned a Data Protection Impact Assessment (DPIA) and security risk assessment on the migration to Microsoft Office 365 public cloud environment, as required by the adopted EU regulation on the protection of personal data by EU institutions and bodies (Regulation (EU) 2018/1725). The DPIA identified the inherent risks that can be mitigated through a series of identified measures with the conclusion that the residual risks are qualified as "under control". Along with the progressive implementation of these mitigating measures, EU-Rail started in 2021 to migrate to Office 365 in synergy with the other JUs, first to Teams for meetings, then to SharePoint and OneDrive. The main Office 365 assets were migrated in 2022, starting with Exchange online as well as the document libraries in SharePoint, and Teams groups. The mitigating measures and migration for the other assets were implemented at end-2022.

2.7. Human Resources

2.7.1. HR Management

In 2023, no new Staff Implementing Rules (SIR) were adopted. The adoption of the new Decision on Working Time and Hybrid working, and its' adaptation to the specificities for EU-Rail is tabled for early 2024. In line with the 2023 Establishment Plan, all recruitment procedures were launched and finalized within the year in order to recruit and replace departing statutory staff. At the end of the year, EU-Rail was staffed with 29 staff members including 2 Seconded National Expert (SNE). The occupational rate for statutory staff was 97%, due to the vacant post of Executive Director.

In 2023, 2 contractual agents were recruited by means of an external selection procedure, 2 were recruited making use of existing reserve lists (internal and inter-Agency).

In addition to statutory staff members and the SNEs already in place, EU-Rail made recourse to Interim Staff and made use of the European Commission's Bluebook scheme to hire trainees.

Further details on the staffing are provided in the Staff Establishment Plan in Annex B.

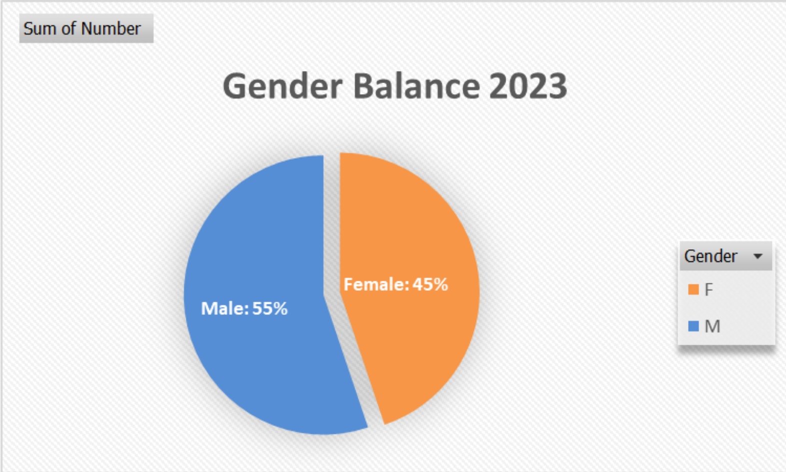
In addition to recruitment activities, the EU-Rail HR Officer ensured the conduct of the day-to-day personnel-related administration not covered by the Commission central services and continued to ensure improvement of all HR processes and to develop its internal guidelines, policies, and legal framework, paying particular attention to how EU Staff Regulations' Implementing Rules shall apply to the JU's particularities (in accordance with Article 110 of the EU Staff Regulations).

Annual appraisal and reclassification exercises were set up by HR within the limits of the Staff Establishment Plan and the EU-RAIL Financial Rules.

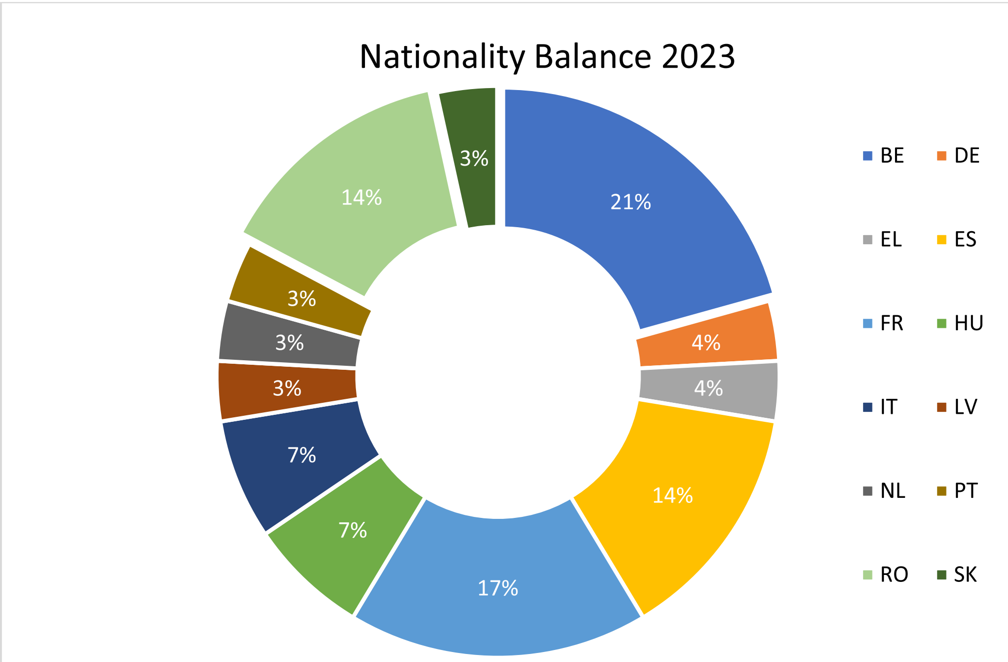
In line with the applicable Decision on working time and hybrid working, EU-Rail ensured on a continuous basis a good working environment and team spirit. In-house trainings/info sessions were also developed and proposed to staff with regard to HR-related aspects. The EU-Rail organized its first Away Day in order to ensure team cohesion. In 2023, the JU provided team coaching in order to develop a common understanding and ensure a wide adoption of the EU-Rail corporate values. Synergies with other JUs were exploited in terms of training, with colleagues participating in trainings dedicated to Respect and Dignity at work and to Prevention and Detection of Fraud.

The JU also continued to implement its action plan resulting from its last staff survey. A fit-for-purpose organisational structure with clear roles and responsibilities was designed and the EU-Rail Governance and Process Handbook was adapted in light of the changes to the organisation structure and governance, reflecting the new Programme content and processes.

In 2023, the gender representation in the JU was as follows:



Geographical balance:



2.7.2. Efficiency gains and synergies

In 2023, the JU's major challenge was to continue in the successful and smooth transition towards the new EU-Rail Programme.

From the HR perspective, EU-RAIL is committed to ensuring the well-being of staff and that every staff member reaches their full potential. Trainings were strongly encouraged, and staff events were organised on regular basis in order to reinforce the cohesion of the team, the staff engagement and motivation.

The JU continued to review its processes with the support of a consultancy company and defined 3 main HR areas to work on:

- Develop a future-proof competency framework to guide recruitment and sourcing of expertise;
- Establish a sourcing strategy for ensuring optimal delivery of services with limited resources;
- Establish a talent development plan to provide perspective and training;

In 2023, the JU defined priorities among these topics and developed an action plan and indicative timeline for each one of them. In order to ensure synergies and efficiencies are exploited, the EU-RAIL HR ensured close collaboration with the Network of JUs' HR officers. In detail, EU-RAIL optimised synergies and efficiency gains by sharing reserve lists to shorten time to recruit, providing expertise and resources for selection procedures of other JUs and contributing to the development of a common legal framework among JUs by sharing ED and GB decisions on diverse regulatory topics.

In terms of operational efficiencies, EU-Rail was the first body of the Union together with the Commission to introduce since 2018 the Lump Sum form of granting. Based on the experience acquired and in line with the overall targets of Horizon Europe, the lump sum approach is the primary implementation way of the Programme. This will provide opportunities to focus the resources on added value functions, in particular on the cost effectiveness of the projects towards achieving the EU-Rail Programme results.

In terms of synergies and collaboration with the other Joint Undertakings, the Single Basic Act[63] establishes that the JUs shall achieve synergies via the establishment of back office arrangements (BOA), operating in some identified areas and by concluding service level agreements (SLAs). The SBA also underlines that these synergies should be implemented where screening of resources has proved to be efficient and cost-effective, while respecting the autonomy and the responsibility of each Authorising Officer.

In order to obtain an independent view on the possible synergies among the JUs and the impact in terms of efficiencies, the JUs contracted an external consultant to perform a study on BOA. The study was finalised in July 2022 and the JUs identified and decided to implement from 2022 and 2023 the preferred model for the back office arrangements considering a setup with one JU taking the lead dealing in coordinating tasks with one backup JU, organising the work among staff of several JUs and having a clear scope and decision-making power, as was used in BOA for the provision of accounting services (following DG BUDG decision to terminate the respective contract with the JUs).

For some synergies, a more flexible option was chosen, with collaboration involving only some JUs, while remaining open for the others to join at a later stage.

The preparation work led to establishment of coordinated plans, prioritising those aspects of the BOA that had the objective to bring most value in the short term. These included, as top priorities, (i) the accounting function (ii) IT deployment (iii) joint procurement opportunities and (iv) HR support. These topics encompass 4 of the 7 synergies as per SBA Article 13. This approach was endorsed by the respective JUs Governing Boards.

When these arrangements were presented, the respective JUs Governing Boards stressed the need to have a balanced approach to the BOA implementation ensuring, as a priority, the execution of JUs' core businesses (ensuring budget execution and call implementation) which is very challenging in the context of a new programme with new legislation, new actors and ambitious timelines due to the delayed launch of the Horizon Europe programme.

The BOA that were put in place between 2022 and 2023, or submitted for proposal for implementation, were:

[63] Article 13, Council Regulation (EU) No 2021/2085, of 19 November 2021

AREA	CONTENT	LEAD JU
Accounting	Accounting services	EU RAIL JU
ICT	ICT services	Clean Hydrogen JU
HR	Common Recruitment, HR Legal framework and HR digitalisation	CBE JU
Legal	Administrative procurements	Clean Aviation JU

In detail, those BOA were put in place or submitted for proposal through the following action plans:

- **BOA for Accounting Services**

The JUs took over the Accounting services that until 30 November 2022 were provided by DG BUDG and succeeded in implementing the BOA for Accounting Services in 2022, and immediately for the accounting closure 2022.

EU-Rail is the lead JU of this BOA and concluded the SLA with the other JUs on 16 December 2022. Accounting services will be provided by 3 Accounting Officers coming from the following JUs: CA JU, SESAR JU and EU-Rail JU.

Organisation:

- The Executive Director of the Lead JU is responsible for the organization, oversight and coordination of the accounting services to the other JUs on the basis of an annexe of the BOA SLA.
- The Head of Corporate Services or another officer with the necessary grade, skills and competencies of the Lead JU shall act as Accounting Coordinator of the BOA Accounting Officers.
- The Accounting Officer(s) of the JU Accounting Providers delivers the service to one or more JU Accounting Beneficiary and is responsible for the accounts she/he signs off, while counting on the support and coordination with the lead JU.

In order to ensure the provision of these services, it was agreed between the EC and the JUs to make use of the support of 3 additional Contractual Agents and of an external Accounting Services provider.

The BOA for Accounting services are fully operational and are delivering the intended services, including the preparation of the Annual Accounts for 10 Joint Undertakings. As of January 2024, the BOA team is composed of 3 Accounting Officers supported by 3 Accounting Assistants.

- **BOA HR**

For what concerns the HR domain, the study recommended to explore synergies by coordinating the management of SYSPER, possibly obtaining a single contract for all JUs, perform joint recruitments, harmonise job profiles and procedures.

These synergies will allow to obtain a better harmonisation among the JUs, exploiting best practices, achieving efficiency gains and economies of scale. The particular areas where this BOA will act are recruitment, legal framework and IT landscape in the HR domain.

Following the screening of HR resources in each JU, the study also points out that no more than marginal FTE gains would be achieved in this area due to the very limited HR dotation of the JUs.

These arrangements were presented to the GB during its 8th meeting on 23 June 2023 and the GB approved the Back Office Arrangements – Human Resources by written procedure on 28 July 2023[64]. The signature of the SLA, under the lead of CBE JU, is on-going.

- **BOA ICT**

The ICT area covers a list of ~50 services (service catalogue) structured in 6 service groups:

1. Inter-JU IT Governance,
2. Management of shared ICT infrastructure,
3. Management of ICT tools, services and contracts,
4. Workplace services provision,
5. Security and compliance management,
6. ICT activities specific per JU.

The underlying concept is that, out of the ICT service catalogue, everything that is non-specific to a JU should be managed through the ICT BOA. Therefore, ICT developments and other activities specific to each JU will be under the responsibility of each ED and will not be part of the ICT BOA, that in any case will have to ensure the integrity of the overall ICT architecture.

Following the formal proposal for BOA in the area of information and communication technologies sent by the Clean Hydrogen JU to the Executive Directors of the Joint Undertakings, on 20 December 2023, EU-Rail expressed interest in joining this BOA.

- **BOA Procurement**

To agree on the concept of the BOA Procurement, the Clean Aviation JU (CA JU) organised on the 7 October 2022 a 'BOA co-design Workshop' addressed to all JUs which expressed their interests in the BOA Procurement, presenting the concept and the principles of the joint cooperation.

This BOA has been established with the objective of centralising administrative procurement capability and process to maximise open tenders for award of inter-JUs FWCs and middle value negotiated procedures.

The concept was supported by the bi-annual Joint Public Procurement Planning reflecting the common needs identified by the Parties. On this basis a Service Level Agreement was drafted by the BOA Procurement Coordinator (CA JU) and following the conclusion of the consultation and approval by all the JUs is currently under the signature process.

The focus is on the critical joint administrative procurement such as ICT, building management/corporate services and common support services that will be identified and agreed via joint Public Procurement Planning (PPP).

These arrangements were presented to the GB during its 8th meeting on 23 June 2023 and the GB approved the Back Office Arrangements – Human Resources by written procedure on 28 July 2023[65]. The SLA, under the lead of Clean Aviation JU, was signed on 8 November 2023.

2.8. Data protection

In 2023, the JU continued to implement the EU data protection policies and legal framework. As regards the processing of personal data, the JU applied the current EU Data Protection rules (Regulation (EU)

[64] Governing Board Decision n°12/2023
[65] Governing Board Decision n°12/2023

2018/1725 or "EUDPR"[66]) that entered into force on 11 December 2018. In particular, the JU Data Protection Officer (DPO) followed the recommendations and guidance provided by the European Data Protection Supervisor (EDPS), attended the different data protection meetings and networks, coordinated his work with the other DPOs and provided guidance to JU staff on data protection issues.

To ensure compliance with the data protection principles and synergies with the other Joint Undertakings, EU-Rail took the following actions:

- as a "leading contracting authority" in 2023:
  - continued the monitoring of a common inter-JU central on-line register of records of activities processing personal data (article 31(5) Regulation (EU) 201 8/1725) tailor-made to the needs of the JUs;
  - In accordance with article 43(4) of Regulation 2018/1725, in 2022 EU-Rail started the process of exploring the possibility to externalise – at least partially- the DPO function to an external provider via a procurement contract, which is allowed for small or medium sized EU agencies and bodies (article 43(2) of the Regulation). In addition, sharing the same DPO tasks amongst several JUs is in line with the synergies of the back office arrangements in the legal field (Article 13 of the SBA).On this sense, EU-Rail signed in July 2023 a specific contract implementing the EU-Rail framework contract for legal assistance related to the DPO externalisation services for EU-RAIL, EuroHPC, SNS and EDCTP3 JU joint undertakings.

- Continued to reply to the EDPS requests, such as a survey ("questionnaire)" on the designation and position of the Data Protection Officer
- continued to update privacy policies and the central data protection register (https://rail-research.europa.eu/dpregister/) in order to provide transparent information, communication and modalities for the exercise of the rights of the data subjects (Articles 14 to 16 of Regulation (EU) 2018/1725).

In 2023, with the support of the external contractor Privanot under the EU-Rail framework contract for legal assistance, DPO finalised the EU-Rail data protection gap analysis and the Data Protection Action Plan.

In 2023, neither Data Protection Impact Assessments (Article 39 EUDPR) were performed by EU-Rail, nor personal data breaches were reported and notified by the DPO to the EDPS.

As in the previous year, the role of the DPO was exercised in 2023 by the JU's Chief Legal Officer. The current mandate of the DPO will expire on until 12/11/2024 (was renewed in 2019 for an additional 5 year's duration).

[66] Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC.

3. GOVERNANCE

3.1. Major developments

With the Europe's Rail Joint Undertaking going live after the SBA came into force, several new elements with regard to the organisation and governance of the JU were implemented, reflecting the design of the new EU-Rail Programme built around the two Pillars (the System Pillar and the Innovation Pillar) reinforced by a Deployment Group, including the integration/adaptation of the European DAC Delivery programme in the new structure. Further changes in this respect follow from the new Staff Establishment Plan (additional statutory staff members compared to the S2R JU and creation of the "Senior Programme Managers" layer within the Innovation Pillar Unit). The Governing Board adopted the new EU-Rail organisation structure in its meeting on 1 March 2022 (see Annex A).

Furthermore, new JU bodies were introduced as per the SBA (the System Pillar Steering Group) or are to be still introduced (the Deployment Group). On the other hand, the activities of the Innovation Programme's Steering Committees pertaining to the S2R Programme, with more and more S2R projects being finalized, are progressively getting in their phase-out stage.

Further details on EU-Rail's current governance and organisation are available by means of its Governance and Process Handbook.

3.2. Phasing-out Plan monitoring

EU-Rail adopted in December 2023 by means of the respective GB Decision[67] its Phasing-out Plan reflecting on the fact that the Joint Undertaking is set up as a Union body for a period ending on 31 December 2031 and financed under the EU multiannual financial framework 2021-2027. The phasing-out adopted by the GB followed a template provided by the Commission services and concerned only the administrative and operational adaptations needed for the "winding-up procedure", should the scenario materialize of non-renewal of the JU after 31 December 2031.

A complete plan (with short and long-terms targets, strategic alignment with the SRIA) has been submitted to the GB, with a view of the update of the plan for adoption by the end of 2024, further elaborating on other above-mentioned elements.

EU-Rail, as was the case in 2023, will continue to closely follow-up and actively contribute to the discussions among the relevant stakeholders regarding the future of the EU partnerships in the area of Research and Innovation and their possible extension for the next EU multiannual financial framework, so as to also reflect in further elaboration of its Phasing-out Plan.

3.3. Governing Board

In accordance with the Single Basic Act, the Europe's Rail Governing Board (GB) continued its work steering the Joint Undertaking through the adoption of decisions to be implemented and executed by the Executive Director. Three ordinary and one extraordinary meetings of the Governing Board were convened in 2023. The extraordinary meeting held on 30 January 2023 was due to the previously announced early retirement of the Executive Director of Europe's Rail JU, Carlo Borghini, which required the GB's confirmation, as well as the appointment of the Executive Director *ad interim*, Giorgio Travaini.

These GB meetings dealt with both operational and administrative aspects. Important decisions were taken, such as the adoption of amendments Nr 1 and 2 of the Europe's Rail JU Work Programme 2023-2024 and its Work Programme 2024, the adoption of the Consolidated Annual Activity Report 2022 and the approval of the Final Accounts - including the Budgetary Implementation Report 2022 - and of the Phasing-out plan. Additionally, the GB gave its approval to the list of actions selected for funding under the Europe's Rail Call

[67] EU-Rail GB Decision no. 14/2023.

for Proposals HORIZON-ER-JU-2022-02, including the outcome of the re-evaluation of one of the project proposals.

The GB also adopted a decision on the launch of the Call for expression of interest for the selection of the members of the Europe's Rail Scientific Steering Group (SSG) – in replacement of the Scientific Committee – and which resulted in the selection of 12 members who already had its first meeting on 15 November 2023.

The Executive Director a.i. regularly provided at each GB meeting with an update on the different activities ongoing, such as the System and Innovation Pillars, the DAC Delivery Programme and activities of performed by the JU. He informed Board members about the Programme status, in particular on the results of the Call for proposals HORIZON-ER-JU-2022-02 during its meeting of 15 March 2023. In the next meeting held on 23 June 2023, the ED a.i. presented the first concept of the Deployment Group (areas of action, scope, legal setup, resources, and any other elements, as previously endorsed by the ED-SIPB), which was later followed by a GB decision approving the selection process and specific criteria for its establishment. In the same meeting, he also provided an update on the Back Office Arrangements on human resources and procurement. Lastly, the ED a.i. also informed members on the request from CD to participate solely in FA5, and the consequent reduction of the commitment to the JU accordingly. His advice was that, in view of the updates needed for the MAWP and the technological and operational evolutions and Union priorities, to hold on before reaching an agreement on how to share the collective contribution (in accordance with article 28.2 of the SBA). GB members agreed to the request by CD and to the proposal by the ED a.i.

In the last GB meeting of the year, on 5 December 2023, the ED a.i. presented an indicative planning for the launch of the Call for expression of interest to become EU-Rail Associated Members – to be presented for approval in the upcoming meeting of June 2024. He also informed on the European Court of Auditors Annual Report outcome for JUs and on the hearing in the European Parliament with the CONT Committee about the discharge of 2022. He also provided with an update on the call for tenders "Passengers and railway workers perspective in rail transformation", which was part of the Work Programme 2022-2023.

In every GB meeting, the ED a.i. referred to the deliberations and opinions provided by the advisory bodies SRG and former SC - replaced by the SSG - during the year.

The second General Assembly was organised on 6 December 2023. According to the SBA establishing the Joint Undertakings under Horizon Europe, the GB shall meet once a year in a General Assembly and all participants to the research and innovation activities of the Europe's Rail JU shall be invited to attend.

3.4. Executive Director

According to the SBA the Executive Director (ED) is the Chief Executive Officer responsible for the day-to-day management of the JU in accordance with the decisions of its GB and being accountable to the GB. The ED is the legal representative of the Joint Undertaking. He is supported in performing his duties by the Head of Programme, the Head of Corporate Services, the Head of the System Pillar Unit as well as by all JU staff organized in the Programme Office.

In 2023, the Executive Director continued to make use of the dedicated advisory body - the ED System and Innovation Programme Board (ED-SIPB) - which replaced the ED Programme Board established under the Shift2Rail programme. The ED-SIPB provides advice and support to the Executive Director, focusing on strategic exchanges on the Innovation and System Pillars, their evolution, and interdependencies as well as strategic guidance and recommendations with regard to the management of integrated Programme and its progress.

The ED who was appointed initially in 2016 and whose mandate was renewed in 2021, informed the Governing Board at its meeting held on 30 November 2022 about his decision to step down from the position. Subsequently, based on the respective GB Decision, the EU-Rail Head of Programme was appointed Executive Director ad interim as of 1 March 2023 for a period which should not exceed one year, until the new ED is appointed. The process of the recruitment of the new Executive Director was not yet finalized in 2023, nor beginning of 2024. In this context, as of 1 March 2024, the EU-Rail Head of

Programme executes the position of the Acting Executive Director, in line with the respective EU-Rail GB Decision laying down the deputising rules.

3.5. States' Representatives Group

Under the Europe's Rail Programme, 31 countries nominated representatives to the JU's State Representatives Group (SRG).

During 2023, the SRG held three meetings. In each of them participants were informed in detail by the ED a.i. about the ongoing and planned activities of the JU, including status of the Programme, in particular the ongoing calls for proposals. They were updated on the System Pillar, the European DAC delivery programme, and the communication and dissemination activities of the Europe's Rail.

In its first meeting of 2 March 2023, the SRG discussed about the launch of the procedure to select the SRG Chair and Vice-Chair and the need to amend the SRG rules of procedure. The ED a.i. informed about the Call for expression of interest on the appointment of the Europe's Rail Scientific Steering Group (SSG), to which the SRG could propose candidates. The members also discussed on how to structure MS contributions on national R&I programmes and projects and their potential synergies with Europe's Rail JU Programme.

During the SRG meeting of 7 June 2023, in which Mr Miroslav Haltuf was elected as Chair of the SRG, 2023, members agreed on how to proceed for the presentation of candidatures to the SSG. The SRG provided a positive opinion on the Annual Activity Report 2022 and on the draft Annual Work Programme 2023. These documents were subsequently adopted by the Governing Board, taking into consideration the opinion of the SRG, in accordance with the provisions of the SBA. The SRG also continued their discussion on the MS contributions on national R&I activities for which a template was proposed by the ED a.i. for consolidation in one position document in view of the EU-Rail General Assembly. Lastly, the ED a.i. presented the results on the Call for proposals HORIZON-ER-JU-2022-02.

The last meeting of the year was on 16 November 2023 and served to elect the new SRG Vice Chair, Mr Adnan Jelin. In this meeting, the SRG agreed to include permanently a point of information on the System Pillar Steering Group in every SRG meeting. The members discussed about the Call for associated members under preparation and the process of setting up the new Deployment Group. The Chair presented the SRG new perspectives and proposed to strengthen the collaboration with other organisations and countries. The members gave a positive opinion on the Work Programme 2023-2024 and Work Programme 2024. They also discussed on the Phasing Out Plan.

3.6. Scientific Committee / Scientific Steering Group

The Scientific Committee (SC) is an advisory body to the JU focusing on the long-term research and on identifying scientific and technological achievements and development priorities. The SC held two meetings in 2023. The SC was replaced by the Scientific Steering Group (SSG), which had its first meeting at the end of the year.

The Members of the SC were equally informed by the ED a.i. – as for the SRG- on a regular basis of the developments in the Europe's Rail Programme and the JU activities. In the SC meeting of 16 March 2023, the ED a.i. informed members on the Call for expression of interest for a new Scientific Steering Group (SSG) just adopted by the Governing Board, and its timeline. The SC members were also invited to contribute to the Call 2023 topics.

In its meeting of 8 June 2023, the ED a.i. informed members of the adoption of an amendment to the Work Programme 2023-2024 scheduled for the Governing Board meeting of 23 June 2023, which included the SC contribution on the topics for the planned Call of 2023.The ED a.i also informed on the publication of the Call for expression of interest for the establishment of the new SSG.

The new SSG meeting composed of 12 members held its first meeting on 15 November 2023. One of the members declared a conflict of interest in this first meeting, which would require appointing one of the candidates in the reserve list for next meeting. The ED a.i. reminded members on the SSG mandate and responsibilities. Two associations would also become observers to the SSG. The rules of procedure of the SSG were adopted. The Chair, Ms Angela di Febbraro, and the Vice-Chair, Mr. Juan de Dios Sanz Bobi, were appointed by consensus. The SSG members provided positive feedback to Work Programme 2024, as well as to the Phasing-Out Plan.

3.7. Deployment Group

As per Article 97 of the Single Basic Act, the Deployment Group is to advise the Governing Board on the market uptake of rail innovation developed in EU-Rail and to support the deployment of innovative solutions.

The Deployment Group shall provide recommendations on issues related to the deployment of rail innovative solutions upon request of the Governing Board. The Deployment Group may also issue recommendations on its own initiative.

During 2023, diverse steps were taken on the setup of the Deployment Group.

In the EU-Rail Government board of 23 June the establishment of a Deployment Group concept was presented. This process was finalised with the Governing Board (GB) Decision No 11/2023.

In accordance with the Article 22(3) of the Single Basic Act, the EU-Rail Executive Director a.i. consulted on 21/12/2023 the States' Representatives Group requesting the members wishing to put forward any potential candidates in such upcoming EU-Rail stakeholders' group.

On 21/12/2023 the EU-Rail Executive Director a.i. also invited the EU-RAIL Founding Members as well as the network list of representative bodies established under the Commission Decision C(2021)7945to nominate candidate members for the Deployment High-Level Group from their organisation, in accordance with the GB decision 11-2013. Applications should be sent before January 31st 2024. In assisting the Commission in the selection process, EU-rail set up an evaluation panel which will assess the applications and subsequently EU-Rail will advise the commission for the nomination of candidates, after consulting the System and Innovation Programme Board and considering potential candidates proposed by the States' Representative Group.

The proposal made by EU-RAIL shall be not binding for the Commission. The European Commission will take a final decision on the composition, structure, and list of candidates to become Members of the Deployment Group in accordance with Articles 22 and 97 of the Single Basic Act.

3.8. System Pillar Steering Group

As per SBA Article 96, the System Pillar Steering Group (SPSG) is responsible for providing advice to the Executive Director and the Governing Board on:

- the approach to operational harmonisation and the development of system architecture,
- the detailed annual implementation plan for the System Pillar in line with the work programmes adopted by the Governing Board,
- monitoring the progress of the System Pillar.

Domain Teams and Core Group are preparing decisions to be validated at the System Pillar Steering Group and Governing Board levels.

