

PRIORITISING COLLABORATIVE RAIL INNOVATION

A BOOST FOR INTEROPERABILITY TO TRANSFORM THE SECTOR AND STRENGTHEN EUROPEAN INDUSTRIAL LEADERSHIP

*Horizon Europe/FP10 and the European Competitiveness Fund (ECF)
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A European commitment in line with the sector's strategic importance

On June 8th, in recognising the strategic role of the rail sector in Europe's industrial future, the Transport Council highlighted the need to bolster initiatives that enable the development of common technologies, accelerate innovation and strengthen Europe's leading position.

For the rail sector, the continuation of a collaborative initiative on rail research and development within the framework of the 10th Framework Programme – the successor to the current Horizon Europe programme – and its link to the future European Competitiveness Fund (ECF) must be fundamental when tackling challenges such as improving the user experience, the digital transformation of the railway system, increasing its capacity, efficiency, resilience and sustainability, as well as strengthening connectivity and territorial cohesion in Europe.

These challenges will shape the development of the rail sector over the coming decades and will require interoperable design solutions that are coordinated at European level. Only by fostering public-private partnerships between the various stakeholders in the rail ecosystem – who, together with the European Commission, establish appropriate governance arrangements – will it be possible to accelerate the sector's transformation and consolidate Europe's industrial leadership in the sector within an increasingly competitive global environment.

Europe's Rail, a key tool for driving innovation and transformation in the sector

Joint Undertakings are an instrument that provides a reliable governance framework to coordinate the contributions of infrastructure managers, railway operators, industry, SMEs and academia across the entire railway value chain, reducing the risks associated with innovation, fostering equitable collaboration and accelerating the development and market deployment of new technologies for the benefit of the entire European railway sector.

A Joint Undertaking dedicated to the rail sector, with a focus on innovation, has mitigated the risks associated with innovation and its development. It provides a neutral governance structure, shared strategic leadership, coordinated funding and access to the entire ecosystem of stakeholders. This ensures that innovation within the sector can be developed collaboratively, tested and scaled up and

In the next Framework Programme, this role for the sector must be strengthened, with particular attention paid to maintaining the cycle that begins with pure research, in order to harness innovation as a lever for the development of demonstration, validation and pre-deployment activities. The aim is to bridge the gap between research and deployment, with innovation playing a key role in accelerating the adoption of new technologies and operational processes, maximising the impact of public investment and contributing to the transformation of the European railway system under balanced conditions.

Abandoning institutional collaboration in the field of innovation would compromise the competitiveness of the European industrial sector

Europe's Rail has demonstrated the value of structured collaboration between industry, operators, infrastructure managers, technology centres and research organisations, facilitating a transfer of knowledge that would be difficult to achieve through conventional funding instruments, which are more rigid and less suited to the sector's cooperation needs.

This collaborative approach accelerates the technological maturation of innovations, encourages their adoption and boosts the European Union's industrial leadership. Indeed, this programme makes it possible to:

- Provide the stability and visibility needed to guide long-term public and private investment.
- Align the strategic priorities, resources and capabilities of the various stakeholders.
- Maintain a common governance framework that facilitates cooperation and decision-making on shared challenges.
- Encourage the development of interoperable and standardised solutions from the outset.
- Reduce the time needed to bring innovations to market.

This role in the rail sector is particularly important for developments at TRL 7 and 8, where technologies move from the demonstration and validation phase to real-world operational environments and face the challenges of market acceptance, industrialisation, certification, procurement and deployment. At this stage, innovators in the sector often encounter asymmetrical relationships, fragmented demand, intellectual property issues and limited access to operational test environments, which are the preserve of the relatively few operators and infrastructure managers at Member State level.

This creates further barriers on top of the lack of operational harmonisation, which discourages new investment and delays the transition from innovation to commercial adoption. Without a dedicated Joint Undertaking for the sector, the railway ecosystem and the resulting outcomes would risk further fragmentation, slower technology transfer, duplication of effort and reduced alignment between research, operations and market needs, which would ultimately reduce Europe's ability to rapidly translate innovation into competitive and applicable railway solutions, and would therefore hinder the achievement of the Single European Railway Area (SERA).

Maintaining European leadership in the rail sector through collaborative innovation

Against a backdrop of growing global technological competition, Europe must maintain its capacity to develop its own railway technologies, take the lead in setting standards and bring innovation to market. The railway sector is one in which Europe retains a position of international leadership, underpinned by a solid industrial and technological base.

To maintain this advantage, we must remain firmly committed to collaborative research and development, strengthening Europe's capacity to generate innovation, bring new solutions to maturity and roll them out across the continent. This is a matter of competitiveness, industrial leadership and technological autonomy.

Spain is committed to ensuring the continuation of Europe's Rail in order to consolidate Europe's role as a global leader in the sector

For Spain, the future of the European railway system requires transforming research into solutions that are ready for market launch, operational adoption and roll-out. In this context, the continuation of Europe's Rail will be key to accelerating the implementation of solutions that will enable further improvements to rail transport, strengthen European technological autonomy and bolster the sector's industrial capacity.

Why Spain is seeking an ambitious institutional partnership in the 10th Framework Programme

The rail sector is of strategic importance to the competitiveness, sovereignty and security of the European Union, as well as being an indispensable driver of the green transition.

In Spain, it is a cornerstone of the economy, driven by a unique ecosystem that brings together manufacturers, operators, research centres, universities and world-class engineering firms. In fact, the Spanish railway sector accounts for 7.4 per cent of Spain's GDP and represents 20 per cent of the sector's turnover in Europe. Exports account for 70 per cent of the total turnover of Spanish railway companies. Rail transport in Spain accounts for just 0.4 per cent of total CO₂ emissions, compared with 7.6 per cent for the EU, whilst carrying out 8 per cent of total passenger journeys and over 9,000 million net tonne-kilometres of freight transport; these latter figures are set to rise as European decarbonisation targets are met.

In this context, Europe's Rail is much more than a research programme: it is the main European tool for the sector's competitiveness. As the successor to Shift2Rail, it has gradually expanded the existing value chain — comprising manufacturers (CAF, Talgo, Indra), multi-service companies specialising in the sector (CEMOSA, COMSA, ENYSE, VÍAS, ACCIONA) and research centres (CEIT, UPM) — to include other organisations covering all segments, such as railway administrators and operators (ADIF and RENFE), engineering consultancies (INECO) and public testing and experimentation centres with their laboratories (CEDEX), with the aim of developing the technologies, standards and regulatory changes that will shape the European railway of the future.

The results show that the collaborative model works:

- Thanks to its two pillars — Innovation and System — 'Europe's Rail' delivers concrete results in key European priorities: automation (ATO), artificial intelligence, cybersecurity, traffic management, data analytics, robotics, predictive maintenance, infrastructure resilience to climate change, the promotion of multimodality, and the reduction of rail system costs.
- Beyond the technological outcomes, institutional collaboration is a genuine tool for European industrial policy. By supporting an innovative and competitive rail industry, it contributes directly to the implementation of the Single European Railway Area (SERA) and the Trans-European Transport Network (TEN-T), as well as to a high-speed network that directly connects the capitals of Member States, whilst enabling Europe to set international technological standards in a sector in which it remains a world leader. Preserving this leadership is a key challenge for technological sovereignty in the face of intensifying international competition.

- The partnership also provides the visibility and stability that are essential for the entire railway value chain. Thanks to its multi-annual programming, it creates an environment favourable to industrial investment and the private sector's long-term commitment. By contrast, annual funding, without an institutional partnership under the 10th Framework Programme, would neither enable nor guarantee private investment, nor maintain a pace of innovation commensurate with Europe's ambitions.

What strategic directions should a new 'Europe's Rail 2028–2034' partnership follow?

The future partnership to succeed Europe's Rail, which will form part of the new FP10 framework programme for the period 2028–2034, must be fully aligned with the EU's priorities, particularly in terms of competitiveness, and geared towards the strategic development objectives of the SERA and the TEN-T. To maximise its added value, the partnership should focus its efforts on a limited number of strategic priorities.

Supporting the implementation of European policies

This collaboration should contribute directly to:

- The development of the Single European Railway Area (SERA) and the TEN-T.
- The harmonisation of technical and regulatory requirements.
- The simplification of procedures.

The European Commission, in collaboration with the Member States, will set the priorities.

Further expanding innovation

Future calls for proposals should promote:

- Greater participation by SMEs.
- The integration of academia and research centres from the outset of the JU, as full members, with tailored funding rules.
- Synergies with technologies from other sectors (AI, software, chips, cybersecurity, batteries, etc.).
- Inclusion of urban rail transport.

Research topics and strategic technologies that should be supported

Although there are many, the following are particularly noteworthy:

- Increased automation up to full autonomy (GoA3/4), human-machine interfaces, sensors and precise positioning for safety purposes.
- AI-assisted decision-making for safety.
- Secure telecommunications, both terrestrial and satellite-based (LEO, GovSatCom, etc.).
- The digital twin for virtual certification.
- Development of sustainable materials suitable for the rail sector.
- Biodiversity conservation and vegetation management.
- Quantum computing for rail operations.
- Automation and robotisation for asset monitoring and maintenance.
- Adaptation to climate change and strategic decision-making.
- Cybersecurity and system resilience.
- AI for the operational and multimodal management of urban transport systems.
- Harmonisation of operational standards for control and command systems.

- Harmonisation of digital chains through the development of ontologies, data models and the harmonised description of interfaces.

The R&I cycle covered by the Joint Undertaking

- 1 Requirements and associated research: development of harmonised standards and support for regulatory developments.
- 2 Industrial research: projects with technology readiness levels (TRL) of 3 to 6/7 involving industry, SMEs, universities and research centres.
- 3 Flagship projects: TRL 5 to 8, aimed at accelerating commercialisation and preparing for deployment.
- 4 Pre-deployment investments under the ECF, backed by multi-stakeholder funding from the EU, Member States and private investors.

The link between ‘Europe’s Rail 2028–2034’ and the ECF

The link between the successor partnership to Europe’s Rail – to be established between Horizon Europe 2028–2034 and the ECF is essential to accelerate the transfer of innovations to the market and enable innovative solutions to overcome ‘the valley of death’ created by the separation between infrastructure managers and operators and the lack of harmonisation of rules and operational processes across the European Union’s rail network.

- The innovations developed may be tested through pre-deployment projects funded by the ECF (ATO, ETCS, FRMCS, digitalisation of freight). It is essential to ensure continuity between research, innovation and industrial deployment. The aim is not to pit innovation against pre-deployment, but rather to organise their complementarity in order to accelerate the arrival of innovative solutions on the market and address recurring criticisms regarding the dissemination of innovations at European level.
- These projects will also enable the validation of new implementation, homologation and certification processes.
- Selection will be carried out by the Commission in conjunction with the Member States, whilst ‘Europe’s Rail 2028–2034’ will propose the projects.

The aim is to continue the ‘Europe’s Rail’ partnership under ‘Horizon Europe/FP10’, in line with FP10 and the ECF, in order to ensure the global competitiveness of the European rail sector and to implement European rail policy.

The key elements are:

- Funding targeting the entire innovation chain.
- More effective governance.
- Better integration of SMEs and academia from the outset, with tailored funding rules.

The link with the ECF should accelerate technology transfer, encourage real-world testing and improve deployment, homologation and certification processes.

About the PTFE

The Spanish Railway Technology Platform (PTFE, *Plataforma Tecnológica Ferroviaria Española*) is an industry-led public-private partnership in which stakeholders from the Spanish science, technology and innovation system with an interest in railways work together in a coordinated manner to identify and prioritise medium- and long-term technological, research and innovation needs. It was established in 2005 by the then Ministry of Education and Science.

Currently, the State Research Agency (Ministry of Science, Innovation and Universities) is the body that funds and oversees the PTFE's activities. Its Technical Secretariat is managed by the Spanish Railways Foundation (FFE, *Fundación de los Ferrocarriles Españoles*).

There are currently 524 organisations affiliated with the PTFE, comprising universities, research centres, infrastructure administrators, railway operators, large companies and SMEs.



In partnership with:



Europe's Rail Joint Undertaking 2028-2034

Vision for a Cost-Efficient Railway Transformation

Executive Summary

Rail is strategically important to the European economy and its security. Rail R&I is a key success factor in strengthening the Single Market, delivering efficient zero emission mobility through a harmonized Single European Rail Area (SERA) and Trans-European Transport Network (TEN-T) and maintaining the competitiveness and global market leadership of the European rail supply industry. Stakeholders across the European rail sector call on the European Institutions to ensure a successor to the Europe's Rail Joint Undertaking is established within the next European Research Framework Programme.

There is a strong need to accelerate the digital transformation and enhance resilience of the European railway system. This requires breakthrough innovation in areas such as digitalisation, automation, artificial intelligence, predictive maintenance, advanced signalling, system integration and standardisation. Equally important, it requires the development of solutions that are affordable to deploy across Europe's diverse railway networks and that can be implemented rapidly and at scale. All the above cannot be achieved by one stakeholder or member state alone but by a successor Rail Joint Undertaking only. Maintaining a standalone rail R&I Joint Undertaking under Article 187 TFEU will ensure long-term private investments can be leveraged, bringing all rail stakeholders together to address in a comprehensive programme the system-level solutions that no single member state or company can deliver alone. A dedicated Joint Undertaking provides far more than funding for R&I. It creates the unique governance structure required to align the entire railway ecosystem behind common objectives, shared priorities and interoperable solutions. It ensures that research is translated into deployable innovations and that investments generate tangible benefits for the European railway system as a whole.

Innovation is not a precursor to deployment but a permanent strategic capability; reducing investment in early-stage R&I would directly weaken Europe's ability to deliver future system transitions.

The successor to Europe's Rail must have a sufficient budget for R&I with a minimum budget of €3 billion, of which half will come from Horizon Europe and the other half from sector contributions, plus €15 billion for pre-deployment funding via the ECF, national and private investments, to support the needed technological maturity level and accelerating market uptake of flagship European programmes: the completion, validation and deployment of the Future Railway Mobile Communication System (FRMCS); the industrialisation and deployment of Digital Automatic Coupling (DAC) for European rail freight; the next generation of cost-efficient ERTMS and automated train operations; and the development of globally competitive high-speed rolling stock in line with the European High-Speed Rail Action Plan. Such a commitment would maintain and strengthen the competitiveness and global leadership of Europe's rail supply industry, accelerate innovation, support a sustainable and cost-efficient transport system for the European rail operating community, and deliver lasting benefits for European citizens, society and the economy.

