Europe's Rail Blueprint:

DESIGNING THE FUTURE OF RAIL INNOVATION

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Manuscript completed in 2026.

The information set-out in this paper is a summary from the EU-Rail Executive Director of the views expressed by the EU-Rail Joint Undertaking Members by the GB decisions n°06/2025 of June 2025 (High Level Paper on “A Future Policy-Based Public Private Partnership for Rail”) and n° 09/2025 of December 2025 (Annex to the High Level Paper) and does not necessarily entirely reflect the official position of the European Union. Neither EU-Rail nor any person acting on the EU-Rail’s behalf may be held responsible for the use which may be made of the information contained therein.

Brussels: Europe’s Rail Joint Undertaking, 2026.

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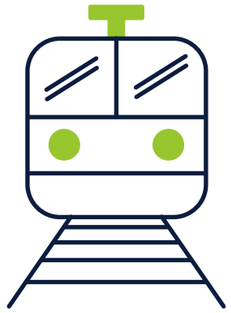
01 Setting the Scene

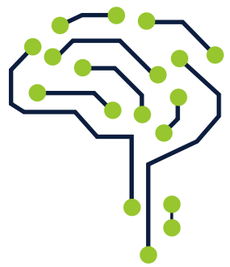


Who are we?

Established under Article 187 Treaty on the Functioning of the European Union (TFEU)[1] and the EU's programme for research and innovation, Horizon Europe, Europe's Rail Joint Undertaking (JU) is a unique public-private partnership that mobilises Europe's best scientific and industrial resources to address critical societal, environmental, and economic challenges.

What do we do?

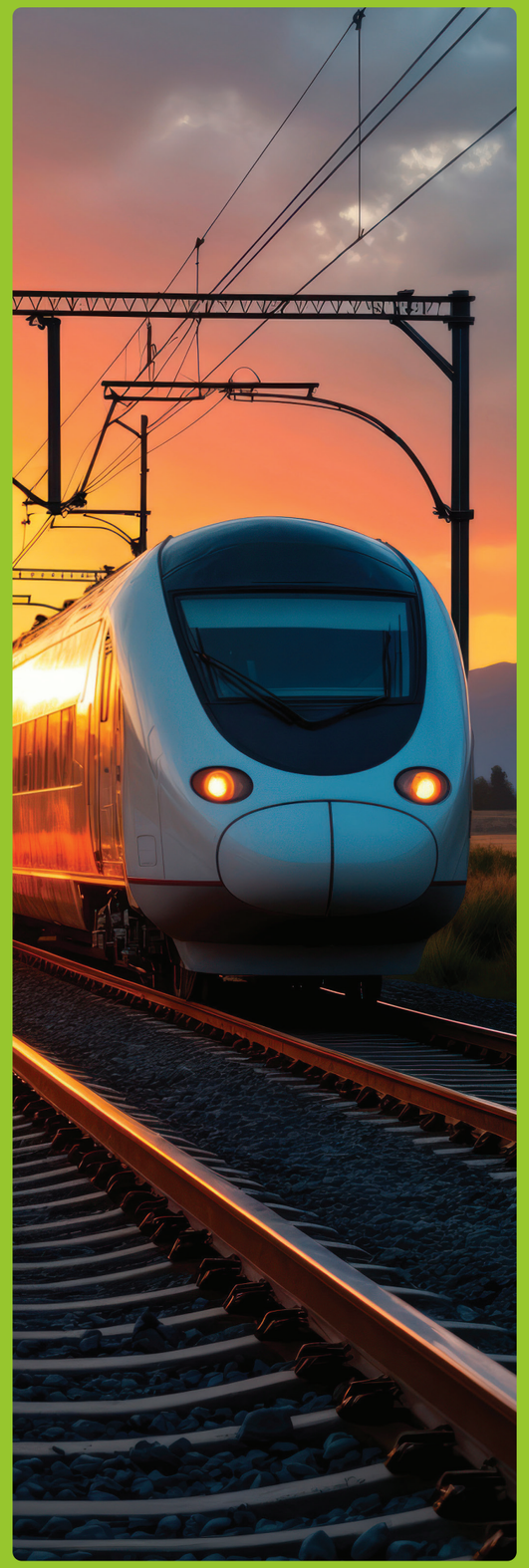
Our unique funding model allows us to launch large-scale, ambitious research and innovation projects that unite the skills, resources and expertise of leading stakeholders in the rail sector.
This includes academics, large and small companies including start-ups, regulators, civil society and end-users. Together, we turn ideas into real-world solutions.



What are we delivering?

Thanks to our collaborative approach, we're delivering scientific excellence and closing the innovation gap, from lab to market.
We strengthen Europe's competitiveness and leadership in the strategically vital rail sector and support security and resilience, boosting its geopolitical influence and contributing actively to the European Green Deal.

1 https://eur-lex.europa.eu/eli/treaty/tfeu_2016/art_187/oj/eng



What sets us apart?