The SPSG is composed of the following members:

- Chair: DG MOVE
- Members: Commission (DG MOVE and DG RTD), EU-Rail, Chairperson of the States Representative Group, ERA, ERRAC, AllRail, CER, EIM, UNIFE, UITP, UIP
- Observers (technical bodies responsible for providing advice to members): EUG, UIC, UNISIG, UNITEL
- Observers (other): ERTMS Coordinator, EPF, EUSPA, ETF, NB-Rail, RNE

During 2023, the SP Steering Group has given strategic direction and consent on the following topics in the several meetings held throughout the year:

- SP STG Meeting 4
    - Finalised task and domain deliverables and milestones
    - Approach to energy savings
    - Approach to align FRCS programme with ERJU agreed
    - Approach on advance train positioning/EGNOS discussed and agreed
- SP STG Meeting 5
    - Harmonisation and TSI Input plan, document "EU Rail and Harmonisation" endorsed
    - System pillar FRMCS V2 report
    - Directions on EGNOS
    - Subset of the EULYNX specifications B4R2 was endorsed as SP document
- SP STG Meeting 6
    - Draft of System Pilar CCS/TMS Data model discussed - DRAFT input of Data Topology –
    - First baselining Absolute Train Positioning
    - Computing Environment: Recommendations of Interfaces to be standardized. Agreement to perform CBA on interfaces not yet agreed.
- SP STG Meeting 7:
    - Architecture: Granularity Concepts and Principles. Guide on harmonisation granularity endorsed
    - System Engineering Management Plan (SEMP), Version 2 approved
    - Annual Work Programme endorsed

3.9. Innovation Programme's Steering Committees (SteCos)

The JU Programme Office convened regular IPs and CCA SteCos meetings (four per each IP/CCA in 2022, in total 24 meetings) accordingly to the IPs/CCA Rules of Procedure. The aim of these meetings was to ensure the necessary coordination of activities within each IP/CCA and to provide input in assisting the JU in the monitoring of the Programme activities, notably ensuring the Demonstrations activities planning, especially in view of the closing of the S2R programme in 2023 and coordinated dissemination and communication activities. The coordinators of the CFM and OC projects were invited to participate to the SteCo meetings in order to present the progress of their works in a way to ensure coordination of actions and to maximise synergies among projects.

3.10. European Union Agency for Railways (ERA)

Both the S2R Statutes, and as of 30 November 2021 the SBA for EU-Rail, provide for a collaboration between the JU and ERA. In this respect, the rules of procedures of all relevant groups/bodies established under the JU foresee the participation of representatives from ERA (either as observers or their direct members). This ensures that the Agency is duly prepared to take into account the results of the Programme in its activities.

As a result, staff members of ERA have been participating in meetings of the JU's GB, SRG, SP-STG, Scientific Committee, and the IP/CCA SteCos. Due to participation in the work of these bodies, the representatives of ERA had access and contributed to the draft documents in preparatory work for establishment of the Europe's Rail Joint Undertaking. Additionally, ERA are members of the System Pillar Core Group.

The JU's Governance and Process Handbook[68] clarifies the way ERA can access the R&I activities performed within the S2R Programme in the areas of their competence, interoperability and safety.

[68] https://rail-research.europa.eu/wp-content/uploads/2023/01/EU-Rail-Governance-and-Process-Handbook.pdf

In terms of contribution to the development of Technical Specifications for Interoperability (TSIs), the System Pillar has coordinated the input from the whole EU-Rail programme into the EU-Rail Standardisation and TSI Input Plan, which sets out the expected outputs from the EU-Rail programme into different harmonisation channels including TSIs. The first draft of this was published at the end of 2023 and it will be approved by the SP-STG (including ERA and the EC). Additionally the System Pillar supports the maintenance of the CCS TSI, including the update for the FRMCS specifications.

In addition, regular coordination meetings have been organised between the two EDs, operational staff and communication staff. At a working level there is a close working relationship with ERA being involved where necessary in programme review and assessment, including Flagship Project maturity checkpoints. The overall objective is to ensure that the R&I innovative solutions that will be delivered by the S2R Programme will be considered in the pipeline of ERA activities in order to avoid any step back in the future market uptake.

4. FINANCIAL MANAGEMENT AND INTERNAL CONTROL

4.1. Effectiveness of controls

4.1.1. Legality and regularity of the financial transactions

EU-Rail uses internal control processes to ensure sound management of risks relating to the legality and regularity of the underlying transactions for which it is responsible for, taking into account the multiannual character of programmes and the nature of the payments concerned.

The current JU Financial Rules were adopted on 20 December 2019 by its Governing Board (Decision N°11/2019) and entered into force on 1 January 2020. By means of these amended Financial Rules, the framework for the JU's financial procedures reflected the applicable version of the General EU Financial Regulation 2018/1046 which entered into force on 18 July 2018. As per this legal framework, the JU's financial procedures are designed in a manner allowing compliance with the principle of sound financial management.

As it was under the S2R JU, with EU-Rail becoming operational as of 30 November 2021, the JU continued to comply with the provisions of the applicable Model Financial Regulation. Any future departure from this Model Financial Regulation, as potentially required for the purpose of the Joint Undertaking's specific needs, shall be subject to the Commission's prior consent.

With regard to ICT tools applied to support its financial procedures, since 2016, the JU has utilized ABAC Workflow (accounting system of the European Commission). During the past years, the processes have been further reinforced with the introduction of the JU Cooperation Tool (including for in-kind contribution declarations and certifications) and the implementation of ICT tool ABAC Assets.

At the time of deployment of ABAC Workflow as mentioned above, the JU adopted its Manual of Financial Procedures including the applicable Financial Circuits. This Manual of Financial Procedures was lastly revised in January 2024. It has been designed to guarantee a segregation of duties and to apply the four eyes principle in JU's financial transactions. In this respect, the initiation of a financial transaction and its verification are performed by different actors (ABAC users). Furthermore, the document describes in detail the financial circuits the JU implements per type of transactions and the roles and responsibilities of each actor involved in the implementation of its budget. To a lesser extent, it also describes the basic principles of main procedures (grants & procurements).

As for the JU budget, it comprises in principle two main types of expenditure:

- Administrative Expenditure covering both Titles 1 and 2 of the Budget, and
- Operational Expenditure covering Title 3 (for the S2R Programme) and Title 4 (for the EU-Rail Programme) of the Budget.

The Title 5 is dedicated to account for unused appropriations.

Due to their nature and the difference in ICT tools implemented at the JU to manage them, the financial circuits for these two expenditure types are different.

It should be noted that in addition to the JU-specific methodological framework for financial procedures, common rules of the R&I Family (Vademecum) established for Horizon 2020 and for Horizon Europe are applied by EU-Rail as well.

With regard to the accounting services, a significant change took place in 2022. In particular, with the exception of the treasury function, the Accounting Officer of the Commission ceased their services for EU-Rail and these were taken over by the JU's newly appointed Accounting Officer within the framework of the common back office arrangements (BOA) established among the Joint Undertakings. Moreover, in line with the provisions of the respective Service Level Agreement, EU-Rail took the role of the lead JU for the accounting part of the BOA and started acting as one of the three accounting service providers (complemented in this role by CA JU and SESAR JU) under the SLA. More information about synergies among JUs can be found in the section 2.7.2 "Efficiency gains and synergies" of the present document.

Ex-ante Controls on operational Expenditure

In 2023, the JU continued to follow the procedures for ex-ante controls defined internally (JU Financial Rules) as well as the common Horizon 2020 / Horizon Europe ex-ante control framework.

EU-Rail has followed the Article 21(1) of its Financial Rules providing that "*each operation shall be subject at least to an ex-ante control relating to the operational and financial aspects of the operation, on the basis of a multiannual control strategy which takes risk into account*". The ex-ante controls are considered essential to prevent errors and to avoid the need for ex-post corrective actions. They take the form of checking contracts and grant agreements, initiating, checking and verifying invoices and cost claims and carrying out desk reviews (such as mid-term reviews carried out by external experts on JU's projects and other).

The JU applied standard financial circuits in ABAC Workflow for the commitments and payments. The circuit has a three-step authorisation performed by the following financial actors:

- Initiating Agent (OIA and FIA)
- Verifying Agent (OVA and FVA) and
- Authorising Officer (AO).

Staff members designated by the AO to verify financial operations are chosen on the grounds of their knowledge, skills, and appropriate professional experience.

The JU financial circuits comply with the requirements of the four eyes principle, segregation of duties and the independence of the verifier. At the same time, they allow also for the necessary flexibility to ensure the continuity of operations within the existing staff number limitations. The fact that the Head of Programme was appointed the ED ad interim as of 1 March 2023, thus becoming the AO, was reflected in the financial circuits by means of amendment to the JU's Manual of Financial Procedures introduced in February 2023.

For the operational expenditure, the JU recognises two different types of transactions: the ones solely performed in the ABAC Workflow and the ones with the initiation and verification functions outside of the ABAC environment - in the SyGMa tool. This tool is also linked to ABAC which allows real time controls over the budget and its implementation.

The particular system where the initiation and verification are to be performed is derived from the nature of the transaction, as follows:

- ABAC for all procurement related transactions, and
- SyGMa for any transactions related to grant management.

However, in all transactions, irrespective of whether initiated in SyGMa or ABAC, the AO will always give his/her authorisation in ABAC only.

A key element of the ex-ante controls is the "*Guidance Horizon 2020 ex-ante controls on interim & final payments*" adopted by the CSC Steering Board on 15 Dec 2016 and applicable as such to the JU. As a consequence of the approach introduced in this guidance, simplified ex-ante controls are applied. In particular, the level of details asked from the beneficiaries to be provided in each periodic report is limited, allowing the JU to check a limited number of conditions regarding the eligibility of costs. Ex-ante controls in Horizon 2020 are therefore trust-based, focusing on whether:

- the work has been done (as described in the periodic reports),
- the reported effort and use of resources are reasonable and in accordance with the plan,
- sufficient explanation and justification are provided for any substantial deviations.

In practice, the assessment involves comparing the Description of the Action (DoA) and the budget earmarked with the work actually carried out, as per explanation provided in the periodic report, and with the costs being claimed by the beneficiaries in connection with it.

Certain elements (such as risk factors or deviations) are scrutinized to a lower extent when checking interim periodic reports when compared to assessing final reports. Moreover, since CFS are required only as part of the final reports, ex-ante controls in final periods are more in-depth. In addition, officers may take a more flexible approach to ex-ante controls in interim periods by asking beneficiaries for additional clarification in the ensuing reporting period. However, by the time the final payment is made, all outstanding issues should have been dealt with.

EU-Rail also applies for the actions falling under its current Programme the common guidelines for Horizon Europe, such as the "*HE Ex ante controls*" or "*HE Ex ante anti-fraud checks*" guidelines. The HE ex ante controls developed in these guidelines build upon the principles and practices adopted under H2020 with enhancements based on lessons learnt. It combines a pre-defined set of simple and straight-forward standard controls with additional risk-based checks that are triggered when specific risks are detected. The main principles of the common HE ex ante control strategy are:

- Controls must provide reasonable assurance about legality and regularity, based on the information available at the time;
- Controls must strike the right balance between reducing the administrative burden and exercising effective financial control;
- Controls must be risk-based and cost-effective;
- Beneficiaries should be treated equally.

To complement the common HE guidance documents put in place by the European Commission, EU-Rail adopted end of 2023 its own HE Control Strategy for Grants, where especially the additional control practices performed by the JU on top of the standard level of checks are described (e.g. the maturity checkpoints). This Strategy is built on a risk-based approach and reflects the fact that EU-Rail applies solely the lump sum form of grants under its current programme.

Ex-post controls of operational expenditure and error rates identified

Ex-post controls are defined as the controls executed to verify the financial and operational aspects of finalised budgetary transactions in accordance with Article 22 of the JU Financial Rules. The main objectives of the ex-post controls are to ensure that the principles of legality, regularity, and sound financial management (economy, efficiency and effectiveness) have been respected and to provide the basis for corrective and recovery activities, if necessary. These controls are the last stage of the JU's control strategy in the project life cycle.

For the **HE programme**, under the lump sum funding, EU-Rail payments will not depend on the costs actually incurred by the beneficiaries. Beneficiaries will not have obligation vis-à-vis the JU to document and report costs incurred in the course of action implementation. The checks, reviews and audits will focus on the fulfilment of the conditions for releasing lump sum contributions per work package, and on compliance with other obligations embedded in the grant agreement, such as for example in the area of ethics and research integrity, dissemination and exploitation of results, management of intellectual property, etc. There will be no financial ex-post audits conducted by the Common Audit Service ("the CAS") of DG RTD for EU-Rail lump sum grants. However, EU-Rail intends to perform for its lump sum grants ex-post reviews of qualitative (technical) nature with deployment of external experts as described in its HE Control Strategy for Grants adopted end of 2023, and as tested by means of a pilot review conducted in June 2023. By these ex-post reviews, which will represent a supplementary control layer to the ex-ante control activities, instead of dealing with eligibility of individual cost items incurred during the life of the project and detection of errors pertaining thereto, emphasis will be put on scientific/technical performance and output of projects. Hence the overall JU's control approach for grants under Horizon Europe is characterized by shifting from quantitative (financial) type of controls to qualitative (technical) type of controls. On the other hand, EU-Rail foresees that the implementation of its own ex-post reviews of lump sum grants will be complemented by the assurance, especially in the form of audits, provided by the dedicated EU audit bodies, most notably by the European Court of Auditors and by the Internal Audit Service of the Commission, the latter acting as internal auditors of EU-Rail. Such independent audit activities of those bodies would be based, in line with their mandates, on their own methodology as applicable to the lump sum form of funding.

For the **H2020 programme**, the ex-post controls include the financial ex-post audits as well as the recovery/correction of any amounts found to have been paid in excess of the sum eligible.

Ex-post controls of operational expenditure at EU-Rail are covered by the Horizon 2020 Audit Strategy. The implementation of the Horizon 2020 Audit Strategy falls under the responsibility of the CAS. The role of the CAS is defined in the Commission Decision "C(2014) 2656 final" on the operating rules for the Common Support Centre for Horizon 2020, the Framework Programme for Research and Innovation (2014-2020)[69]. As follows from this Decision "*The Common audit service shall contribute to assessing the legality and regularity of Horizon 2020 project payments by means of ex-post financial controls carried out, either by its own auditors or by independent audit firms in accordance with the decisions of the Steering Board. It shall provide the relevant Authorising Officers by Delegation (AODs) with necessary elements of assurance on the research budget for which they are responsible.*"[70]

The main actions identified to realise the objectives following from the Horizon 2020 Audit Strategy include:

- the gradual achievement, in a cost-effective way, of quantitative multi-annual targets in terms of audited participations[71];
- the closure and communication of audit findings and extension of audit findings to those responsible for their implementation providing the basis for corrective and recovery activities, if necessary.

For Horizon 2020, the CAS carries out all audits, including those concerning grants concluded by the Executive Agencies and the Joint Undertakings. This is a major step towards ensuring efficiency gains, a harmonised approach, legal certainty, equality in treatment of beneficiaries and the least audit burden on beneficiaries.

The main indicators on legality and regularity of EU Framework Programmes for Research and Innovation are:

- **Cumulative representative detected error rate**, based on errors detected by ex-post audits on a Common Representative Sample of cost claims across the R&I Family.

- **Cumulative residual error rate**, which is the extrapolated level of error after corrective measures have been implemented by the respective services following the audits, accumulated on a multi-annual basis.

The **targets** set at the R&I Family level for this control system are, respectively:

- For Horizon 2020, to ensure that the cumulative residual error rate remains within a range of 2-5 %, aiming to be as close as possible to 2%. Progress against Horizon 2020 targets is assessed annually based on the results of the implementation of the ex-post audit strategy and taking into account the frequency and importance of the detected errors along with cost-benefit considerations regarding the effort and resources needed to detect and correct the errors.
- For Horizon Europe, to ensure that cumulative detected and residual error rates do not exceed 2%[72].

It should be noted, however, that due to its multi-annual nature, the effectiveness of the ex-post control strategy of the R&I Family can only be measured and assessed fully in the final stages of the EU Framework Programme, once the ex-post audit strategy has been fully implemented, and errors, including those of a systemic nature, have been detected and corrected.

The Horizon Europe Audit Strategy of the R&I Family is risk-based and draws on the achievements of lessons learnt from Horizon 2020.

However, as EU-Rail will be applying exclusively lump sum form of grants under the Horizon Europe Programme, and since such grants cannot in principle be subject to financial type of ex-post audits conducted by the CAS, the JU intends to establish a framework for conducting its own ex-post reviews

[69] https://ec.europa.eu/transparency/documents-register/detail?ref=C(2014)2656&lang=en
[70] In principle, the same mandate of the CAS applies also for the Horizon Europe Framework Programme as defined in Article 23 of the Commission Decision C(2021) 4472 final.
[71] A participation is the combination of a beneficiary and an action. An audit can cover more than one participation.
[72] No representative error rate for Horizon Europe is available in 2023 as the ex-post audit campaign for the Programme is planned for launch in 2024.

focused more on the qualitative (technical) aspects of implementation of such grants. First pilot of such an ex-post review of the respective lump sum participation was carried out by EU-Rail in June 2023.

Ex-post controls of the Horizon 2020 programme globally in 2022

In 2020, the Commission refined its methodology for calculating the Horizon 2020 error rates in line with the European Court of Auditors' observations in its 2018 and 2019 Annual Reports. The IAS has carried out a limited review on the methodology for calculation of the error rates of Horizon 2020 in the year 2020. The findings of this limited review confirmed that there is no weakness in the calculation of the detected error rate and that the impact of these findings on the accuracy of the calculation of the residual error rate is minor. The 3 recommendations issued were closed by IAS with the Note on audit conclusions in January 2024.

The error rates for Horizon 2020[73] globally as of 31 December 2023 were the following:

- Cumulative representative detected error rate: 2,57%[74],
- Cumulative residual error rate for the for the Framework Programme: 1,55% (1,64% for DG Research and Innovation[75]).

These error rates are calculated on the basis of the audit results available when drafting the Consolidated Annual Activity Report. They should be treated with caution as they may change subject to the availability of additional data from audit results.

Since R&I Framework Programmes are multi-annual, the error rates, and the residual error rate in particular, should be considered within a time perspective. Specifically, the implementation of the audit results over time will tend to lower the cumulative residual error rate thus increasing its difference with the representative detected error rate.

Given the results of the audit campaign, and the observations made by the European Court of Auditors in its Annual Reports, the Common Implementation Centre of DG Research and Innovation, in close cooperation with central Commission services, defined actions aimed at significantly simplifying the rules and paving the way for an important reduction of the error rate in Horizon Europe. Actions were undertaken including further simplification, increased use of simplified forms of funding (including lump sums and unit costs), focused communication campaigns to more "error-prone" types of beneficiaries with higher-than-average error rates (such as SMEs and newcomers), and enhanced training to external audit firms performing audits on behalf of the Commission. Focusing on the most common errors, these actions will be straightforward and achieve higher impact.

Horizon Europe Framework Programme

2023 was the third year of implementation of the Horizon Europe Framework Programme. No representative error rate for Horizon Europe is available in 2023 as the ex-post audit campaign for the Programme is planned to be launched in 2024, once a meaningful number of payments is available for audit.

Ex-post controls 2023: EU-Rail specific sample

The number of ex-post audits of EU-Rail participations carried out by the CAS until year end 2023 corresponds to the relatively small share of the JU's budget (less than 1%) in relation to the overall H2020 budget. However, the JU in cooperation with the CAS continuously strive for ensuring on an ongoing basis

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[73] The Horizon 2020 audit campaign started in 2016. At this stage, five Common Representative Samples with a total of 788 expected results have been selected. By the end of 2023, cost claims amounting to EUR 49.2 billion have been submitted by the beneficiaries to the services. The audit coverage for Horizon 2020 is presented in Annex 7. In addition to the Common Representative Samples, Common Risk Samples and Additional Samples have also been selected. The audits of 4.707 participations were finalised by 31/12/2023 (of which 648 in 2023).

[74] Based on the 581 representative results out of the 788 expected in the five Common Representative Samples.

[75] It should be noted that in 2021 most of Horizon 2020 grants managed by DG Research and Innovation were delegated to Executive Agencies. Hence, this figure is based only on the actions that remained with the DG.

sufficient ex-post audit coverage allowing to provide the respective reasonable assurance to the EU-Rail Executive Director to support his declaration of assurance, also in light of the discharge procedure.

The previous years of the H2020 audit campaign were still marked for the CAS with the effects of the Covid-19 pandemic, which adversely influenced the execution of the ex-post audits in 2020 and 2021, and created a backlog reflected in the reduced number of new sample selections for the 2022 target (9 participations in the case of EU-Rail). The EU-Rail sample counting towards its 2023 local representative audit target counted 5 participations.

The CAS managed to close 11 ex-post audits of EU-Rail participations in 2023.

In Q3 2023, after the sampling exercise was commonly performed, the CAS confirmed the selection of the EU-Rail participations counting towards its 2024 local audit target, covering 5 participations/6 reporting periods.

As of 31 December 2023, total cumulative cost claims related to projects managed by EU-Rail, hence representing its potentially auditable population, reached the amount of EUR 270.117.144,28 for 93 projects. As for the amount of cost claims actually audited by the end of 2023, it was EUR 18.629.334,36 representing the direct EU-Rail audit coverage of 6,9%. The indirect coverage, i.e. the total directly non-audited cost claims of all audited EU-Rail beneficiaries amounted to EUR 188.257.869,83 (69,69%).

The overall status for H2020 ex-post audits related to the JU projects as of yearend 2023 is shown below[76].

Number of participations for which audits were launched during individual years (risk-based audits not included):

GROUP	Total Launch 2017	Total Launch 2018	Total Launch 2019	Total Launch 2020	Total Launch 2021	Total Launch 2022	Total Launch 2023	Launch Total	Closed Total	Sched Total	Open Total	Sched + Open + Closed Total
EU-RAIL	16	17	12	39	12	5	5	106	101	3	5	109

H2020 - CAS - PARTICIPATIONS CLOSED PER CLIENT - OVERALL VIEW - TOP-UPS and ECA JOINT AUDITS INCLUDED

Framework	Domain	Client	Closed 2016	Closed 2017	Closed 2018	Closed 2019	Closed 2020	Closed 2021	Closed 2022	Closed 2023	Closed Total
H2020	CAS	EU-RAIL	0	0	4	22	22	30	12	11	101

Overview of cost claim figures related to the JU projects as of 31/12/2023:

Total number of validated cost claims	2320
Total cost accepted by JU (cumulative) (A)	270.117.144,28
Total cost audited by the end of 2023 (B)	18.629.334,36
Total non-directly audited cost claimed by audited JU's beneficiaries (C)	188.257.869,83
Direct audit coverage ratio (B / A)	6,9%
In-direct audit coverage ratio (C / A)	69,69%

As of 31 December 2023, 87 final audit reports from ended ex-post audits covering the JU's projects were available.

Overall detected error rate based on 103 participations: by applying simple average is 2,32% and by applying weighted average is 1,94%.

[76] As per the data files provided by the CAS.

Representative Error Rate based on 97 participations: by applying simple average is 2,39% and by applying weighted average 2%.

EU-Rail Residual Error Rate: by applying simple average is 1,06% and by applying weighted average is 0,85%.

As at the cut-off date 31.12.2023, **the JU's H2020 cumulative residual error rate is below the targeted threshold of 2%**[77] under both methodologies - the simple and the weighted average.

4.1.2. Fraud prevention, detection, and correction

Early July 2022, EU-Rail adopted its new Anti-Fraud Strategy for 2022-2025[78] which replaced the previous one initially introduced in 2017. The adoption was preceded by a thorough specific fraud risk assessment. Part of this assessment, in particular the one pertaining to the fraud risks in grant management, was conducted commonly at the level of the entire Family of the EU Research & Innovation Services, Agencies and Joint Undertakings (Research Family) and steered by DG RTD. This was complemented at EU-Rail level with the assessment of other risks of fraud, such as those related to procurement, recruitment, misuse of internal information, misuse of JU's reimbursement schemes, etc.

EU-Rail also actively participated in the activities of the Fraud and Irregularities in Research (FAIR) Committee which in 2023 included the preparation of the new Common Anti-Fraud Strategy in the Research and Innovation Family (RAFS). The document was finally adopted in January 2024.

By means of its current own Anti-Fraud Strategy, similarly to the previous one, EU-Rail continues to cover, to the applicable extent, all four elements of the anti-fraud cycle, namely: prevention, detection, support to investigation and correction.

The main anti-fraud objectives of the JU for the period of 2022-2025 are the following:

1) keeping the JU's internal legal framework related to anti-fraud policy up to date,
2) fostering an anti-fraud culture throughout the organisation,
3) maintaining a high level of awareness and knowledge among the staff members on the subject matter,
4) ensuring high level of reactivity towards OLAF/EPPO,
5) preventing the misuse of internal information/data.

These objectives are pursued by means of particular measures and actions, as listed in the below action plan. The actions are subject to follow-up and to assessments regarding potential updates conducted, as a minimum, once a year. For 2023, the follow-up of the anti-fraud actions brought the following outcomes:

	Action	Follow-up on the action plan for 2023
1	The EU-Rail management strives for ensuring the appropriate overall anti-fraud culture throughout the organisation and sets the tone at the top by conveying messages to staff on the subject matter stressing the importance of acting according to the highest professional and ethical standards.	2 communications related to fraud prevention and ethics were provided to EU-Rail staff from the Executive Director a.i.
2	The EU-Rail bodies are informed about the JU's anti-fraud policy and its practical application and their members are reminded of their duties related to the subject matter, most importantly on the obligation of reporting any conflicts of interests.	Information on the anti-fraud policy implementation as part of the internal control framework assessment outcomes was provided in the EU-Rail GB meeting held on 23/06/2023 in which also the 2022

[77] See Annex I for materiality criteria regarding the error rate.
[78] https://rail-research.europa.eu/wp-content/uploads/2022/07/ED-DECISION_ED-22-02_Anti-Fraud-Strategy-2022-2025_Annex_AFS.pdf

	Action	Follow-up on the action plan for 2023
		CAAR was adopted, containing information on the EU-Rail anti-fraud policy. Other written communications were provided to the EU-Rail GB members and observers, including reminders on submitting declarations of interests.
3	The EU-Rail internal legal framework related to the anti-fraud matters is regularly reviewed in order to keep it up to date and complete.	A review was performed.
4	The EU-Rail staff members are regularly provided with information and updates with regard to anti-fraud matters by means of a dedicated section on the JU's intranet.	A dedicated intranet page and a comprehensive repository of files related to anti-fraud matters and ethics was maintained and made available to staff.
5	Regular information sessions and trainings are organised for EU-Rail staff on the subjects of anti-fraud and ethics.	Two dedicated anti-fraud training sessions were made available to EU-Rail staff. The EU-Rail ICC participated also in a presentation of OLAF on the Fraud risk management in decentralised agencies. Specific communications were made to EU-Rail staff on ethics-related matters, especially with regard to declarations of interest. Several awareness-raising communications were made to EU-Rail staff with regard to cybersecurity and IT threats, and a phishing test campaign was participated to by the JU.
6	Ensure comprehensive and timely cooperation with the respective EU bodies (OLAF, EPPO) and swift provision of requested information and documents in cases of investigations or other activities with regard to potential fraud.	No case occurred at EU-Rail requiring reporting to OLAF/EPPO. EU-Rail provided comments to OLAF within the update of the Methodology and Guidance for the Drafting of an Anti-Fraud Strategy by Decentralised Agencies and Joint Undertakings.
7	Ensure appropriate follow-up and the necessary action based on the results of OLAF's/EPPO's investigations and other activities by means of recovery of the concerned amount of funds, application of administrative sanctions and other measures.	No case investigated by OLAF/EPPO occurred requiring follow-up actions by EU-Rail.
8	Participate in the Research Family anti-fraud activities by contributing to common discussions, outputs and documents. Utilising of the knowledge shared within the Research Family in JU's internal anti-fraud documents, activities and trainings.	EU-Rail participated in the FAIR Committee meetings held in 2023 and actively contributed to the common R&I Family activities, such as the survey on the 2019 RAFS action plan implementation or the preparation of the new 2023 RAFS.
9	Ensure an appropriate level of cooperation with the parent Commission Service – DG MOVE.	EU-Rail proactively provided to DG MOVE updated information on the developments regarding the anti-fraud matters. EU-Rail representatives actively participated in a DG MOVE/DG ENER SRD workshop on ethics and conflict of

	Action	Follow-up on the action plan for 2023
		interest management in the decentralised agencies and JUs.