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1. Introduction

As the greenest mode of transport, rail transport is vital for Europe’s economy, security, and sustainability. The European Commission’s ‘Sustainable and Smart Mobility Strategy’¹ sets concrete objectives and milestones towards the digitalisation and greening of the transport sector and rail. Achieving Europe’s climate neutrality targets by 2050, including a targeted 90% reduction in European transport GHG emissions, is only possible by attracting more passengers and freight to the rail system (long-distance, regional, suburban and urban rail). Rail therefore needs to increase its efficiency, attractiveness, accessibility and to maintain the worldwide competitiveness and technological leadership of the rail supply industry.

Rail is the only transport mode in which the Union retains genuine global technical and industrial leadership. With an annual global market growth of 3% (expected value of EUR 240bn by 2029²), and an investment of 3.6% of its annual revenue to R&I activities, the European rail supply industry is a global leader in design, manufacturing and maintenance of rail systems and products, corresponding to over 650,000 jobs in Europe. However, this status is under threat. State-subsidised global competitors are investing in R&I at a scale the Union does not match and are entering the European market. Staying at the forefront of R&I will be a key factor for Europe to maintain its industrial lead

Rail is a therefore competitiveness question, not solely a transport one, falling within the three imperatives of the Commission’s Competitiveness Compass: closing the innovation gap, aligning decarbonisation with competitiveness, and reducing dependencies while strengthening security.

In 2023, EU rail passenger transport hit its highest level in years, reaching 429bn passenger-kilometers. Rail accounts for 1.8% of the EU’s total energy consumption in transport, while carrying 17% of freight and around 8% of passengers of EU27 inland transport. At urban node level and close to citizens’ daily needs, light rail,

¹ EC’s Sustainable and Smart Mobility Strategy’ - https://transport.ec.europa.eu/transport-themes/mobility-strategy_en

² World Rail Market Study, forecast 2024 to 2029 - <https://www.unife.org/news-resources/wrms/>

metro and regional/suburban rail have a combined patronage of over 30bn passengers per year in Europe, evenly distributed among them, meaning each local rail mode carries 10 times more passengers than air travel. With a total contribution of €247 billion to the EU economy and supporting 3.1 million jobs³, railways offer one of the largest economic footprints of any transport mode while preserving the lowest carbon footprint. With estimated investments at €866 billion by 2040⁴ and €1,625 billion by 2050 to complete the TEN-T Network⁵, Infrastructure Managers are making substantial, long-term commitments to transform the continent's many national rail networks into a single European rail system. It is therefore essential that the EU rail innovations are efficiently transferred into the market for this transformation to succeed.

A coordinated European approach to R&I is vital to accelerate the overcoming of the historic and obstructive fragmentation in the rail system and to deliver harmonised European-wide solutions, making the European rail system more agile, innovative, resilient, capacity-performant, achieve the goals of the Single European Railway Area (SERA) and Trans-European Transport Network (TEN-T), including the comprehensive network) and make Europe more competitive.

Stakeholders from both the European rail supply industry and rail operating community have collaborated together in the first two European rail Joint Undertakings (JU), namely Shift2Rail (2014-2021; EUR 450M funding through Horizon 2020), and its successor, Europe's Rail JU (EU-RAIL, launched in 2021; EUR 600M funding through Horizon Europe) to accelerate research and innovation. The success of Shift2Rail, and now EU-RAIL, in contributing to achieving EU policy by addressing its common objectives outlined below, validates the significance of such public-private collaboration for the future rail system.



The continuation of this work is essential to maintain the rail innovation funnel and advance the Technology Readiness Level (TRL) and maturity of the European innovative solutions initiated and developed within these programmes. It also ensures the next steps in bringing innovations and their benefits to the market faster through targeted pre-deployment and implementation across the EU rail network.

Research and innovation must not be seen only as a preliminary step towards pre-deployment. It is a strategic capability in its own right for the rail sector. Continuous R&I is required to strengthen European competitiveness and sovereignty, to manage and reduce the cost of large-scale infrastructure investments, and to develop scalable solutions that can be deployed across the European network. Given the high capital intensity of rail infrastructure, coordinated R&I at European level is essential to create economies of scale, avoid fragmentation of solutions, and ensure that future investments lead to a more efficient and standardised system.

Stakeholders across the sector have voiced their readiness to commit to a third rail Joint Undertaking to these objectives. The cost of inaction and prolonging the national fragmentation of the European railway networks and R&I would far exceed the investment.

³ https://www.cer.be/images/publications/reports/250922_Railways_Economic_Footprint_Study_2025.pdf

⁴ Schade, W., Khanna, A.A., Mader, S., Streif, M., Abkai, T., de Stasio, C., Fermi, F., Bielanska, D., Deidda, C., Thiery, W., Maatsch, S. Support study on the climate adaptation and cross-border investment needs to realise the TENT network. Report on behalf of the European Commission. Karlsruhe, Milano, Brussels, Bremen. July 2024.

⁵ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52021SC0472>

2. A rail JU – Addressing the problems identified in the Call for Evidence

The Call for Evidence identifies five problem areas. The experience confirms that a well-designed Rail Joint Undertaking under the Single Basic Act is the right vehicle to address the challenges.

1. EU steering gap. Europe's Rail Joint Undertaking is already essential for channelling European strategic vision in the sector. Holding 50% of voting rights, the EU is the keystone decision maker, with strategic priorities driven by overall European goals—such as cross-border interoperability and cost reduction. A strengthened Rail JU, with clear 2035 targets and a competitiveness focus, would deliver effective research and innovation aligned with EU policy priorities.

2. Deployment deficit. By focusing not only on demonstration but also on integration into European regulation and standards, Europe's Rail Joint Undertaking has already begun strengthening the link between research, innovation and deployment through flagship projects and deployment-oriented recommendations. A strengthened Rail JU, with direct links to higher-TRL support and use of the ECF, would deliver a qualitatively new European capability and facilitate faster deployment: not replacing deployment actors, regulators or funding authorities, but providing an institutional mechanism that connects innovation, system architecture, validation, pre-deployment, market readiness and implementation feedback. Addressing the deployment gap must not come at the expense of upstream innovation, which is the source of future deployment-ready solutions. This is a game changer that accelerates the SERA and TEN-T and boosts EU industry's competitiveness leadership and strategic autonomy – enabling pilots, real-life cross-border validation and risk-sharing with early adopters, all needed for rail's network and system approach in Europe.

3. Cross-fertilisation. As a single-entry point for the rail innovation ecosystem, Europe's Rail Joint Undertaking already enables system synergies with other Joint Undertakings (e.g. joint calls with SNS, Clean Hydrogen and SESAR), facilitating knowledge transfer and the harmonised application of cross-sector solutions to rail, thereby creating economies of scale. This role can be further strengthened across future ECF and FP10 policy windows to reduce fragmentation and maximise EU-wide impact.

4. Investment leverage. Europe's Rail and Shift2Rail already leveraged Union funds well beyond their reported figures, exceeding initial SBA expectations. However, a gap (the so-called “valley of death”) between R&I and deployment still persists. For instance, in order to test the innovation in freight automation being developed in Europe under real commercial conditions on routes across several countries, additional CEF funding was sought. This included an exhaustive additional proposal and consortium building process, adding time and layers of admin burden to the process. With a more integrated approach in FP10 between R&I and pre-deployment, both processes and admin burden will be reduced and delivery of results become more integrated. In-kind contributions span national and EU-funded actions, so pre-deployment unlocks further investment from industry and from Member States wishing to validate R&I results on their own networks. Coupled with FP10, the ECF will draw meaningful contributions beyond the Union's own – leverage that is quantifiable and aligned with the billions rail must invest to renew its network this decade and stay globally competitive. EU-Rail's private members stand ready to keep matching Union investment and co-invest substantially in pre-deployment.

5. Access and lock-in risk. Europe's Rail Joint Undertaking has built a European ecosystem that did not exist before. Rail is a network operating at European scale, and only the JU instrument has proven able to unite stakeholders around EU rail policy through innovation and to design the interoperable, connected system Europe needs. No national or regional actor could bring together 28 countries, over 100 research centres, around 60 SMEs, more than 400 entities and over 30 private members across the value chain. The sector supports simpler governance and open specifications to ensure scalability and accessibility, competition and SME participation without lock-in.

A strengthened JU should cover the full innovation spectrum, from academic research onwards but with a deployment-oriented mindset, ensuring SME and start-up innovations are matured, validated and taken up by integrators and end-users — raising market uptake and reducing fragmentation.

Europe's Rail Joint Undertaking has transformed Europe's railways into a more sustainable, digital, and integrated transport system by uniting industry, railway undertakings, infrastructure managers, wagon keepers and researchers around shared solutions. Together with its predecessor Shift2Rail (S2R), it has advanced key technologies such as ERTMS, autonomous train operation, real-time traffic management, next-generation traction, and the Digital Automatic Coupler for competitive freight. These breakthroughs improve safety, efficiency, reliability, and cost-effectiveness while supporting green mobility, European jobs, and the global competitiveness of one of the few rail industries still able to compete worldwide. Ongoing work on digital train control, AI-driven decision support, and digital twins will further boost capacity and enable predictive maintenance. Under S2R, 695 prototype testing activities were completed by 2023, with many solutions now at TRL 7/8 and listed in EU-Rail's catalogue of solutions for market uptake. By convening all stakeholders and working closely with the European Union Agency for Railways and the Commission, EU-Rail ensures effective policy implementation with full sector buy-in—standing as a successful model of innovation-driven transformation and reaffirming rail as the backbone of Europe's sustainable mobility. For this reason, there is a strong need to continue the journey paved by Europe's Rail JU and S2R.

3. European Rail R&I Joint Undertakings – Key to unlocking the SERA

A standalone R&I Joint Undertaking under Article 187 TFEU is essential because the challenges it addresses are structural and system-wide rather than project-specific. The Europe's Rail Private members have already pre-identified its needs and mission, together with the European Commission which, following its inter-service consultation, gave a fully positive vote to the Governing Board Decision 06/2025 approving the High-Level Paper on “A Future Policy-Based Public Private Partnership for Rail”⁶: *Simplify the rail systems and operations while enhancing its fundamental capabilities, with European innovation to make rail systems more agile, resilient and competitive*. The High-Level Paper incorporates the strategic vision set out in the Commission's Communication “Connecting Europe through High-Speed Rail”⁷, which provides a comprehensive plan to accelerate the development of high-speed rail across the EU and it is fully supported by the rail sector. In the Communication, the European Commission calls for EU harmonised digital and automation technologies - such as automated and autonomous trains, modern ERTMS signalling, communication and traffic management systems – to be brought to the market and to support a continued joint research under the 2028-2034 Horizon Europe programme and the proposed European Competitiveness Fund, together with the rail supply industry, infrastructure managers and railway companies.

Europe's rail network remains fragmented across more than two dozen national systems, each with distinct technical, operational, and regulatory legacies; overcoming this requires sustained, coordinated investment in interoperable, system-level solutions that no single member state or company can deliver alone. An institutionalised Joint Undertaking provides exactly this: a stable legal framework, pooled long-term funding, binding commitments from public and private partners, and unified governance capable of steering R&I towards the coherent, network-wide architecture needed to complete the Single European Railway Area and the TEN-T network. Cooperating and developing new solutions for the Single European Railway Area will increase the EU supply industries' economies of scale and boost their competitiveness on the global market.

⁶ https://rail-research.europa.eu/wp-content/uploads/2025/06/GB-Decision_06-25_High-level_Paper_final_MK-signed.pdf

⁷ https://transport.ec.europa.eu/document/download/774e79c9-1ece-4514-8f16-a2b98049c82e_en

Deployment of innovative solutions on a heterogeneous network consumes a high amount of time as well as financial and engineering resources. Those resources are bound and not available for competing on the non-European market. The EU rail supply industry, however, competes essentially on the non-European market where they need to affirm their role as technological leaders. The ERJU's efforts in the area of harmonization and deployment in the EU market might not seem directly linked to innovation and research at first glance but they have a direct effect on the innovative capacity and the EU rail industry's position as a technology leader on the global market. By contrast, the Work Programme-based partnership offers neither the continuity, the strategic steering capacity, nor the depth of member commitment that these objectives demand. Its lighter, more transactional structure risks reverting to the fragmented, bottom-up approach that has historically slowed deployment—funding discrete projects without the long-term institutional anchor required to translate research into harmonised, deployable solutions across the whole European network.

The benefits of a standalone Joint Undertaking are:

- ▶ **A coordinated EU-level approach** is essential to align new technology deployment across varying national and local systems, to shape future harmonised rail system architectures, standards and regulations to speed up R&I to market. This requires long-term investment and collaboration among stakeholders within a comprehensive framework. Before the creation of Shift2Rail JU in 2014, R&I budget was spent mostly nationally, research efforts were without coordination across countries and not oriented towards achieving the SERA. Coordination was further constrained due to fragmentation among national railway ecosystems, among subsystems and along the innovation life cycle. Since rail is a system, consisting of the complex interaction of rail system components, coordination at EU level is vital. A joint public-private R&I partnership is the best platform to ensure close coordination among all stakeholders along the value chain and the effective implementation of EU priorities, therefore strengthening EU's rail competitiveness as underlined by the 2024 Letta report⁸. A lack of successor JU and the shifting to open collaborative calls fragments rail R&I into disconnected, project-by-project efforts with no coherent target-system roadmap to replace EU-Rail's.
- ▶ **Tangible results with real added value:** Before a standalone rail JU, projects funded under the EU's research programmes were not long enough (3-4 years) to go through all stages of the innovation cycle for high complex technologies. The consistency and long-term nature of the JU's programme allow for the development of technologies from low TRL to pre-deployment and market uptake. Success stories include sector support for the development of the Future Railway Mobile Communication System (FRMCS), the Digital Automatic Coupling (DAC), evolution of European Rail Traffic Management System (ERTMS), Digital Twin technologies, solutions supporting the use of zero-emission propulsion engines or low-cost solutions for regional rail, where the basic principles were developed in Shift2Rail, and the market-ready development is taking place in EU-RAIL.
- ▶ **Predictability & shared risk management to leverage private investment:** Considering the long-life cycle environment of the rail sector, a Joint Undertaking facilitates long-term planning, migration strategies and predictability through large scale R&I projects and serves as a stable platform for innovative initiatives while enhancing financial contributions and synergy within the rail sector. The JU structure has proven key in attracting and leveraging meaningful contributions from private partners in Shift2Rail and Europe's Rail that exceed the initial Single Basic Act (SBA) expectations and requirements.
- ▶ **Creating a rail R&I ecosystem including SMEs, start-ups & academia:** a joint initiative which promotes collaboration between the public and private sectors. The involvement of SMEs, start-ups and the academia will ensure that Europe's ecosystem of rail R&I is strengthened, and new ideas are taken up by the sector.