- Stable legal structure with clear intellectual property rules builds confidence for 10+ year commitments.
- Dedicated European structure avoiding R&I duplications and ensuring policy-market alignment.
- Shared risk management with visibility on future research.
- Unique focal point for rail sector in EU R&I framework - stimulates private investment, attract SMEs.
- Evidence-based programme approach linking R&I results to pre-deployment and market uptake.

Europe's Rail Joint Undertaking is a unique public-private partnership mobilising Europe's best scientific and industrial expertise.

Rail as a Sector

The EU railway value chain makes a significant contribution of €143 billion to the total EU GDP [2].

The EU railway value chain provides employment to 2.3 million Europeans, including 659,000 jobs in the rail supply industry [3].

Rail transport accounts for only 2% of the estimated cost of negative externalities in transport (such as congestion, noise, climate change, and air pollution) [4].

With a track network spanning 201,000 kilometres, 8 billion passenger trips are made annually on Europe's railways and 378 billion tonne-kilometres of freight are transported [5].

GVA multiplier of 3.7.
For every €1 gross value added (GVA) generated by railway transport, another €2.7 is supported in other industries [6].

Critical rail challenges

- **System fragmentation and system costs:** Diverse national standards hinder harmonisation.
- **Investment constraints:** Insufficient public/private investment limits modernisation, especially digital transformation.
- **Competitiveness pressure:** Global competitors (especially China) threaten EU technological leadership.
- **Resilience issues:** Climate change, cybersecurity, and geopolitical risks demand coordinated response.
- **Structural challenges:** Interconnected components with lifecycles up to 40 years (trains) and 100 years (infrastructure).
- **Cross-border challenges:** Currently there are more than 20 train control systems across the European Union. Each system is standalone and non-interoperable.
- **Multi-year migration plans across national boundaries:** This exceeds any market initiative from single or limited players.

Why a rail joint undertaking is essential

- **A coordinated EU level approach is necessary:** Cross-border rail operations require standardised EU solutions developed with and accepted by the sector.
- **Driving the single european rail area:** It is vital to align innovation and interoperability across Europe.
- **Long-term binding commitments:** Coherent innovation in the rail system (40-year train lifetime, 100-year infrastructure lifetime) exceeds any market initiatives, ensures joint resource mobilisation and leverage effects.
- **Address market failure:** Complex stakeholder interactions require deep coordination under shared EU governance.
- **Maintaining EU leadership:** EUR 143-billion sector, 2.3 million jobs – competitive advantage needs an active EU undertaking.

The EU cannot work alone: cross-border rail requires European solutions.

2 Source: The transition pathway for the EU Mobility Industrial Ecosystem, European Commission, 2024 https://ec.europa.eu/docsroom/documents/57674/attachments/1/translations/en/renditions/native

3 Source: The transition pathway for the EU Mobility Industrial Ecosystem, European Commission, 2024 https://ec.europa.eu/docsroom/documents/57674/attachments/1/translations/en/renditions/native

4 Source: The transition pathway for the EU Mobility Industrial Ecosystem, European Commission, 2024 https://ec.europa.eu/docsroom/documents/57674/attachments/1/translations/en/renditions/native

5 Source: Oxford Economics Study: The Economic Footprint of Railway Transport, 2025 https://cer.be/images/publications/reports/250922_Railways_Economic_Footprint_Study_2025.pdf

6 Source: Oxford Economics Study: The Economic Footprint of Railway Transport, 2025 https://cer.be/images/publications/reports/250922_Railways_Economic_Footprint_Study_2025.pdf

02 From Shift2Rail to Europe's Rail: A proven concept for success

Shift2rail Joint Undertaking achievements

EU-Rail and the Shift2Rail (S2R) Joint Undertaking before it have reshaped the landscape of rail research and innovation in Europe. Together, these initiatives have helped develop key technologies and contributed to harmonising the European rail system.

Milestones include advancements in:

- European Rail Traffic Management System (ERTMS).
- Autonomous train operation.
- Real time traffic management solution.
- Next-generation traction systems for improved energy efficiency.
- Digital Automatic Coupler (DAC), a game-changer for competitive and efficient rail freight.

Within S2R, 695 prototype testing activities were carried out under a coherent and impactful programme approach until 2023, and were technology-validated or demonstrated in relevant environments.

Europe's Rail Joint Undertaking work and next steps

The **pioneering technological advancements delivered by EU-Rail are transforming the rail industry**; they are not only crucial for reducing costs but also play a pivotal role in promoting sustainable and eco-friendly mobility solutions. The European rail sector, at the forefront of global excellence, is leveraging these breakthroughs to further enhance its competitiveness and contribute meaningfully to Europe's economy and job market.

In Europe, the ongoing development of cutting-edge digital and automated train control systems is set to transform the operational landscape of its dense rail networks. This development promises increased efficiency and capacity, ensuring more reliable and timely train services every day. At the same time, the integration of AI-driven decision support tools, advanced monitoring systems, and digital twin technologies is expected to revolutionise rail asset management, allowing for more predictive and data-driven maintenance strategies.

Europe's Rail has also proven its strength by bringing together **all stakeholders,** including clients, suppliers, academia and industry. Through the EU-Rail System Pillar, it works hand in hand with the European Union Agency for Railways and the European Commission, to deliver inputs to specifications and standards necessary to implement solutions at European-level.