In accordance with the current EU-Rail Anti-Fraud Strategy, and in line with agreement on usage of common indicators within the Research Family, the below indicators with regard to the results of fraud prevention/detection/correction activities are reported as at year end 2023:

	Indicator	Result for 2023
1	Number of messages/communications on anti-fraud matters addressed to the staff by the Executive Director.	2 communications related to fraud prevention and ethics were provided to EU-Rail staff from the Executive Director a.i.
2	Number of information on anti-fraud matters communicated to the EU-Rail Governing Board and other JU bodies, as applicable.	1 dedicated presentation in the EU-Rail GB meeting. 1 written communication to the EU-Rail GB members and observers.
3	Number and value of contracts subject to close monitoring or additional controls due to an assessment of a high risk of fraud.	0
4	New cases sent to OLAF and opened in the respective year, and cases handled by OLAF relevant to EU-Rail in that year.	0
5	Timeliness and completeness of JU's implementation of financial recommendations received from OLAF.	No recommendations were received from OLAF.
6	Time elapsed between OLAF requests for information and date when the information is provided to OLAF.	No requests for information were received from OLAF.
7	Number and content of performed trainings and other activities aimed at awareness-raising of the EU-Rail staff.	2 anti-fraud trainings were made available to EU-Rail staff. The EU-Rail ICC participated also in a presentation of OLAF on the Fraud risk management in decentralised agencies. 2 communications were made to EU-Rail staff on ethics-related matters, especially with regard to declarations of interest. 3 awareness-raising communications were made to EU-Rail staff with regard to cybersecurity and IT threats.
8	Number of cooperative activities in the field of anti-fraud policy with relevant stakeholders (e.g. FAIR Committee, other JUs) to which representatives of EU-Rail participated and contributed to.	EU-Rail participated in the 2 FAIR Committee meetings held in 2023. EU-Rail actively contributed to the preparation of the new 2023 RAFS. The JU proactively provided to DG MOVE updated information on the developments regarding the anti-fraud matters. EU-Rail representatives actively participated in a DG MOVE/DG ENER SRD workshop on ethics and conflict of

	Indicator	Result for 2023
		interest management in the decentralised agencies and JUs.

4.1.3. Assets and information, reliability of reporting

EU-Rail continued in 2023 to apply various measures and control activities in order to safeguard its assets and information.

In that respect and to protect EU public funds from potential irregular or illegal application, EU-Rail thoroughly applies within the grant and procurement management all the requirements regarding controls and checks following from the applicable legal framework as well as from the common methodological guidance provided by the Commission. These are complemented, where deemed necessary, by additional internal guidelines and manuals application of which is then reflected in the day-to-day conduct of control activities at the JU. Apart from various ex-ante and ex-post controls, continuous monitoring is ensured with regard to the implementation of the JU's budget, to operational and administrative payments and to the JU Members' reporting of their in-kind contributions/total project costs. Follow-up is conducted with particular beneficiaries to JU's grants, if the financial ex-post audits performed by the CAS reveal systemic or recurrent errors indicating deficiencies in beneficiaries' control systems.

In addition to the safeguards aimed at financial aspects, EU-Rail pays attention also to non-financial elements of its assets and information. Due care is taken with regard to personal data protection (see Section 2.8). For example, a comprehensive Data Protection Impact Assessment was carried out in connection with the Microsoft Office Online services implementation, results of which were properly documented. Measures are applied for the deployed IT tools and IT infrastructure so that information processed electronically is adequately protected from theft or loss. Similarly, measures for physical protection of assets, documents and data contained therein are in place at the EU-Rail premises. Awareness-raising activities are held regularly for the benefit of the JU's staff to draw their attention to the importance of protection of assets and information, especially with regard to phishing, being still the most common way how intruders from the external environment seek their way to gain unauthorised access to non-public data. A comprehensive Document Management Policy is applied at the JU which is formalised by means of the respective ED Decision.

As is described in more details in other parts of Chapter 4 of this CAAR, no material issues were detected in 2023 at EU-Rail in terms of inadequate safeguarding of assets or information neither in the audits conducted by the ECA/IAS, nor by the comprehensive self-assessment of the EU-Rail internal control system. No case of exception or non-compliance event of this kind occurred in 2023.

As for reliability of reporting, EU-Rail continuously strives for utilising precise and up-to-date information for reporting purposes, most notably for the production of its consolidated annual activity reports. In this respect, especially in the field of grant management, the IT tools and systems owned by the Commission, and deployed also by EU-Rail (Compass, SyGMa, Corda), are used as the primary source for collecting various sets of data. These are further complemented by internal tools, databases and repositories maintained by the respective staff members. Possibilities for improvements in internal data processing and record-keeping are considered on an ongoing basis. Attention is paid to maintaining audit trail so that the reported data can be traced back to its initial source, as necessary, mostly by means of registering files in Ares.

4.2. Efficiency of controls

Similarly to other EU services and bodies, EU-Rail, as follows from its Financial Rules, is subject to requirements pertaining to the efficiency of controls and checks applied in the grant agreement management and, as applicable, in management of other types of contracts and agreements. This means that the JU should on one hand ensure due diligence in performing the necessary checks ensuring the sound financial management, but at the same time, meet the set time limits for certain milestones in the preparation of, or during the lifetime of the grant/contract. Such time limits are referred to as:

- "time to inform" – i.e. the time elapsed from the submission of complete proposal to the moment of informing the applicant on the evaluation outcome (should not be longer than 6 months),
- "time to sign/grant" – i.e. the time elapsed from informing the successful applicant on the results of the call evaluation to the moment of signing of the grant agreement (should not be longer than 3 months),
- "time to pay" – representing different time limits for making the respective payment to the counterparty, being 90 calendar days maximum in case grants-related payments.

EU-Rail uses various monitoring tools in order to comply with the above-mentioned time limits.

The average values of the "time to" indicators applicable to all JU's grants are included in Annex E, Table I of this CAAR.

It can be concluded that despite the ad hoc accumulation of workload in certain periods of the year, the JU managed on average to meet the deadlines represented by the "time to" indicators. However, due to having exceptionally two calls for proposals in 2022, some reporting and payment workflows which would have been normally dealt with still in 2022 were shifted in a planned manner to 2023, as preference needed to be given to evaluation of proposals and preparation of new grant agreements in Q4 2022. This might reflect in the "time to pay" indicator to be reported in the 2023 CAAR.

4.3. Economy of controls

This section provides information about the JU's cost of the controls applied in connection with grant management and procurements[79].

JU's resources dedicated to ex-ante controls in connection to grants:

Stage of the control	Description	Year			
		2022		2023	
		EUR	FTE	EUR	FTE
Stage 1 – Programming, evaluation and selection	Cost of programming + evaluating + selecting / value contracted	107.200	1,1	95.900	1,1
Stage 2 – Contracting including financial (commitments, guarantees,…) and legal checks	Cost of controls related to the contracting / amount paid	45.300	0,5	42.800	0,5
Stage 3 – Monitoring the execution and ex-ante financial management	Cost of controls related to the monitoring of the execution / amount paid	338.900	3,6	320.200	3,9
	Total ex-ante	491.400	5,2	458.800	5,5

JU's resources dedicated to ex-post controls in connection to grants:

Stage of the control	Description	Year			
		2022		2023	
		EUR	FTE	EUR	FTE
Stage 4 – Ex-post controls and recoveries	Total cost related to ex-post audits / grants audited	38.000	0,4	45.500	0,5
	Total ex-post	38.000	0,4	45.500	0,5

JU's resources dedicated to ex-ante controls in connection to procurements:

[79] The information presented in this CAAR Section corresponds with data reported to DG MOVE with respect to cost of control.

Stage of the control	Year			
	2022		2023	
	EUR	FTE	EUR	FTE
Stage 1 – Planning the procurement procedures, including legal checks	68.900	0,7	68.800	0,7
Stage 2 – Contracting, including financial (commitments, guarantees,…) and legal checks	61.200	0,7	65.600	0,8
Stage 3 – Monitoring the execution and Financial operations (ex-ante), controls on the acceptance of goods and services	80.300	0,9	90.000	1
Total ex-ante	210.400	2,3	224.400	2,5

JU's resources dedicated to ex-post controls in connection to procurements:

Stage of the control	Year			
	2022		2023	
	EUR	FTE	EUR	FTE
Stage 4 – Supervisory checks (ex-post), audit, ex-post technical controls if relevant	9.100	0,1	11.200	0,1
Total ex-post	9.100	0,1	11.200	0,1

The internal JU's overall cost of controls (both ex-ante and ex-post) related to grants then represented approximately 0,5% of the EU-Rail operational expenditure/total expenditure in 2023.

The internal JU's overall cost of controls (both ex-ante and ex-post) related to procurements represented approximately 0,2% of the EU-Rail operational/total expenditure in 2023.

The ratios of combined internal cost related to both grants and procurements to the overall 2023 JU's costs are included in the following table:

JU expenditure in 2023 in EUR millions		Estimated overall costs of **ex-ante** controls in 2023 in EUR	Overall costs of **ex-ante** controls in relation to expenditures in %
Operational	94,8	683.200	0,72%
Total	99,1		0,69%
JU expenditure in 2023 in EUR millions		Estimated overall costs of **ex-post** controls in 2023 in EUR	Overall costs of **ex-post** controls in relation to expenditures in %
Operational	94,8	56.700	0,06%
Total	99,1		0,057%

In terms of own human resources allocated in 2023 to controls related to grants and procurements, both ex-ante and ex-post, approximately 8,5 FTEs were involved. This represents about 30,4% of the total FTEs employed by the JU as at year end 2023.

4.4. Cost-effectiveness of controls

The total estimated cost of controls (ex-ante + ex-post) related to grant management and procurement in 2023 represent approximately the amount of EUR 740.000, hence, no significant change occurred compared to the previous year.

Given the fact that many internal controls related to grants and procurements are standardised under the established workflows and procedures, and, given the available personnel resources following from the EU-Rail staff establishment plan, it is expected that the number of FTEs dedicated to internal controls will probably not change dramatically in the future. Nevertheless, there might be qualitative changes in the deployment of controls, especially in the field of ex-post controls related to grants. With the application of lump sum form of grants, the focus of ex-post controls will no longer be on verifying the costs actually incurred by the beneficiaries, but rather on technical aspects of the grant implementation. Since the JU intends to conduct/steer, using its own capacities, the qualitative (technical) ex-post reviews, apart from the expected qualitative changes in the internal deployment of capacities dedicated to grant-related controls, also quantitative changes can be expected in this respect in the future – towards the increase of the total capacities used for ex-post controls. The volume of control capacities dedicated to the procurement and contract management should remain at a similar level, reflecting the amount of JU's funds deployed through procurements.

With regard to cost-effectiveness of controls, the following table presents figures on overall cost spent at EU-Rail in 2023on controls related to grants and procurements, compared to total cost[80]:

Cost of controls / Total expenditure 2023 (administrative + operational)	0,75%
Cost of controls / Operational expenditure 2023	0,78%

The increase compared to 2022 (0,55%) is attributable to the overall lower amount of expenditure, rather than to the actual changes in the volume of JU's control activities.

As for the benefits and particular financial effects of the controls carried out, in most of the cases, these are not possible to be effectively calculated in a precise manner. In general, the main benefit of controls resides in the continuous reasonable assurance on the fact that the principle of sound financial management is being pursued which includes preventing and detecting potential irregularities. To a limited extent[81], the recoveries following from the financial ex-post audits carried out by the CAS could be considered as a form of particular positive financial impact (benefit) resulting from controls. In this respect, Annex E, Table I of this CAAR provides the respective KPI on implementation of audit results.

In conclusion, from the JU's perspective, controls applied in grant management and procurement are considered cost-effective. Emphasis is given to adequate balance between low error rates and timely payments on one hand, and the costs dedicated to carrying out controls on the other hand. By deploying lump sum form of funding for the grants under its Programme, EU-Rail also strives for simplification for its beneficiaries by decreasing their administrative burden regarding reporting of costs during the lifetime of projects funded by the JU. In this connection, the fact that EU-Rail will need to a larger extent steer the ex-post control activities related to lump sum grants by means of its internal capacities and will not be able to count on the CAS in that respect, could increase the JU's cost of controls in the future, having potentially implications on the overall cost-effectiveness of controls. Anyway, achieving reasonable assurance with regard to the sound financial management of the grant implementation will continue to be in focus of EU-Rail.

4.5. Audit observations and recommendations

4.5.1. Internal Audit

In accordance with Article 28 of the JU Financial Rules, the internal audit function shall be performed by the Commission's Internal Audit Service (IAS). IAS reports on its findings and recommendations to the Joint Undertaking's GB and ED.

The internal auditor shall advise the JU on dealing with risks, by issuing independent opinions on the quality of management and control systems, and by issuing recommendations for improving the implementation of operations and promoting sound financial management.

In line with the International Standards for the Professional Practice of Internal Auditing[82] IAS confirmed in March 2024 to the Chairperson of the EU-Rail GB and to the ED its organisational independence of their internal audit activity conducted in 2023, as well the fact that their work in 2023 was free from interference in determining the scope of internal auditing, performing work and communicating results. IAS also confirmed that in 2023, there was no impairment to individual objectivity, in particular through conflict of

80 It should be noted that the quantification of JU's cost of controls is based to a certain extent on qualified estimates and simplified assumptions, as a more precise cost calculation would require continuous detailed time recording throughout the year of all particular control activities conducted at the level of all concerned staff members. Such recording would create excessive administrative burden and would not be considered feasible in terms of the cost-benefit ratio.

81 The primary aim of the control system should be on prevention, that is to minimise as such the occurrence of errors in grants and the necessity of subsequent recoveries.

82 As of 9 January 2024, the Standards maintained by the Institute of Internal Auditors are referred to as the "Global Internal Audit Standards".

interest, scope limitations, restrictions on access to records, personnel, and properties, or resource limitations.

Following its in-depth risk assessment performed at the JU during Q4 2023, IAS drew up their Strategic Internal Audit Plan for EU-Rail for 2024-2026. The JU was notified in March 2024 by IAS that their engagement planned to start in 2024 and to be finalized in 2025 will be the audit on the set up of back office arrangements between the joint undertakings.

Within the agreed timeline following from the action plan, EU-Rail provided to IAS the respective information and documents with regard to the remaining three outstanding recommendations that resulted from the "Audit on H2020 grant implementation and closing". In March 2024 IAS confirmed that the JU has adequately and effectively implemented those recommendations and that they were closed. Hence, there are currently no pending IAS audit recommendations.

4.5.2. Audit of the European Court of Auditors

The European Court of Auditors (ECA) with its mission of February 2024 completed its work which resulted in the JU's Annual Audit Report for the year 2023, in accordance with the ECA mandate as defined in the TFEU.

During 2023, for the 2022 Financial Year, the European Court of Auditors released the following opinions:

Opinion on the reliability of the accounts

"In our opinion, the accounts of the EU-Rail JU for the year ended 31 December 2022 present fairly, in all material respects, the financial position of the EU-Rail JU as at 31 December 2022, the results of its operations, its cash flows, and the changes in net assets for the year then ended, in accordance with its Financial Regulation and with accounting rules adopted by the Commission's accounting officer. These are based on internationally accepted accounting standards for the public sector."

Opinion on the legality and regularity of revenue underlying the accounts

"In our opinion, the revenue underlying the accounts of the EU Rail JU for the year ended 31 December 2022 is legal and regular in all material respects."

Opinion on the legality and regularity of payments underlying the accounts

"*In our opinion, payments underlying the accounts for the year ended 31 December 2022 are legal and regular in all material respects."*

First, the ECA confirmed in its Annual report on EU Joint Undertakings for the financial year 2021, that all observations under follow-up for EU-Rail issued prior to 2021 have all been completed.

Then, the ECA reported no major or critical findings for the JU in its Annual report on EU Joint Undertakings for the financial year 2022. However, two observations were raised:

- In its 2022 Annual Accounts, the amounts of contributions recognised per member category (EU and private members) differ significantly from each other. This is because EU cash contributions are validated and recognised when paid to the JU at the beginning of the project implementation, but members' in-kind contributions are only recognised after validation of the costs incurred and declared for project implementation. The gap between the recognised amount of cash contributions on the one hand and in-kind contributions on the other hand, was addressed in a suboptimal way in the JU's 2022 Annual Accounts by not providing information on the JU members' legal commitments at year end, in terms of signed grant agreements and contracts.

- For Horizon 2020 activities, the JU received no new operational commitment appropriations, as the JU had finished its last call for proposals by the end of 2021. The implementation rate for the operational payment appropriations, including operational unused and reallocated appropriations, fell to 47 % (2021: 61 %). According to the JU, this was due to the rising costs and delivery problems faced by beneficiaries arising from the COVID-19 crisis and the war in Ukraine. Therefore, the duration of most Horizon 2020 projects had to be prolonged and final payments postponed to 2023.

On the first observation, the JU acknowledged the observation of the ECA and has been addressing the issue in the preparation of its 2023 Annual Accounts. Under the supervision of the BOA for Accounting services, the requested information was introduced in the annual accounts document of the 10 Joint Undertakings.

On the second observation, the JU replied that as stated in last year's Annual Activity Report, project extensions were granted due to the impact of the COVID-19 pandemic. In some cases, the beneficiaries had to revise insufficient technical reports/deliverables or provide additional evidence of project results. Consequently, some interim and final payments of the JU's Horizon 2020 programme agenda had to be postponed, but the programme's completion remains on target for the end of 2024. To mitigate as much as possible the delays in technical activities in 2021 and confirmed in 2022, the JU together with its private members implemented an action plan to implement €36.6 million in payments. This action plan, which is being implemented, was endorsed by the JU's governing board in April 2023 and revised in June 2023. Its success also depends on the ability of the projects to produce the expected quality outputs.

4.5.3. Overall Conclusions

In 2023, no critical findings/observations were issued for EU-Rail, neither by IAS, nor by ECA, which would indicate any serious issues or deficiencies with regard to the JU's risk management or to the design and implementation of its internal control system.

4.6. Assessment of the effectiveness of internal control systems

4.6.1. Continuous monitoring

In 2019, the JU started the process of implementing its new Internal Control Framework (ICF) based on the EC Internal Control Standards, also with the objective of introducing a more pro-active approach in the design and implementation of internal controls, rather than focusing mostly on the compliance aspects. This process resulted in 2020 in the adoption of a revised ICF by means of the Executive Director's Decision ED-20-08.

The JU's ICF is designed to provide reasonable assurance regarding the achievement of the following objectives:

- Effectiveness, efficiency and economy of operations;
- Reliability of reporting;
- Safeguarding of assets and information;
- Prevention, detection, correction and follow-up of fraud and irregularities;
- Adequate management of the risks relating to the legality and regularity of the underlying transactions, taking into account the multiannual character of the JU Programme as well as the nature of the payments concerned.

Ever since the revised ICF was adopted, it has been implemented by the Executive Director in the organisation's day-to-day activities, with the support of the Internal Control Coordinator, involving all staff across all JU functions as well. This process included also further fine-tuning of the internal controls and maintaining awareness among the staff of the ICF and its importance for achieving the JU's objectives.

The design of internal controls and their effective implementation is subject to continuous considerations and the ICF is amended, as deemed necessary. Such continuous monitoring is supplemented by annual in-depth self-assessment exercises aimed at comprehensive evaluation of the presence and functioning of all 17 internal control Principles, forming the five Components of the EU-Rail internal control system[83]:

[83] The EU-Rail ICF is based on the COSO Internal Control Integrated Framework, also applied by the Commission services.

1. Control environment
2. Risk assessment
3. Control activities
4. Information and communication
5. Monitoring activities

The latest annual ICF self-assessment evaluating the situation in 2023 was conducted in Q1-Q2 2024. The assessment was carried out on the basis of 53 indicators and taking into account all relevant information available at that time, including the results from previous internal/external audits and the records in the JU's register of exceptions and non-compliance events.

After due assessment, no major or critical deficiencies in internal controls were identified. All individual ICF Principles as well as Components were found to be present and functioning, however some improvements are needed for the Component no. 3 where minor shortcomings were identified. Thus, on this basis, it can be concluded that the JU's control system as a whole is present and functioning well.

4.6.2. Risk assessment and management

EU-Rail's risk assessment and risk management activities follow the principles of the recognised international standards and are aligned to the requirements of the Commission as indicated in its Communication SEC(2005)1327 "*Towards an effective and coherent risk management in the Commission services*"[84]. It is a continuous process involving clear communication to governance bodies, staff, and stakeholders on how EU-Rail positions itself in the management of risks and opportunities that can affect the achievement of its objectives, taking into consideration the assessment of the level of uncertainty that the JU is willing to accept (risk appetite). The Executive Director approves the policy and sets the tone, staff at the different levels implement the policy in the day-to-day operations. The Governing Board takes account of the most relevant risks and of the related action plan depicted in the JU's risk register, brought to its attention by means of the Consolidated Annual Activity Report and the Work Programmes.

Risk is defined as "*any event that could occur and adversely impact the achievement of the Joint Undertaking's strategic and operational objectives. Lost opportunities are also considered a risk*".

The Risk Management system aims at enabling informed decision making with the objective of optimising the ratio between the level of risk acceptable to the JU on one hand, and, on the other hand, the use of the relevant resources related to identifying, analysing, treating, and monitoring of risks and opportunities.

In the months of October and November 2023, in accordance with the JU's Policy for Risk Management as defined in its Governance and Process Handbook, the JU performed a risk assessment exercise with the aim of updating the elements related to risks and opportunities already included in its risk register, as well as identifying potential new ones. Within this exercise, due account was taken of topical internal and external factors and developments having influence on JU's business. Attention was given also to the fraud risks. The updated EU-Rail risk register was shared with its parent Commission service – DG MOVE, as well as EU-Rail actively participated within the respective cluster of JUs and Agencies in the peer review of the most important risks for 2024 steered by EUAN Performance Development Network.

The risks identified in the above-mentioned risk assessment activities which require, due to their criticality, continuous attention and treatment of the Executive Director and, where relevant, of the Governing Board, are presented in the JU Work Programme 2024 and the follow-up outcomes on these risks will be presented in the 2024 CAAR. Follow-up considerations applicable to the most relevant risks identified for 2023 are presented in Section 1.1 of this CAAR.

Further to the risk assessments mentioned above, in Q4 2023, the IAS performed at EU-Rail their in-depth risk assessment which resulted in the establishment of their Strategic Internal Audit Plan 2024-2026 for the JU.

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[84] https://commission.europa.eu/publications/risk-management_en

4.6.3. Prevention of Conflict of Interest

As for the treatment of potential conflicts of interests, and to implement the requirements following from its constituent act with regard to this matter, the JU has adopted the respective rules by means of its internal legal framework applicable to its managers, staff, as well as the members of its Governing Board. The annual declarations of interests of the latter are publicly available in the JU official website.

Thus, as it was the case in the past, EU-Rail will continue also in the future to apply various measures, such as:

- requiring annual declarations of interests from the staff members;
- obliging the independent experts used by the JU to declare any potentially conflicting interests;
- assessing potential conflicts of interests of persons (including those coming from outside of EU-Rail) involved in recruitment procedures, calls for proposals/tenders evaluations, etc.;
- requiring annual declaration of interests from the Governing Board members, as well as declaration of confidentiality and conflict of interest from all attendees to each EU-Rail's Governing Board meeting.

Furthermore, the JU Executive Director will continue in the practice of stressing to the staff and to the GB members the importance of compliance to the highest standards in ethical matters, including the situations potentially involving conflicts of interests. The JU's Internal Control Coordinator and HR Officer will support the ED in this respect, especially by engaging in awareness-raising activities addressing the EU-Rail staff.

4.7. Conclusion on the assurance

The EU-Rail Acting Executive Director is not aware of any element that would bring him to introduce a reservation in this 2023 CAAR.

In addition to the specific supervisory activities carried out by the Acting ED himself, the main elements supporting further the reasonable assurance related to the principle of sound financial management are:

- the Certificate of the Accounting Officer;
- the information received from the Programme Unit, the Head of Corporate Services, Head of the System Pillar Unit, the Chief Stakeholder Relations and Dissemination, and from the Chief Legal Officer/Data Protection Officer;
- the assessment of the Internal Control Framework carried out by the JU's Internal Control Coordinator;
- the results of the audit of the ECA;
- audits and risk assessments performed by the Internal Audit Service of the Commission;
- the overall risk management performed in 2023 and supervised by the ED;
- the assessment of the key performance indicators;
- the dedicated ex-ante controls of the JU's operational and administrative expenditure;
- the results from ex-post audits carried out by the Common Audit Service of DG RTD;
- the JU Members' reporting of their in-kind contributions/total project costs, as applicable;
- the monitoring and follow-up of the processes related to the calls for proposals/tenders;
- the deployment of independent external experts and observers in grant management;
- information reported in the JU's register of exceptions and non-compliance events and the related remedial measures put in place.

4.8. Statement of Assurance

4.8.1. Assessment of the Consolidated Annual Activity Report by the Governing Board

The ED submits the draft CAAR to the Joint Undertaking's Governing Board for assessment and approval. Once approved by the GB, the CAAR is made publicly available. No later than 1 July of each year the CAAR together with its assessment shall be sent by the Executive Director to the European Court of Auditors, to the Commission, to the European Parliament and to the Council.

The EU-Rail GB takes note of the results achieved and recommends the JU to continue improving its effectiveness and efficiency with the Members' stronger support.

4.8.2. Declaration of assurance

I, the undersigned, Giorgio Travaini, Executive Director of the Europe's Rail Joint Undertaking

In my capacity as authorising officer by delegation

Declare that the information contained in this report gives a true and fair view[85].

State that I have reasonable assurance that the resources assigned to the activities described in this report have been used for their intended purpose and in accordance with the principles of sound financial management, and that the control procedures put in place give the necessary guarantees concerning the legality and regularity of the underlying transactions.

This reasonable assurance is based on my own judgement and on the information at my disposal, such as the results of the self-assessment, ex-post controls, the work of the Internal Control Coordinator, the observations of the Internal Audit Service and the lessons learnt from the reports of the Court of Auditors for years prior to the year of this declaration.

Confirm that I am not aware of anything not reported here which could harm the interests of the Joint Undertaking.

Brussels, 21 June 2024

Digitally signed by:

GIORGIO TRAVAINI (EUROPE'S RAIL JOINT

UNDERTAKING (EU-RAIL JU))

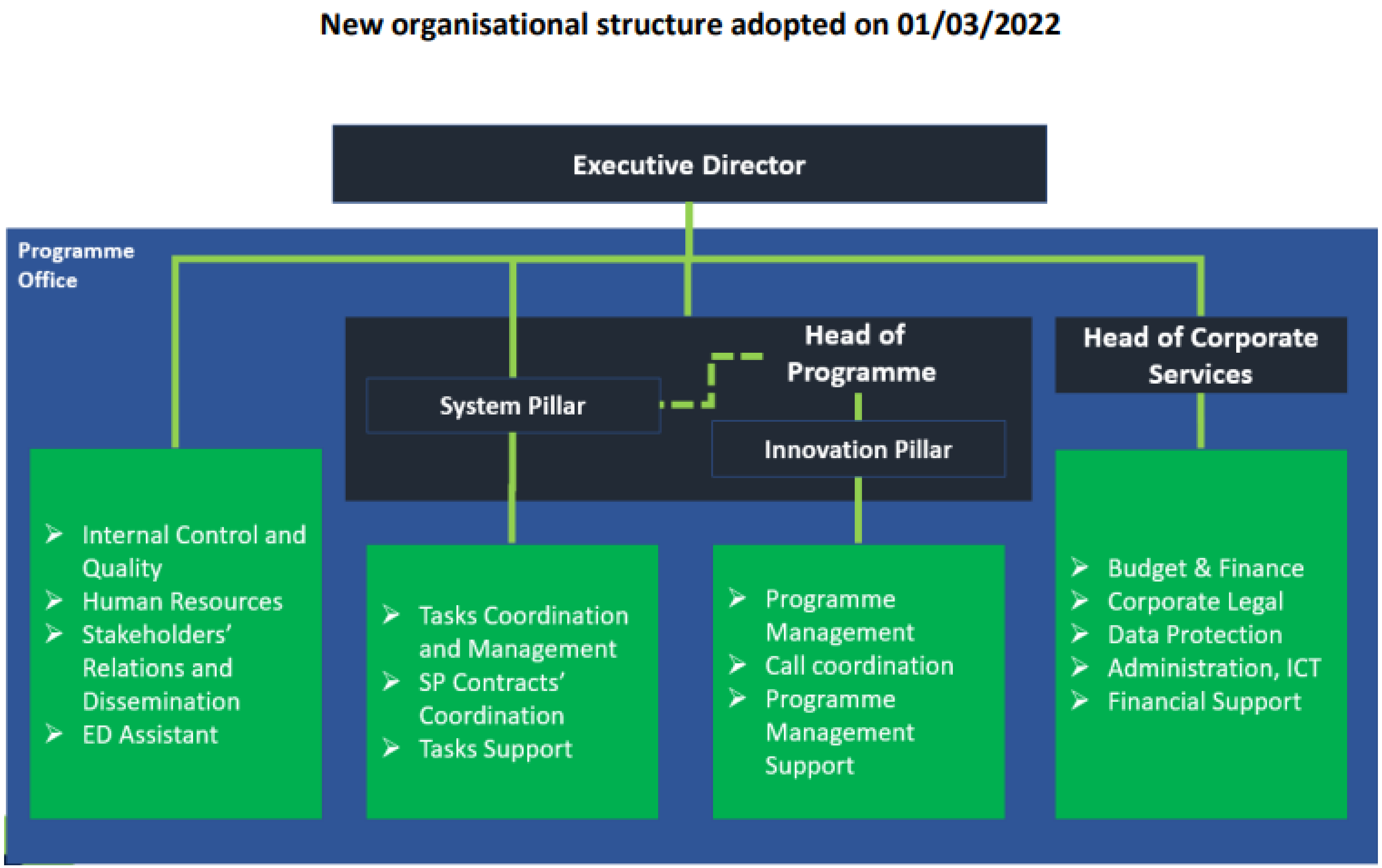
Date: 2024-06-21 16:30:46 UTC

Giorgio Travaini
Executive Director

[85] True and fair in this context means a reliable, complete, and correct view on the state of affairs in the Joint Undertaking.