⁸ <https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf>

It is supporting the Draghi report⁹ by optimising national rules to ensure competitive markets and the investment in key digital solutions with incentives for market uptake. The sector believes that a future collaborative rail research programme shall deliver:

- ▶ **Stronger European rail industry:** strengthen the global leadership of the European rail supply industry and maintain its positive trade balance in the context of an increasingly competitive global market, notably from Asia. Staying at the forefront of R&I will be a key factor for Europe to foster its industrial lead.
- ▶ **Reduced costs & simplification of the European rail system:** using R&I as a key tool to significantly reduce the complexity and costs of the current European rail system.
- ▶ **Completion of SERA and TEN-T:** coordinated and deployable R&I through a European sector wide cooperation, coordinated between different stakeholders, is needed to deliver an agile and resilient European system covering passenger mobility, freight and EU industrial and military strategic capabilities on high-density corridors in rural as well as urban areas.
- ▶ **Pre-deployment under operational conditions:** All projects should systematically target demonstrators and pilots under real operational conditions, with migration pathways carefully integrated into the technology development process from the outset. Pre-deployment validation under live conditions will accelerate market uptake and reduce innovation risk, necessitating robust regulatory support and the development of adapted approval methodologies.
- ▶ **Innovation funnel:** R&I programmes should support projects across all Technology Readiness Levels, establishing a seamless pipeline from fundamental research through to market deployment. Funding mechanisms should accommodate both high-risk, low-TRL research and deployment-oriented, high-TRL implementation projects to ensure continuity across the innovation lifecycle.
- ▶ **Resilient rail system:** ensuring reliable asset availability, climate-resilient and robust network operations, and prioritising advanced cybersecurity for a reliable and future-proof mobility.
- ▶ **Role of the Joint Undertaking:** Beyond enabling deployment, R&I is essential to structurally reduce system costs and to optimise future infrastructure investments through innovation in design, construction, and maintenance approaches.
- ▶ **Increasing the impact and leverage mechanisms of rail R&I:** the impact of future rail R&I will be further increased by structurally including urban rail research priorities and by allowing a wider range of stakeholders playing an active part in relation to their capacities and characteristics.
- ▶ **Standardisation, harmonisation, interoperability & migration:** Standardisation and harmonisation must be embedded from the outset to simplify and align operational processes across the system. A technology-neutral approach should be pursued to facilitate the scalability and interoperability of emerging technologies, enabling structured migration of existing systems toward digital and sustainable targets. This requires close engagement of railway operators, industry, and European approval authorities in development processes, with strong institutional links to ERA and CEN/CENELEC to ensure research outcomes are systematically integrated into standards and authorisation frameworks. The JU's coordinated interface with ERA and the standardisation bodies turns R&I outputs into TSIs and harmonised standards; losing it risks renewed national fragmentation and slower interoperability.

⁹ https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

- ▶ **Active collaboration with other sectors:** In line with the EU Competitiveness Compass¹⁰, the rail sector should align its R&I priorities with the Sustainable Transport Investment Plan and intensify research in areas such as artificial intelligence, quantum computing, and robotics. Cross-sectoral and cross-disciplinary collaboration should be systematically pursued to maximise knowledge transfer and increase the impact of R&I investments on high-priority challenges.
- ▶ **Attracting new skills:** Investment in innovation reinforces the rail sector's appeal to academic talent and emerging professionals by demonstrating a strong commitment to advanced technologies. The adoption of cutting-edge digital tools — including predictive maintenance, smart infrastructure, and data-driven operations — generates demand for specialised profiles such as software engineers, data analysts, and cybersecurity experts, thereby contributing to addressing the sector's structural workforce shortages.

While the strong focus of FP10 on pre-deployment and system integration is fully acknowledged and justified, it is important to highlight that several key dimensions currently covered by the exploratory research need to be represented. This concerns in particular low-TRL disruptive technologies, socio-economic and human-centric aspects, long-term system economics, supply chain resilience, and the broader rail integration into multimodal and urban systems.

A discontinuation or weakening of such exploratory research and innovation activities over the FP10 execution timeline risks progressively eroding Europe's long-term innovation capacity. In particular, deprioritising early-stage research and emerging technologies may create a growing innovation gap that becomes increasingly difficult to close in later phases. Maintaining a balanced pipeline from exploratory research to pre-deployment is therefore essential to ensure sustained technological leadership and avoid structural weaknesses in the future European rail innovation ecosystem. Elements which should be considered include: (i) low-TRL and disruptive technology development, (ii) socio-economic, human and skills-related research, (iii) system-level economic and financing models, (iv) supply chain and raw material resilience, (v) deep engineering and fundamental research topics, (vi) multimodal and urban system integration, (vii) digital platform and ecosystem perspectives, and (viii) structured knowledge and academic research networks.

4. The Joint Undertaking's contribution to EU policies and priorities

The opportunity is the mirror image of the risk: the European Union and the sector can meet the strategic challenges ahead – resilience, intensifying global competition, decarbonisation, digitalisation and automation, - **together, once, and at scale**. That opportunity is bounded by the 2028–2034 financial framework and is to be realised through the creation of a strengthened Rail Joint Undertaking,

Through coordinated efforts in policy-oriented research, innovation, and pre-deployment activities, a new European Rail Partnership will have significant wide-ranging impact to deliver on numerous EU-level strategies and priorities as described here below:

- **A Competitiveness Compass for the EU¹¹.** Rail is the only transport mode in which the Union retains genuine global technical and industrial leadership. State-subsidised competitors are investing in R&I at a scale the Union does not match and are entering the European market. Rail is therefore a competitiveness question, not solely a transport one, falling within the three imperatives of the Commission's

¹⁰ https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

¹¹ A Competitiveness Compass for the EU - https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0ed18105a34_en?filename=Communication_1.pdf

Competitiveness Compass: closing the innovation gap, aligning decarbonisation with competitiveness, and reducing dependencies while strengthening security.

- **Draghi report on Competitiveness of the EU¹².** The report recommends boosting EU rail competitiveness through coordinated investment in cross-border TEN-T infrastructure, digital technologies (ERTMS, Digital Automatic Coupling), and public-private R&I partnerships. It also calls for targeted EU funding and regulatory harmonization to improve interoperability and support sustainable rail freight and passenger services, aligning infrastructure development with the green and digital transitions.
- **Letta Report “In Much more than a market”¹³.** The report recommends strengthening EU rail competitiveness through coordinated modernization and innovation. Priority actions include advancing cross-border TEN-T infrastructure, deploying digital technologies like ERTMS and Digital Automatic Coupling, and promoting public-private R&I partnerships. It also calls for targeted EU funding and regulatory harmonization to boost interoperability and support sustainable rail services, aligning infrastructure development with the green and digital transitions.
- **EU High-Speed Rail Plan¹⁴.** The EU High-Speed Rail Plan aims to better connect Europe, cut travel times, and reduce emissions, while an EU Rail Partnership would build an integrated, high-capacity network by removing interoperability barriers. The Plan relies on EU-RAIL to deliver its technical goals, including a 2026 research call to develop next-generation rolling stock and a harmonised ERTMS deployment plan. The High-Speed Rail Plan also explicitly calls on the rail supply industry, infrastructure managers and railway companies to continue joint research under the 2028-2034 Horizon Europe programme and ECF to bring the latest High-speed technologies to the market. EU-RAIL also co-funded the FP2-MORANE-2 project to test next-generation FRMCS communications technology on real rail lines, feeding results into future interoperability standards. In short, the HSR Plan sets the political and infrastructure targets, while EU-RAIL and its successor supply the research, pilots, and technical standards to achieve them.
- **EU Council Strategic Agenda 2024/2029¹⁵.** Through coordinated efforts in policy oriented research, innovation, and pre-deployment activities, the initiative is capable to respond to the European Union priorities through cutting-edge rail solutions developed by its industries for retaining their global leadership role (Prosperous and Competitive Europe), strengthening the rail resilience of its system and ensure harmonised and secure operations in critical infrastructures (for a Strong and Secure Europe), and providing an accessible, affordable and attractive transport mode across borders to all its citizens (for a Free and Democratic Europe).
- **2023 “Joint Communication to the European Parliament, European Council and the Council on European Economic Security Strategy”¹⁶.** Promoting, among others, railway competitiveness by making the EU economy and supply chains more resilient bolstering innovation and industrial capacity - fostering the research and industrial base in strategic areas such as clean energy and net-zero industries.
- **Net-Zero Industry Act¹⁷.** The Net-Zero Industry Act aims to scale up EU manufacturing of clean technologies that produce minimal or no greenhouse gas emissions, strengthening the clean energy transition. It frames R&I as central to industrial resilience, strategic autonomy, and competitiveness, while addressing vulnerabilities from gaps in technological and manufacturing expertise.
- European Commission Report **“Addressing European research and innovation challenges for system**

¹² https://commission.europa.eu/document/download/ec1409c1-d4b4-4882-8bdd-3519f86bbb92_en?filename=The%20future%20of%20European%20competitiveness_%20In-depth%20analysis%20and%20recommendations_0.pdf

¹³ <https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf>

¹⁴ https://transport.ec.europa.eu/document/download/774e79c9-1ece-4514-8f16-a2b98049c82e_en?filename=COM_2025_903_HSR.pdf

¹⁵ https://www.consilium.europa.eu/media/yxrc05pz/sn02167en24_web.pdf

¹⁶ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52023JC0020>

¹⁷ https://single-market-economy.ec.europa.eu/publications/net-zero-industry-act_en

transitions in energy and mobility”¹⁸. The report affirms rail's strategic role in achieving the EU's sustainable mobility and climate goals, supporting territorial cohesion and regional connectivity, guiding future R&I under Horizon Europe and the Europe's Rail Joint Undertaking. Critically, the gap between research and real-world implementation must be bridged by focusing on higher technology readiness levels, large-scale demonstrators, and deployment support mechanisms.

- **EU Military Mobility Package**¹⁹. The EU Military Mobility Package 2025 reinforces the case for a European rail partnership. Its emergency framework, dual-use upgrades and military corridors require exactly what such a partnership delivers: harmonised gauges, signalling and loading standards for rapid cross-border movement. It could also address shortages like flatbed wagons through coordinated procurement and help plan the package's ~500 infrastructure "hotspot" projects with Member States and industry.
- *Clean Industrial Deal*²⁰. It mirrors the core aim of bringing together climate action and competitiveness under one overarching growth strategy, positioning rail as a cornerstone of Europe's transformational business plan that simultaneously accelerates decarbonisation, reindustrialisation, and innovation across the entire continent.

5. Europe's Rail Key Challenges

A number of rail sector documents published recently illustrates both the challenges of the rail sector as well as its responses adapted to each rail segment.

- **Protecting rail global competitiveness and leadership.** The European rail supply industry is increasingly exposed to unfair competition from foreign heavily subsidised manufacturers which benefit from non-market financing, preferential procurement, and a protected home market. Operating in the EU's open market, European firms must meet high regulatory, environmental, and labour standards their competitors face no equivalent of abroad. Without decisive action from the European Union, this asymmetry risks eroding Europe's technological leadership and industrial sovereignty in rail.
- **Fostering SERA for one harmonized European market.** Despite progress, cross-border rail operations remain challenged by differences in signalling, electrification, track gauges, and slot allocation — legacies of history, long asset lifecycles, and varying national regulations. Operational rules also diverge, impacting efficiency and train drivers in particular. Harmonisation efforts begun in Europe's Rail must still be completed, implemented, and validated with the European Union Agency for Railways.
- **Optimising Lifecycle Costs Across the Rail System.** Europe's fragmented railway networks drive up costs through duplicated systems, incompatible technical standards, and costly cross-border modifications. Outdated infrastructure, and complex regulatory approval processes add further financial burden. Cost reduction hinges on streamlining and harmonising operations, processes, and products. Addressing these structural cost drivers requires sustained innovation in infrastructure design, standardisation, modularisation, and automation, which can only be achieved through coordinated European R&I efforts.
- **Unlocking Competitive Pricing and Flexibility in Rail Freight.** Freight trains have faced decades of challenges — including increased truck flexibility, declining heavy industry, poor digitalisation, inflexible services, limited last-mile connectivity, and lengthy border delays — making rail freight less competitive than road transport. Widespread adoption of the Digital Automatic Coupler (DAC), combined with new

¹⁸ <https://op.europa.eu/en/publication-detail/-/publication/46e16a85-9d7f-11ef-85f0-01aa75ed71a1/language-en>

¹⁹ https://transport.ec.europa.eu/news-events/news/commission-moves-towards-military-schengen-and-transformation-defence-industry-2025-11-19_en

²⁰ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025DC0085>

digital services, data analytics, and operational automation, could significantly boost efficiency and restore rail freight's appeal.

- **Scaling up investment in maintenance, regeneration & modernisation.** Many rail networks struggle with deteriorating infrastructure, causing service disruptions, reduced speeds, and unreliable operations. Governments frequently prioritise road and aviation funding over rail upgrades, leaving the sector underfunded. Increased use of robotic solutions for inspection and installation, designed to operate on modular infrastructure components, combined with digital twins and data analysis, can reduce execution costs, standardise interventions and improve asset availability, partially mitigating this funding gap.
- **Bridging Urban, Last-Mile and Regional & Rural Networks.** Across much of Europe, poor integration between rail and other local transit options makes trains impractical for final-leg journeys. This is particularly acute in regional and rural areas, where it deepens transport poverty and restricts mobility for underserved communities. Developing multimodal systems and targeted last-mile solutions is therefore essential to reduce transport poverty, strengthen regional and rural rail connections, and extend public transport's reach where it is needed most.
- **Enabling seamless ticketing & end-to-end integration.** Rail ticketing, unlike aviation's Global Distribution Systems (GDS), is fragmented across markets, operators, and national regulations — whether publicly managed or open to competition. This makes cross-modal and cross-border travel planning cumbersome. Digitalization, cybersecurity, harmonization, and targeted regulation are key to addressing this challenge.
- **Rail system transformation is not a fixed target:** emerging requirements in energy, digital security, automation and climate resilience require continuous development of new solutions. A system focused only on scaling current technologies risks locking in suboptimal solutions.

6. Estimated JU Investment

The new rail Joint Undertaking would implement a “policy-based budget”, with a performance-based approach relying on the ability to track progress towards achieving the above-mentioned targets for the EU policy objectives.