5. ANNEXES

ANNEX A: Organisational structure of EU-Rail



ANNEX B: Establishment plan and additional information on HR management

Function group and grade	YEAR 2022				YEAR 2023			
	Authorised		Actually filled as of 31/12		Authorised		Actually filled as of 31/12	
	Perm. posts	Temp. posts	Perm. posts	Temp. posts	Perm. posts	Temp. posts	Perm. posts	Temp. posts
AD 16								
AD 15		1				1		
AD 14				1				(1)
AD 13								
AD 12								
AD 11								
AD 10		2		2		2		2
AD 9		1		1		1		1
AD 8		1		1		1		1
AD 7								
AD 6		4		4		4		4
AD 5		1		1		1		1
TOTAL AD	**10**		**10**		**10**		**9**	
AST 11								
AST10								
AST 9								
AST 8								
AST 7								
AST 6								
AST 5								
AST 4								
AST 3								
AST 2								
AST 1								
TOTAL AST								
AST/SC 6								
AST/SC 5								
AST/SC 4								
AST/SC 3								
AST/SC 2								
AST/SC 1								
TOTAL AST/SC								
GRAND TOTAL	**10**		**10**		**10**		**9**	

Contract Agents	Authorized	Actually filled as of 31/12/2023
Function Group IV	15	9
Function Group III	1	7
Function Group II	1	2
Function Group I		
TOTAL	17	18

Seconded National Experts	Authorized	Actually filled as of 31/12/2023
	2	2
TOTAL	2	2

The full staffing as per the JU's Staff Establishment Plan comprises 29 posts. As of 1 March 2023, the Head of Programme executed the function of the ED ad interim.

ANNEX C: Publications and external events participated to by the joint undertaking in 2023

Overview of publications and events

JU 2023 PUBLICATIONS

Title	Publication Date	Link to publication
Smart and affordable rail services in the EU: a socio-economic and environmental study for High-Speed in 2030 and 2050	23 January 2023	https://rail-research.europa.eu/wp-content/uploads/2023/01/HSR_Executive_Report_Final_240123.pdf
European DAC Investment Plan	20 March 2023	https://rail-research.europa.eu/wp-content/uploads/2023/03/DAC-Investment-Plan-Report-final.pdf
Final Report: Work to support with a cost-benefit analysis the definition of migration paths for the implementation of S2R selected innovations on the European network	25 August 2023	https://rail-research.europa.eu/wp-content/uploads/2023/01/S2R-I4-V2-Final-report-2022-11-03_clean_.pdf
Definition of the KPI Model for the EU-Rail Programme: KPI Cards	25 August 2023	https://rail-research.europa.eu/wp-content/uploads/2023/08/Societal_KPI_cards.pdf
Annual Activity Report 2022: Executive View	22 September 2023	https://rail-research.europa.eu/wp-content/uploads/2023/09/Europes-Rail-Annual-activity-report-2022_WEB.pdf

JU 2023 PRESS RELEASES

Title	Publication Date	Link to publication
A study on smart and affordable high-speed services in the European Union shows the way to future sustainable mobility	23 January 2023	https://rail-research.europa.eu/press-releases/a-study-on-smart-and-affordable-high-speed-services-in-the-european-union-shows-the-way-to-future-sustainable-mobility/
Europe's Rail awards eight grants for its Call for Proposals 2022-2	31 March 2023	https://rail-research.europa.eu/press-releases/europes-rail-awards-eight-grants-for-its-call-for-proposals-2022-2/

Europe's Rail launches a Call for Expressions of Interest to establish a new scientific advisory body	5 April 2023	https://rail-research.europa.eu/press-releases/europes-rail-launches-a-call-for-expressions-of-interest-to-establish-a-new-scientific-advisory-body/
Memorandum of Understanding signed between RailNetEurope and Europe's Rail Joint Undertaking	30 May 2023	https://rail-research.europa.eu/press-releases/memorandum-of-understanding-signed-between-railneteurope-and-europes-rail-joint-undertaking/
Single System for Europe's Train Control needs Satellite Technology	13 September 2023	https://rail-research.europa.eu/press-releases/single-system-for-europes-train-control-needs-satellite-technology/
EUR 7 million investment for European multimodality under rail and aviation synergy call	4 October 2023	https://rail-research.europa.eu/press-releases/eur-7-million-investment-for-european-multimodality-under-rail-and-aviation-synergy-call/

JU 2023 NEWSLETTERS

Title	Publication Date	Link to Publication
Europe's Rail Interim Executive Director Appointed: January 2023 Newsletter	31 January 2023	https://mailchi.mp/rail-research.europa.eu/january2023newsletter
Thank you for 7 years of leadership: February 2023 Newsletter	28 February 2023	https://mailchi.mp/rail-research.europa.eu/february2023newsletter
Europe's Rail awards eight grants for its Call for Proposals 2022-2: March 2023 Newsletter	3 April 2023	https://mailchi.mp/rail-research.europa.eu/march2023newsletter
European Year of Skills, meet the Europe's Rail team: April 2023 Newsletter	26 April 2023	https://mailchi.mp/rail-research.europa.eu/april2023newsletter-new
Visit the Europe's Rail stand 6B212 at the UITP Public Transport Summit 2023: May 2023 Newsletter	31 May 2023	https://mailchi.mp/rail-research.europa.eu/may2023newsletter
Join us for the 'Space for Innovation in Rail – Towards Satellite Based ERTMS' event: June 2023 Newsletter	30 June 2023	https://mailchi.mp/rail-research.europa.eu/june2023newsletter
JOIN US: Europe's Rail Info Day 2023: September Newsletter	29 September 2023	https://mailchi.mp/rail-research.europa.eu/september2023newsletter
Call for Proposals 2023: October Newsletter	31 October 2023	https://mailchi.mp/rail-research.europa.eu/october2023newsletter

Europe's Rail Scientific Steering Group Established: November 2023 Newsletter	30 November 2023	https://mailchi.mp/rail-research.europa.eu/november2023newsletter
Apply now for the Europe's Rail Call for Proposals 2023: December 2023 Newsletter	20 December 2023	https://mailchi.mp/rail-research.europa.eu/december2023r

PRESS ARTICLES ABOUT THE JU PUBLISHED IN 2023

Press Outlet	Title	Link to the Publication
International Railway Journal	Europe's Rail launches six flagship projects	1. https://www.railjournal.com/analysis/europes-rail-launches-six-flagship-projects/
	Carlo Borghini to depart Europe's Rail	2. https://www.railjournal.com/news/carlo-borghini-to-depart-europes-rail/
	European rail research leader bows out	3. https://www.railjournal.com/in_depth/european-rail-research-leader-bows-out/
	Launch of DAC+ pilot project tests automated	4. https://www.railjournal.com/analysis/launch-of-dac-pilot-project-tests-automated-features-of-dac/
	Alstom Bombardier Integrationenters Home Straight	5. https://www.railjournal.com/in_depth/alstom-bombardier-integrationenters-home-straight/
	Europe needs a high-speed masterplan	6. https://www.railjournal.com/in_depth/europe-needs-a-high-speed-masterplan/
	Wagonload freight needs to change	7. https://www.railjournal.com/in_depth/wagonload-freight-needs-to-change/
	Testing of Knorr-Bremse DAC begins in Sweden	8. https://www.railjournal.com/innovations-showcase/testing-of-knorr-bremse-dac-begins-in-sweden/
	EC and Europe's Rail seek to allay fears over DAC deployment plan	9. https://www.railjournal.com/analysis/ec-and-europes-rail-seek-to-allay-fears-over-dac-deployment-plan/
	Europe's Rail and RailNetEurope sign MoU	10. https://www.railjournal.com/policy/europes-rail-and-railneteurope-sign-mou/
	FRMCS moves from concept to reality	11. https://www.railjournal.com/in_depth/frmcs-moves-from-concept-to-reality/
	Precise digital references track measurement with RTG	12. https://www.railjournal.com/in_depth/precise-digital-referenced-track-measurement-with-rtg/
Global Railway Review	Supporting development with an integrated approach	13. https://www.globalrailwayreview.com/article/140300/frmcs-supporting-development-integrated-approach/
	Europe's Rail launch Call for Expressions of Interest for new scientific advisory body	14. https://www.globalrailwayreview.com/news/142996/europes-rail-launches-a-call-for-expressions-of-interest/
	Europe's Rail awards eight grants under Call for Proposals 2022-2	15. https://www.railjournal.com/financial/europes-rail-awards-eight-grants-under-call-for-proposals-2022-2/
	MoU signed between RailNetEurope and Europe's Rail Joint Undertaking	16. https://www.globalrailwayreview.com/news/144667/mou-signed-between-railneteurope-and-europes-rail-joint-undertaking/

	ESEP4Freight – Shift to Rail in Freight Transport	17. https://www.globalrailwayreview.com/news/146542/esep4freight-shift-to-rail-in-freight-transport/
Railway Gazette	Study proposes massive expansion of Europe's high speed rail network	18. https://www.railwaygazette.com/high-speed/study-proposes-massive-expansion-of-europes-high-speed-rail-network/63401.article
	Railway supply industry news round-up	19. https://www.railwaygazette.com/business/railway-supply-industry-news-round-up/63518.article
	Europe's Rail JU seeks scientific steering group members as latest grants announced	20. https://www.railwaygazette.com/research-training-and-skills/europes-rail-ju-seeks-scientific-steering-group-members-as-latest-grants-announced/63968.article
	Space Technology: European aerospace bodies see rail opportunities	21. https://www.railwaygazette.com/in-depth/space-technology-european-aerospace-bodies-see-rail-opportunities/64408.article
	Train operators propose 32 000 km high speed rail 'Metropolitan Network'	22. https://www.railwaygazette.com/high-speed/train-operators-propose-32-000-km-high-speed-rail-metropolitan-network/64501.article
	Policy: Data sharing is essential to build the "Internet of Trains"	23. https://www.railwaygazette.com/in-depth/policy-data-sharing-is-essential-to-build-the-internet-of-trains/65023.article
	World rail freight news round-up	24. https://www.railwaygazette.com/freight/world-rail-freight-news-round-up/65165.article
The Brussels Times	EU institutions and some of Europe's largest corporations are looking for clean mobility startups	25. https://www.brusselstimes.com/478627/eu-institutions-and-some-of-europes-largest-corporations-are-looking-for-clean-mobility-startups
The European Files	Leveraging the many benefits of high-speed rail	26. https://www.europeanfiles.eu/environment/leveraging-the-many-benefits-of-high-speed-rail
RailTech.com	What will 2023 bring for international European passenger rail?	27. https://www.railtech.com/all/2023/01/03/what-will-2023-bring-for-international-european-passenger-rail/
	Hyperloop pioneers establish first international Hyperloop Association	28. https://www.railtech.com/infrastructure/2023/02/09/hyperloop-pioneers-establish-first-international-hyperloop-association/
	From patchwork to true European high-speed rail network: the costs and benefits	29. https://www.railtech.com/infrastructure/2023/01/25/from-patchwork-to-true-european-high-speed-rail-network-the-costs-and-benefits/
	OTIV rolls out solution for shunting operations with SNCF's Rail Logistics Europe	30. https://www.railtech.com/innovation/2023/04/18/otiv-rolls-out-solution-for-shunting-operations-with-sncfs-rail-logistics-europe/
Railway Technology	RNE and Europe's Rail Joint Undertaking sign MoU	31. https://www.railway-technology.com/news/rne-europes-rail-joint-undertaking-sign-mou/
Rail Business Daily	Instrumental wins project to develop digital twin technology for GCRE	32. https://news.railbusinessdaily.com/instrumentel-wins-project-to-develop-digital-twin-technology-for-gcre/
	Horizon Europe briefing for UK Rail Suppliers	33. https://news.railbusinessdaily.com/horizon-europe-briefing-for-uk-rail-suppliers/
BtoB Rail	BtoB Rail Magazine2023	34. https://www.btobrail.com/latest-edition

Newswire Today	Knorr-Bremse Tests Digital Automatic Coupler on Real Freight Train by	35. https://www.newswiretoday.com/news/179790/Knorr-Bremse-Tests-Digital-Automatic-Coupler-on-Real-Freight-Train/
Euractiv	Will accelerating high-speed rail put the brakes on cars, planes?	36. https://www.euractiv.com/section/transport/news/will-accelerating-high-speed-rail-put-the-brakes-on-cars-planes/?utm_source=piano&utm_medium=email&utm_campaign=16830&pnespid=q6tjAT5Nba4LgKKRpSjpS46GohKoD5JqLufnyLoypx1mKiMpBFrwyOodV4I00DMCl3GUKr7Q
UITP	Advancing our railways with automation	37. https://www.uitp.org/news/advancing-our-railways-with-automation/
Railway Pro	Tripling EU HSR network would need EUR 550 billion	38. https://www.railwaypro.com/wp/tripling-eu-high-speed-rail-network-would-need-eur-550-billion/?utm_source=rss
RAILTARGET	A study on smart and affordable high-speed services in the European Union shows the way to future sustainable mobility	39. https://www.railtarget.eu/interviews-and-events/a-study-on-smart-and-affordable-highspeed-services-in-the-european-union-shows-the-way-to-future-sustainable-mobility-4394.html
	"Europe's Rail Is Not Just Doing Research for the Sake of It, We're Ensuring Success from It," Says Giorgio Travaini.	40. https://www.railtarget.eu/interviews-and-events/europes-rail-is-not-just-doing-research-for-the-sake-of-it-were-ensuring-success-from-it-says-giorgio-travaini-eurail-7134.html
	"There Are Different Philosophies for Europe's Railway Revolution that Need to be Aligned," says Christian Bedau, Siemens	41. https://www.railtarget.eu/interviews-and-events/there-are-different-philosophies-for-europes-railway-revolution-that-need-to-be-aligned-says-christian-bedau-siemens-7274.html?fbclid=IwAR1SY3E8vD2McNPP8C-Cy2ijat1oSZ6WfAfklyyg0O-df6ayK9geyZ_tQFI
Electric & Hybrid Rail Technology	High-speed rail has potential to deliver massive transport emissions reductions, new study finds	42. https://www.electricandhybridrail.com/content/news/high-speed-rail-has-potential-to-deliver-massive-transport-emissions-reductions-new-study-finds
Adif	Adif advances in new R+D+i projects on predictive maintenance and safety of railway infrastructures (in Spanish)	43. https://www.adif.es/w/2022/12/20-i-d-i-ctf-m%C3%A1laga
Railway Age	Wabtec: Indian, European, ESG Initiatives	44. https://www.railwayage.com/mechanical/wabtec-indian-european-esg-initiatives/
Railways Africa	Automated Rail Freight: Knorr-Bremse Tests Digital Automatic Coupler On Real Freight Train	45. https://www.railwaysafrica.com/news/automated-rail-freight-knorr-bremse-tests-digital-automatic-coupler-on-real-freight-train
TravelDailyNews.com	Dr. Josef Doppelbauer (ERA): "The future of rail transport in Europe"	46. https://www.traveldailynews.com/column/interviews/dr-josef-doppelbauer-era-quot-the-future-of-rail-transport-in-europe-quot/
MarketScreener.com	Hydrogène De France : HDF Energy announces a strategic partnership with DIGAS to jointly develop hydrogen freight locomotives	47. https://www.marketscreener.com/quote/stock/HYDROGENE-DE-FRANCE-124047110/news/Hydrogene-De-France-HDF-Energy-announces-a-strategic-partnership-with-DIGAS-to-jointly-develop-43634964/

Wabtec Corporation	Wabtec's 2022 Sustainability Report Highlights Progress on Key Initiatives	48.	https://www.wabteccorp.com/newsroom/press-releases/wabtec-s-2022-sustainability-report-highlights-progress-on-key-initiatives
	Wabtec, Fret SNCF and RDT13 to expand freight rail in Europe through the MONITOR Project	49.	https://www.wabteccorp.com/newsroom/press-releases/wabtec-fret-sncf-and-rdt13-to-expand-freight-rail-in-europe-through-the-monitor-project
Transport Research and Innovation Monitoring and Information System	TRIMIS NEWS: February 2023	50.	https://mailchi.mp/trimiseuropa/trimis-news-february-2023
Trade Arabia	Hyperloop industry giants join forces to set up global association	51.	https://www.tradearabia.com/news/CONS_407053.html
Construction Week	Hyperloop pioneers join forces to reignite development in the game-changing industry	52.	https://www.constructionweekonline.com/business/hyperloop-pioneers-join-forces-to-reignite-development-in-the-game-changing-industry
Electronics360	Hyperloop vendors form global association	53.	https://electronics360.globalspec.com/article/19310/hyperloop-vendors-form-global-association
Spanish railway news	Adif, Adif AV, Renfe, Cedex and Ineco participate in European railway R&D&I partnership	54.	https://www.spanishrailwaysnews.com/noticias.asp?not=9476&cs=home
Adif	Adif advances in new R+D+i projects on predictive maintenance and safety of railway infrastructures (in Spanish)	55.	https://www.adif.es/w/2022/12/20-i-d-i-ctf-m%C3%A1laga
	Adif will test the extension of ERTMS on non-main lines, in the La Asunción Universidad-Guardo section (in Spanish)	56.	https://www.adif.es/-/adif-probar%C3%A1-la-extensi%C3%B3n-del-ertms-en-l%C3%ADneas-no-principales-en-el-tramo-la-asunci%C3%B3n-universidad-guardo
Braga TV	UMinho School of Engineering creates hub for mobility (in Spanish)	57.	https://bragatv.pt/escola-de-engenharia-da-uminho-cria-hub-para-a-mobilidade/
El Estrecho Digital	Five companies from the Mitma Group will participate in the Europe's Rail Joint Undertaking (in Spanish)	58.	https://www.elestrechodigital.com/2023/04/18/cinco-empresas-del-grupo-mitma-participaran-en-la-europes-rail-joint-undertaking/
FerPress	Adif, Adif AV, Renfe, Cedex and Ineco participate in ERJU with projects worth 568.4 million (in Spanish)	59.	https://www.ferpress.it/adif-adif-av-renfe-cedex-e-ineco-partecipano-a-erju-con-progetti-del-valore-di-5684-mln/
Interempresas.net	Spain, more present than ever at JEC World with Aemac (in Spanish)	60.	http://www.interempresas.net/Plastico/Articulos/480136-Espana-mas-presente-que-nunca-en-JEC-World-con-AEMAC.html
auto-revista.com	AEMAC organized its fourth national pavilion at the JEC World fair (in Spanish)	61.	https://www.auto-revista.com/texto-diario/mostrar/4284302/aemac-organizo-cuarto-pabellon-nacional-feria-jec-world
LaRepublica.cat	Adif, Renfe, Cedex and Ineco will participate in a European railway partnership with projects valued at 568.4 MEUR (in Spanish)	62.	https://www.larepublica.cat/minut-a-minut/adif-renfe-cedex-i-ineco-participaran-en-un-partenariat-europeu-ferroviari-amb-projectes-valorats-en-5684-meur/
Via Libre	Presentation of results of the European maintenance project Stream (in Spanish)	63.	Presentación de resultados del proyecto de mantenimiento europeo Stream (vialibre-ffe.com)

	Space for Innovation in the Railway. Towards a satellite-based ERTMS	64. https://www.vialibre-ffe.com/noticias.asp?not=40459&cs=inte
Istituto Italiano Di Techologia	The STREAM exoskeleton to support workers in railway maintenance (in Italian)	65. https://opentalk.iit.it/lesoscheletro-stream-per-supportare-i-lavoratori-nella-manutenzione-delle-ferrovie/
Aostasera.it	The second edition of The First Thursday on sustainability, circular economy and energy (in Italian)	66. https://aostasera.it/notizie/societa/la-seconda-edizione-di-the-first-thursday-su-sostenibilita-economia-circolare-e-energia/
	The challenges of sustainability in the first appointment of The First Thursday (in Italian)	67. https://aostasera.it/notizie/ambiente/le-sfide-della-sostenibilita-nel-primo-appuntamento-di-the-first-thursday/
Rynek Kolejowy	PKP Energetyka joins Europe's Rail Joint Undertaking (in Polish)	68. https://www.rynek-kolejowy.pl/wiadomosci/pkp-energetyka-dolacza-do-europes-rail-joint-undertaking-111902.html
	Without high-speed rail, we will not save the climate (in Polish)	69. https://www.rynek-kolejowy.pl/mobile/bez-szybkiej-kolei-nie-uratujemy-klimatu-111904.html
Kolejowy Portal	PKP Energetyka is developing Polish railways under the Europe's Rail Joint Undertaking Partnership (in Polish)	70. https://kolejowyportal.pl/pkp-energetyka-rozwija-polska-kolej-w-ramach-partnerstwa-europes-rail-joint-undertaking/
rynek-lotniczy.pl	EVE. Will we fly from Warsaw to the CPK? (in Polish)	71. https://www.rynek-lotniczy.pl/wiadomosci/eve-czy-z-warszawy-polecimy-do-cpk-17481.html
SpoorPro	Hardt Hyperloop one of the founders of worldwide hyperloop association (in Dutch)	72. https://www.spoorpro.nl/innovatie/2023/02/08/hardt-hyperloop-een-van-grondleggers-van-nieuwe-wereldwijde-hyperloop-vereniging/?gdpr=accept
SNCF	The "Sailing Yard" for Major Railway Innovation Projects (in French)	73. https://www.sncf.com/fr/innovation-developpement/innovation-recherche/corifer-itw-carole-desnost
LOK Report	France: Wabtec, Fret SNC and RDT13 launch sensor monitoring of freight wagons (in German)	74. https://www.lok-report.de/news/europa/item/39204-frankreich-wabtec-fret-snc-und-rdt13-starten-sensorueberwachung-von-gueterwagen.html
	Switzerland: "Digital Freight Train" pilot project launched (in German)	75. https://www.lok-report.de/news/europa/item/39543-schweiz-pilotprojekt-digitaler-gueterzug-gestartet.html
Businessinfo.cz	Weekly overview of events in the EU from 27 February to 5 March 2023 (in Czech)	76. https://www.businessinfo.cz/clanky/tydenni-prehled-deni-v-eu-ve-dnech-27-unora-5-brezna-2023/
Dagensinfrastruktur	Railway Metric and Dynamics CEO Jan Lindqvist: "Digitalisation of railways is more than positioning of vehicles and maintenance windows" (in Swedish)	77. Railway Metrics and Dynamics vd Jan Lindqvist: "Digitalisering av järnväg är mer än positionering av fordon och underhållsfönster" - dagensinfrastruktur
Eurail Press	The DAC should be the enabler	78. https://www.eurailpress.de/nachrichten/fahrzeuge-komponenten/detail/news/die-dak-soll-der-enabler-sein.html
CleanTechnica	Wabtec Sends Electric Train Love Letter To World's Largest Iron Mine	79. https://cleantechnica.com/2023/07/17/wabtec-sends-electric-train-love-letter-to-worlds-largest-iron-mine/
FS news	Il Gruppo fs A Milano per Expo Ferrovia 2023	80. https://www.fsnews.it/it/focus-on/corporate/gruppo-fs-expo-ferroviaria-2023.html

WhaTech	Rolling Stock Market worth $65.6 billion by 2028 according to a new research report	81. https://www.whatech.com/og/markets-research/transport/758734-rolling-stock-market-worth-65-6-billion-by-2028-according-to-a-new-research-report
JEC Group	Integrated lightweight rail vehicle composite structures meet high fire requirements	82. https://www.jeccomposites.com/news/integrated-lightweight-rail-vehicle-composite-structures-meet-high-fire-requirements/
Euractive.cz	Decarbonisation awaits freight transport. Carriers support it, but they lack the infrastructure	83. https://euractiv.cz/section/doprava/news/nakladni-dopravu-ceka-dekarbonizace-dopravci-ji-podporuji-chybi-jim-ale-infrastruktura/
Latvian Ministry of Transport	During a working visit to Brussels, Briškens discusses cooperation issues in the field of transport	84. https://lvportals.lv/dienaskartiba/357153-briskens-darba-vizite-brisele-parruna-sadarbibas-aktualitates-transporta-joma-2023
Huddersfield's University's Institute of Railway Research	The Shift2Rail Pivot 2 Project at the University of Huddersfield's Institute of Railway Research	85. https://www.youtube.com/watch?v=4NquKOWMeKw

Events participated to by the Joint Undertaking in 2023

In 2023, the JU participated to major events across Europe and beyond, presenting concrete results achieved by JU Members together with other key stakeholders.

JU events

Press event: high-speed rail services in the European Union – 23 January, online

During this press event, a study on high-speed rail services in the European Union was launched. The event was attended by MEP Dorien Rookmaker.

The report, contracted by Europe's Rail Joint Undertaking (EU-RAIL) in collaboration with the Alliance of Passenger Rail New Entrants in Europe (ALLRAIL), the Community of European Railway and Infrastructure Companies (CER) and the European Rail Supply Industry (UNIFE) analyses the impact of the European High-Speed Rail (HSR) Network connecting the Capitals of Europe and the main European cities and regions.

Space for Innovation in Rail – Towards Satellite Based ERTMS – 13-14 September, Madrid

The JU organised the event against the backdrop of the Spanish Presidency of the Council of the European Union, together with the European Commission, the European Union Agency for the Space Programme (EUSPA), and the European Union Agency for Railways (ERA).

The event gathered Europe's major transport stakeholders, including key decision makers and the railway sector representatives across the entire value chain, debating the introduction of the European Union's Space Programme assets in the railway domain. The main focus of the event was on the European Global Navigation Satellite Systems (GNSS) utilisation for fail-safe train localisation within the European Rail Traffic Management System (ERTMS) evolution.

Europe's Rail Info Day Call 2023 – 4 October, online

The event took place on the day of the Call opening and gave participants an overview of the aims of the Europe's Rail Research and Innovation Programme and introduced them to the possibilities to get involved in making rail a more attractive transport mode for both people and businesses in Europe. During the day, participants were able to find out about Europe's Rail funding opportunity 'Europe's Rail Call for Proposals 2023'.

Europe's Rail General Assembly – 5-6 December, Brussels & online

The event was open to all the participants to Europe's Rail Joint Undertaking research and innovation activities. It was an opportunity to reflect on the overall direction of the JU's activities, while conducting an open and transparent discussion on the progress of the Master Plan and the Multi-Annual Work Programme implementation.

External events

TRB 102nd Annual Meeting – 8-12 January, Washington, D.C.

Executive Director took part in the event that covered all transportation modes, with sessions and workshops addressing topics of interest to policy makers, administrators, practitioners, researchers, and representatives of government, industry, and academic institutions.

The ED participated to the International Council Committee on Decarbonising transport where he presented the work of the JU to deliver the objectives of the European Green Deal. The ED also presented the work of the projects IN2TRACK and ASSETS4RAIL on the resilience of infrastructure and participated to the meeting of the rail group of TRB presenting the new Europe's Rail programme.

Railway Direction Days 2023 – 18 January, Warsaw

Senior Programme Manager discussed high-speed rail as a path to a sustainable transport system. The European Commission regards developments in High-Speed Rail as one of the key tools facilitating decarbonisation of the transport system.

International Transport Forum's Summit Consultation – 24 January, Paris

Executive Director and Chief Stakeholder Relations and Dissemination contributed to discussions on greening transport and enabling sustainable economies.