The railway supply sector strongly advocates for the retention of in-kind contributions as the principal modality for mobilising private members within a future European Joint Undertaking. This approach ensures that private-side commitments are channelled directly through the members' own research and innovation activities and resources, thereby securing genuine industrial engagement, sustained co-investment, and shared ownership of results. A shift towards cash-based contributions would, by contrast, risk diminishing the active involvement of private members and undermining the collaborative, demand-driven character that constitutes the principal added value of the partnership model.

The investment effort required to simplify the rail system and deliver improved services for the entire EU network should focus on both Research and Innovation and pre-deployment.

Research and Innovation. Approximately **€3 billion for R&I activities**, with half (€1.5 billion) coming from EU funding (Horizon Europe (2028–2034)) and half from industry contributions to make the rail system more agile, resilient, and competitive. This expanded R&I scope, compared to previous initiatives, addresses the need for costly yet essential one-time developments of innovative solutions aiming to transition the diverse existing legacy systems into a new, simplified European rail system, building upon past Joint Undertaking achievements and incorporating new R&I advancements.

Sustaining R&I funnel means significant new research and innovation remains essential — not for its own sake,

but as the foundation on which deployment depends. A strengthened Rail Joint Undertaking must keep funding the breakthroughs the new European architecture requires: digitalisation, automation, control-command and signalling, traffic management, cybersecurity and resilience. A clear priority is migrating the existing network — developing novel adaptor solutions that let legacy systems and assets operate in line with the new EU target architecture. Because rail assets last decades, the installed base cannot be replaced at once; the proven ability to bridge old and new with standardised adaptors, demonstrating their safe coexistence, is what makes a brownfield transition affordable, avoids stranded investment, and lets the network capture the new architecture's performance gains far sooner. This is a genuine research challenge in its own right — one only a coordinated European partnership can solve once for the whole network, rather than repeatedly, system by system and country by country.

Pre-deployment. Approximately **€15 billion for pre-deployment activities** via the European Competitiveness Fund (ECF). The scale of investment needed is substantially larger as it requires the diverse participation of stakeholders across different countries to upgrade their systems and make investments in their network. It would require significant European procurement activities to enable a first implementation at system level, that can then be replicated based on the pre-deployment results at scale.

Within the European rail sector, pre-deployment designates the phase during which technologies or solutions, having attained sufficient maturity through prior R&I demonstration activities, undergo large-scale validation in genuine operational environments and proof of applicability under commercial conditions to demonstrate readiness for system-wide or commercial rollout.

This phase corresponds broadly to the transition from TRL 8 — where a complete system prototype has been demonstrated in an operational environment — to TRL 9, where performance has been proven at scale.

Its primary objectives are to:

- Mitigate residual technical and operational risk,
- Validate system behaviour across diverse operating conditions, and
- Establish the evidentiary foundation required for subsequent full deployment decisions.

Pre-deployment thus constitutes the phase in which technologies are validated at scale in operational environments, functionally distinct from, yet directly preparatory to, deployment activities financed through instruments such as CEF, but depends on a continuous inflow of new solutions from ongoing R&I activities.

Pre-deployment funding under the ECF must be additional to, and must not displace or reduce, deployment support under the Connecting Europe Facility, on which cross border network-wide rollout continues to depend.

The simplification and modernisation of the rail future do not only rely on an equivalent European future Traffic Management implementation, but of several other European standardised solutions to be deployed as a system in the network. Considering the past ERTMS support efforts from the Union through the Connecting Europe Facility, the estimate of the investment needed for DAC, FRMCS, Satellite applications, other technology game changers and possibly future Traffic Management solutions harmonised at European level. Additionally, pre-deployment instruments could be used to facilitate the integration and promotion of a new generation of High-Speed solutions, directly supporting the creation of a European High-Speed network linking capitals and major cities, requiring further private investments and also possible dual use solutions of rail assets. The estimated amount for all those pre-deployment activities across the network seems the appropriate order of magnitude for a strategic investment in Europe's future, supporting both technological sovereignty and economic sustainability.

7. Activities

The present document is closely aligned with the activities outlined in the Annex to the Europe's Rail Joint Undertaking High-Level Paper on a future policy-based Public-Private Partnership for Rail²¹, which sets out four Flagship Initiatives as a living roadmap for the future of European rail. The Annex details strategic areas of R&I and pre-deployment to simplify the rail system and its operations, while enhancing its fundamental capabilities, grouped into four Flagship Initiatives that together form a cohesive roadmap for the future of European rail.

In particular, the activities described in this document directly reflect the pre-deployment rationale articulated in the Annex, which emphasises the need to engage infrastructure managers, vehicle keepers, terminal operators, maintenance companies, rail operators, and suppliers, and to build confidence and ownership across the sector to support smooth transition into future system European-wide deployment, while using pre-deployment activities to identify and resolve potential technical and operational risks early, reducing delays and cost overruns, and trialling new business cases and addressing potential new policy approaches. This strong alignment confirms that the activities proposed herein are consistent with the strategic direction endorsed at the highest level of the Europe's Rail Joint Undertaking, including the European Commission, and contribute directly to its overarching mission of making European railways more agile, resilient, and competitive.

7.1. The Working Areas: The Flagship Initiatives

The sector supports the Working Areas proposed and defined by Europe's Rail Joint Undertaking's High-Level Paper which address the strategic areas of Research and Innovation (R&I) and pre-deployment to simplify the rail system and its operations, while enhancing its fundamental capabilities in alignment with the core objectives of making European railways more agile, resilient, and competitive. Those areas are grouped in four Flagship Initiatives, which needs to be complemented by other policy actions beyond the field of R&I and pre-deployment to reach the intended objectives.

- The first Flagship Initiative - **the European Simplified and Integrated Railway System (ESIRS)** – is an initiative for increased Europe's railway competitiveness and lowering European rail system costs through automation, cutting-edge technology and harmonized operations. This based on simplification/standardisation and improvement of Command-Control and Signalling Systems, Capacity and Traffic Management Systems, digital infrastructure information systems, systems for digital operational communications and unified data management solutions and related processes, aiming at optimum system cost-effectiveness and efficiency. This initiative directly addresses upgradability and scalability through secure modular systems and simplified certification and to harmonised approaches or adaptors solutions towards legacy systems, resilience by design and through harmonized cybersecurity frameworks, and competitiveness through cost reduction and industrial leadership.
- The second Flagship Initiative - **the Next-Generation Rail Freight Operations with European Digital solutions** – is an initiative for transforming Europe's rail freight operations and making rail freight transportation more competitive. For this purpose, a comprehensive plan is needed to favour a competitive European rail freight through automated processes, digital automatic coupling with advanced communication systems technologies, and intelligent capacity management. Transition pathways are developed jointly, to identify the actions needed to achieve the twin greening and digital transitions for logistics with rail with proper solutions' cost effectiveness and efficiency. This initiative enhances competitiveness of rail freight accelerating modal shift, supports quick adaptability to demand through

²¹ <https://rail-research.europa.eu/wp-content/uploads/2026/01/Europes-Rail-Private-Partnership-for-Rail-2025-Pages.pdf>

dynamic freight planning, and strengthens resilience through multimodal integration and strategic logistics capabilities.

- The third Flagship Initiative - **Resilient Railway (Re²Rail)** – is an initiative addressing the fundamental challenge of maintaining reliable, secure rail operations under increasingly complex and unpredictable disruption scenarios. Climate change (floods, heavy storms or landslides), cybersecurity threats, geopolitical tensions, and system interdependencies create vulnerability patterns that demand integrated resilience strategies built into the core architecture of European railway systems while enabling seamless civilian-military interoperability and logistics (dual-use) when required. This initiative addresses the entire system with a focus in the area of automation, digitalization and control command (on-board and trackside), but as well design and maintenance of infrastructures and rolling stock in order to create a system which is resilient and recoverable. This flagship directly delivers resilience through climate adaptation and cybersecurity, supports agility through adaptive systems, and enhances competitiveness through dual-use infrastructure optimization.
- The fourth Flagship Initiative - **Innovative EU High-Speed Rail Corridors** – is an initiative unifying the innovation, deployment, and operation of next-generation high-speed systems within a harmonised European architecture. It ensures unmatched interoperability across borders. The initiative will pioneer harmonised pre-deployment corridors serving as early implementation pilots for pan-European high-speed expansion. These corridors will validate new rolling stock and infrastructure technologies, including ETCS L2-only operations, predictive maintenance, and EU traffic management under real conditions, ensuring safe, reliable, and cost-effective scaling. This flagship directly delivers competitiveness through cost reduction, energy efficiency, and industrial technological sovereignty; enhances service quality through reliability improvements and multimodal integration; and strengthens resilience through climate-adaptive infrastructure, cybersecurity, territorial inclusion, and strategic autonomy in critical high-speed technologies.

These four Flagship Initiative are focussed on areas involving an EU system thinking that necessitate activities of European pre-deployment and associated research to ensure a long-lasting positive impact. There are further activities that should also be considered under the work of a future Joint Undertaking:

- **Horizontal Research and Innovation at lower TRLs:** There are a number of important areas of work where further research and innovation is required to improve future railway systems, but which may lead to full pre-deployment activities within the identified time frame, still providing a valuable input to the works of the Flagship Initiatives. The focus would be on a set of areas related to the four flagships initiatives and on fostering new ideas. These are captured in a dedicated chapter.
- **System and deployment integration:** the production and validation of harmonised specifications and standards with the sector, and the coordination of the outputs of the Flagship Initiatives towards the European regulatory harmonisation and standardisation framework is an essential consideration within the overall programme. Additionally, the broader deployment considerations, including the coordination of European and national deployment programmes resulting from the pre-deployment activities is also necessary within the programme.

These flagship initiatives and additional horizontal activities share the same mission and focus together, they form a cohesive living roadmap for the future of European rail that extends the scope beyond SERA to include complete rail market coverage, including urban rail systems and multimodal transport integration, as urban nodes are included in the revised TEN-T guidelines aligned with the EC Communication on EU Urban Mobility Framework. They represent a holistic effort to ensure that through coordinated investments onto legacy systems, the European Single Rail Area will be delivered capitalising on the strength of the European Single Market. They will

bring innovation, sustainability, and security—delivering long-term environmental, economic, and social benefits for Europe and beyond. By expanding the scope to include urban, suburban, or regional rail aligns with the aim of bringing new partners into the partnership—thereby increasing the share of private funding—and will enable greater ambition in light of significant needs and key priorities. Beyond its strong alignment with the Flagship Initiatives of the JU High-Level Paper, the sector recognises a number of additional strategic areas that present important opportunities for a potential successor programme to Europe's Rail, as highlighted by ERRAC²². These include:

- A stronger focus on users' needs and the whole journey experience — encompassing both passengers and logistics customers;
- A dedicated attention to urban, suburban, and regional rail, where the specific challenges of these environments merit targeted treatment beyond the current scope;
- Significant potential has been also identified in advancing multimodality and the fuller integration of rail within the wider transport system, including the fight against transport poverty as called for by the Social Climate Fund and Commission Recommendation (EU) 2025/1021 on transport poverty, championed by Commissioner Tzitzikostas;
- Further opportunities lie in infrastructure innovation, notably through modularisation and the use of robotic construction and maintenance techniques, which could substantially improve efficiency and reduce costs;
- Finally, the sector highlights materials — including raw materials — as a strategically critical area, directly relevant to European competitiveness and sovereignty, as underscored by recent competitiveness reports, and with tangible implications for both rolling stock and infrastructure.

Taken together, these areas reflect the sector's ambition to build a comprehensive and forward-looking research and innovation agenda that fully captures the breadth of rail's contribution to a sustainable, inclusive, and competitive European transport system.

8. Partner composition and target group

The RailJoint Undertaking should bring together all those ready to perform research and innovation — exploring new concepts and driving step-changes across rail sub-systems, validating them through demonstration, and implementing solutions into systems in operation to pave the way for market deployment. This structure bringing together all the stakeholders of the network is unique. Developing new technologies and determining research priorities for a network that is inherently cross-border requires all concerned parties to cooperate. The European added value of the EU-RAIL JU therefore goes beyond research and innovation. The EU-RAIL JU is a unique forum for cooperation for the railway sector in the area of research and innovation.

Infrastructure Managers. Infrastructure managers strongly support bridging the gap between research and deployment. They carry the largest trackside investment burden for ERTMS, FRMCS and future digitalisation, often assuming costs and risks long before network-wide benefits emerge. The next Rail Joint Undertaking must continue to harmonise the system, develop new solutions, and support funding mechanisms that let infrastructure managers validate harmonised solutions once and reuse them across Europe. To that end, ECF pre-deployment co-funding must be directly accessible to the infrastructure managers and railway undertakings that bear these

²² <https://www.eurnex.org/3d-flip-book/future-tracks/>

deployment costs and explicitly structured to address the business-case asymmetry between those who invest and those who benefit.

Passenger Railway Operators. A dedicated European Rail Joint Undertaking is essential: it underpins the Single European Railway Area and cuts costs significantly through the design, piloting and integration of European solutions that also safeguard the value of the massive long-term investments already under way. Only a Rail Joint Undertaking can ensure a fully integrated, predictable and coordinated migration of new technologies across Europe — delivering harmonised onboard specifications, value-sharing frameworks and ECF-supported fleet renewal, so that cross-border, automated and more reliable services can be rolled out in practice without penalising those who move first.

Urban rail operators (metros, suburban and light rail networks). They represent an important new stakeholder group for the future JU. As a key link in the TEN-T and the interface between long-distance rail services and citizens' daily mobility needs, they play a central role in delivering seamless and sustainable transport across Europe. Operating complex, high-capacity systems serving millions of passengers every day, they bring unique operational expertise and access to large-scale real-life testing environments. Continued investment in research and innovation is essential to help urban rail operators maintain service excellence, strengthen the competitiveness of European mobility solutions and support Europe's technological sovereignty. Their involvement would broaden the Europe's Rail ecosystem, accelerate the deployment of innovative solutions and reinforce synergies between urban and mainline rail systems.

Rail Freight Operators. A dedicated Rail Joint Undertaking is essential to digitalise and automate rail freight and grow its market share. Freight is an ecosystem challenge, requiring coordination across operators, infrastructure managers, suppliers, terminals and logistics actors so that innovation reaches daily operations consistently across Europe. This is especially urgent for next-generation freight built around Digital Automatic Coupling (DAC) and automated operations, which can unlock capacity, faster transshipment and lower costs while shifting traffic from road to rail. A strengthened Rail Joint Undertaking is needed to coordinate an EU-level, risk-shared and co-funded roll-out, turning fragmented pilots into a single European system.

Rail Supply Industry. A Rail Joint Undertaking is essential to deliver European-by-design standardisation, coordinated deployment and industrial-scale uptake. The message is simple: a strong, competitiveness-focused Rail Joint Undertaking must be preserved. It is the only EU-level instrument proven capable of turning European innovation into scalable deployment and safeguarding the global leadership on which our competitiveness, autonomy and sovereignty depend.

Lessors/vehicle keeper/new entrants. The European solutions and simplification a dedicated JU delivers are the precondition for rail's commercial viability: without them, costs stay too high and the sector risks a reverse modal shift. A single, stable European technology for systems like ERTMS would itself be a major strategic innovation, ending the fragmentation that undermines the sector. The JU's pre-deployment activities help close the innovation 'valley of death' and speed rollout, with a coordinated path agreed in dialogue with infrastructure users so locomotives and infrastructure advance together. A more inclusive, proportionate approach to SME participation would strengthen the ecosystem further.

SMEs and Start-ups. SMEs and Start-ups are an indispensable source of agility and disruptive innovation, and a successor Joint Undertaking should actively widen their participation. By lowering barriers to entry — accessible calls, simplified requirements and targeted support — the partnership can mobilise their specialised expertise in fast-moving fields such as AI, sensing and advanced materials. Embedding them across the full innovation cycle, from early research to pre-deployment, diversifies the European supply chain beyond the large integrators and strengthens the long-term competitiveness and resilience of the entire rail ecosystem.

Member States. Member States shall help set the strategic agendas for harmonisation and deployment, ensuring coherence between European and national programmes. An institutionalised partnership is the right vehicle: it secures binding long-term private investment, strengthens Europe's standing against competitors, and covers the full innovation cycle — from low and medium TRL to pre-deployment of near-market products, validated in ECF-funded projects.

Academia. University and research organisation stress that Europe's Rail must continue to anchor a strong research base. The Joint Undertaking already connects more than 100 universities and research centres, sustaining lower-TRL R&I (TRL 1–4) that will deliver the breakthroughs Europe needs beyond 2035, linking PhD funding and research training to industry needs, and bringing critical disciplines — AI, cybersecurity, digital twins, autonomy, telecommunications — to bear on rail's operational and regulatory realities, while reinforcing open science and the talent pipeline. New research is equally vital to the transition itself: designing the solutions and coexistence methods to run the network under the new EU architecture remains an unsolved scientific and engineering problem, with a direct pay-off in lower migration costs and better performance. Continuous R&I investment is essential to sustain Europe's research and engineering talent pipeline, ensuring that the next generation of expertise remains engaged in rail rather than moving to competing sectors.

Passengers. For passengers — including persons with disabilities and older people — rail must become the first choice for mobility: reliable, affordable, accessible and seamless, not a last resort. A strengthened Rail Joint Undertaking delivers the harmonised, interoperable, digital system behind end-to-end cross-border journeys, higher punctuality and shorter travel times, while lower costs make services more affordable across all regions. Accessibility must be designed in from the outset, and passengers' representative organisations should help shape priorities — ensuring a system that is sustainable, smart, fair and inclusive.

Freight customers / shippers. To double by 2050 the rail freight market share, the digital integration all along the operators, infrastructure managers, suppliers, terminals and logistics actors' chain is far more necessary to ensure that innovation reaches day-to-day operations in consistently across Europe. Along the European TEN-T corridors, the freight trains operate reliably, optimised flexibility providing the right insurance to the shippers and their customers for their goods.

ERA and Standardisation bodies. The European Union Agency for Railways (ERA) and the European standardisation bodies (CEN, CENELEC, ETSI) would be essential partners in a successor Joint Undertaking. Early, structured involvement would ensure that research outputs feed directly into TSIs, standards and the regulatory framework — turning innovation into deployable, interoperable solutions. This alignment would accelerate the path from validated results to certification and market uptake across the Single European Rail Area, avoiding fragmentation and securing the JU's lasting regulatory impact.

9. Governance

The Governance structure of the future EU rail Joint Undertaking shall reflect its expanded dual mandate, encompassing both research and innovation (R&I) and a new pre-deployment strand funded through the European Competitiveness Fund. Importantly, both pillars (R&I and Pre-Deployment) would sit under a single Joint Undertaking and a single Executive Director, ensuring coherence across work programmes and facilitating the systematic transfer of Europe's Rail and future R&I outputs into the pre-deployment pillar.

This programme could be organised around three distinct but complementary strands.

The **Innovation Pillar** will continue focusing on longer-term research aimed at developing the breakthrough

technologies and knowledge base that will underpin the future of rail, and it will be structured around a set of strategic priority areas as described in Section 7 (Flagship Initiatives);

The **System Pillar**, by contrast, will gear towards the integrated development and validation of the technologies and solutions needed through a shared operational vision and common system architecture, supporting the deployment of harmonised and innovative solutions across Europe. To address this, the System Pillar develops further a common operational concept and a functional, safe and secure system architecture. This System Pillar should build on, and maintain continuity with, the existing Europe's Rail System Pillar, and its common-architecture role should remain clearly distinct from the regulatory remit of the European Union Agency for Railways.

The **Deployment Pillar**. Recognising the importance of covering the full spectrum of TRL within a Joint Undertaking, the sector called for a stronger deployment focus by transforming the current Deployment Group into a fully-fledged Deployment Pillar with dedicated resources and financing links. It also supports closer alignment between FP10, ECF, CEF-T, and national programmes, alongside stronger Member State involvement, while fully preserving ERA's regulatory independence. It will consist of dedicated projects for large-scale validation in genuine operational environments ensuring successful translation of innovations from concept to implementation. It would require significant European procurement activities to enable a first implementation at system level, supporting a more integrated approach to innovation transition than country by country programme specific implementation. This pillar will comprehensively address the funding challenges, industrial capacity and coordination complexity across actors and borders, to bridge the gap between research and full rollout thereby reducing risks and validating solutions in real conditions.

Unlike its predecessor, Europe's Rail JU, established solely under Horizon Europe for R&I activities, the new body will require a more complex institutional architecture capable of overseeing the abovementioned distinct but complementary workstreams. It will therefore be essential to design a governance framework that clearly delineates responsibilities, decision-making processes, and funding flows amongst these pillars, while ensuring coherence and strategic alignment across the organisation as a whole. When redesigning such a framework, decision-makers should bear in mind possibilities to speed up the internal processes (drafting of MAWP, grant agreements, feedback processes).

The future partnership should also build on the positive experience of Europe's Rail Joint Undertaking to encourage openness to increased membership, participation of SMEs, start-ups & academia, and potential collaboration with other joint undertaking where potential synergies are identified.

The governance structure of the ERJU should take due account of the EU's overarching simplification objective, ensuring that institutional arrangements remain proportionate, avoid unnecessary administrative burden, and preserve the legal and financial predictability needed to deliver simplification in practice rather than merely on paper.

While a cross-modal Joint Undertaking may be perceived as a simplification from an institutional standpoint, it would in practice generate substantial additional governance complexity, as reconciling the divergent research and innovation priorities, technology maturity cycles, and stakeholder architectures of the different transport modes under a single decision-making structure would render day-to-day management considerably more burdensome and resource-intensive than under mode-specific governance arrangements.

Far from delivering the intended streamlining of the EU R&I landscape, a combined multimodal JU risks introducing significant coordination overheads and operational inefficiencies, insofar as the distinct needs and objectives of each transport mode are unlikely to be adequately accommodated within a single, undifferentiated governance framework.

10.The Signatories

AERRL – Association of European Rail Rolling Stock Lessors

ALE – The Federation of European Train Drivers' Unions

ALLRAIL – The Alliance of Passenger Rail New Entrants

CER – Community of European Railway and Infrastructure Companies

EAL – Association of ERTMS Accredited Labs

EIM – European Rail Infrastructure Managers

ERFA – European Rail Freight Association

FEDECRAIL – European Federation of Museum & Tourist Railways

NB-Rail – Notified Bodies Association

UIP – International Union of Wagon Keepers

UIRR – International Union for Road-Rail Combined Transport

UITP EUROPE – International Association of Public Transport

UNIFE – The European Rail Supply Industry Association

UIC – International Union of Railways

EUG – The ERTMS Users Group

A unified rail research community calls for a successor to Europe's rail joint undertaking

Under Horizon Europe/FP10 and the European Competitiveness Fund
28th January 2026

A unified academic and research community is fully committed

EURNEX, the European Rail Research Network of Excellence, unites 43 leading universities and research centres across Europe. As an academic voice in rail R&I, EURNEX drives scientific excellence, independent validation, open knowledge dissemination, and skills development critical to Europe's mobility, climate, and industrial sovereignty objectives.

Rail research, spanning engineering, digitalization, human factors, sustainability, operations, and socio-economic analysis, is indispensable to realizing the Single European Railway Area (SERA), completing the Trans-European Transport Network (TEN-T), and achieving climate neutrality by 2050.

Academic institutions provide system-level insights, long-term thinking, and cross-sectoral innovation that complement industry-led development, ensuring solutions are interoperable, inclusive, and publicly accountable.

Yet Europe's rail system remains fragmented. National standards, legacy infrastructure, and uneven digital maturity hinder scalability. Only a stable, coordinated, and well-resourced R&I framework can overcome these structural barriers and accelerate the deployment of harmonized, green, and digital rail solutions.

A successor to EU-RAIL

Europe's Rail Joint Undertaking (EU-RAIL) has proven that structured public-private-collaboration delivers impact. Its successor under Horizon Europe/FP10 must be improved and enlarged to maintain Europe's technological edge amid global competition, particularly from state-backed actors.

Academia must be embedded as a core partner from day one, not an afterthought. Independent research ensures evidence-based policy, safeguards public interest, and fuels innovation with spillovers to SMEs and adjacent sectors. Without dedicated support, Europe risks losing its rail R&I capacity, talent pipeline, and strategic autonomy.

Our call to the European institutions

Within the proposed FP10) and European Competitiveness Fund and any other European public fund source, we urge the European Commission, Parliament, and Member States to:

1. Establish a successor to EU-RAIL, ensuring legal continuity, governance clarity, and strategic focus on systemic rail challenges.
2. Secure robust, predictable funding:
 - €3 billion for research and innovation (50% EU / 50% industry co-funding),
 - €15 billion for pre-deployment via the ECF, and private investment, enabling demonstrators, testbeds, and market uptake.
3. Guarantee inclusive governance, with formal, balanced representation of universities, research centres, SMEs, operators, infrastructure managers, regulators, and industry, reflecting their roles.
4. Engage the research community early in defining work programs, KPIs, and evaluation criteria to uphold scientific excellence, independence, and long-term capacity building.

With ERRAC, the European Rail Research Advisory Council, EURNEX and Europe's academic rail community stand ready to co-design and co-implement a successor to EU-RAIL that places scientific excellence, independence, and skills development at the core of Europe's mobility future.

We call on EU institutions to act decisively in the FP10 and ECF negotiations to secure a rail R&I ecosystem that is not only competitive but also sustainable, resilient, and sovereign. The time to lock in this framework is now, before strategic capacity erodes and global competitors fill the scientific gap.

Signed by Council:

Marion Berbineau, Université Gustave Eiffel, EURNEX Chairperson
Andrew Smith, University of Leeds, EURNEX Vice-chairperson
Armando Carrillo Zanuy, EURNEX Secretary General

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ERRAC

The European Rail
Research Advisory Council

2025

FUTURE TRACKS

Vision and Goals for Rail Transport Research
& Innovation in a Changing Europe



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FUTURE TRACKS

Vision and Goals for Rail
Transport Research & Innovation
in a Changing Europe

Autor: ERRAC 2025

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Abbreviations

ACEA	European Automobile Manufacturers' Association
AI	Artificial Intelligence
ASTP	Absolute Safe Train Positioning
ATO	Automated Train Operation
CAPEX	Capital Expenditures
CCS	Control-Command and Signalling
CER	Community of European Railway and Infrastructure Companies
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CMMS	Computerized Maintenance Management System
CT	Combined Transport
DAC	Digital Automatic Coupling
ERA	European Union Agency for Railways
ERTMS	European Rail Traffic Management System
ESA	European Space Agency
EU	European Union
EU-Rail	Europe's Rail Joint Undertaking
EUSPA	European Union Agency for the Space Program
FDFTO	Full Digital Freight Train Operations
FRMCS	Future Railway Mobile Communication System
GDS	Global Distribution System
GHG	Greenhouse Gas
GoA	Grade of Automation
GVA	Gross Value Added
HE	Horizon Europe
HVAC	Heating, Ventilation, and Air Conditioning
IATA	International Air Transport Association
IT	Information Technology
JU	Joint Undertaking
LEO	Low Earth Orbit
MaaS	Mobility as a Service
Mt CO ₂ e	Million tons of CO ₂ equivalent
OPEX	Operational Expenditures
PSO	Public Service Obligation
R&D	Research and Development
R&I	Research and Innovation
RFC	Rail Freight Corridors
RRIA	Rail Research and Innovation Agenda
SERA	Single European Railway Area
SIL	Safety Integrity Level
SSMS	Sustainable and Smart Mobility Strategy
SWL	Single Wagon Load

TEN-T	Trans-European Transport Network
TMS	Traffic Management System
TRL	Technology Readiness Level
UIC	International Union of Railways
UNIFE	The European Rail Supply Industry Association
VR/AR/XR	Virtual Reality / Augmented Reality / Extended Reality

1.



1 Railway in Europe

Europe faces a shifting landscape marked by heightened geopolitical tensions, supply chain vulnerabilities, and the imperative for climate action. The Draghi Report (2024)¹ underscores that the EU competitiveness is threatened by fragmented markets, insufficient investment, and persistent regulatory barriers, particularly in transport. Labor market transformations, driven by automation and digitalisation, are altering workforce requirements, necessitating upskilling and reskilling to match new technological demands. The development of new technologies is also necessary to tackle the labour gap. As Europe advances toward climate neutrality and strategic autonomy, as the most efficient, resilient, and future-ready mode, rail is key for the European mobility of persons and goods. It is not only key to reducing emissions, but also essential for economic strength, energy security, and geopolitical stability.

Unmatched energy efficiency and climate performance: Rail produces just 25 kg of CO₂ per Euro of economic output - 24 times less than road transport (600 kg/€), and far below maritime (255 kg/€) and aviation (243 kg/€)². At the European level (EU27), in 2022, the rail mode was representing 0,3% of the total of Greenhouse gas emissions from transport with a continuous decrease since 1990 for a 7,2% market share for the passenger transport and 16,6% for the freight transport. This isn't just about emissions - rail also consumes far less energy overall. Thanks to its physical efficiency (steel wheels on steel rails), trains require 3 to 5 times less energy per ton-km or passenger-km than road or air, and such efficiency rises-up much more in case of metro. Most of the European rail network is already electrified, providing the best energy efficiency for the mobility. Moreover, land consumption caused by rail is low compared to other modes of transport. This is a real advantage as it increases the quality of life, particularly in large and dense urban areas.