The Secret Benefits of the High-Speed Rail – 26 January, Brussels

Executive Director discussed the wider impact of high-speed rail on the citizens and how they can contribute as well as what the role of local politicians is. Participants discovered the best practices in bringing and maintaining high-speed rail on the political agenda.

High-level meeting on accelerating electrification of transport in Europe – 31 January, Stockholm

Senior Programme Manager participated in a breakout session titled, "Electrification of the railway – how can we close the gap?" and discussed how rail has the potential to become emission free through innovative solutions such as hydrogen engines.

Kick-off Europe's Rail Norge – 9 February, Oslo

Our Founding Member the Norwegian Railway Directorate organised the kick-off for Norwegian participation in Europe's Rail. The JU's Executive Director, joined the event by sending a video message welcoming and wishing our partners the best for the upcoming year.

TRANSIT & SILVARSTAR final event – 15 February, Brussels

Programme Manager gave a keynote speech and presented the main achievements of both projects.

TRANSIT gave an overview of the results on rail source and transmission characterisation for exterior noise, pass-by noise source separation, separation of track noise and vehicle noise and innovative materials for interior noise, with a focus on standardisation. SILVARSTAR presented their ground vibration prediction tool, including transposition and vehicle indicator and validation. Participants also had the opportunity to test the auralisation and virtual reality tool for railways.

OPTIMA final conference – 16 February, Brussels

Seconded National Expert, opened the conference focused on the Next Generation of Traffic Management System (TMS). OPTIMA worked closely with Shift2Rail Innovation Programme 2 project, X2RAIL-4, and Cross-Cutting Activities project, FINE-2, and its main objective was the specification, design and development of a communication platform using standardised data structures and processes to manage the Communication/Data exchange between different services/clients and supporting TMS applications.

Rail Excellence Summit – 21 February, Pristina

Head of Programme highlighted the importance of attracting talents and the young generation to the rail sector. He emphasised that investment on skills should also be considered, thus making a link to the European Year of Skills.

The Summit brought together rail experts, universities, and government representatives to discuss how to modernise rail in the Western Balkans region by creating job opportunities and attracting young people to railway companies and administrations.

12th International Railway Summit – 21-23 February, Rome

Head of Programme moderated two panel discussions. The first one titled 'How can we maximise rail infrastructure to grow market share?' debated route planning, capacity management and timetabling. The second gathered rail experts in discussions on achieving sustainable asset management to attract green funding. Attendees discovered what we look for when allocating green funding.

UIC Railway Noise Days – 28 February-1 March, Paris

As part of the UIC Sustainability Action Week, the event was designed to engage international noise and vibration experts and to spark new ideas and encourage knowledge sharing through interactive activities. Programme Manger took part to discuss trends for reducing railway noise.

World Congress on High–Speed Rail – 7-19 March, Marrakech

The JU was present with a stand at the Congress. Head of System Pillar together with representatives from across the globe, took part in the closing ceremony titled 'High Speed on the Move'. Chief Stakeholder Relations and Dissemination presented the results of our new report on 'Smart and affordable rail services in the EU: a socio-economic and environmental study for High-Speed in 2030 and 2050'.

Mobility Transition Pathway – 14 March, Brussels

Senior Programme Manager was invited to the collaborative creation of a roundtable for the Mobility Transition Pathway, specifically dedicated to research and innovation. Participants shared insights on current best practices, explored potential areas for improvement, and hinted at possible commitments and pledges regarding the twin transition.

SIFER 2023 – 28-30 March, Lille

Europe's Rail was present with a stand at SIFER 2023. Head of Corporate Services presented the programme to VIPs and expanded on the involvement of our Founding Members in our Flagship Projects. Furthermore, Senior Programme Managers presented a masterclass on energy efficiency in the rail sector.

EPSF Conference – 29 March, Paris

Executive Director a.i. discussed the rise of digital technologies and the new risks and uses that come with it, with Mr Lionel Arnold, EPSF Director of Authorisations, who led the panel, and other experts in the field.

Transportation and Mobility Research Hub – 30 March, Guimarães

Executive Director a.i. gave a keynote speech to address the impact of digitalisation and automation as well as discuss the role of research and innovation in the rail sector.

Presentation at the Université Libre de Bruxelles – 18 April, Brussels

Executive Director a.i. presented the JU's study on the on Smart and Affordable High-Speed Services in the European Union to the master students of Geographics Science and Tourism at the Université Libre de Bruxelles. After the presentation, the students were given the opportunity to engage in a debate by sharing their thoughts on the importance of HSR.

5th edition of the European Startup Prize for Mobility Opening Ceremony – 19 April, Paris

Executive Director a.i. during the opening ceremony to give a reverse pitch and discuss the future of mobility in Europe.

The opening ceremony brought together the political, business and tech leaders from across Europe and was kicked-off with speeches from the French Minister Delegate for Transport Mr Clément Beaune and Ms Karima Delli, Chair of the European Parliament's Transport Committee.

Routes Europe Conference – 9-11 May, Lodz

Programme Manager participated in the "Sustainability: Multimodality as an alternative to short-haul flights" session where she addressed the potential opportunities and challenges associated to integrating rail and air travel. She emphasised the socioeconomic and environmental advantages for high-speed lines.

This event was a great opportunity to present the ambition of Europe's Rail regarding a connected and coordinated multimodal traffic management, as well as the work done in Shift2Rail Innovation Programme 4 on passenger information focusing on ticketing and booking.

Transport Logistics – 10 May, Munich

Senior Programme Manager gave a presentation on the European DAC Delivery Programme as well as Flagship Project 5 TRANS4M-R that are both working towards transforming Europe's rail freight.

Executive Director a.i. shared his message virtually and talked about the commitment of the JU to greening freight transport and the commitment to the deployment of the Digital Automatic Coupler (DAC) solution in Europe.

High Speed Rail Conference 2023 – 17 May, online

Executive Director a.i. presented the outcomes of our joint study on Smart and Affordable High-Speed Services in the European Union at the High-Speed Rail conference on 17 May in Washington, DC.

X2RAIL-4, X2RAIL-5 and TAURO Final Rolling Event – 23-14 May, Berlin

Executive Director a.i. delivered a keynote speech with a video message, highlighting the importance of the project's results in the work of the Europe's Rail Innovation and System Pillar. The event was also attended by a Senior Programme Manager and Seconded National of the JU.

Attendees embarked on a two-day train journey to Berlin-Dresden-Berlin. During the event the latest results of the Shift2Rail Innovation Programme 2 projects X2RAIL-4 and X2RAIL-5, and the Innovation Programme X project, TAURO were presented. It was an opportunity to discuss the future of rail digitalisation, and how this knowledge can be transferred to the Europe's Rail Flagship Project 2 R2DATO.

LinX4Rail & LinX4Rail-2 final joint event – 23 May, Paris

Head of System Pillar attended the final event that focused on System Architecture and Conceptual Data Model for railways. In order to enable interoperability and seamless data exchange between subsystems, as well as the integration of innovative technologies, an ontology related federation of the existing railway related source data and functional models was developed, within the scope of the two projects, as the Conceptual Data Model (CDM).

International Transport Forum Summit 2023 – 24-16 May, Leipzig

Executive Director a.i. took part in a session titled 'Is transport on track for the circular economy?' that explored how the rail sector can introduce and scale up more circular economy solutions that will also answer to other elements such as climate change adaptation.

We took the opportunity to also present the work of EU-Rail on tracking environmental data and the harmonisation of methods, processes and tools for a wide application of solutions.

RAILS final workshop and roadmapping event – 30 May, online

Programme Manager attended the event that shared the project's conclusive findings. Attendees were invited to discuss the effective integration of Artificial Intelligence (AI) in railways during an interactive session.

Rail Transport Day – 30 May, Stockholm

Executive Director a.i. signed an MoU together with RailNetEurope. The MoU aims at formalising the collaboration between RailNetEurope and the Europe's Rail Joint Undertaking. Through this agreement, both organisations are committed to foster an integrated, high-capacity European railway network by eliminating barriers to interoperability and building upon a harmonised functional system architecture shared by the sector.

Executive Director a.i. also gave a speech at the opening ceremony and took part of a panel session on 'Optimising Rail Capacity Management'.

UITP Global Public Transport Summit – 4-7 June, Barcelona

Europe's Rail participated in the UITP Global Public Transport Summit with a stand where visitors had the opportunity to meet the JU's team and experience our latest innovations, including the holoLens for enhancing passenger experiences in train stations, the auralisation and visualisation tool, the Travel Companion app, and the lightweight seats.

Executive Director a.i. moderated and presented the rail challenges and how EU-Rail is addressing them through innovation at the 'Automation in Trams and Trains: Optimising Capacity and Operations' session.

The event also offered an opportunity to discuss and to explore the synergies between the rail sector and the broader transport industry. We discussed potential future collaborations in joint research and innovation studies with Mr Young Tae Kim, Secretary General of the International Transport Forum (ITF) as well as Ms Elżbieta Łukaniuk, Member of the Cabinet of Adina Vălean, European Commissioner for Transport.

The final event of our Shift2Rail projects IP4MaaS - ExtenSive - Connective also took place during the summit with the presence of a Programme Manager from the JU.

3rd Railway Development Congress – 6 June, Warsaw

Executive Director a.i. took part in a panel discussion titled 'Research and development across borders. How can cooperation between business and science change railroads in Europe?', to share his insights alongside the Polish Minister of Digital Affairs.

The event delved into the topic of how technologies can transform rail in Europe, how to finance projects that support rail development and how the European Union supports these projects.

Transport Infrastructure and Biodiversity at a nexus of challenges seminar – 7 June, Strasbourg

Programme Manager shared her insights on innovation and research as drivers for transformative change in the railway industry and the role and objectives of Europe's Rail in the dialogue between partnerships, the research ecosystem, private actors, start-ups and the academia.

The event focused on the final scientific findings of the BISON project and explored the synergies between the project's outcomes and the broader sustainable transport infrastructure community.

UIC Global FRMCS Conference – 7-8 June, Paris

Executive Director a.i. and Head of System Pillar attended the event that brought together industry experts and leaders to discuss and present the latest developments in the Future Railway Mobile Communication System (FRMCS).

During the conference, attendees had the opportunity to engage with FRMCS leaders and contributors, gaining in-depth insights into the technology and its implications for the railway sector.

Artificial Intelligence Made Easy for Railway and Mobility Value Chain – 7 June, online

Senior Programme Manager gave a keynote speech titled 'AI for Europe's Railway system in 2030' and discussed how we move towards common European data spaces.

The event focused on Artificial Intelligence with the aim to facilitate participants to develop solutions that use this innovative technology to provide better solutions for the railway sector.

STREAM final event – 8 June, Port of Tarragona

During the event, attendees had the opportunity to witness two demonstrations on rail tracks. The first demonstration showcased an 'On-Track Autonomous Multi-Purpose Mobile Manipulator', an automated excavator operating on railway tracks by converting rail excavators into robotic systems. The second demonstration featured the 'Modular Multi-tasking Powered Exoskeleton', a back-support innovation developed to improve the safety and conditions of workers in rail maintenance and renewal operations. Senior Programme Manager gave an opening speech.

European Youth Event – 9-10 June, Brussels

Head of Corporate Services was in the jury of the 'Draw Your Route!' workshop at the 5th edition of the European Youth Event alongside Ms Dorien Rookmaker, Member of the European Parliament, Ms Francesca Pagliara, Associate Professor in Transport Engineering at the University of Naples Federico II, and Mr Victor Antoni, Mobility and Transport Engineer at Egis.

During the workshop, participants examined three potential routes between Berlin and Amsterdam and chose their preferred route. The jury assessed each team's reasoning, and the winning team was rewarded with Interrail Passes to discover Europe.

PIVOT2 final event – 13 June, Brussels

Senior Programme Manager attended the final event of our Shift2Rail Innovation Programme 1 project, PIVOT2 that presented the project's results and achievements on the development of light-weight innovations.

UNIFE General Assembly – 14-16 June, Madrid

Executive Director a.i. joined a panel titled 'Rail mobility and digitalisation challenges in Europe' to discuss how EU-Rail can help speed-up the market uptake of new innovations.

FR8RAILIV final event – 15 June, Frankfurt

Programme Manager attended this event that showcased the project's outcomes dedicated to enhancing efficiency, sustainability, and safety of rail freight in Europe.

Attendees were able to connect with industry experts, exchange ideas and knowledge, and discover the latest innovations shaping the field of rail freight.

Hyperloop Conference – 15 June, Busan

Programme Manager gave a keynote speech at the conference and took part in the 'Challenges in the Hyperloop ecosystem for freight transportation' where she pointed out that using the experience from rail is a key factor for freight hyperloop success.

This event focused on high-speed transportation and offered keynote speeches from experts and various stakeholders in the fields of business, politics, and science. Participants had the opportunity to gather valuable insights, exchange ideas, and explore the latest advancements in the hyperloop technology.

PTFE Conference – 21 June, online

Executive Director a.i. delivered a video message to talk about the future of research and development in rail freight and the role that Europe's Rail is playing, particularly the objectives of our Flagship Project 5 TRANS4M-R

The conference focused on technologies and innovations that will help rail become the 'backbone' of mobility and increase its notable role in the decarbonisation of transport.

'Building a Just Transition Towards a Smart and Sustainable Mobility' workshop – 28 June, Cologne

Executive Director a.i. participated in a panel titled 'Innovation and new technologies - the digital transformation and just transition' to discuss the 'JT 4 Mobility' project and how it explores the social consequences of decarbonising transport and pathways towards a Just Transition for workers across the mobility ecosystem.

60th ETCR Seminar on EU Transport Policy and Railway Affairs 3-14 July, Bruges

Executive Director a.i. attended the 60th edition of the ETCR Seminar on EU Transport Policy and Railway Affairs and joined a panel discussion on digital railways to present the work of Europe's Rail that will contribute to digitalising rail in Europe.

This annual seminar presents the latest developments within the railway sector at a European level. Participants have the opportunity to work for two weeks in an international environment, to set up a network among colleagues from all European and Non-European countries.

Webinar on Full Digital Freight Train Operations enabled by the Digital Automatic Couple – 13 September, online

Europe's Rail Flagship Project 5 TRANS4M-R and the System Pillar Task 4, in collaboration with the European DAC Delivery Programme, organised an open discussion focusing on the operational procedures for digital automatic coupling (DAC).

The preliminary target operational procedures were explained in terms of general content and structure to enable all interested parties to examine them and to provide further input. The webinar was attended by over 300 participants including a Europe's Rail Senior Programme Manager.

TRAKO 2023 – 19-22 September, Gdańsk

The JU participated in various sessions and conferences at TRAKO. Executive Director a.i. took part in the 'Digital Automated Couplings: challenges and costs for railway industry' conference where he presented the work of Europe's Rail and joined a panel to discuss the challenges and benefits of DAC, focusing on facts, figures, timelines, and regulations. The ED also joined a debate on the 'Technologies of the Future for Railways'. The main objective of the panel was to share to the listeners that innovations are essential for the future of railways across the continent.

Additionally, Programme Manager attended the Hyperloop Conference where she joined a panel to discuss the challenges and opportunities in the Hyperloop ecosystem for freight transportation.

The European DAC Delivery Programme, enabled by Europe's Rail, was also present at the event, bringing experts to discuss all aspects related to Digital Automatic Coupling during dedicated 'DAC Expert Talks' across the conference venue.

FINE-2: Noise & Vibration Final Event – 27 September, Berlin

Our Shift2Rail Cross-Cutting Activities project, FINE-2, organised its final conference about noise and vibration prediction with the attendance of a Europe's Rail Programme Manager.

Attendees learned about the outcomes of: Testing and validation including usability of a ground vibration prediction tool; Challenges and requirements for using auralisation technologies with railway noise; Testing and application of different innovative methodologies on noise source separation during pass-by noise assessment and their impact on future standardisation work; The prediction of noise sources of stand-alone aggregates and their integration in trains for exterior noise prediction.

During the conference, participants also got to test the ground vibration prediction tool and auralisation software or attend a live demonstration and learn about their performance.

EXPO Ferroviaria 2023 – 3-5 October, Milan

Executive Director a.i. joined a panel discussion titled 'Digital Automatic Coupling: the chance to revolutionise European rail freight transport' during an event organised by Mercitalia and Wabtec Corporation.

Info Day – Türkiye – 9 October, online

Executive Director a.i. took part in the online Info Day dedicated to the Europe's Rail Call for Proposals 2023, organised by the Scientific and Technological Research Council of Türkiye. He presented Europe's Rail programme and gave participants information on the topics of the 2023 Call, and opportunities on how to get involved.

Official Inauguration Ceremony of the Hyperloop Association – 10 October, Brussels

Programme Manager took part in the official inauguration ceremony of the Hyperloop Association which marked the official kick-off of the Association's activities. Our PM welcomed the creation of the Association and highlighted that the Europe's Rail programme is in line with its spirit to work together and cooperate.

During the event, the Association presented the objectives and impact of an implemented hyperloop network enabling sustainable and seamless connections of passengers and goods, as well as explained how to get involved in the Hyperloop Association's activities.

Debate Day of the Italian Association for Quality Culture (AICQ) on Rail Transport – 12 October, online

Executive Director a.i. gave a presentation that touched upon the crucial role of European research for a sustainable and digital railway system, and how R&I results are coordinated by the Sector within the System Pillar activities to ensure quality and applicable standards and regulations.

CER and UIC High-Level Passenger Meeting – 13 October, Rome

Executive Director a.i. participated in a panel discussion on rail networks. In his intervention he highlighted the importance of investment in High-Speed Rail, underlining the outcome of the socio-economic and environmental study for High-Speed in 2030 and 2050, commissioned by EU-Rail together with CER, ALLRAIL and UNIFE, and independently performed by Ernst and Young, together with the Bocconi University.

The High-Level Passenger Meeting, organised by CER, gathered key stakeholders of the European rail passenger operators to discuss various issues of political and business relevance.

Railway Days 2023 – Club Feroviar Investment Summit – 17-18 October, Bucharest

Executive Director a.i. took part in a panel discussion surrounding the modernisation of railways as a solution to ensure safety and quality in rail transport services and presented the EU-Rail programme, its importance, impact at local and European levels and encouraged the participants to apply to Europe’s Rail Call for Proposals 2023.

ALICE webinar – 18 October, online

Senior Programme Manager presented the EU-Rail programme’s focus areas and addressed how to be more competitive. The European Technology Platform ALICE is set-up to develop and implement a comprehensive industry lead strategy for research, innovation, and market deployment in the field of logistics and supply chain management in Europe.

Decarbonisation of the Czech Economy 2023 – 23 October, Prague

Executive Director a.i. participated in a roundtable discussion, with the Czech Transport Minister Martin Kupka, titled ‘Freight Transportation in Times of Sharp Emissions Reduction’. Among other topics, our ED discussed how rail freight is part of the solution in achieving the European Union goals of climate neutrality in 2050 and continue to grow the freight transport.

Assembly of the Spanish Railway Technology Platform – 24 October, Madrid

Executive Director a.i. took part in a discussion on the future of railways where he was joined by Manuel Villalante, General Manager of Development and Strategy at RENFE, Luis López, Director of Business Strategy at ADIF, and Javier Ponce, General Director at CDTI, as part of the Spanish Ministry of Science and Innovation.

European Startup Prize Final Ceremony – 26 October, Brussels

Our Executive Director a.i. attended the Final Ceremony and participated in a High-level Round Table discussion titled 'The Road towards a European 'Startup Continent' together with Kris Peeters, Vice President of the European Investment Bank, Maria Tsavachidis, CEO at EIT Urban Mobility, Lionel Rouillon, Director of Development at VNF, and Derya Guran, Head of Innovation at Die Autobahn GmbH des Bundes.

Our Executive Director a.i. was part of the jury for the selection of the four best Startups of this edition and awarded RAILwAI for the prize category of Digital and Green Rail Mobility, directly supported by the JU.

Seminar on Railway Infrastructures of the Paris-Saclay Institute for Mobility Infrastructure – 6 November, Paris

Executive Director a.i. gave a keynote speech during the first session, as well as participated in a roundtable where he discussed the important role that research plays in improving railway systems in Europe.

CONNECTA-3 and Safe4Rail-3 Final Conference – 7 November, San Sebastián

Seconded National Expert provided a presentation on information about the new Joint Undertaking, EU-Rail’s Flagship Projects, and the duties after closure of the projects. This event offered a great opportunity to receive an insight into Next-Generation Train Control Management solutions.

Info Day France – 7 November, online

Executive Director a.i. presented the general objectives of Europe’s Rail Call 2023. Following the launch of the Europe’s Rail Call for Proposals 2023 on 4 October, the Horizon Europe national contact point in France and the French cluster i-Trans organised a specific webinar for France to learn more about our funding opportunities.

ICT for railways – 15-16 November, Munich

Head of System Pillar was a panellist at a session titled 'Digitalisation and sustainability of the railway system' together from representatives from DG MOVE, UIC, UNIFE, ENISA, CER, UITP, and AERRL. The panel addressed how regulations, standardisation and research contribute to the evolution and competitiveness of the railway sector.

Rail Live 2023 – 29 November-1 December, Madrid

This year, Europe's Rail was once again present at Rail Live in Madrid with a stand and participation in four pivotal moments during the conference. We were honoured to greet Mr Óscar Puente, Minister of Public Works and Transport for Spain to the EU-Rail stand, present our mission and exchange ideas.

Senior Programme Manager participated in a session focused on freight titled "The role of Europe's Rail in delivering transformation in Freight" and gave participants an insight into EU-Rail's Programme. Additionally, Seconded National Expert contributed to discussions on "What does the future of FRMCS implementation look like for operators and infrastructure managers?".

SPM also took part in the Europe's Rail session, organised in collaboration with our European DAC Delivery Programme, on Digital Automatic Coupling (DAC). During the session, the objectives of our Flagship Project 5 (FP5) TRANS4M-R were presented.

During the last day of Rail Live, on Friday, 1 December, Executive Director a.i. took part in a session dedicated to Smart Infrastructure, where participants were updated on Europe Rail's focus on asset management innovation.

CER/EIM High Level Infrastructure Meeting – 30 November, Madrid

Executive Director a.i. joined the event as a panellist in a session dedicated to the European Year of Skills, titled: 'Year of Skills: rail digitalisation enabling a skilful workforce'.

The event took place against the backdrop of the Spanish Presidency of the Council of the EU and it was an opportunity for key rail stakeholders to address relevant strategic and political issues facing the railway sector.

In2Track3 Final Event – 30 November, Stockholm

Senior Programme Manager together with Project Coordinator, opened the event and introduced the project. Some of the topics of discussion included improving the assessment of the status of the rail tracks, predicting the deterioration of the tracks so that we can plan and optimise maintenance, limiting railway noise and vibration.

High-level Freight Meeting – 6 December, Brussels

Programme Manager and Seconded National Expert attended the High-level Freight Meeting organised by CER and discussed how Europe's Rail is supporting the Digital Automatic Coupling (DAC) developments with our European DAC Delivery Programme and our Flagship Project 5 TRANS4M-R.

During the event, European rail freight CEOs and stakeholders exchanged with the Belgian Vice Prime Minister and Minister of Transport Mr Georges Gilkinet on the upcoming Belgian Presidency of the Council of the European Union and the priorities for transport, as well as with MEPs Ms Isabel García Muñoz and Mr Markus Ferber.

'Work at public/private research institutions' Conference – 12 December, online

Executive Director a.i. gave a speech at the 'Work at public/private Institutions' Conference. The event, organised by CIU-Unionquadri "Corrado Rossitto Centre" with CERIC-ERIC, served to address questions surrounding the hurdles in attracting and managing human resources due to the legal framework of private employment that fits very different entities and does not allow to attract, manage and retain research personnel of international level and mobility within the European research market.

Communication statistics in 2023

Website User statistics

JU's website was visited by 144,645 unique visitors in 2022, which is a significant increase compared to 134,123 unique visits in 2022. Most visitors (121,819) were based in Europe, followed by Asia (12,575) and North America (7,471). The largest number of visitors by country were based in Belgium, followed by Germany, Spain and France. JU's website was mostly visited by people using a personal computer (124,368 visitors), second most popular device being smartphone (18,910 visitors). Average time spent on the JU website in 2022 was 2,49 minutes.

Newsletter

The 2023 editions continued to include more project results and news regarding final events and conferences deriving from information fed to the Communication Team by the Programme Unit and the S2R projects themselves. 2023 saw an increase in project news coming from the Europe's Rail programme, as more Europe's Rail projects have kick started their activities. Similar to last year, newsletter content saturated with promotional material about Europe's Rail participation to various events and conferences. Furthermore, a new section was created in light of the European year of Skills where we shared through video messages the personal experiences of our Founding Members, partners, and staff, encouraging young people to build their careers in rail. The average number of articles per newsletter has remained at high number of 29 in 2023 (higher compared to 26 in 2022), clearly showcasing the increasing involvement of Europe's Rail in various activities in Europe and beyond.

The readership of the JU newsletter has increased from 1,857 at the end of 2022 to 2,105 at the end of 2023. Various factors have fed into the growth of the audience including JU's participation to numerous events, more promotion of the newsletter by staff through their meetings and networks, and increased promotion of the newsletter and its individual articles on JU's corporate social media, the inclusion of more project news and deliverables stemming from the Europe's Rail programme.

Social media

Generally, the JU's social channels are used to engage with the rail community and other stakeholders, including the end users. In 2023 the EU-Rail Communication Team continued to produce more in-depth content on its LinkedIn account. Such content was well-received by the audience as it consists of mostly technical stakeholders and engineers. During 2023 EU-Rail has increased efforts in communicating with the projects and getting regular updated on their news in order to spread the word through social media. In 2022, the average number of tweets per month was 28.

The audiences JU targets on social media depend on the channels. While on Twitter the JU is followed by a wide audience with different backgrounds, LinkedIn attracts a more specialised community interested rather in technical details and longer in-depth articles. JU's Communication Team creates different content in order to tailor the message to these different audiences. On Twitter the JU shares daily events, short articles and posts illustrated with images and videos. On LinkedIn, however, the audience expects longer, more thought-provoking material including technical details about our innovations. In 2023 LinkedIn was most viewed social media channel of EU-Rail.

JU has also increased its presence on its YouTube channel. Efforts have been made to publish videos showing our innovations as well as recordings of our online events to ensure that even those who were unable to join, have access to the content.

JU has increased the number of followers on all its social media channels during 2023. In 2023 an important milestone was reached on Linked when the number of followers surpassed 10,000. At the end of 2022 the Europe's Rail LinkedIn account had 12,098 followers. 2.431 new followers. On the other hand, JU's Twitter account has 4.910 followers out of whom 169 started following the JU account in 2023.

Throughout 2022, the JU has continued putting more effort into long-term social media planning to make sure that all relevant news is promoted through EU-Rail's social media platforms in a timely and effective manner. The JU also focused in 2023 on engaging more intensively with other relevant stakeholders on social media (DG MOVE, DG RTD, CINEA and other EU-institutions; Members and key associations) that helped to support the dissemination of JU messages and vice-versa. Additionally, in 2023 more and more Founding Members have started promoting Europe's Rail on their social media accounts. This has resulted in a multiplier effect due to their high number of followers and reach. Such information sharing is made possible thanks to the close contact developed between the Communication team and Founding Members Communication Officers via the Communication Networks Meetings.

Just like in previous years, in 2023, JU also had at the heart of its strategy the promotion of the JU project results through its social media channels. Thanks to the collection tool developed by the JU, projects are able to directly propose content for organic or re-shared posts. The projects are encouraged to send content directly to the Communication Team to ensure it is promoted across the social media channels in a timely manner. In 2023 the Communication Team launched the pilot phase of the dedicated Microsoft 365 Teams environment which is being used for collecting content from the projects for publication via social media.

Press

The JU published six press releases in 2023, covering the study on smart and affordable high-speed services in the European Union, the results of the Europe's Rail Call for Proposals 2022-2, the Call for Expressions of Interest to establish a new scientific advisory body, the signage of the Memorandum of Understanding between RailNetEurope and Europe's Rail Joint Undertaking, the need for Satellite Technology, and the joint topic call between Europe's Rail Joint Undertaking and Sesar 3 Joint Undertaking.

In 2023, the JU was featured in more than 80 articles in a range of magazines, industry press and online media. JU's Communication Team has continued to build relations with journalists and editors from different media outlets to find ways for cooperation and to offer ideas for stories.