Stable employment, high-tech leadership, and export potential: Rail creates 1,09 % of EU jobs (road 3,42 %, air 0,44 %, maritime 0,33%)³, with an employment multiplier like the one of automotive sector but much more stable and less volatile - each direct job

¹ https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

² Calculation based on market value data from ACEA, IATA, UNIFE, CER, UIC, EMSA and Eurostat on GHG production in Mt CO₂e/year

³ Direct, indirect and induced jobs. Source: Land transport jobs: Key figures on European transport 2024 edition (Eurostat), rail transport jobs: Eighth monitoring report on the development of the rail market under Article 15(4) of Directive 2012/34/EU of the European Parliament and of the Council. Indirect and induced jobs multiplier: Source1 Trends, challenges and opportunities in the EU transport labour market, Ecorys, requested by the TRAN Committee, EU Parliament 2024. Source2 Employment in Sustainable Transport, Ekosgen UK, 2010

supports further employment in services and industry. It offers stable, long-term workplaces in infrastructure, manufacturing, operations, and innovation.

Europe is also a global leader in rail technologies, engineering and services, exporting high-speed systems, digital signalling, and rolling stock, the capacity to manage the engineering. Demonstrating its commitment to next-generation technology, the European rail supply industry reinvests 3.6% of its annual revenue to R&I activities. With an annual global market growth of 3% and an expected value of 240 billion Euro by 2029⁴, the European rail supply industry is a global leader in the design, manufacturing and maintenance of railway systems and products, corresponding to over 650,000 jobs in Europe. In addition, European industry is also world leader in metro automation (Unattended Train Operation) ensuring unique performances in terms of scalability, adaptation and resilience of urban transport services. The sector is a cornerstone of EU industrial competitiveness and sovereignty, driving high-tech development and green innovation/clean-tech, but not in a consumer-oriented market. Market launch depends primarily on socio-political factors.

- *Compared to other modes of transport, railway jobs enjoy a certain degree of stability, resistant to crisis and market fluctuations.*
- *Investing in rail strengthens a competitive strategic industrial base with global reach and resilience against economic shocks.*

Strategic infrastructure for emergencies and defence: Rail is more than just a means of transport - it is a critical infrastructure. In times of crisis - be it pandemics, natural disasters, or other emergencies - rail ensures the reliable transport of people and vital goods across regions and borders.

- *It also plays a key role as strategic logistics factor, enabling the rapid deployment of heavy equipment and personnel, reinforcing Europe's strategic and defence capabilities.*
- *In large urban areas, urban rail systems are the main tool to make cities liveable and attractive.*

Rail at the service of the socioeconomic growth, the freedom of movement and the right to travel: Throughout all European countries, rail is the mobility backbone for both goods and people, acting as an essential mobility service for socioeconomic advance and well-being of European cities and citizens, as well as a tool for building liveable, democratic and people-centred region and cities. Urban rail systems, including metros,

⁴ World Rail Market Study, forecast 2024 to 2029 - <https://www.unife.org/news-resources/wrms/>

trams, and suburban trains, highly contribute to enable over 25 billion passenger journeys annually. Urban and regional rail allow to connect citizens with workplaces, schools and healthcare institutions, their families and their social life, easing the tourism all over Europe. It is at service of every person being mobile all over Europe even relevant for low-income families, elderly, and less mobile people. It reduces congestion in cities, which costs the EU some €270 billion a year, avoiding in urban areas greater inequality, reduced productivity and greater environmental and economic stresses. In cities, a metro line can support 40.000 passengers per hour when the equivalent road in terms of width supports a traffic of 700 cars per hour which means serving around 900 people by car (1,3 average number of people/car) at a speed of less than 15 km/h.

1.1 Six Key Challenges

Rail is at a cornerstone of Europe's green transport future - yet despite its environmental, economic and social benefits, it remains underutilised. In 2022, rail accounts for just 7-8% (stagnating) of passenger transport output and a modest 18% (declining stagnating) of freight in the EU, dwarfed by roads (75-80%) and undercut by aviation, especially low-cost companies⁵. Europe's rail strength comes from nationally rooted systems working together under a common EU vision, fostering innovation, accountability, and local adaptability.

This model has turned Europe into a global rail leader - pioneering high-speed technology, fostering competitive industry giants, engineering companies and transport operators, and setting standards for seamless cross-border travel. While exact investment figures vary, the EU and its member states invest big amounts annually into rail, support smart modernization and infrastructure expansion to keep rail competitive and performing towards the other modes.

Challenges like fragmented rail systems and freight inefficiencies persist - but Europe is addressing them through the TEN-T network and the Single European Rail Area (SERA), which aim to delete the barriers for the rail operations all over Europe. Meanwhile without rail, urban areas would experience greater inequality, reduced productivity and greater environmental and economic stresses.

The European rail supply industry is a global leader in the design, manufacturing and maintenance of railway systems and products. Maintaining its positive trade balance through the development of innovative solutions will not only support Europe's rail industry on a global level, make the European railway system stronger but also address climate change and ensure economic growth. Because of this, hurdles are opportunities

⁵ Eurostat 2024, detailed datasets, transport, railways, railway transport measurement. Values in passenger-km and tkm

for Europe to pioneer a uniquely collaborative, green, and people-centred rail renaissance, proving that sustainability and progress can go hand in hand.

- **Fragmented rail systems & lack of standardisation:** despite tangible progress, differences in signalling systems, electrification, track gauges, and rail slot allocation due to the history, the long-life cycle of the assets and the associated evolution of the national regulations still pose challenges for seamless cross-border rail operations. Operational rules also vary, affecting overall efficiency and in particular of train drivers. Harmonisation activities which started in Europe's Rail must still be completed, implemented and validated in cooperation with the European Union Agency for Railways.
- **High System Costs:** The European railway system is facing high costs due to fragmented national networks, increased costs of a fragmented digitalisation, causing inefficiencies and rail systems duplication. Variations in technical standards and associated certification processes necessitate costly modifications not only to ensure cross-border operations. Additionally, elevated asset require investment in modernizing infrastructure and implementing technologies like ERTMS further escalates costs. Regulatory complexities and lengthy approval processes for projects also contribute to higher operational and development expenses. Simplification and harmonisation of operations, processes and products is cornerstone to reduce costs.
- **Low competitive rail freight operations and lack of competitive pricing & flexibility:** Freight trains have suffered for many dozens of years of a long list of hurdles even with the total opening of competition at the European level, an increase flexibility of the trucks (decrease of oil prices, definition of European regulations, low level of the road charges, etc.), with the decrease of the heavy industry, insufficient digitalisation, lack of offers and service flexibility, limited last-mile connectivity and long waiting time at the borders. They all together make rail freight less appealing to customers and less competitive to road transport. A large-scale deployment of the Digital Automatic Coupler (DAC), the development of new digital services on top of it, consolidation, integration and advanced data analytics and automation of freight operations would significantly increase the efficiency of rail freight operations and making them attractive again.
- **Underinvestment in maintenance, regeneration & modernisation:** aging infrastructure is an issue for many rail networks, leading to delays, speed restrictions, and loss of reliability. Some governments often prioritise roads and aviation over rail upgrades. New maintenance and retrofitting solutions, using

Digital Twins or AI for instance, could mitigate low investment by cost-efficient alternatives.

- **Urban congestion & last-mile connectivity issues and regional/rural services;** In many European cities, weak links between rail and other local transport modes make trains less convenient for the last mile. This is especially true in regional and rural areas, contributing to transport poverty and limiting access for underserved communities. It deems necessary to create multimodality and specific last mile solutions to fight transport poverty and feed regional and rural rail lines, ensuring capillarity.
- **Lack of seamless ticketing & integration:** Unlike aviation with the Global Distribution Systems (GDS), the rail ticketing services are fragmented, mainly governed by fragmented markets, operators and national rules/regulations, they are managed by public authorities under the Public Service Obligation or open to competition. Given the lack of a common framework for booking systems, making cross modes and cross-border travel planning can be easily cumbersome. Digitalisation and cybersecurity and harmonisation are the required tools, together with regulation if needed given the sector initiatives for cross-country ticketing, to overcome this challenge.



1.2 EU Objectives vs. Investment: Bridging the Gap

While the European Union has placed rail at the core of its decarbonisation and sustainable mobility agenda, a closer look at funding patterns reveals a persistent imbalance between ambition and allocation. Despite rail's proven environmental, economic, and social benefits, investment in rail research remains disproportionately low compared to other transport modes.

To achieve Europe's long-term mobility goals especially towards an shift in modal split, budgets must, support not only the construction of tracks but also the innovation that powers them.

It is time to put brains to the muscles of rail: aligning investments with the EU's strategic objectives to unlock the full potential of Europe's most sustainable mode of transport.

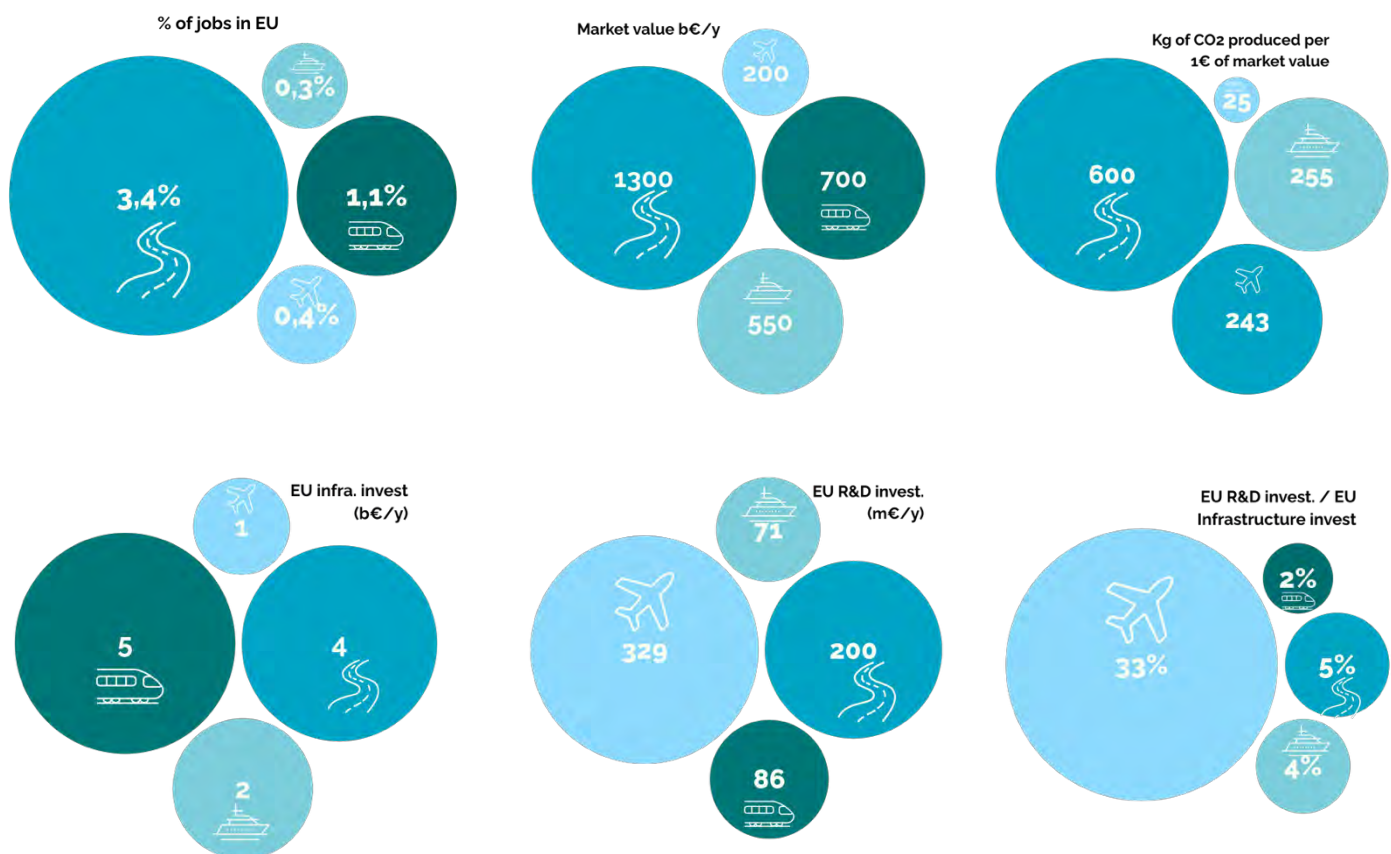


Figure 1. Comparison of EU Transport Modes: Market Value, Employment, CO₂ Efficiency and Investment Patterns. Source and data: EURNEX www.eurnex.org/wp-content/uploads/2025/10/image.png

This section aligns closely with the recent Oxford Economics study for CER, “The Economic Footprint of Railway Transport in Europe” (2025), which confirms and reinforces the trends illustrated above. The study shows that rail now contributes €247 billion to EU GDP and supports over 3.1 million jobs, equivalent to 1.6% of total EU employment, marking an increase in both economic value and employment since previous assessments. These results demonstrate that rail is not only the most climate-efficient mode of transport, but also a powerful driver of industrial competitiveness, innovation, and regional cohesion. Yet, as the investment comparison highlights, the sector still receives disproportionately low levels of R&I funding.

Closing this gap is vital for Europe to fully realise rail’s potential, fostering sustainable growth, advancing the Green Deal, and aligning financial priorities with the EU’s long-term climate and mobility objectives.



2 The European Context

2.1 European Union Goals supporting Rail

The European Green Deal aims to achieve a 90% reduction in transport-related greenhouse gas emissions by 2050⁶. The European Commission's "Sustainable and Smart Mobility Strategy (SSMS) – putting European transport on track for the future" of December 2020 sets concrete objectives and milestones towards the digitalisation and greening of the transport sector and rail. Achieving Europe's climate neutrality targets by 2050, including a targeted 90% reduction in European transport GHG emissions, is only possible by attracting more passengers and freight to the rail mode which therefore needs to increase its efficiency, attractiveness, accessibility and competitiveness. The targets are ambitious for the rail mode, i.e. traffic on high-speed rail to double by 2030 and triple by 2050, rail freight traffic to increase by 50% by 2030 and double by 2050, rail and waterborne-based intermodal transport to compete on an equal footing with road-only transport in the EU by 2030.

A coordinated European approach to R&I, like through Shift2Rail and Europe's Rail, has proven to be vital to overcome the historic and obstructive fragmentation in the rail system and to deliver harmonised European-wide technical and operational solutions making the European rail system more agile, innovative, reliable, resilient, capacity-performant and achieve a Single European Railway Area (SERA)⁷ and the objectives set out in the SSMS.

The Letta Report on the Future of the Single Market (2024)⁸ rightly points to key objectives that need to be achieved in the future to ensure that the Single Market serves as a catalyst for seamless and sustainable transportation in the EU.

"The completion of the European transport network, with a special focus on railways, must be accelerated if the Single Market is to regain dynamism and strategic depth" Letta Report (2024)

The Draghi Report (2024) warns that Europe's competitiveness is at risk due to fragmented markets, underinvestment, and dependence on foreign suppliers. It calls for Europe to re-industrialise and to invest more in sectors like rail. Rail infrastructure and supply chains are now seen as essential, not only for the environment, but also for keeping Europe strong and secure. In addition, the report supports the development of a

⁶ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

⁷ <https://www.consilium.europa.eu/en/policies/rail-transport-policy/>

⁸ https://single-market-economy.ec.europa.eu/news/enrico-lettas-report-future-single-market-2024-04-10_en

high-speed rail network connecting all EU capitals and major cities, which would enhance rail attractiveness and contribute to decarbonisation. Indeed, the Starline blueprint, published by the think tank 21st Europe, envisions a transformative high-speed rail network connecting major European cities by 2040. It claims to reduce emissions by up to 95% and cut short-haul flights by 80%⁹.

"Strengthening strategic infrastructures such as rail is vital to enhance Europe's competitiveness and autonomy in a more contested global environment." Draghi Report (2024)

Various political initiatives at European level (e.g. the March 2025 EU transport minister meeting¹⁰, The Targeted Consultation on Military Mobility establishing a new regulatory framework¹¹), are currently emphasising the need for dual-use technologies. Railway, which is predestined for the rapid transport of goods and people, has a special role to play here. This shows how rail is no longer just about transport - it's about resilience and sovereignty

To be sovereign and more independent from external supply chains, we need to support our own rail supply industry. Europe has a strong rail industry with many capable companies, large and small. But they need support to stay competitive. The ERRAC Rail Research and Innovation Agenda (RRIA, 2024)¹² and UNIFE's industry priorities for 2024–2029¹³ both stress the need for investment, innovation, and better coordination.

Rail is not just about tracks and trains - it's also about people. As rail systems become more digital and more automated, people working in rail sector need new skills. At the same time, the sector is facing a shortage of skilled workers, especially in areas like IT, engineering, and operations. The World Economic Forum and the RRIA both point to a big gap between current skills and what is needed for the future. If we do not invest in training and attract new talent, the sector will fall behind.

2.2 The Need for European Rail R&I

A well-functioning rail system is strategically important for the EU citizens, the economy as well as for security of the EU and its Member States. Rail is central to decarbonise the transport sector, being the most environmentally friendly transport mode in Europe

⁹ <https://21st-europe.com/blueprints/starline>

¹⁰ <https://polish-presidency.consilium.europa.eu/en/events/informal-meeting-of-transport-ministers-17-183/>

¹¹ https://defence-industry-space.ec.europa.eu/consultations/targeted-consultation-military-mobility-package_en

¹² <https://errac.org/publications/rail-research-and-innovation-agenda-rria/>

¹³ https://www.unife.org/wp-content/uploads/2024/03/UNIFE_Priorities_2024-2029.pdf

today. This role must be further strengthened and expanded by upgrading and extending the necessary infrastructure and retrofitting rolling stock as well as by supporting innovative solutions to current and future challenges, taking in account the significant investment's needs rail is facing to maintain a coherent and performing European rail system.

Given today's challenges, it is particularly important to further strengthen the European railway system as an essential part of services in the general interest and to take the necessary steps in the field of research and innovation to this end. All types of rail services (high speed, freight, regional, urban, and suburban trains, metros, tramways) must be a reliable element of the European transport network, running even in situation of crisis. To achieve this, a focused, fast, use-case and business-case approach is needed. Only this allows us to achieve a true Single European Railway Area (SERA) with a well-running and customer-oriented rail transport that contributes to reach the objectives of the SSMS and lays the foundation of a competitive Europe.

Following the RRIA published in September 2024, further research is needed for **System Optimisation**, **Lowering Costs** strengthening **Sustainability**, improving **Multimodality and Intermodality** as well as **Inclusive and Personalised Services** in the sense of comprehensive “Mobility as a Service” solutions. This means to increase the capacity of existing infrastructure, improve traffic management systems, lower costs, simplify the system and improve interfaces with other transport modes as well as become more reliable and resilient against climate change, armed conflicts, and cyberattacks. Decarbonisation can also be fostered with advances in asset management, deepening on asset monitoring and hence, planning and execution of works using "cutting-edge" technology, techniques and processes, which could, amongst other targets adequately support Regulatory Asset Based (RAB) models for investment in (high speed) railway infrastructure, suggested for its development by the Draghi Report. Likewise, increased research activities are necessary to achieve total decarbonisation of rail as well as set up a circular economy to further strengthen the railway system as the most environmentally friendly and sustainable means of transport. This will lead to a system in which productivity, capacity quality and attractiveness will be significantly increased.

2.3 Success of Past European Rail R&I

The European rail sector has made significant progress in recent years, driven by ambitious research and innovation programmes of Shift2Rail and the ongoing Europe's Rail Joint Undertaking “EU-Rail”. These initiatives have laid the foundations for greater interoperability, digitalisation, and efficiency across the sector, supporting the competitiveness of the European rail industry. Stakeholders from both the European rail

supply industry and rail operating community have together invested, collaborated and benefitted from the first two European rail Joint Undertakings (JU). The success of Shift2Rail and EU-Rail in contributing to EU policy and addressing its common objectives outlined below validate the significance of such public-private collaboration for the future rail system and have demonstrated that collaboration across the value chain is not only possible but essential.

R&I remain essential levers for the railway sector to safeguard and further develop the system. The previous programs have shown that it is not sufficient to just look at rail research innovation, but also to consider the full lifecycle, including the future concept for operation and the functional system architecture. Shift2Rail and the EU-Rail fostered a cross-industry collaboration unlike anything that had come previously. Success stories include:

- **Traffic Management System:** Further developments for TMS were made to develop a more dynamic strategic planning for the network and a dynamic and optimised network traffic management at European level including European cross-border scheduling and optimisation, contributing to ERTMS, enabling automatic management of cross-border rail traffic and attempting to connect rail and aviation Information System.
- **Automated Train Operations:** Success stories of the past programmes included the test of up to GoA4 train tests, automated shunting and stabling, remote train operations also for tramway systems, train positioning development (incl. joint actions with other EU-body as EUSPA and ESA), preliminary tests of virtual coupling, development of the moving block concepts, tests of the new European telecommunications standard FRMCS – all technologies which allow to increase the capacity and efficiency on existing infrastructure.
- **Rail Freight:** For the freight sector, huge steps were made with the development and testing of the Digital Automatic Coupling (DAC) under operational conditions. European harmonised, scalable, upgradable DAC systems were developed to support digital-enabled operational procedures and digital yard automation, and management solutions were developed and tested. In addition, solutions to digitalise freight transport such as standardized European railway checkpoints easing cross-border traffic, harmonized maintenance data exchange, and multi-country driver licensing new wagon concepts to make freight more competitive were developed.
- **Resilience, sustainability & maintenance:** to increase resilience and improve the system maintenance, a common European asset management framework using digital technologies and data analytics to minimize lifecycle costs and extend the service life of rail assets was developed, wayside monitoring

technologies were improved, additive manufacturing was successfully applied to railway technologies and field test campaigns for robotic platforms were carried out. To improve the sustainable footprint of the railway sector, a 200km demonstrator testing for a battery electric multiunit was carried out. Silicon Carbide developments are now a reality and part of the portfolio of the rail traction industry. Moreover, technologies to improve air quality in passenger cars through innovative HVAC systems, solutions for airless trains and SIL 4 braking systems are notable success stories.

- **Regional Railway:** For regional railway lines, cost-efficient, energy self-sufficient wayside solutions as well as digital solutions to help reducing the number of necessary wayside devices and the associated concepts of simplified operations were developed. This will ensure the long-term economic sustainability of regional railways by lowering CAPEX and OPEX.

In addition to the challenges the sector is facing, i.e. to introduce research and development results already achieved or the integration of new technologies in a system that serves the general public and is not anchored in a traditional consumer market, and to make the associated resources available, the continuation of R&I activities is crucial to increase the technology readiness level (TRL) and maturity of the innovative European solutions initiated and developed within these programs and to ensure the next development steps to bring innovations and their benefits to the market more quickly through targeted upfront testing and implementation across the entire EU rail network. In this context, the Pre-Deployment Group of Europe's Rail, initially focusing on the Future Railway Mobile Communication System (FRMCS), provides the necessary framework to accelerate the time-to-market of such innovations. Furthermore, both Shift2Rail and Europe's Rail have proven to be essential instruments in strengthening cooperation among rail stakeholders at the European level. They have fostered the creation of enduring networks of expertise and collaboration, successfully integrated universities and start-ups into these ecosystems, and laid the groundwork for the harmonisation of the European railway system, supported by key enablers such as the System Pillar.

3 Areas of Attention Requiring Joint Innovation

Despite the important advances achieved, several challenges remain and still limit the sector's ability to reach its full potential. At the same time, there is a growing cultural shift across Europe: an increasing alignment and willingness among stakeholders to break traditional silos, embrace joint innovation, and drive simplification forward. The momentum is there to take stronger and more decisive steps toward a fully competitive, agile, attractive and sustainable European rail system.

The primary R&I areas are therefore:

- **Increase of Rail Capacity and Boost Agility:** Use of innovative solutions and digitalisation to increase capacity as a supplement to conventional expansion methods. Develop a system that can react dynamically to disruptions and implement shorter innovation cycles through enhanced modularity and simplified certification processes. Accelerating the validation and authorisation of innovations and encouraging faster deployment of new technologies.
- **Sustainable and Resilient Rail Transport:** Ensure safety and security of critical infrastructure in all areas and expand capacity to improve resilience and continuous availability of the system, also addressing the shortage of skilled workers in the railway sector. Increasing the resilience of the railway system, in particular to be able to adequately manage critical disturbances. In addition, define measures to further improve energy efficiency and energy supply, the use of sustainable materials to further reduce the system's ecological footprint, and massive investments in sustainable competitiveness.
- **Address Customer's Needs for Freight Transport as well as for Passenger Transport, especially Urban and Regional:** Improve quality and attractiveness of rail transport for freight and passengers by further development of multimodal and intermodal integration in all dimensions, better door-to-door service solutions so that customers and their needs are at the heart of all activities by inclusive and personalised services.
- **Drive Simplification by Ensuring a Standardised and Harmonised Approach:** innovation plays a crucial role in standardising and harmonising the European railway system. This will lead to cost reductions, lower barriers to new entrants to make railway more efficient, providing the suppliers/manufacturers a competitive advantage by shorter technology innovation life cycles. The known challenges underline that a lack of a European approach towards a system simplification would significantly undermine a) the EU industrial leadership and competitiveness, b) the European ability to respond to passengers' and businesses' needs and c) the achievement of a Single European Railway Area. Based on the European and national challenges.



Figure 2. Vision of achievable goals from a new R&I programme

3.1 Increased Rail Capacity and Boosting Agility

3.1.1 Motivation & Objectives

The creation of a comprehensive pan-European high-speed rail network and the establishing of a truly integrated Trans-European Network of Transport (acc. to TEN-T Regulation (EU) 2024/1679)¹⁴ seamlessly connecting all EU capitals and major urban centres (among the 431 “urban nodes” identified by the Regulation) represent a unique opportunity to revolutionise European rail transport and advance EU integration. By ambitiously connecting the continent's most important cities, this project stands to

¹⁴ <https://eur-lex.europa.eu/eli/reg/2024/1679/oj/eng>

significantly elevate rail's role in long- and medium-distance transport, aiming to capture more than 50% of the market share. This initiative is not merely an advancement in transportation infrastructure; it represents a critical step toward forging a more connected, accessible, and unified Europe. Its realisation will serve as a cornerstone in the EU's journey towards enhanced connectivity, economic growth, and environmental sustainability, underscoring its profound importance for the future of the European Union. In addition to these challenges, increased efforts are also needed for covering all parts of cities, suburbs and rural areas, providing better opportunities to commute between cities as “core” and the suburbs and the wider (rural) environment, increased capacities and affordable services to all citizens including the elderly and persons with reduced mobility. To be able to cope with the ever-increasing demands and the expected higher transport performance in passenger and freight transport, it is necessary to further increase the adaptability, agility and rapid response capacity to changes in the railway system.

3.1.2 Needed Technical Enablers

To achieve this objective, research and innovation are necessary in the following areas, among others:

- **Modular & Scalable Technology Development:** Develop plug-and-play modules/components for different fleet sizes and use cases
- Higher automation up to autonomous operation for railways (GoA 3/4), e.g., in the field of Safe-AI, Sensor Systems and Absolute Safe Train Positioning (ASTP), Virtual Coupling and Unmanned Operation, and thus higher route utilisation. Role of humans and the interface with the automated systems.
- **Safe-AI-Driven Decision Support:** Use Safe-AI to optimise traffic flow, train path allocation, and logistics planning
- High speed vehicle components including aerodynamic and engine improvements for less energy consumption
- **Safe Communication Network for Rail,** e.g., in the fields of FRMCS, 6G, European Satellite System (LEO satellites)
- **Predictive Maintenance Technologies:** Innovate maintenance strategies through AI and big data to shift from reactive to predictive maintenance, reducing downtime and lifecycle costs for both rolling stock and infrastructure.
- **Integration of Construction Innovation:** Leverage new construction methods (e.g., modular bridge building, 3D printing, robotized track laying) to speed up the building and renewal of infrastructure while minimising disruptions

- Digital Twins and Virtual Certification: Establish a pan-European approach to digital twins and virtual testing environments to speed up certification processes and reduce physical testing requirements
- Digital twins to support increased decision processes by the integration of modelling and simulation.

3.2 Sustainable and Resilient Rail Transport

3.2.1 Motivation & Objectives

Given today's challenges, it is particularly important to maintain and enhance the SERA and non-SERA European railway system as an essential part of services in the general interest and to take the necessary steps in the field of research and innovation to this end. Rail in all its kinds (High speed, Freight, Long Distance and Regional Trains, Metros and Tramways) must be a reliable component of the European transport network, usable even in crisis situations. Increasing the resilience of the railway system requires research into the impacts of climate change, health crises, dangerous interventions in critical infrastructure, cyberattacks, military conflicts, and tackle the skills and labour gap, as well as research into general railway operations to cope with increased loads on the railway network and enable faster decisions to deploy alternative solutions. Likewise, increased research activities are necessary to achieve total decarbonisation of rail transport to further strengthen railway's position within the European transport system.