ANNEX D: Patents from projects

Project Number	Project Acronym	Project Call Id	Number Of CR Patents
777576	ETALON	H2020-S2RJU-OC-2017	4

ANNEX E: Scoreboard of Horizon 2020 (H2020) legacy KPIs

TABLE I - Horizon 2020 Key Performance Indicators[86] common to all JUs

	Correspondence to general Annex 1	Key Performance Indicator	Definition/Responding to question	Type of data required	Data to be provided by	Baseline at the start of H2020 (latest available)	Target at the end of H2020	Automated	Result 2023
INDUSTRIAL LEADERSHIP	12*	SME - Share of participating SMEs introducing innovations new to the company or the market (covering the period of the project plus three years);	Based on Community Innovation Survey (?). Number and % of participating SMEs that have introduced innovations to the company or to the market	Number of SMEs that have introduced innovations;	H2020 beneficiaries through project reporting	N/A [new approach under H2020]	50%	Yes	259 (99%)
	13	SME - Growth and job creation in participating SMEs	Turnover of company, number of employees	Turnover of company, number of employees;	H2020 beneficiaries through project reporting	N/A [new approach under H2020]	To be developed based on FP7 ex-post evaluation and /or first H2020 project results	Yes	N/A
SOCIETAL CHALENGES	14*	Publications in peer-reviewed high impact journals in the area of the JU	The percentage of papers published in the top 10% impact ranked journals by subject category	Publications from relevant funded projects (DOI: Digital Object Identifiers); Journal impact benchmark (ranking) data to be collected by commercially available bibliometric databases.	H2020 beneficiaries through project reporting; Responsible Directorate/Service (via access to appropriate bibliometric databases)	N/A [new approach under H2020]	[On average, 20 publications per €10 million funding (for all societal challenges)]	Yes	664

86 Based on Annex II to Council Decision 2013/743/EU

	Correspondence to general Annex 1	Key Performance Indicator	Definition/Responding to question	Type of data required	Data to be provided by	Baseline at the start of H2020 (latest available)	Target at the end of H2020	Automated	Result 2023
	15*	Patent applications and patents awarded in the area of the JU	Number of patent applications by theme; Number of awarded patents by theme	Patent application number	H2020 beneficiaries through project reporting; Responsible Directorate/Service (via worldwide search engines such as ESPACENET, WOPI)	N/A [new approach under H2020]	On average, 2 per €10 million fu–ding (2014 - 2020) RTD A6	Yes	4
	16*	Number of prototypes testing activities and clinical trials	Number of prototypes, testing (feasibility/demo) activities, clinical trials	Reports on prototypes, and testing activities, clinical trials	H2020 beneficiaries through project reporting	N/A [new approach under H2020]	[To be developed on the basis of first Horizon 2020 results]	Yes	695
	17*	Number of joint public-private publications in projects	Number and share of joint public-private publications out of all relevant publications	Properly flagged publications data (DOI) from relevant funded projects	H2020 beneficiaries through project reporting; Responsible Directorate/Service (via DOI and manual data input-flags)	N/A [new approach under H2020]	[To be developed on the basis of first Horizon 2020 results]	Yes	49
	18*	New products, processes, and methods launched into the market	Number of projects with new innovative products, processes, instruments, methods, technologies	Project count and drop-down list allowing to choose the type processes, products, instruments, methods, technologies	H2020 beneficiaries through project reporting	N/A [new approach under H2020]	[To be developed on the basis of first Horizon 2020 results]	Yes	72

	Correspondence to general Annex 1	Key Performance Indicator	Definition/Responding to question	Type of data required	Data to be provided by	Baseline at the start of H2020 (latest available)	Target at the end of H2020	Automated	Result 2023
EVALUATION	N/A	Time to inform (average time in days) all applicants of the outcome of the evaluation of their application from the final date for submission of completed proposals	To provide applicants with high quality and timely evaluation results and feedback after each evaluation step by implementing and monitoring a high scientific level peer-reviewed process	Number of days (average)	Joint Undertaking	H2020		Yes	all calls (TTI): average 94 / Maximum 176 2023 calls: N/A**
	N/A	Time to inform (average time in days) successful applicants of the outcome of the evaluation of their application from the final date for submission of completed proposals		Number of days (average)	Joint Undertaking	H2020		Yes	all calls (TTI): average 94 / Maximum 176 2023 calls: N/A**
	N/A	Redress after evaluations	To provide applicants with high quality and timely evaluation results and feedback after each evaluation step by implementing and monitoring a high scientific level peer-reviewed process	Number of redresses requested	Joint Undertaking	H2020			N/A**
GRANTS	N/A	Time to grant (average) measured from call deadline to signature of grants	To minimise the duration of the granting process aiming at ensuring a prompt implementation of the Grant Agreements through a simple and transparent grant preparation process	Average in days under H2020 TTG < 270 days (as % of GAs signed)	Joint Undertaking	H2020		Yes	all calls (TTG): average 191 2023 calls: N/A**
	N/A	Time for signing grant agreements from the date of informing successful applicants (average values)		Average in days under H2020	Joint Undertaking	H2020		Yes	all calls (TTS): average 94 2023 calls: N/A**

	Correspondence to general Annex 1	Key Performance Indicator	Definition/Responding to question	Type of data required	Data to be provided by	Baseline at the start of H2020 (latest available)	Target at the end of H2020	Automated	Result 2023
AUDITS	N/A	Error rate		Representative error in %; residual error in %	CAS	H2020	The residual error rate should be within the threshold of 2%	No	representative error of 2% for the JU (weighted average); residual error of 0,85% for the JU (weighted average)
	N/A	Implementation of ex-post audit results		Number of cases implemented; in total €million; Number of cases implemented/total cases	Joint Undertaking	H2020		No	83 implemented cases, EUR 0,49 million 95,4% of total cases

	Correspondence to general Annex 1	Key Performance Indicator	Definition/Responding to question	Type of data required	Data to be provided by	Baseline at the start of H2020 (latest available)	Target at the end of H2020	Automated	Result 2023
PAYMENTS	N/A	Time to pay (% made on time) -pre-financing - interim payment -final payment	To optimize the payments circuits, both operational and administrative, including payments to experts	Average number of days for Grants pre-financing, interim payments and final payments; Average number of days for administrative payments;	Joint Undertaking	H2020	-pre-financing (30 days) - interim payment (90 days) -final payment (90days)	Yes	Operational: Pre-financing: N/A Interim/final: 32 (91%) Average number of days: 78 Administrative: Pre-financing: 6 (100%) Average number of days: 18 Interim/final: 708 (98,7%) Average number of days: 17
HR	N/A	Occupancy rate (%)		post filled in %, composition of the statutory JU staff and seconded national experts (SNEs)[87]	Joint Undertaking	H2020			97% (vacancy rate 3%)

[87] Additional indicators can be proposed/discussed with R.1 and/or DG HR

	Correspondence to general Annex 1	Key Performance Indicator	Definition/Responding to question	Type of data required	Data to be provided by	Baseline at the start of H2020 (latest available)	Target at the end of H2020	Automated	Result 2023
JU EFFICIENCY	N/A	Budget implementation/execution: 1. % CA to total budget 2. % PA to total budget	Realistic yearly budget proposal, possibility to monitor and report on its execution, both in commitment (CA) and payments (PA), in line with sound financial management principle	% of CA and PA	Joint Undertaking	H2020	100% in CA and 90% in PA	Yes	CA: 100% PA: 82,4%
	N/A	Administrative Budget: Number and % of total of late payments	Realistic yearly budget proposal, possibility to monitor and report on its execution in line with sound financial management principle	Number of delayed payments % of delayed payments (of the total)	Joint Undertaking		H2020	Yes	17 late payments 2%

NOTES:

12,14,15,16,17,18*: The upcoming Control Gates (April) and project Reviews could generate improved data for this KPI which is cumulative on the S2R running projects in 2022.

18*: This indicator is not a legally compulsory one, but it covers several additional specific indicators requested for more societal challenges by the services in charge.

**: In 2023, there were no new EU-Rail calls for proposals under H2020. Statistics related to the 2023 EU-Rail call pertaining to the Horizon Europe Programme are provided in Section 1.5 of this CAAR.

TABLE II - Indicators for monitoring H2020 Cross-Cutting Issues[88] common to all JTI JUs

Correspondence to the general Annex 2	Cross-cutting issue	Definition/Responding to question	Type of data required	Data to be provided by	Data to be provided in/to	Direct contribution to ERA	Automated	Result 2023
2	Widening the participation	2.1 Total number of participations by EU-28 Member State	Nationality of H2020 applicants & beneficiaries (number of countries)	H2020 applicants & beneficiaries at the submission and grant agreement signature stage	JU AAR RTD Monitoring Report	Yes	Yes	N/A**
		2.2 Total amount of EU financial contribution by EU-28 Member State (EUR millions)	Nationality of H2020 beneficiaries and corresponding EU financial contribution	H2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report	Yes	Yes	N/A**
N/A		Total number of participations by Associated Countries	Nationality of H2020 applicants & beneficiaries (number of countries)	H2020 applicants & beneficiaries at the submission and grant agreement signature stage	JU AAR RTD Monitoring Report	Yes	Yes	N/A**
N/A		Total amount of EU financial contribution by Associated Country (EUR millions)	Nationality of H2020 beneficiaries and corresponding EU financial contribution	H2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report	Yes	Yes	N/A**
3	SMEs participation	3.1 Share of EU financial contribution going to SMEs (Enabling & industrial tech and Part III of Horizon 2020)	Number of H2020 beneficiaries flagged as SME; % of EU contribution going to beneficiaries flagged as SME	H2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report		Yes	N/A**

[88] Based on Annex III to Council Decision 2013/743/EU

Correspondence to the general Annex 2	Cross-cutting issue	Definition/Responding to question	Type of data required	Data to be provided by	Data to be provided in/to	Direct contribution to ERA	Automated	Result 2023
6	Gender	6.1 Percentage of women participants in H2020 projects	Gender composition of participants in H2020 projects	H2020 Beneficiaries throughout project reporting		Yes	Yes	N/A**
		6.2 Percentage of women project coordinators in H2020	Gender of MSC fellows, ERC principle investigators and scientific coordinators in other H2020 activities	H2020 beneficiaries at the grant agreement signature stage		Yes	Yes	N/A**
		6.3 Percentage of women in EC advisory groups, expert groups, evaluation panels, individual experts, etc.	Gender composition of memberships in advisory groups, panels, etc.	Compiled by Responsible Directorate/ Service /Joint Undertaking based on existing administrative data made available by the CSC		Yes	No	EU-Rail Governing Board: 14,8% of representatives are female among the GB members, 10,7% among all members including alternates - Observers in the GB on behalf of the JU States' Representatives Group: The single observer for this body is male - Observers in the GB on behalf of the JU Scientific Steering Group: 100% of members are female (the single observer for this body) - Observers in the GB on behalf of the European

Correspondence to the general Annex 2	Cross-cutting issue	Definition/Responding to question	Type of data required	Data to be provided by	Data to be provided in/to	Direct contribution to ERA	Automated	Result 2023
								Union Agency for Railways: 66,7% of representatives are female
7	International cooperation	7.1 Share of third-country participants in Horizon 2020	Nationality of H2020 beneficiaries	H2020 beneficiaries at the grant agreement signature stage	JU AAR RTD Monitoring Report	No	Yes	N/A**
		7.2 Percentage of EU financial contribution attributed to third country participants	Nationality of H2020 beneficiaries and corresponding EU financial contribution	H2020 beneficiaries at the grant agreement signature stage	JU AAR RTD Monitoring Report	No	Yes	N/A**
9	Bridging from discovery to market[89]	9.1 Share of projects and EU financial contribution allocated to Innovation Actions (IAs)	Number of IA projects	Project Office – at GA signature stage he/she will be required to flag in SyGMa. Responsible Directorate/Service (WP coordinator)/Joint Undertaking - via tool CCM2	JU AAR RTD Monitoring Report		Yes	N/A**
		9.2 Within the innovation actions, share of EU financial contribution focused on demonstration and first-of-a-kind activities	Topics properly flagged in the WP; follow-up at grant level	Responsible Directorate/Service (WP coordinator)/Joint Undertaking - via tool CCM2	JU AAR RTD Monitoring Report		Yes	N/A**

[89] The indicator 9.2 initially intended to monitor the Digital Agenda (its applicability could be limited)

Correspondence to the general Annex 2	Cross-cutting issue	Definition/Responding to question	Type of data required	Data to be provided by	Data to be provided in/to	Direct contribution to ERA	Automated	Result 2023
N/A		10 Scale of impact of projects (High Technology Readiness Level)	Number of projects addressing TRL[90] between 4-6 and 5-7	Joint Undertaking	JU AAR RTD Monitoring Report		No	N/A**
11	Private sector participation	11.1 Percentage of H2020 beneficiaries from the private for-profit sector	Number of and % of the total H2020 beneficiaries classified by type of activity and legal status	H2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report		Yes	N/A**
		11.2 Share of EU financial contribution going to private for-profit entities (Enabling & industrial tech and Part III of Horizon 2020)	H2020 beneficiaries classified by type of activity; corresponding EU contribution	H2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report		Yes	N/A**
12	Funding for PPPs	12.1 EU financial contribution for PPP (Art 187)	EU contribution to PPP (Art 187)	Responsible Directorate/Service	JU AAR RTD Monitoring Rep ort		Yes	S2R: EUR 11,8M EU-Rail: EUR 74,2M
		12.2 PPPs leverage: total amount of funds leveraged through Art. 187 initiatives, including additional activities, divided by the EU contribution	Total funding made by private actors involved in PPPs - in-kind contribution already committed by private members in project selected for funding - additional activities (i.e. research expenditures/investment of industry in the sector, compared to previous year)	Joint Undertaking Services	JU AAR RTD Monitoring Report			119% 161%

[90] TRL: Technology Readiness Level

Correspondence to the general Annex 2	Cross-cutting issue	Definition/Responding to question	Type of data required	Data to be provided by	Data to be provided in/to	Direct contribution to ERA	Automated	Result 2023
13	Communication and dissemination	13.3 Dissemination and outreach activities other than peer-reviewed publications - [Conferences, workshops, press releases, publications, flyers, exhibitions, trainings, social media, websites, communication campaigns (e.g. radio, TV)]	A drop-down list allows to choose the type of dissemination activity. Number of events, funding amount and number of persons reached thanks to the dissemination activities	H2020 Beneficiaries throughout project reporting	JU AAR RTD Monitoring Report	Yes	Yes	6.323 Dissemination and outreach activities other than peer-reviewed publications People reached: 2.866.292
14	Participation patterns of independent experts	14.2 Proposal evaluators by country	Nationality of proposal evaluators	Responsible Directorate /Service/Joint Undertaking in charge with the management of proposal evaluation			Yes	N/A**
		14.3 Proposal evaluators by organisations' type of activity	Type of activity o' evaluators' organisations	Responsible Directorate /Service/Joint Undertaking in charge with the management of proposal evaluation			Yes	N/A**

Correspondence to the general Annex 2	Cross-cutting issue	Definition/Responding to question	Type of data required	Data to be provided by	Data to be provided in/to	Direct contribution to ERA	Automated	Result 2023
N/A	Participation of RTOs and Universities	Participation of RTOs[91] and Universities in PPPs (Art 187 initiatives)	Number of participations of RTOs to funded projects and % of the total Number of participations of Universities to funded projects and % of the total % of budget allocated to RTOs and to Universities	H2020 beneficiaries at the grant agreement signature stage	JU AAR RTD Monitoring Report	Yes	Yes	N/A**
N/A	Ethics	The objective is ensuring that research projects funded are compliant with provisions on ethics	% of proposals not granted because non-compliance with ethical rules/proposals invited do grant (target 0%); time to ethics clearance (target 45 days)[92]	Responsible Directorate /Service/Joint Undertaking	JU AAR RTD Monitoring Report			N/A**

NOTES:

*H2020–applicants - all those who submitted H2020 proposals
*H2020 beneficiaries - all those who have signed a H2020 Grant Agreement
**: In 2023, there were no new EU-Rail calls for proposals under H2020. Statistics related to the 2023 EU-Rail call pertaining to the Horizon Europe Programme are provided in Section 1.5 of this CAAR.

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[91] RTO: Research and Technology Organisation
[92] Data relates to pre-granting ethics review. This time span runs in parallel to granting process.

TABLE III - Key Performance Indicators specific for EU-Rail

#	Key Performance Indicator	Objective	Data to be provided by	Baseline at the start of H2020	Target at the end of H2020	Automated	Result 2023
EU-Rail							
1	% reduction in the costs of developing, maintaining, operating and renewing infrastructure and rolling stock and increase in energy efficiency compared to "Stat"-of-the-art"	Reduce the life-cycle cost of the railway transport system	JU	"State-of-the-art" 2014	> 50 %	No	See Table IV
2	% increase the capacity of railway segments to meet increased demand for passenger and freight railway services compared to "Stat"-of-the-art" 2014	Enhance the capacity of the railway transport system	JU	"State-of-the-art" 2014	100%	No	See Table IV
3	% decrease in unreliability and late arrivals compared to "State-of-the-art" 2014	Increase in the quality of rail services	JU	"State-of-the-art" 2014	> 50%	No	See Table IV
4	Reduce noise emissions and vibrations linked to rolling stock and respectively infrastructure compared to "State-of-the-art" 2014	Reduce the negative externalities linked to railway transport	JU	"State-of-the-art" 2014	> 3 - 10 dBA	No	TD1.5 Brake system activities concluded that a reduction of brake noise and dust emissions between 5 and 15% can be expected. The first preliminary investigation showed that, in some conditions, the noise level could be reduced up to 5 dB. TD5.2 with deliverable FR8RAIL iv D2.3 Demonstration of enhanced and integrated line- and yard planning.
5	Addressing open points in TSIs, compared to "State-of-the-art" 2014	Enhance interoperability of the railway system	JU	"State-of-the-art" 2014		No	- One open point of the TSI Infra (tender and IN2TRACK-2) and open point TSI ENE (tender pantograph overhead contact line)

#	Key Performance Indicator	Objective	Data to be provided by	Baseline at the start of H2020	Target at the end of H2020	Automated	Result 2023
							- ATO over ETCS up to GoA3/4 (X2RAIL-4 TD2.2 D.3.1 https://projects.shift2rail.org/s2r_ip2_n.aspx?p =X2RAIL-4) - Contribution to FRMCS Readiness (no direct TD reference, Activity financed via operational procurement "Support to the ERTMS Deployment action as baseline for Shift2Rail (IP2) innovative solutions")
6	Number of Integrated Technology Demonstrators (ITDs) and System Platform Demonstrations (SPD)	Improve market uptake of innovative railway solutions through large-scale demonstration activities	JU	Multi-Annual Action Plan	4 SPD	No	- ITD IP2: Integrated Technology Demonstrator gathering S2R TD2.1 (Adaptable Communication System), S2R TD2.3 (O8Moving Block), S2R TD2.5 (Train Integrity): X2RAIL-5 D12.1 (publicly available) - IP4 ITD4.7 Cohesive final release - IP3 - IN2STEMPO – D10.2 (TD3.9/3.10)
7	Share of the fund allocated to the different Innovation Programmes and to cross-cutting themes	Ensure that funding covers the railway system as a whole	JU	N/A	> 80%	No	100% of the operational funding
8	Percentage of topics resulting in signature of GA	Ensure a sufficiently high call topics success rate	JU	N/A	> 90%	Yes	N/A*
9	% of resources consumption versus plan (members only)	WP execution–by members - resources	JU	N/A	> 80%	Yes	-

#	Key Performance Indicator	Objective	Data to be provided by	Baseline at the start of H2020	Target at the end of H2020	Automated	Result 2023
10	% of deliverables available versus plan (members only)	WP execution–by members - deliverables	JU	N/A	> 80%	No	91,8% - 2015-2020 71,3% - 2020 72,7% - 2021 57% - 2022** 89% - 2023

NOTES:

*: In 2023, there were no new EU-Rail calls for proposals under H2020. Statistics related to the 2023 EU-Rail call pertaining to the Horizon Europe Programme are provided in Section 1.5 of this CAAR.

**: The KPI value for 2022 was affected by the fact that several amendments to the Grant Agreements proposed by the members were in the process of approval by the cut-off date, and consequently, until the amendments are approved, the concerned deliverables are formally considered delayed.

TABLE IV – Release 5 - of the Key Performance Indicators of the Shift2Rail Programme

SPD	LCC	Capacity	Punctuality
Target	-50%	+100%	+50%
High Speed	-20% -21% -14% -15% -18%	58% 58% 68% 69% 74%	39% 35% 35% 29% 19%
Regional	-29% -30% -21% -21% -24%	90% 90% 62% 57% 49%	55% 53% 52% 51% 15%
Metro	-16% -16% -15% -16% -18%	21% 21% 27% 23% 28%	n/a n/a n/a n/a 19%
Freight	-41% -40% -39% -39% -40%	96% 87% 111% 42-114% 91%	57% 57% 57% 78% 71%

release 4.0 release 3.0 release 2.0 release 1.0

One of the objectives of the Shift2Rail Joint Undertaking defined in its regulation is to seek developing, integrating, demonstrating and validating innovative technologies and solutions that uphold the strictest safety standards and the value of which can be measured against, inter alia, 3 quantitative Key Performance Indicators (KPIs). The targets defined are the following: reduction of LCC by 50%, improving the reliability & punctuality by 50% and doubling the capacity.

As the railway is a very interlinked and complex system, it is required to have specific tools and methods to evaluate the effect of technological developments. This question is highly relevant for Shift2Rail as the technologies, which are developed, are to be evaluated with respect to four scenarios called System Platform Demonstrators (SPDs). Hence an approach of estimating the above mentioned KPIs applied on the four generic SPDs based on the market segments high-speed rail, regional rail, metro and freight rail[93] has been applied which were defined in the S2R Master Plan[94].

As some of the Shift2Rail technologies (e.g. Innovation Programme on IT Solutions for Attractive Railway Services) are targeting to increase modal share of rail within the transport sectors by satisfying the customer's travel experience, those innovations cannot be taken directly into account in the three quantitative KPIs,

[93] IMPACT-1 – D4.1 "Reference Scenario" – 2018, Issue 1
[94] Shift2Rail - Shift2Rail Master Plan (MP) – 2015

only via an increased load factor. Therefore, a dedicated model on the improvement of the attractiveness of the rail system is developed independent from the model discussed here (see also explanations to "demand effect").

In 2022, the Release 5 of the KPI model was published. After Release 4, the model was frozen and in 2022, the collection of updated improvement values and accuracy levels was carried out.

The Accuracy of the improvement data was developed for Release 3 to increase the robustness of the model. In Release 4 and 5, the reported numbers of data set linked to the accuracy level and the values of the accuracy level increased.

Key Performance Indicators – KPI

The KPI Life-Cycle-Cost (LCC) is defined as the cost for the railway undertaking over the lifespan of the systems. Hence, they are the investment cost, operative cost like maintenance, labour or energy cost and, where applicable, the dismantling cost.

The KPI Capacity is defined as the maximum possible capacity, which is the maximum number of transportable passengers in one peak hour for the passenger transport scenarios and the maximum of tonne-kilometres in 24 hours for freight.

The KPI Reliability and Punctuality is measured as a 50% decrease of late arrivals mainly caused by unreliability of technologies.

System Platform Demonstrators – SPDs

The reference scenarios (state of the art technologies in 2013) described in the deliverable D4.1 "Reference Scenarios" of IMPACT-1 and were further developed in IMPACT-2. The data for these scenarios were collected from various sources whereas usually there could only one source for each certain parameter be found. The coherence check is scheduled for the next iteration of the model.

Further there are aspects for the four different market segments of the SPDs, which need to be kept in mind, when reviewing the result table. Those aspects are due to the inherent structure and specificities of the different market segments:

For the High-Speed passenger transport (SPD1), relatively new or constantly upgraded vehicles and lines are taken into account, which are more or less best of class in Europe. Therefore, it is on the one hand a much-elaborated basis to start from and on the other hand it can be assumed that effects at less developed railways will show much higher results.

The main relevant KPIs for typically Regional Rail (SPD2) lines are LCC and punctuality. Hence the challenge is here to provide a punctual service at lower cost.

Concerning Metro Rail (SPD3), there are few activities dedicated directly on Metro in direct relation to the specific S2R JU objectives in the short term. Therefore, the results for Metro are mainly based on positive effects of the innovations developed for High Speed or Regional trains as e.g. reduction of energy consumption or improved maintenance. They are not optimised for this special form of rail transport but can help to reduce LCC and improve capacity.

Because SPD4, Freight rail, is not focussing on passenger transport, but freight transport, it differs in some definitions and focus points from the other three SPDs. Further the modelling has not only to consider technological improvements, but also operational optimisation for rail freight transport. Moreover, as generally the introduction of innovations in freight rail operation takes more time than in passenger transport, the technology level in execution is quite moderate. Taking both into account, the more legacy basis to start from and the technological and operational effects, the achievable benefits are much higher than for the other three SPDs.

Furthermore, some innovations cannot show their full potential, because there is only one scenario per market segment. Those scenarios are optimised to show the majority of positive effects but cannot be set to show every effect of every Shift2Rail innovation.

Demand effect

As already explained in the background, large parts of positive effects especially for the passenger transport (SPD1-3) are not adequately measurable through LCC, capacity and punctuality, e.g. new IT solutions (IP4), effects of other innovations such as noise mitigation, customer-oriented services and better quality, increased comfort for the customers, better governance etc. Those will be included in the attractiveness model. Therefore, the increase of demand is not considered in the results for the passenger SPDs, yet, meaning that for the first results there is no change in the load factor and therefore in the demand included. For the freight SPD, a demand increase could already be considered and therefore also its positive effect on the contribution margin.

ANNEX F: HORIZON EUROPE KPIs

Scoreboard of Horizon Europe common Key Impact Pathway Indicators (KIPs)*

Key Impact Pathway**	Short-term	Medium-term	Longer-term	Detail per action or globally for 2023
Towards scientific impact				
1-Creating high-quality new knowledge	Publications - Number of peer-reviewed scientific publications resulting from the Programme	Citations - Field-Weighted Citation Index of peer-reviewed Publications resulting from the Programme	World-class science - Number and share of peer-reviewed publications resulting from the projects funded by the Programme that are core contribution to scientific fields	No data available for 2023
2-Strengthening human capital in R&I	Skills - Number of researchers involved in upskilling (training, mentoring/coaching, mobility and access to R&I infrastructures) activities in projects funded by the Programme	Careers - Number and share of upskilled researchers involved in the Programme with increased individual impact in their R&I field	Working conditions - Number and share of upskilled researchers involved in the Programme with improved working conditions, including researchers' salaries	213
3-Fostering diffusion of knowledge and open science	Shared knowledge Share of research outputs (open data/publication/software etc.) resulting from the Programme shared through open knowledge infrastructures	Knowledge diffusion -Share of open access research outputs resulting from the Programme actively used/cited	New collaborations - Share of Programme beneficiaries which have developed new transdisciplinary/trans sectoral collaborations with users of their open access research outputs resulting from the Programme	No data available for 2023
Towards societal impact				
4-Addressing Union policy priorities and global challenges through R&I	Results - Number and share of results aimed at addressing identified Union policy priorities and global challenges (including SDGs) (multidimensional: for each identified priority) Including: Number and share of climate-relevant results aimed at delivering on the Union's commitment under the Paris Agreement	Solutions - Number and share of innovations and research outcomes addressing identified Union policy priorities and global challenges (including SDGs) (multidimensional: for each identified priority) Including: Number and share of climate-relevant innovations and research outcomes delivering on Union's commitment under the Paris Agreement	Benefits - Aggregated estimated effects from use/exploitation of results funded by the Programme on tackling identified Union policy priorities and global challenges (including SDGs), including contribution to the policy and law-making cycle (such as norms and standards) (multidimensional: for each identified priority) Including: Aggregated estimated effects from use/exploitation of climate-relevant results funded by the Programme on delivering on the Union's commitment under the Paris Agreement including contribution to the policy and law-making cycle (such as norms and standards)	No data available for 2023

5-Delivering benefits and impact through R&I missions	R&I mission results - Results in specific R&I missions (multidimensional: for each identified mission)	R&I mission outcomes - Outcomes in specific R&I missions (multidimensional: for each identified mission)	R&I mission targets met - Targets achieved in specific R&I missions (multidimensional: for each identified mission)	No data available for 2023
6-Strengthening the uptake of R&I in society	Co-creation - Number and share of projects funded by the Programme where Union citizens and end-users contribute to the co-creation of R&I content	Engagement - Number and share of participating legal entities which have citizen and end-users engagement mechanisms in place after the end of projects funded by the Programme	Societal R&I uptake - Uptake and outreach of co-created scientific results and innovative solutions generated under the Programme	No data available for 2023
Towards technological / economic impact				
7-Generating innovation-based growth	Innovative results - Number of innovative products, processes or methods resulting from the Programme (by type of innovation) & Intellectual Property Rights (IPR) applications	Innovations - Number of innovations resulting from the projects funded by the Programme (by type of innovation) including from awarded IPRs	Economic growth - Creation, growth & market shares of companies having developed innovations in the Programme	No data available for 2023
8-Creating more and better jobs	Supported employment - Number of full time equivalent (FTE) jobs created, and jobs maintained in participating legal entities for the project funded by the Programme (by type of job)	Sustained employment - Increase of FTE jobs in participating legal entities following the project funded by the Programme (by type of job)	Total employment - Number of direct & indirect jobs created or maintained due to diffusion of results from the Programme (by type of job)	No data available for 2023
9-Leveraging investments in R&I	Co-investment - Amount of public & private investment mobilised with the initial investment from the Programme	Scaling-up - Amount of public & private investment mobilised to exploit or scale-up results from the Programme (including foreign direct investments)	Contribution to '3 % target' - Union progress towards 3 % GDP target due to the Programme	317,5M

** (based on Annex V to Regulation 2021/695/EU)*
*** NB: For some of those KIPs the data will not be available in the short or even medium term.*

Horizon Europe Partnership common Key Performance Indicators

Criterion addressed	Name of the Indicator	Baseline at the start of HE	Results for 2023	Target 2027
Additionality	Progress towards (financial and in-kind) contributions from partners other than the Union – i.e. committed vs. actual	N/A	EUR 5,3K IKAA certified for a total 166K signed	Total In kind contribution: EUR 576M Total financial contribution to the JU running costs: EUR 24M
Additionality / Synergies	Additional investments triggered by the EU contribution, including qualitative impacts related to additional activities	N/A	Over the course of the programme, EU-Rail members contribute with additional activities, including mobilisation of private investment and national/regional programmes. Expected according to IKAA Plan 2022- 2024: 2023 = EUR 64,9M Estimated 2023 value of IKAA linked to JU objectives/KPIs - EUR 2,6M Estimated 2023 value of IKAA link to JU projects/topics - EUR 62,3M	Target 2022-2024: EUR 150,5M
Directionality	Overall (public and private, in-kind and cash) investments mobilised towards EU priorities	0	EUR 243,9K funding in signed grants linked to the following EU priorities: - European Green Deal - Europe fit for digital age	EUR 600M

International visibility and positioning	International actors involved	0	28 entities from Associated countries and Third countries are participating in projects as associated partners (8 from Norway, 9 from Switzerland, 8 from UK, 1 from Ukraine, 1 from Serbia and 1 from Turkey) By type: 1 public organization (4%), 12 higher or secondary education establishment (43%), 6 research organizations (21%), 7 private for profit organizations (25%) and 2 other organizations (7%)	N/A
Transparency and openness	Share & type of stakeholders and countries invited/engaged	0	In general the entire rail value chain. In projects: 329 beneficiaries (9 public organizations (3%), 56 higher or secondary education establishments (17%), 45 research organizations (14%), 202 private for profit organizations (61%) and 17 others (5%)) from: 26 countries (20 from EU and 6 associated and third countries) In the EU-Rail States' Representatives Group: 31 member states demonstrating interest (27 from EU and 4 associated countries)	N/A

<table>
<tr>
<td>Transparency and openness</td>
<td>No. and types of newcomer members in partnerships and their countries of origin (geographical coverage)</td>
<td>0</td>
<td>
<table>
<tr><th>Organisation Name</th><th>Category</th><th>Countr</th></tr>
<tr><td>Administrador de Infraest</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>ES</td></tr>
<tr><td>Alstom Transport SA</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>FR</td></tr>
<tr><td>ANGELRAIL consortium le</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>IT</td></tr>
<tr><td>AŽD Praha s.r.o</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>CZ</td></tr>
<tr><td>Construcciones y Auxiliar</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>ES</td></tr>
<tr><td>Asociación Centro Tecnol</td><td>[RES Public research organisation (including international research organisation as well as private research organisation controlled by a public authority)]</td><td>ES</td></tr>
<tr><td>České dráhy, a.s.</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>CZ</td></tr>
<tr><td>Deutsche Bahn AG</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>DE</td></tr>
<tr><td>Deutsches Zentrum für Lu</td><td>[RES Public research organisation (including international research organisation as well as private research organisation controlled by a public authority)]</td><td>DE</td></tr>
<tr><td>European Smart Green Ra</td><td>[PRV Other Industrial and/or profit Private organisation] + [RES Public research organisation (including international research organisation as well as private research organisation controlled by a public authority)]</td><td>ES</td></tr>
<tr><td>Faiveley Transport SAS</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>FR</td></tr>
<tr><td>Ferrovie dello Stato Italiar</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>IT</td></tr>
<tr><td>Hitachi Rail STS S.p.A.</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>IT</td></tr>
<tr><td>INDRA SISTEMAS S.A & PATE</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>ES</td></tr>
<tr><td>Jernbanedirektorate (Norv</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>NO</td></tr>
<tr><td>Knorr-Bremse Systems für</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>DE</td></tr>
<tr><td>Österreichische Bundesba</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>AT</td></tr>
<tr><td>Polskie Koleje Państwowe</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>PL</td></tr>
<tr><td>ProRail B.V. & NS Groep N.V.</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>NL</td></tr>
<tr><td>Siemens Mobility GmbH</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>DE</td></tr>
<tr><td>Société nationale SNCF, s</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>FR</td></tr>
<tr><td>Strukton Rail Nederland B</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>NL</td></tr>
<tr><td>THALES SIX GTS France SA</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>FR</td></tr>
<tr><td>Trafikverket</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>SE</td></tr>
<tr><td>voestalpine Railway Syste</td><td>[PRV Other Industrial and/or profit Private organisation]</td><td>AT</td></tr>
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<td>N/A</td>
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Transparency and openness	No. and types of newcomer beneficiaries in funded projects (in terms of types and countries of origin)	N/A	51 newcomers (50 EU & 1 non-EU) of which 9 are SMEs. PRC: 15 PUB: 1 REC: 9 OTH: 3 HES: 23	
Coherence and synergies	Number and type of coordinated and joint activities with other European Partnerships	0	4 back office arrangements (2 of them as leading and lead backup contracting authorising)	7 arrangements among JUs in accordance with Art. 13 of the SBA
Coherence and synergies	Number and type of coordinated and joint activities with other R&I Initiatives at EU /national/regional/sectorial level	0	Coordinated activities at EU level with national / sectorial R&I actions on the Digital Automated Couplers with the European DAC delivery Programme, enabled by EU-Rail. Rail system architecture coordinated in the System Pillar with national and sectorial input notably around signalling activities. Coordination also with Rail Net Europe on infrastructure capacity planning and R&I on traffic management.	N/A

Coherence and synergies	Complementary and cumulative funding from other Union funds (Horizon Europe, National funding, ERDF, RRF, Other cohesion policy funds, CEF, DEP, LIFE, other)	0	Synergies with EU Missions – EUR 0,7M for Smart Cities (Contribution Agreement between the European Union, represented by the European Commission, and EU-Rail, with the objective to provide a financial contribution to finance the implementation of the action "Pilot project - IRS Smart Cities project: new railway station concept for green and socially inclusive smart cities") EUR 2,5M Joint topic call with SESAR	N/A
International visibility and positioning	Visibility of the partnership in national, European, international policy/industry cycles	0	• Published 10 newsletters • Published 6 press releases • Released 5 publications • Organised 4 events • Participated in 62 industry events • Average number of tweets per month was 28 • 4.910 twitter followers by the end of 2023 • 12.098 LinkedIn followers by the end of 2023 • 2.105 newsletter subscribers by the end of 2023 • 116 members in the general contact list (receiving the newsletter and mailshots) • 181 members in media list • 85 mentions in press articles • 39 project deliverables highlighted in the news section of the website • 144.645 unique visitors on the website • 26 articles produced by EU-Rail	N/A

Scoreboard of Key Performance Indicators specific to EU-Rail

#	Impact areas	Key Performance Indicator	Objective	Baseline at the start of HE	Results of 2023	Target at the end of HE
1	Customer requirements	Accuracy in total planned travel time of passengers from improved matching between supply and demand, #	Increase availability and predictability of intermodal rail transport offer	State of art in 2020 (including results from S2R)	* Methodology defined in FP1	75%
		Traffic planning certainty, #	Planning certainty, considering the demand forecast, is a key requirement for planning on time, reliable and efficient service delivery	State of art in 2020 (including results from S2R)	* Methodology defined in FP1	Between 65% and 80%[1]
		Handling/response time for intermodal freight offers and regional passenger services, mins	Improve overall customer experience, including growing intermodal freight transport and regional passenger services	State of art in 2020 (including results from S2R)	* Methodology defined in FP5	-50%
2	Improved Capacity	Trains on the line per hour and direction, #	Increased frequency is a key element for improved capacity	State of art in 2020 (including results from S2R)	* Methodology defined in FP2	At least +10%[2]
		Reduction of total freight transport time, mins	Reduced freight transport time leading to better asset utilization and increased capacity	State of art in 2020 (including results from S2R)	* Methodology defined in FP5	-33%
		Increased average freight train length in existing infrastructure limitations or higher loads, meters	Increased length directly leads to more available capacity	State of art in 2020 (including results from S2R)	* Methodology defined in FP5	Up to 1.500m

3	Reduced Costs	Overall OPEX and CAPEX costs of regional lines, incl. maintenance, infrastructure and vehicles	Direct link to lower costs of the regional lines	State of art in 2020 (including results from S2R)	* Methodology defined in FP6	tbc[3]
		Maintenance costs, including thanks to the use of digital twins, €	Direct link to lower costs	State of art in 2020 (including results from S2R)	* Methodology defined in FP3 and FP4	-10%[4]
		Design and manufacturing costs, €	Leading to reduced investment cost	State of art in 2020 (including results from S2R)	* Methodology defined in FP3	-20%
		Virtual certification tasks that can be conducted in a laboratory, #	Cost of virtual certification activities is much lower than cost of physical certification activities, hence more tasks done virtually leads to lower costs	State of art in 2020 (including results from S2R)	*	+80%[5]
4	Sustainable and resilient transport	Optimized energy consumption and higher punctuality in regional services, kWh per pax-km or tons-km; mins	More efficient operations, leading to lower energy consumption (with lower CO2 emissions)	State of art in 2020 (including results from S2R)	* Methodology defined in FP6	-10% (energy); +15% (punctuality)
		CO2 equivalent emissions	Further decrease rail carbon intensity	State of art in 2020 (including results from S2R)	* Methodology defined in FP4	Up to 30% for specific use cases (e.g. regional operation and heavy duty inspection vehicles)
		Traffic prediction performance, secs	Improve network resilience through dynamic infrastructure restriction handling, train regulation and automated conflict resolution	State of art in 2020 (including results from S2R)	* Methodology defined in FP1	<120 secs[6]

		Time to respond and resolve a vulnerability (regarding cyber security), mins	Reduced impact of events and increased availability of the rail system	State of art in 2020 (including results from S2R)	*	tbc[7]
5	Harmonized approach	CCS system CAPEX and OPEX (of main line and regional lines systems (while maintaining or increasing the present safety level	Reducing costs associated with the interoperability of the network will enhance harmonization	State of art in 2020 (including results from S2R)	* Methodology defined in FP6	CAPEX: -25% (regional lines) and -10% (main lines); OPEX -20% (regional and main lines)
		No new national technical rules triggered by innovative solutions coming from the Joint Undertaking and potential reduction of national rules in relation to ERTMS and interlocking	By decreasing the amount of national rules in force, rail transport will evolve towards the Single European Railway Area	State of art in 2020 (including results from S2R)	*	N/A
		Reduction of answering time between the short-term request of a cross-border train path and the answer with a firm offer, mins	Indicator for more efficient border crossing	State of art in 2020 (including results from S2R)	* Methodology defined in FP1	Down to 5 mins
		Operational dwell time at borders and other handover points relying also on relying on more homogenous system approaches (leading to increase in number of trains on given infrastructure), mins	Indicator for more efficient border crossing	State of art in 2020 (including results from S2R)	* Methodology defined in FP5	-50%
6	Reinforced role for rail	Accuracy in total planned travel time of passengers from improved matching between supply and demand, %	The combination of the indicators from Impact Areas 1 and 3 contribute to more effective and cost-efficient rail transport, thereby improving attractiveness of rail compared with other transport modes	State of art in 2020 (including results from S2R)	* Methodology defined in FP1	75%
		Traffic planning certainty, #		State of art in 2020 (including results from S2R)	* Methodology defined in FP1	Between 65% and 80%[1]
		Handling/response time for intermodal freight offers and regional passenger services, mins		State of art in 2020 (including results from S2R)	* Methodology defined in FP5	-50%

		Overall OPEX and CAPEX costs of regional lines, incl. maintenance, infrastructure and vehicles		State of art in 2020 (including results from S2R)	* Methodology defined in FP6	tbc[3]
		Maintenance costs, including thanks to the use of digital twins, €		State of art in 2020 (including results from S2R)	* Methodology defined in FP3 and FP4	-10%[4]
		Design and manufacturing costs, €		State of art in 2020 (including results from S2R)	* Methodology defined in FP3	-20%
		Virtual certification tasks that can be conducted in a laboratory, #		State of art in 2020 (including results from S2R)	*	+80%[5]
7	Improved	Maturity of innovative technologies	Innovative technologies will deploy rail capabilities and leverage potential competitive advantages for the EU rail industry	State of art in 2020 (including results from S2R)	* Methodology defined in FP4	TRL 8

1 Depending on point in time, e.g. one week in advance or one hour in advance

2 At the moment this KPI is limited with the outcome of FA2 only, in the course of the Programme a consolidated KPI will be measured

3 The nature of the activity requires a full system approach analysis from improvement at components level, which will be conducted during the course of the Programme

4 In specific use cases for both rolling stock and infrastructure and asset management

5 Costs only related to the execution of the on-site tests

6 In a typical scenario of at least 100 trains running in a 2h interval ahead of actual time

7 Due to the confidentiality nature of the baseline, a KPI measure will be assessed and consolidated during the course of the Programme

8 As reflected in the ERA database(s) in relation to OPE TSI Appendix A, annex C and other TSIs in relation to ERTMS and interlocking

* As indicated, a Europe's Rail KPI model is under development.

ANNEX G: IKAA REPORT

As the EU-Rail started officially on 30 November 2021, the operational activities performed in 2022 and in 2023 in relation to EU-Rail are summarized in this current section Annex G. All Private Founding Members shall report about the Amount of certified IKAA for the years 2022 and 2023 by 31 May 2024.

Consequently, this section includes the IKAA reported and certified by 31 May 2024.

IKAA Report 2023

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
1. Support to additional R&I	***21.173.919,09***	***13.881.284,62***	***41.996.546,11***	***47.881.008,32***	***63.170.465,20***	***61.762.292,94***
FP1 - MOTIONAL, FP2 - R2DATO, FP3 - IAM4RAIL	***120.000,00***	***91.757,96***	***100.000,00***	***312.763,09***	***220.000,00***	***404.521,05***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Projects 1,2, and 3 in the context of achieving the objectives and KPIs of the related Flagship Areas	*120.000,00*	*91.757,96*	*100.000,00*	*312.763,09*	*220.000,00*	*404.521,05*
FP1 -MOTIONAL	***3.529.973,85***	***2.539.383,33***	***4.977.243,71***	***2.192.618,03***	***8.507.217,56***	***4.732.001,36***
Additional activities are part and contribute to the Member's activities performed in the context of achieving the objectives and KPIs of the EU-RAIL Programme			*50.000,00*		*50.000,00*	*-*
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 1 in the context of achieving the objectives and KPIs of the related Flagship Area	*3.488.270,43*	*2.539.383,33*	*4.526.173,91*	*2.143.516,81*	*8.014.444,34*	*4.682.900,14*
CFD Simulations and Real operations 1:1 scale tests to determine the admissible pressure load in a freight train during the crossing with a HST in a tunnel	*41.703,42*		*281.069,80*		*322.773,22*	*-*
Reduced models for efficient optimization processes	*-*	*-*	*100.000,00*	*49.101,22*	*100.000,00*	*49.101,22*

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
SW development to automatize ETCS tests, ETCS simulation tools to be adapted to the new TSI releases, Development of a Robot actuator for remote tests, Image Processing system to process images at ETCS DMI to perform automatic tests analysis			*20.000,00*		*20.000,00*	*-*
FP2 - R2DATO	***7.462.874,13***	***2.403.835,25***	***10.983.804,11***	***17.109.161,99***	***18.446.678,24***	***19.512.997,24***
Additional activities are part and contribute to the Member's activities performed in the context of achieving the objectives and KPIs of the EU-RAIL Programme			*100.000,00*		*100.000,00*	*-*
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 2 in the context of achieving the objectives and KPIs of the related Flagship Area	*7.142.508,43*	*2.333.916,53*	*9.607.569,09*	*17.103.463,77*	*16.750.077,52*	*19.437.380,30*
Low costs signalling system for train collition avoidance (e.g. EGNSS)	*200.000,00*	*69.918,72*	*1.200.000,00*	*5.698,22*	*1.400.000,00*	*75.616,94*
Maintenance of ETCS lab Quality system for ISO/IEC 17025 Accreditation and Internal activities/projects to maintain ERTMS labs			*36.100,00*		*36.100,00*	*-*
R&D internal projects related to and complementary to ERJU FAs topics.	*15.851,27*		*40.135,02*		*55.986,29*	*-*
SW development to automatize ETCS tests, ETCS simulation tools to be adapted to the new TSI releases, Development of a Robot actuator for remote tests, Image Processing system to process images at ETCS DMI to perform automatic tests analysis	*104.514,43*				*104.514,43*	*-*
FP2 - R2DATO, FP6 - FutuRe	***154.000,00***	***249.875,56***	***40.000,00***	***138.603,88***	***194.000,00***	***388.479,44***

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Projects 2 and 6 in the context of achieving the objectives and KPIs of the related Flagship Areas	*154.000,00*	*249.875,56*	*40.000,00*	*138.603,88*	*194.000,00*	*388.479,44*
FP3 - IAM4RAIL, FP4 - RAIL4EARTH	***-***		***-***		***-***	***-***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Projects 3 and 4 in the context of achieving the objectives and KPIs of the related Flagship Areas	*-*		*-*		*-*	*-*
FP3 -IAM4RAIL	***5.824.073,16***	***4.585.900,01***	***10.973.407,34***	***12.065.670,27***	***16.797.480,50***	***16.651.570,28***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 3 in the context of achieving the objectives and KPIs of the related Flagship Area	*5.604.073,16*	*4.272.212,10*	*9.713.407,34*	*11.586.753,53*	*15.317.480,50*	*15.858.965,63*
Infrastructure degradation models of metallic components and customized powder manufacturing for AM	*200.000,00*	*313.687,91*	*1.200.000,00*	*478.916,74*	*1.400.000,00*	*792.604,65*
R&D internal projects related to and complementary to ERJU FAs topics.			*20.000,00*		*20.000,00*	*-*
Smart Structural Health Monitoring for High Speed Railway Bridges, including Predictive Maintenance of these infrastructures through Intelligent Systems.	*20.000,00*		*40.000,00*		*60.000,00*	*-*
FP4 - RAIL4EARTH	***1.961.681,08***	***2.454.813,28***	***7.613.993,08***	***7.893.710,44***	***9.575.674,16***	***10.348.523,72***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 4 in the context of achieving the objectives and KPIs of the related Flagship Area	*1.761.681,08*	*2.094.260,11*	*7.393.993,08*	*7.527.674,96*	*9.155.674,16*	*9.621.935,07*

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
High efficiency power electronics and electromagnetic machines, rare earth recovery sustainable processes	*200.000,00*	*360.553,17*	*200.000,00*	*366.035,48*	*400.000,00*	*726.588,65*
R&D internal projects related to and complementary to ERJU FAs topics.			*20.000,00*		*20.000,00*	*-*
FP5- TRANS4M-R	***837.098,76***	***1.475.242,00***	***4.600.098,76***	***6.797.826,07***	***5.437.197,52***	***8.273.068,07***
Additional activities are part and contribute to the Member's activities performed in the context of achieving the objectives and KPIs of the EU-RAIL Programme			*50.000,00*	*5.220,11*	*50.000,00*	*5.220,11*
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 5 in the context of achieving the objectives and KPIs of the related Flagship Area	*837.098,76*	*1.475.242,00*	*4.550.098,76*	*6.792.605,96*	*5.387.197,52*	*8.267.847,96*
FP6-FutuRe	***951.218,11***	***80.477,23***	***677.999,11***	***1.247.786,08***	***1.629.217,22***	***1.328.263,31***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 6 in the context of achieving the objectives and KPIs of the related Flagship Area	*951.218,11*	*80.477,23*	*657.999,11*	*1.247.786,08*	*1.609.217,22*	*1.328.263,31*
R&D internal projects related to and complementary to ERJU FAs topics.			*20.000,00*		*20.000,00*	*-*
Programme	***270.000,00***	***-***	***1.830.000,00***	***122.868,47***	***2.100.000,00***	***122.868,47***
Additional activities are part and contribute to the Member's activities performed in the context of achieving the objectives and KPIs of the EU-RAIL Programme	*120.000,00*		*1.670.000,00*	*122.868,47*	*1.790.000,00*	*122.868,47*
OCORA: Non-funded activities	*150.000,00*	*-*	*150.000,00*	*-*	*300.000,00*	*-*

Additional activities per type and project	IKAA Planned 2022	IKAA Certified 2022	IKAA Planned 2023	IKAA Certified 2023	Total IKAA Planned 22-23	Total IKAA Certified 22-23
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 7 in the context of achieving the objectives and KPIs of the related Flagship Area	-		10.000,00		10.000,00	-
TT - Project NGT Fun System dynamics: Simulation digital Twin concept					-	-
System Pillar: Non-funded activities	**63.000,00**	**-**	**200.000,00**	**-**	**263.000,00**	**-**
Maintenance of ETCS lab Quality system for ISO/IEC 17025 Accreditation and Internal activities/projects to maintain ERTMS labs	13.000,00				13.000,00	-
System Pillar: Non-funded activities	50.000,00	-	200.000,00	-	250.000,00	-
2. Scale-up of technologies	**2.324.040,20**	**1.212.022,02**	**4.946.523,24**	**4.050.653,23**	**7.270.563,44**	**5.262.675,25**
FP1 - MOTIONAL, FP2 - R2DATO, FP3 - IAM4RAIL	**40.000,00**	**45.878,99**	**30.000,00**	**-**	**70.000,00**	**45.878,99**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Projects 1,2, and 3 in the context of achieving the objectives and KPIs of the related Flagship Areas	40.000,00	45.878,99	30.000,00	-	70.000,00	45.878,99
FP1 -MOTIONAL	**1.781.325,00**	**393.511,02**	**2.427.655,00**	**3.085.678,22**	**4.208.980,00**	**3.479.189,24**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 1 in the context of achieving the objectives and KPIs of the related Flagship Area	1.756.325,00	393.511,02	2.402.655,00	3.085.678,22	4.158.980,00	3.479.189,24
Implementation Methodology for Cloud-based native Architecture. Developing Work Model Definition. Digital Enterprise Architecture	25.000,00		25.000,00		50.000,00	-
FP2 - R2DATO	**30.000,00**		**459.651,00**	**128.000,00**	**489.651,00**	**128.000,00**

Additional activities per type and project	IKAA Planned 2022	IKAA Certified 2022	IKAA Planned 2023	IKAA Certified 2023	Total IKAA Planned 22-23	Total IKAA Certified 22-23
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 2 in the context of achieving the objectives and KPIs of the related Flagship Area	30.000,00		459.651,00	128.000,00	489.651,00	128.000,00
FP3 -IAM4RAIL	**111.000,00**		**419.295,00**	**54.998,75**	**530.295,00**	**54.998,75**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 3 in the context of achieving the objectives and KPIs of the related Flagship Area	111.000,00		170.000,00	54.998,75	281.000,00	54.998,75
Innovative system to perform digital visits to the railway network and support asset management and infrastructure maintenance.			249.295,00		249.295,00	-
FP4 - RAIL4EARTH	**176.000,00**		**-**		**176.000,00**	**-**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 4 in the context of achieving the objectives and KPIs of the related Flagship Area	176.000,00		-		176.000,00	-
FP5- TRANS4M-R	**59.755,20**	**772.632,01**	**529.922,24**	**781.976,26**	**589.677,44**	**1.554.608,27**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 5 in the context of achieving the objectives and KPIs of the related Flagship Area	59.755,20	772.632,01	529.922,24	781.976,26	589.677,44	1.554.608,27
FP6-FutuRe	**125.960,00**	**-**	**180.000,00**		**305.960,00**	**-**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 6 in the context of achieving the objectives and KPIs of the related Flagship Area	125.960,00	-	180.000,00		305.960,00	-

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
Programme	**-**		***900.000,00***		***900.000,00***	
Acount based ticketing and new validation systems	-		*200.000,00*		*200.000,00*	
Moving Block -TRL 5 to 7	-		*500.000,00*		*500.000,00*	
ATO Functionality GoA3/4	-		*200.000,00*		*200.000,00*	
3. Demonstrators	***3.658.155,20***	***809.120,04***	***9.801.010,57***	***1.232.992,61***	***13.459.165,77***	***2.042.112,65***
FP1 -MOTIONAL	***858.735,02***	***587.056,24***	***705.648,58***	***349.221,29***	***1.564.383,60***	***936.277,53***
Additional activities are part and contribute to the Member's activities performed in the context of achieving the objectives and KPIs of the EU-RAIL Programme					-	-
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 1 in the context of achieving the objectives and KPIs of the related Flagship Area	*812.816,00*	*587.056,24*	*544.932,00*	*349.221,29*	*1.357.748,00*	*936.277,53*
Solution for the digitization of the linear infrastructure in BIM 3d format from the massive capture of data from Lidar sensors, 360º RGB cameras, GNSS, inertial positioning systems and automatic processing.	*45.919,02*		*160.716,58*		*206.635,60*	-
FP2 - R2DATO	***17.254,87***		***1.267.637,49***	***208.481,48***	***1.284.892,36***	***208.481,48***
Activities for the definition of the basic equipment for the detection of elements of infrastructure and its digitization, equipment for the monitoring trains, track measurement campaign with inspections train.	*17.254,87*		*68.983,49*		*86.238,36*	-
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 2 in the context of achieving the objectives and KPIs of the related Flagship Area	-		*848.654,00*	*208.481,48*	*848.654,00*	*208.481,48*
Onboard Platform HW prototype developmt	-		*200.000,00*		*200.000,00*	

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
ASTP - Absolute safe train positioning	-		150.000,00		150.000,00	
FP3 -IAM4RAIL	***228.042,18***		***1.805.136,54***	***233.074,20***	***2.033.178,72***	***233.074,20***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 3 in the context of achieving the objectives and KPIs of the related Flagship Area	83.000,00		963.400,00	233.074,20	1.046.400,00	233.074,20
Carrying out tests lab test on models, at a 1:1 scale, in the railway track box to analyze and assess any development or technological innovation considered necessary to quickly upgrade track behavior as a whole or to individual track components	23.920,00		95.680,00		119.600,00	-
Compile the information available from tests in which have simulated the passage of trains at a speed greater than 300 km/h (Very High Speed Trains) and extract the relevant conclusions regarding the maximum vertical deflection and levels of acceleration that might be expected in the rail and the sleeper for the improved commercial, nominal and future design speeds, among others.	14.750,22		59.000,86		73.751,08	-
Deepen the knowledge of the network, through the characterization of the parameters influencing the vertical dynamics of the track, to optimize the standards for design, construction and maintenance of track superstructure	26.371,96		105.487,35		131.859,31	-

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
Development of demonstrators at TRL 7 level for early detection of rail defects or broken rails. Human Machine Interface (HMI) and its Integration in the Central Supervision Post, including development of Web platform and mobile APP for real-time data viewing and alarm notification	*80.000,00*		*268.282,14*		*348.282,14*	*-*
Rock fall detection system based on DAS (Distributed Acoustic Sensing) Technology, supported by the use of CCTV cameras. Also, with a Human Machine Interface (HMI) including development of a Web platform for real-time data viewing and alarm notification			*313.286,19*		*313.286,19*	*-*
FP4 - RAIL4EARTH	***1.207.623,13***		***882.587,96***		***2.090.211,09***	***-***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 4 in the context of achieving the objectives and KPIs of the related Flagship Area	*1.207.623,13*		*791.815,31*		*1.999.438,44*	*-*
Construction of zero emission areas around the stations, to promote sustainable mobility in the first and last mile of travelers (transfer from the initial origin to the station and from the station to the final destination), including implementation of Electric Charging Points fed by DC-powered Railway Network	*-*		*90.772,65*		*90.772,65*	*-*
FP5- TRANS4M-R	***1.266.500,00***	***167.540,85***	***4.585.000,00***	***355.248,45***	***5.851.500,00***	***522.789,30***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 5 in the context of achieving the objectives and KPIs of the related Flagship Area	*1.266.500,00*	*167.540,85*	*4.525.000,00*	*355.248,45*	*5.791.500,00*	*522.789,30*