By enhancing the availability of trains and tracks through improved maintenance, we can significantly increase the reliability of the promised mobility service, reduce the inconvenient disruptions caused by maintenance closures, ensuring safer and more gratifying travel experiences for all passengers *and freight services*. Continuous monitoring allows to identify potential issues before they escalate, thereby decreasing the requirement for human intervention in challenging or hazardous situations. Enhancement and improvement of the human skills of rail working staff to decrease risks coming from the actions involving human factor shall help for the overall abovementioned objectives, especially contributing for an increased resilience of the rail system. In summary, resources *are optimized, downsize educed* to take informed maintenance decisions that prioritize both urgency and cost-effectiveness.

3.2.2 Needed technical enablers

To achieve this objective, research and innovation are necessary in the following areas, among others:

Sustainability

- Decarbonisation strategies for hard-to-electrify rail areas by research in Alternative Propulsion, Smart Power Management and saving Traction Energy
- Energy recovery from operational processes, e.g., safe electric brake, use of waste heat in metro tunnels
- Circular Economy in rail manufacturing, construction, operation, maintenance and service
- Usage of sustainable materials for railway applications, e.g., wood or composite with green fibres, etc.
- Environmentally friendly Vegetation Management, Biodiversity Management along railway corridors and Smart Environmental Monitoring Systems for railways
- Construction of lighter and more energy-efficient vehicles based on new safety technology (active vs. passive safety) and adaptation of the corresponding standards
- Reduction of negative externalities such as noise and air pollution, and vibrations through innovative mitigation technologies and regulatory harmonisation

Resilience

- Determination and evaluation of military requirements regarding dual-use and derivation of necessary research projects
- Cyber Security and Shielded Systems, e.g., common frameworks and solutions for cybersecurity, protecting both digital and physical assets across the rail system
- Quantum Computing for Train Planning and Operation Systems for provision of the better optimised solution in real time in case of disturbance
- Using Extended (Virtual and Augmented) Reality to tackle the skills and labour gap through virtual assistance systems to support operations and maintenance, e.g., as smart helmets and/or glasses
- Wearable Technology for Maintenance Crews, e.g., suits equipped with sensors monitoring the health and safety of maintenance workers in real-time (e.g., detecting fatigue, location, and vital signs).
- Drones for Track and Infrastructure Inspection: Drones equipped with high-resolution cameras, LiDAR, and thermal sensors to inspect tracks, overhead wires, bridges, tunnels, and other infrastructure components.
- Robotic and Autonomous Track Inspection and Maintenance, e.g., for track alignment, ballast cleaning, and rail welding.

- Standardised Modular Infrastructure Components, e.g., track systems, signalling equipment, which can be produced and deployed rapidly with minimal customisation
- Data-Driven Maintenance Management Systems (CMMS) using big data and analytics to streamline the scheduling of infrastructure maintenance tasks, track inventory, and manage work orders.
- Safe-AI-assisted Predictive Maintenance and Real-Time Monitoring for continuous monitoring e.g., vibrations, temperature, pressure, and wear
- Research, investigations and development due to Climate Resilience of Rail Infrastructure, e.g., better predictive capabilities, design principles to increase the resilience of the systems to withstand extreme weather conditions, analyse the different types of hazards faced for decision, in line with climate adaptation goals outlined in broader EU resilience strategies, collaborate on designing rail systems that can withstand extreme weather conditions, in line with climate adaptation goals outlined in broader EU resilience strategies
- Planning rules for reaction to (multiple) local and massive disruptions and definition of the associated strategy for decision-oriented investments
- Innovative rail vehicles for disaster relief and medical care
- Build European-wide train monitoring detector station and data networks

Alongside technical enablers, information on the economic parameters needed to optimise cost, sustainability, and resilience objectives is lacking. Understanding the



trade-offs and even win-wins between these would greatly strengthen research impact and implementation.

3.3 Addressing Customer's Needs for Freight Transport

3.3.1 *Motivation & Objectives*

European freight transport is an important economic sector and at the same time a key element in our collective effort to take on climate change, since rail is nine times less CO₂-emitting than road¹⁵. Clean and decarbonised logistics chains are vital for enhancing Europe's competitiveness, strategic autonomy, security, and defence. In addition to intermodal freight transport, single wagon loads (SWL) and combined transport (CT) are crucial for efficient and sustainable freight transport throughout Europe. To increase rail freight by 50% by 2030 further research and innovation is necessary that aims at increasing rail freight's competitiveness, flexibility, performance, reliability, and profitability. Furthermore, we need the full integration of rail freight transport with other transport modes which then leads to an improved multimodal and intermodal logistics chain and will ensure environmentally friendly and sustainable door-to-door logistics services.

3.3.2 *Needed Technical Enablers*

To achieve this objective, research and innovation are necessary in the following areas, among others:

- Full Digital Freight Train Operations (FDFTO)
- Dynamic Scheduling and Capacity Management for cargo services
- Green City Logistics Concepts and Joint Transport of People and Goods, including modular hubs / micro-hubs
- Fully Automated Yard Management / Freight Hubs
- creating Open Digital Ecosystems for rail freight innovation and improving Rail freight with Personalised, Real-Time Solutions
- Developing new freight wagon models by adapting existing freight wagons including tank wagons to safely transport new commodities and power supply
- Freight vehicle components and overall design development including aerodynamic, weight and load bearing improvements for less energy consumption advancing in performance and efficiency of operations, if possible, allowing maximum compatibility and capacity between high-speed and freight traffic operations in the TEN-T lines and Rail Freight Corridors (RFC)

¹⁵ <https://www.eea.europa.eu/en/analysis/maps-and-charts/term27-specific-co2-emissions-per-passenger-km-and-per-mode-of-transport-in-europe>

3.4 Addressing User Needs for Urban and Regional Passenger Transport

3.4.1 *Motivation & Objectives*

Achieving a modal shift for local and daily mobility must be a European priority. In fact, the fastest and most cost-efficient way to reduce CO₂ and pollutant emissions in people's daily mobility is to accelerate the shift towards mass transit, multi-modal and intermodal mobility. Smart public transport, like Mobility as a Service (MaaS), and increased digitalisation accelerating the deployment of Intelligent Transportation Systems solutions can improve and complement high-capacity urban rail transport to make mobility more sustainable, efficient and inclusive, and benefit all citizens by putting public transport at their core. In addition, Customer Experience is becoming a relevant element of differentiation for transportation modes. That means, user needs will be satisfied by ensuring a customer-centric design beyond efficiency and functionality and laying the foundation for tools and measures for customer experience management, using service as a key differentiator.

3.4.2 *Needed Technical Enablers*

To achieve this objective, research and innovation are necessary in the following areas, among others:

- Artificial Intelligence used to deliver more flexible passenger services and information
- Artificial Intelligence and emerging tools used to optimise urban transport operations, incl. improved data management for enhanced network performance and streamlined flow management
- New services and flexible capacity models, based on demand-responsive and Service-Oriented Rail approaches, e.g., intermodal passenger transport systems, smaller vehicle configurations
- Deployment of small rail vehicles controlled by AI supported swarm intelligence
- Urban Regeneration driven by the deployment of Multimodal and Intermodal Mobility Hubs
- Enhancing Passenger Experience through digital solutions and cooperative systems that support intermodality, provision of personalised services and real-time travel information, and improved safety and security on board, on platforms and at train-platform interfaces
- Flexible, adaptable, comfortable, accessible and inclusive design of rail vehicles
- Solutions for improved journey quality by mitigating negative externalities (e.g., noises, vibration, etc.)

3.5 Horizontal Enablers – Harmonised and Standardised Approach

3.5.1 *Motivation & Objectives*

Simplification and lowering barriers to the European Single Market are essential enablers to safeguard the future of the EU as an economic powerhouse. A key contribution to this is the simplification of regulations and the acceleration of administrative procedures, moving towards flexible, risk-based approvals. Virtual certification methods, common standards, and modular solutions should become the norm, also common processes, lowering requirements due to the introduction of new technologies (e.g. crash). This will drastically shorten lead times and lower barriers for new entrants. To achieve this, in addition to transferring research results into potential new standardisation projects, research is also necessary to fundamentally revise or reduce existing regulations and standards.

In addition to modernising the regulatory governance framework and removing intra-European barriers, tasks also include preventing the emergence of new barriers, as well as activities to reduce regulations, proposals for revising standards and adapting them to the latest state of the art (e.g., crash safety compared to active vs. passive safety technologies), as well as cross-sectoral approaches (e.g., fire protection in passenger transport).

3.5.2 *Needed Technical Enablers*

For reduced lead time/authorisation

- Harmonisation of operational rules as fundament for highly efficient CCS systems (for moving block, virtual coupling deployment models), also for cross-border operations
- Research on the effects of active safety elements on reduced passive vehicle safety, including comparative safety simulations and validation of the resulting dominant models
- Digitisation of the authorisation process (functional approach; system-based model engineering)
- Modular authorisation for safety-related technologies, reusable certification blocks and harmonised criteria for subsystems
- Approval of new technologies before delivery based on e.g. early virtual validation and certification environments, digital twins, AI and predictive compliance metrics
- Modularity and standardisation of interfaces, universal interface protocols, model libraries and semantic interoperability standards

- Re-integrating learnings from deployment of architecture and technology in the EU-RAIL system pillar
- Harmonize operational practices and specifications across borders, using e.g. best-practice harmonisation tools, joint training simulators, corridor alignment pilots...
- Prepare infrastructure managers and railway undertakings for synchronized system rollouts
- Align industrial roadmaps of manufacturers, reducing fragmentation in the rail supply market
- Test and validate specifications and standards for integrated technologies in real conditions via cross-border pilot corridors via pre-deployment activities



4 Requirements for a New Joint EU Rail R&I Initiative

To realise this vision, joint innovation efforts are necessary across the entire rail value chain: including operators (both infrastructure managers and train operators), suppliers, construction companies, Small and Medium-sized Enterprises, wagon keepers and maintenance providers – and in case of urban rail local competent public authorities for sustainable mobility. Equally important is the involvement of Research Institutions and Universities as well as open cooperation with other sectors to avoid the development of singular solutions. By maximising the use of modular, standard components and integrating technologies from other industries (such as automotive, aerospace, and electronics), the rail sector can benefit from economies of scale, reduce costs, and increase the speed of innovation.

The core objective of future European research and innovation in rail transport is joint action to further strengthen the sector's competitiveness and increase the resilience and sustainability of the rail system. Following the Draghi Report's recommendation, this means high-impact research and innovation projects and the promotion of horizontal competitiveness factors, as well as the optimisation and simplification of systems and regulations, and the removal of internal market and intra-community barriers to ensure competitive markets and investment in future-oriented solutions with incentives for industrial deployment. The continued promotion of research and innovation, covering all TRL, will strengthen European industry and the academic research and innovation ecosystem in rail transport and increase global competitiveness through effective research and innovation, as described in the Heitor Report¹⁶. To simplify programs with agile funding, streamlined processes, and reduced administrative burden can help to achieve the R&I goals more effectively and efficiently.

Future European Research and Innovation should also allow clear inclusion of urban rail research topics and clear mechanisms to include urban rail stakeholders with their capabilities and peculiarities. This is particularly important as local operational urban rail scenarios do not match with the today programmes administrative costs, designed for more pan-European scenarios. The approach taken so far to structure European rail research and innovation has been crucial to overcome the divergence and lack of continuity in rail research and innovation. This has been achieved by developing a long-term strategy in close cooperation with all stakeholders (industry, operators, academia, and regulators). A coordinated EU-level approach is essential for aligning new technology deployment across varying national and local systems, shape future standards and regulations to speed-up R&I to market, requiring long-term investment and collaboration

¹⁶ <https://op.europa.eu/en/publication-detail/-/publication/2f9fc221-86bb-11ef-a67d-01aa75ed71a1/language-en>

among stakeholders within a comprehensive framework. To achieve this, the following principles should be considered:

- **Mission-driven innovation:** Focused on climate neutrality, resilience, and digital leadership. Unite stakeholders behind common missions aligned with EU strategic priorities.
- **Standardisation, harmonisation, interoperability & migration:** standardisation and harmonisation must be considered from the very beginning and will also allow for the simplification and harmonisation of operational processes and the overall system. To ensure the migration of new technologies and scalability, a technology-neutral approach and interoperability of the technologies used should be aimed for. This requires a strong involvement of the railways together with industry and European approval authorities in development processes to ensure faster migration paths for existing systems toward digital, sustainable targets. Therefore, tight links with ERA and CEN/CENELEC to embed research outcomes into standards and authorisation processes are needed.
- **Innovation funnel:** Supporting projects across all TRL, ensuring seamless pipeline from research to deployment, to enable future-oriented research and preliminary developments as well as shorter-term implementation-oriented development projects. Combine funding for high-risk research (low TRL) and deployment support (high TRL).
- **Focused, large-scale implementation projects with agile governance:** projects with a single objective and maximum use of existing technologies reduce complexity and enable rapid piloting and implementation of demand-oriented solutions. Projects should have sufficient size to ensure implementation. Flexible, efficient decision-making bodies involving industry, operators, infrastructure managers, and regulators are of utmost importance.
- **Pre-deployment under operational conditions:** to ensure a fast market uptake, all projects need to strive for demonstrators/pilots under real operational conditions, the migration having been carefully considered and taken into account in the technologies development. Pre-deployment pilots under real conditions will accelerate adoption and de-risk innovation. This requires strong support from authorities and regulators and new methods of approval.
- **Active collaboration with other sectors:** in line with the “EU Competitiveness Compass”¹⁷ call to re-orient the innovation pipeline with a new focus on increasing R&D spending and coordinating it on high-impact projects, the rail sector will align its future priorities with the Sustainable Transport Investment Plan (including a plan for an ambitious European high-speed rail network), as well as

¹⁷ https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

increase research in the field of “*digitalisation and diffusion of advanced technologies, such as AI, quantum computing, robotics.*” This also means pursuing and expanding cross-sectoral and cross-disciplinary research activities.

- **Attracting new skills:** investing into innovation helps making the rail sector more attractive. Investment in innovation and brings fresh academic talent into the sector, can attract new talent by showcasing the industry's commitment to cutting-edge technologies and the adoption of digital tools in rail operations, such as predictive maintenance and smart infrastructure, can create demand for software engineers, data analysts, and cybersecurity experts. This will help the sector to reduce the lack of manpower.







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