Additional activities per type and project	IKAA Planned 2022	IKAA Certified 2022	IKAA Planned 2023	IKAA Certified 2023	Total IKAA Planned 22-23	Total IKAA Certified 22-23
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 6 in the context of achieving the objectives and KPIs of the related Flagship Area			60.000,00		60.000,00	-
FP6-FutuRe	**80.000,00**	**54.522,95**	**555.000,00**	**86.967,19**	**635.000,00**	**141.490,14**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 6 in the context of achieving the objectives and KPIs of the related Flagship Area	80.000,00	54.522,95	555.000,00	86.967,19	635.000,00	141.490,14
FP7	**-**		**-**		**-**	**-**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 7 in the context of achieving the objectives and KPIs of the related Flagship Area	-		-		-	-
4. Creating new business opportunities	**36.737,00**	**189.339,00**	**26.962,00**	**263.458,00**	**63.699,00**	**452.797,00**
Programme	**36.737,00**	**189.339,00**	**26.962,00**	**263.458,00**	**63.699,00**	**452.797,00**
Software DISC EMAN	36.737,00	189.339,00	26.962,00	263.458,00	63.699,00	452.797,00
5. Training and skills development	**203.000,00**		**1.222.402,51**		**1.425.402,51**	**-**
FP1 -MOTIONAL	**200.000,00**		**1.200.000,00**		**1.400.000,00**	**-**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 1 in the context of achieving the objectives and KPIs of the related Flagship Area	200.000,00		1.200.000,00		1.400.000,00	-
FP2 - R2DATO			**22.402,51**		**22.402,51**	**-**
Training activities to maintain the level of skills of the ETCS experts and SW development			22.402,51		22.402,51	-
FP3 -IAM4RAIL	**3.000,00**				**3.000,00**	**-**

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 3 in the context of achieving the objectives and KPIs of the related Flagship Area	3.000,00				3.000,00	-
FP6-FutuRe	**-**		**-**		**-**	**-**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 6 in the context of achieving the objectives and KPIs of the related Flagship Area	-		-		-	-
6. Contribution to the development of new standards, regulations and policies	***30.127,52***		***66.836,70***		***96.964,22***	**-**
FP7	***8.280,37***		***11.040,50***		***19.320,87***	**-**
Participation in both Spanish UNE Standardisation and CEN (JTC-20) frameworks and WGs for Hyperloop	8.280,37		11.040,50		19.320,87	-
System Pillar: Non-funded activities	***21.847,15***		***55.796,20***		***77.643,35***	**-**
Participation in the European Group modifying SubSet SS-076 (ETCS Test Specs) to the new TSI releases	21.847,15		55.796,20		77.643,35	-
7. Supporting ecosystem development	***415.000,00***		***3.392.200,00***		***3.807.200,00***	**-**
FP1 -MOTIONAL			***2.500.000,00***		***2.500.000,00***	**-**
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 1 in the context of achieving the objectives and KPIs of the related Flagship Area			2.500.000,00		2.500.000,00	-
FP4 - RAIL4EARTH	***111.000,00***		***126.100,00***		***237.100,00***	**-**

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 4 in the context of achieving the objectives and KPIs of the related Flagship Area	*111.000,00*		*126.100,00*		*237.100,00*	*-*
FP5- TRANS4M-R	***154.000,00***		***616.100,00***		***770.100,00***	***-***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 5 in the context of achieving the objectives and KPIs of the related Flagship Area	*130.000,00*		*260.000,00*		*390.000,00*	*-*
Implementation of LL-type brake blocks shoes on freight wagons minimizing noise emission to replace phosphorous cast iron brake blocks shoes are noisier and exceed the limits set by noise regulations. Likewise, with this type of brake blocks shoes, part of the unwanted fires that are produced by sparks from phosphorous cast iron shoes are avoided.	*24.000,00*		*356.100,00*		*380.100,00*	*-*
Programme	***150.000,00***		***150.000,00***		***300.000,00***	***-***
Participation in national organisations and possible pilots and support of inniatives in the shape of contributions towards new concepts and ideas (Railforum, Energy Roundtable, etc.)	*150.000,00*		*150.000,00*		*300.000,00*	*-*
8. Communication, dissemination, awareness raising, citizen engagement	***174.432,31***		***79.243,08***		***253.675,39***	***-***
FP2 - R2DATO	***14.432,31***		***19.243,08***		***33.675,39***	***-***
Participation in Conferences and/or Seminars to communicate and disseminate lab knowledge	*14.432,31*		*19.243,08*		*33.675,39*	*-*
Programme	***160.000,00***		***60.000,00***		***220.000,00***	***-***

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
Additional activities are part and contribute to the Member's activities performed in the context of achieving the objectives and KPIs of the EU-RAIL Programme	*150.000,00*		*50.000,00*		*200.000,00*	*-*
Events, conventions and articles on BIM and Digital Twin internal research activities and applications.	*10.000,00*		*10.000,00*		*20.000,00*	*-*
TT - Participation with own Stand at Innotrans	*-*		*-*		*-*	*-*
9. Other	***497.660,00***	***2.023,00***	***2.520.120,00***	***422.428,74***	***3.017.780,00***	***424.451,74***
FP1 -MOTIONAL	***-***		***417.000,00***		***417.000,00***	***-***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 1 in the context of achieving the objectives and KPIs of the related Flagship Area	*-*		*417.000,00*		*417.000,00*	*-*
FP2 - R2DATO	***-***		***450.000,00***		***450.000,00***	
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 2 in the context of achieving the objectives and KPIs of the related Flagship Area	*-*		*450.000,00*		*450.000,00*	
FP3 -IAM4RAIL	***-***		***353.920,00***		***353.920,00***	***-***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 3 in the context of achieving the objectives and KPIs of the related Flagship Area	*-*		*353.920,00*		*353.920,00*	*-*
FP5- TRANS4M-R	***130.660,00***		***644.200,00***	***389.882,74***	***774.860,00***	***389.882,74***
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 5 in the context of achieving the objectives and KPIs of the related Flagship Area	*130.660,00*		*644.200,00*	*389.882,74*	*774.860,00*	*389.882,74*

Additional activities per type and project	*IKAA Planned 2022*	*IKAA Certified 2022*	*IKAA Planned 2023*	*IKAA Certified 2023*	*Total IKAA Planned 22-23*	*Total IKAA Certified 22-23*
FP6-FutuRe	**-**		***30.000,00***		***30.000,00***	
Additional activities are part and contribute to the Member's activities performed and described within the Flagship Project 6 in the context of achieving the objectives and KPIs of the related Flagship Area	-		*30.000,00*		*30.000,00*	
Programme	***367.000,00***	***2.023,00***	***625.000,00***	***32.546,00***	***992.000,00***	***34.569,00***
Input into EDDP, DAC4EU, DACcellerate	-		-		-	-
Participation in meetings and active input into WP2, 3 and 4 of EDDP. DAC4EU, DACcellerate, participation in meetings.	*131.000,00*	*2.023,00*	*350.000,00*	*32.546,00*	*481.000,00*	*34.569,00*
Preliminary design for the implementation of an IT platform, for use by all actors in the supply chain	*236.000,00*				*236.000,00*	-
Final design for the implementation of an IT platform, for use by all actors in the supply chain- enable a comprehensive view of services in the market; - enable tracking of shipments.			*275.000,00*		*275.000,00*	-
Grand Total	***28.513.071,32***	***16.093.788,68***	***64.051.844,21***	***53.850.540,90***	***92.564.915,53***	***69.944.329,58***

TOTAL IKAA 2022-2023: BREAKDOWN PER COUNTRY	
Country *(code)*	**Value (€)**
Austria	5.951.263,04
France	741.874,15
Germany	28.835.483,29
Hungary	2.291.647,68
India	1.373.196,26
Italy	11.412.530,95
Netherlands	4.460.750,00
Norway	647.335,88
Spain	7.419.295,29
Sweden	2.809.164,59
Switzerland	2.129.566,79
USA	1.384.855,67
TOTAL CERTIFIED IKAA	**69.944.329,59**

TOTAL IKAA 2022- 2023 (Evolution - Value in €)		
Planned IKAA	**Reported IKAA with pending certification**	**Certified IKAA**
92.482.638,69	**1.215.337,79**	**69.944.329,59**

ANNEX H: FINAL ANNUAL ACCOUNTS

Balance Sheet

	Note	31.12.2023	31.12.2022
NON-CURRENT ASSETS			
Intangible assets	2.1	-	535,00
Property, plant and equipment	2.2	79.798,00	118.527,00
Long term pre-financing	2.3	69.719.201,26	104.484.979,55
		69.798.999,26	**104.604.041,55**
CURRENT ASSETS			
Short term pre-financing	2.3	71.976.851,50	18.392.065,64
Exchange receivables and non-exchange recoverables	2.4	54.323.477,81	63.358.048,14
		126.300.329,31	**81.750.113,78**
TOTAL ASSETS		**196.099.328,57**	**186.354.155,33**
CURRENT LIABILITIES			
Payables and other liabilities	2.7	102.862.624,93	85.123.177,19
Accrued charges and deferred income	2.8	90.551.257,37	53.031.195,37
		193.413.882,30	**138.154.372,56**
TOTAL LIABILITIES		**193.413.882,30**	**138.154.372,56**
Contribution from Members	2.9	908.611.861,66	761.095.899,16
Accumulated deficit		(712.896.116,39)	(567.167.034,40)
Economic result of the year		(193.030.299,00)	(145.729.081,99)
NET ASSETS		**2.685.446,27**	**48.199.782,77**
LIABILITIES AND NET ASSETS		**196.099.328,57**	**186.354.155,33**

Statement of financial performance

	Note	2023	2022
REVENUE			
Revenue from non-exchange transactions			
Recovery of operating expenses	3.1	125.901,38	142.114,26
Financial revenues	3.2	11.087,51	552,87
Revenue from exchange transactions	3.3		
Other exchange revenue		15.260,00	2.523,00
Total revenue		**152.248,89**	**145.190,13**
EXPENSES			
Operating costs	3.4	(188.711.323,66)	(141.317.469,71)
Staff costs	3.5	(2.513.179,05)	(2.096.782,59)
Financial expenses	3.6	(1.125,81)	(52,29)
Other expenses	3.7	(1.956.919,37)	(2.459.967,53)
Total expenses		**(193.182.547,89)**	**(145.874.272,12)**
ECONOMIC RESULT OF THE YEAR		**(193.030.299,00)**	**(145.729.081,99)**

Cash flow statement

	2023	2022
Economic result of the year	*(193.030.299,00)*	*(145.729.081,99)*
Operating activities		
Depreciation and amortization	*55.703,80*	*56.924,76*
(Increase)/decrease in pre-financing	*(18.819.007,57)*	*(46.300.478,53)*
(Increase)/decrease in exchange receivables and non-exchange recoverables	*9.034.570,33*	*(23.081.210,86)*
Increase/(decrease) in payables	*17.739.447,74*	*(12.783.082,12)*
Increase/(decrease) in accrued charges & deferred income	*37.520.062,00*	*(4.456.611,22)*
Increase/(decrease) in cash contributions	*85.252.678,62*	*158.269.110,86*
Increase/(decrease) in in-kind contributions	*62.263.283,88*	*74.047.377,86*
Other non-cash movements	-	-
Investing activities		
(Increase)/decrease in intangible assets and property, plant and equipment	*(16.439,80)*	*(22.948,76)*
NET CASHFLOW	**(0,00)**	**0,00**

Net increase/(decrease) in cash and cash equivalents	-	-
Cash and cash equivalents at the beginning of the year	-	-
Cash and cash equivalents at year-end	-	-

Statement of changes in net assets

	Contribution from Members	Accumulated Surplus/(Deficit)	Economic result of the year	Net Assets
BALANCE AS AT 31.12.2021	**528.779.410,44**	**(433.698.132,96)**	**(133.468.901,44)**	**(38.387.623,96)**
Allocation 2021 economic result	-	*(133.468.901,44)*	*133.468.901,44*	-
Cash contribution	*155.271.954,16*	-	-	*155.271.954,16*
Contribution in-kind	*74.047.377,86*	-	-	*74.047.377,86*
Unpaid cash contributions	*2.997.156,70*	-	-	*2.997.156,70*
Economic result of the year	-	-	*(145.729.081,99)*	*(145.729.081,99)*
BALANCE AS AT 31.12.2022	**761.095.899,16**	**(567.167.034,40)**	**(145.729.081,99)**	**48.199.782,77**
Allocation 2022 economic result	-	*(145.729.081,99)*	*145.729.081,99*	-
Cash contribution	*86.213.991,22*	-	-	*86.213.991,22*
Contribution in-kind	*62.263.283,88*	-	-	*62.263.283,88*
Unpaid cash contributions	*(961.312,60)*	-	-	*(961.312,60)*
Economic result of the year	-	-	*(193.030.299,00)*	*(193.030.299,00)*
BALANCE AS AT 31.12.2023	**908.611.861,66**	**(712.896.116,39)**	**(193.030.299,00)**	**2.685.446,27**

ANNEX I: MATERIALITY CRITERIA

This Annex provides explanation on how the EU-Rail Executive Director defined the materiality threshold as a basis for determining whether significant weaknesses should be subject to a formal reservation to his declaration of assurance. Both qualitative and quantitative criteria were set in this regard, as follows.

Qualitative criteria

Significant weaknesses in the internal control system
Deficiencies in EU-Rail's internal control system (ICS) considered significant, meaning that the existence of such deficiencies does not allow to conclude that the concerned ICS Component(s) and/or the ICS as a whole is present and functioning. ICS weaknesses may be identified by the JU's management activities, through dedicated self-assessment exercises, by internal or external auditors or by a third party, as applicable.

Critical issues outlined by the European Court of Auditors, the Internal Audit Service and OLAF
Any findings/observations made by the ECA, the IAS or OLAF, which, given their nature and/or magnitude, indicate serious deficiencies in management of risks or in the design and implementation of the internal control system at EU-Rail. Significant delay in the implementation of the action plan addressing previously issued critical findings/observations of ECA/IAS/OLAF may also be taken into account.

Significant reputational events
Events or weaknesses which have a significant reputational impact on EU-Rail, on the associated Commission services (DG MOVE, DG RTD), or on the European Union as such, irrespective of the amount of damage to EU-Rail's administrative and operational budget, will be considered for issuing a reservation to the declaration of assurance.

Quantitative criteria applicable to the JU's Programme falling under Horizon 2020 (S2R Programme)

Residual error rate
Given the fact that more than 90% of the JU's operational expenditure allocated to the H2020 Programme was related to its grants, the focus of assurance in terms of the legality and regularity of the underlying transactions will therefore principally be on the level of errors identified in the ex-post audits of cost claims in grants on a multi-annual basis. These ex-post audits are carried out by the CAS based on a common audit approach shared among the research framework programmes' implementing bodies.

As a result of its multiannual nature, the effectiveness of the EU-Rail's controls can only be fully measured and assessed at the final stages of the Programme's lifetime once the ex-post audit strategy has been fully implemented and systematic errors have been detected and corrected.

In this respect, the decision on whether the ED needs to make a formal reservation to his declaration of assurance for the respective financial year is based on the value of the JU's residual error rate. This should, as follows from the common R&I Family target expressed in the legislative financial statement accompanying the Commission's proposal for the Horizon 2020 regulation, remain within a range of 2 to 5%, aiming to be as close as possible to 2%. However, the JU's control objective is to ensure for the H2020 Programme, that the residual error rate, which represents the level of errors that remain undetected and uncorrected, does not exceed 2% of the total expense recognised until the end of the Programme. Nevertheless, even before the end of the Programme, if the value of the residual error rate is not below 2% at the end of the respective reporting year, the ED might still make a reservation. For this, in addition to this quantitative threshold, the qualitative aspects of the underlying weaknesses will be considered as well before finally deciding on making a reservation, such as:

- The nature and scope of the weaknesses;
- The duration of the weaknesses;
- The existence of compensatory measures (mitigating controls which reduce the impact of the weaknesses);
- The existence of effective corrective actions to correct the weaknesses (action plans and financial corrections) which have had a measurable impact.

The starting point to determine the effectiveness of the controls in place is the "representative error rate" expressed as a percentage of errors in favour of the JU detected by ex-post audits measured with respect to the amounts accepted after ex-ante controls.

The representative error rate will be calculated as the weighted average (WAER) for a population, from which a representative sample has been drawn, according to the following formula:

$$\text{WAER\%} = \frac{\Sigma\ (\text{err})}{A} = \text{RepER\%}$$

Where:

Σ (err) = sum of all individual error rates of the sample (in value). Only those errors in favour of the JU will be taken into consideration.

A = total amount of the representative audited sample expressed in EUR.

Second step - calculation of the residual error rate:
To take into account the impact of the ex-post controls, this error level is to be adjusted by subtracting:

- errors detected and corrected as a result of the implementation of audit conclusions;
- errors corrected as a result of the extrapolation of audit results to non-audited contracts with the same beneficiary.

This results in a residual error rate, which is calculated by using the following formula:

$$\text{ResER\%} = \frac{(\text{RepER\%} * (P - A)) - (\text{RepERsys\%} * E)}{P}$$

Where:

ResER% = residual error rate, expressed as a percentage.

RepER% = representative error rate, or error rate detected in the representative sample, in the form of the WAER, expressed as a percentage and calculated as described above (WAER%).

RepERsys% = systematic portion of the RepER% (the RepER% is composed of complementary portions reflecting the proportion of 'systematic' and 'non-systematic' errors detected) expressed as a percentage.

P = total amount of the auditable population of cost claims, expressed in EUR.

A = total of all audited amounts, expressed in EUR.

E = total non-audited amounts of all audited beneficiaries. This will comprise the total amount, expressed in EUR, of all non-audited but validated and paid costs for all audited beneficiaries, excluding those beneficiaries for which an extrapolation is ongoing.

This calculation will be performed on a point-in-time basis, i.e. all the figures will be provided as of a certain date.

ANNEX J: LIST OF ACRONYMS

Abbreviation	
ABAC	Accrual Based Accounting
ADI	Austempered Ductile Iron
AO	Authorising Officer
ATO	Automated Train Operation
AWP	Annual Work Plan
BOA	Back Office Arrangements
CA	Commitment Appropriation
CAAR	Consolidated Annual Activity Report
CAS	Common Audit Service
CAPEX	Capital Expenditure
CBM	Condition-Based Maintenance
CBO	Common Business Objectives
CBTC	Communication Based Train Control
CCA	Cross Cutting Activities
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CFM	Call for Members
Covid-19	'CO' stands for corona, 'VI' for 'virus, and 'D' for disease. Formerly, this disease was referred to as '2019 novel coronavirus' or '2019-nCoV.' The COVID-19 virus is a new virus linked to the same family of viruses as Severe Acute Respiratory Syndrome (SARS) and some types of common cold.
CRS	Common Representative Sample
CREL	Core Release
CSA	Coordination and support action
CW	Cloud Wallet
DOI	Digital Object Identifier
DRIMS	Dynamic Railway Information Management System
EC	European Commission
ECA	European Court of Auditors
ED	Executive Director
EDPS	European Data Protection Supervisor
ED-SIPB	ED System and Innovation Programme Board
EDV	Electronic Distributor Valve
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EN	European Norm
ERA	European Union Agency for Railways
ERRAC	European Rail Research Advisory Council
ERTMS	European Rail Traffic Management System
ETCS	European Train Controlling System
EU	European Union

EUAN	European Union Agencies Network
EUG	ERTMS Users Group
EU-Rail	The Europe’s Rail Joint Undertaking
FACTs	Flexible AC Transmission Systems
FFFIS	Form Fit Functional Interface Specifications
FIS	Functional Interface Specifications
FREL	Final Release
GA	Grant Agreement
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GoA	Grade of Automation
H2020	Horizon 2020, EU framework programme for Research and Innovation
HST	High-Speed Train
HVAC	Heating, Ventilation Air Conditioning and Cooling
IA	Innovation Action
IAMS	Intelligent Asset Management System
IAS	Internal Audit Service
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IKAA	in-kind contributions to additional activities
IP	Innovation Programme/Innovation Pillar
IPR	Intellectual Property Rights
ISO	International Standardisation Organisation
IT	Information Technology
ITD	Integrated Technology Demonstrator
JTI	Joint Technology Initiative
JU	Joint Undertaking
KPI	Key Performance Indicator
LCC	Life Cycle Cost
LIDAR	Light Detection and Ranging
LP	Lighthouse Project
LTE	Long-Term Evolution (standard for wireless communication)
MAAP	Multi-Annual Action Plan
MaaS	Mobility as a Service
MB(S)	Moving block (System)
MC	Mission Critical
MNO	Mobile Network Operator
NaaA	Network as an Asset
NaaS	Network as a Service
NLOS	non-line-of-sight
NTP	Network Time Protocol
OC	Open Call

ODM	Operational Data Management
OMTS	On-board Multimedia and Telematics Services
OPEX	Operating Expenditure
PA	Payment Appropriation
RCA	Railway Command Control and Signalling Architecture
R&I	Research and Innovation
PPP	Public Private Partnership
PRM	Persons with Reduced Mobility
PTC	Positive Train Control
PTI	Platform Train Interface
QoA	Quality of Service
RAL	Unpaid amount
RAMS	Reliability and Maintainability System
RBC	Radio Block Centre
RFID	Radio Frequency Identification
RIA	Research and innovation action
RoI	Return of Investment
S2R	Shift2Rail
SBA	The Single Basic Act - Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe
SC	Scientific Committee
SDG	Sustainable Development Goals
SETA	Single European Transport Area
SEMP	System Engineering Management Plan
SiC	Silicon Carbide
SIR	Staff Implementing Rules
SLA	Service Level Agreement
SME	Small and Medium Enterprise
SNE	Seconded National Expert
SP	System Pillar
SPD	System Platform Demonstration
SPSG	System Pillar Steering Group
SRG	States Representatives Group
SSG	Scientific Steering Group
SWL	Single Wagon Load
TAF	Telematic Application for Freight
TAP	Telematic Application for Passengers
TCMS/NG-TCMS	Train Control and Monitoring System/Next Generation Train Control and Monitoring System
TCO	Total Cost of Ownership
TD	Technology Demonstrator
TL	Train Load
TMS	Traffic Management System
TRL	Technology Readiness Level

TSI	Technical Specifications for Interoperability
TSP	Travel Service Provider
UAV	Unmanned Aerial Vehicle
UG	User Group
UN	United Nations
WA	Work Area
WP	Work Package
WSP	Wheel Slide Protection

ANNEX K: INFORMATION PERTAINING TO THE FORMER SHIFT2RAIL JOINT UNDERTAKING

List of Members of the S2R JU until 29/11/2021

Founding Members

ALSTOM, BOMBARDIER, CAF, Hitachi Rail STS, NetworkRail, SIEMENS, THALES, TRAFIKVERKET

Associated Members

AMADEUS, AŽD Praha, DB, DIGINEXT, Faiveley Transport, HaCon, indra, KNORR-BREMSE, kontron S&T Group, mermec, SNCF, Talgo

Virtual Vehicle Austria Consortium (VVAC+)

AC²T research, AVL, FCP, getzner, KIRCHDORFER, MCL, Plasser & Theurer, PJM, TATRAVAGÓNKA POPRAD, virtual vehicle, voestalpine, WIENER LINIEN

European Rail Operating community Consortium (EUROC)

bls, CP Comboios de Portugal, Infraestruturas de Portugal, ÖBB, ProRail, PKP Polskie Koleje Państwowe Spółka Akcyjna, TCDD, SBB CFF FFS, Slovenske železnice, VÄYLÄ

Swi'Tracken Consortium

egis, EUROTUNNEL, izt, TATA STEEL, TRONICO, RAILENIUM, Universidade do Minho, Universidad del País Vasco / Euskal Herriko Unibertsitatea, U.PORTO, vossloh

Smart DeMain(SDM) Consortium

acciona, cemosa, DLR, Fraunhofer IVI, Strukton Rail

AERFITEC

AERnnova, FIDAMC, tecnalia

Competitive Freight Wagon Consortium(CFW)

ceit, ConTraffic, DIE BAHNINDUSTRIE., DLR, WBN

Smart Rail Control (SmartRaCon) consortium

ceit, DLR, NSL, RAILENIUM

Factsheet of the S2R JU as at 29/11/2021

Name	Shift2Rail Joint Undertaking (also referred to as "S2R JU" or "S2R")
Objectives	The Shift2Rail Joint Undertaking is a public-private partnership in the rail sector, providing a platform for cooperation that drives innovation in the years to come. The S2R JU pursues research and innovation (R&I) activities in support of the achievement of the Single European Railway Area and should improve the attractiveness and competitiveness of the European rail system. The S2R JU contributes to: • a 50 % reduction of the life-cycle cost of the railway transport system (i.e. costs of building, operating, maintaining and renewing infrastructure and rolling stock), • a 100 % increase in the capacity of the railway transport system, • a 50 % increase in the reliability and punctuality of rail services (measured as a 50 % decrease in unreliability and late arrivals). The S2R JU shall propose innovative solutions to be explored, tested and demonstrated in operational environment and/or "zero on site" to achieve market uptake. Beyond that, with the deployment of its innovative solutions the S2R JU will foster connections between people, regions, cities, and businesses, supporting the socioeconomic objectives of the Union.
Founding Legal Act	Council Regulation (EU) No 642/2014 of 16 June 2014 establishing the Shift2Rail Joint Undertaking[95] (S2R Regulation)
Executive Director (ED)	Mr Carlo M. Borghini, as from 16 May 2016
Governing Board (S2R GB) **As at end of Jan 2021**	***European Commission (EC) members:*** • *Henrik Hololei*, DG MOVE ***EC alternates:*** • MOVE DDG 2 *Kristian Schmidt* • RTD D *Rosalinde Van Der Vlies* ***Industry members:*** • ALSTOM *Nicolas Castres Saint Martin* • AŽD Praha *Vladimir Kampik* • BOMBARDIER TRANSPORTATION *Nicolas Castres Saint Martin* • CAF *Imanol Iturrioz* • DEUTSCHE BAHN *Hans Peter Lang* • EUROC *Thomas Petraschek* • HACON *Lars Deiterding* • HITACHI RAIL STS *Antonella Trombetta* • INDRA *Javier Rivilla Lizano* • KNORR-BREMSE *Hans-Christian Hilse* • NETWORK RAIL *Robert Ampomah* • SIEMENS *Roland Edel* • SMARTDEMAIN *Henk Samson* • SMARTRACON *Michael Meyer zu Hörste* • SNCF *Carole Desnost* • THALES *Yves Perreal (Industrial Spokesperson)*

[95] OJ L 177, 17.6.2014, p. 9

	• TRAFIKVERKET *Bo Olsson* • VVAC+ *Filip Kitanoski* ***Industry alternates:*** • ALSTOM *Sophie Perrocheau* • AŽD Praha *Michal Pavel* • BOMBARDIER TRANSPORTATION *Richard French* • CAF *Jorge De Castro* • DEUTSCHE BAHN *Ralf Marxen* • EUROC *not appointed* • HACON *Rolf Gooßmann* • HITACHI RAIL STS *Claudio Monti* • INDRA *not appointed* • KNORR-BREMSE *Jasmina Brackovic* • NETWORK RAIL *Felicity Osborn* • SIEMENS *Jürgen Schlaht* • SMARTDEMAIN *Javier Bonilla Díaz* • SMARTRACON *Jaizki Mendizabal* • SNCF *Christophe Cheron* • THALES *Alberto Parrondo* • TRAFIKVERKET *Christer Lofving* • VVAC+ *Erik Stocker* ***Other participants:*** • *Carlo M Borghini* Executive Director of EU-Rail ***Observers:*** • *Josef Doppelbauer* (ERA) • *Ana Gigantino* (ERA) • *Ny Tiana Tournier* (ERA) • *Angela Di Febbraro* (SC Chair) • *Sarah Bittner-Krautsack* (SRG Chair) • *Miroslav Haltuf* (SRG Vice Chair)
Other bodies	Scientific Committee (SC) States Representatives Group (SRG) Innovation Programmes' Steering Committees (IP SteCos)
Strategic Research Agenda	In accordance with the S2R Regulation, the strategic research and innovation agenda of the S2R JU is described in the Multi-Annual Action Plan (MAAP) adopted in its latest version in November 2019, by means of the GB Decision N° 9/2019. The original MAAP of 2015 is maintained as a reference document.

ANNEX L: LIST OF FOUNDING MEMBERS OF THE EUROPE'S RAIL JOINT UNDERTAKING

Europe`s Rail

RAIL-RESEARCH.EUROPA.EU