Europe's Rail also offers a unique platform to **support deployment activities**. Pre-deployment activities bridge the "valley of death" between mature research and full deployment, by testing EU-harmonised solutions and operational procedures in real-world environments across diverse national networks and regulatory contexts. This process de-risks investment, proves interoperability, and demonstrates economic viability before full-scale rollout. **By validating innovations under commercial conditions, it ensures they can handle the complexity of Europe's railways, enables cost effective scaling, aligns EU and national priorities to support investment decisions, and confirms both technical readiness and manufacturing capacity.**

Additionally, a major market failure in the rail sector is the mismatch between who pays for innovation and who benefits from it, discouraging private investment in breakthrough technologies. Pre-deployment within the EU-Rail JU framework addresses this by coordinating validation across key stakeholders under shared governance and transparent risk-sharing mechanisms.

Therefore, EU-Rail stands as a successful model for innovation-driven transformation in transport, including cutting-edge research, European-level harmonisation, and the drive to deployment. Its achievements reaffirm rail as the backbone of sustainable mobility.

03 Building on success: From past achievements to a new partnership

The case for a future rail Joint Undertaking relies on four connected Flagship Initiatives:

Flagship Initiative 1:
European Simplified and Integrated Rail System (ESIRS)

What we mean

The cost and complexity of improving European railway systems have entered a critical phase. The personalisation of systems at country level is no longer sustainable, nor is every company's bespoke response to such individualised solutions. Those who seek to digitalise and automate are, by necessity, compelled to harmonise.

The **European Standardised Integrated Railway System (ESIRS)** represents a breakthrough Flagship Initiative that disrupts the traditional approach to systemic innovation by drastically simplifying the system architecture – based on but going beyond ERTMS – and deployment/update processes. This means major reductions in both capital and operational expenditures across the European rail system, boosting the competitiveness across both densely operated and low-density lines.

This initiative builds directly on outcomes of Europe's Rail Joint Undertaking in the domain of CCS, TMS and digital spaces – carrying out the necessary pre-deployment activities to test and validate a simplified and more performant operation, based on harmonised operational rules. It also incorporates the urban ecosystem, enabling structural synergies and a more integrated system-wide approach.

This work covers:

- Full trackside CCS system solutions for ETCS-only operations based on harmonised operational rules.
- Automated and modular onboard operations in both urban and non-urban areas.
- Future rail radio communication.
- Future rail traffic and capacity management.
- Common rail ontology and federated rail data space.

Flagship Initiative 2:
Next-Generation Rail Freight operations with European digital solutions

What we mean

Europe needs a breakthrough in freight. The Next-Generation Rail Freight flagship delivers unified, automated, and flexible freight operations at European scale, going beyond localised and fragmented national implementation. It addresses the net-zero logistic challenges head-on, transforming European freight operations into a unified, automated, and data-driven logistics ecosystem.

It integrates automation, digital coupling, intelligent capacity management, and multimodal synchronisation to boost rail's market share, operational efficiency, and environmental performance. By automating processes across the entire freight chain – from digital yard operations and intermodal transfers to on-train coupling and energy management – the initiative will deliver faster transhipment, higher line capacity, and significantly lower lifecycle and logistics costs. Through pre-deployment actions with ports and full integration of the wider logistics chain, this initiative embraces the entire logistics system: helping pave the way toward a truly net-zero logistics network in Europe.

Digital coupling and intelligent capacity management are freight game-changers.

This work covers:

This project builds directly on outcomes of Europe's Rail Joint Undertaking work on enabling the DAC technologies and digital platforms, as well as the Pioneer DAC train project. The result is reduced operational and lifecycle costs, accelerated modal shift from road to rail in line with Green Deal targets, and a strong European leadership position in seamless, future-proof logistics solutions.

Flagship Initiative 3: Resilient and recoverable railway system

What we mean

The rail system is increasingly exposed to climate change impacts, cybersecurity threats, and geopolitical disruptions. This flagship introduces an integrated system-level approach to railway resilience, linking operational continuity, cybersecurity, and climate adaptation within a unified framework for the first time.

It tackles multi-hazard resilience, including climate, cyber, and geopolitical disruptions, through digital continuity planning, predictive adaptation, and autonomous crisis recovery capabilities validated through cross-border pre-deployment corridors.

It will standardise resilience design criteria for infrastructure, rolling stock, and digital ecosystems across the EU. It reinforces Europe's preparedness through both dual-use capabilities for civilian and military transport - integrating the necessary protection requirements and relevant defence actors - and federated digital resilience measures, ensuring continuous operations even during severe disruptions.

This work covers:

- Climate-resilient infrastructure and rolling stock design for operation under extreme climate conditions.
- Integrated cyber-physical protection systems and active surveillance.
- Intelligent asset and health monitoring systems using digital twins, predictive analytics, and IoT.
- Minimum viable operations including self-standing operation under massively disturbed conditions in adjacent networks.
- Real time operational resilience management supported by AI, interoperable with Crisis Management Systems.

This project builds on outcomes of Europe's Rail Joint Undertaking, having provided the core technologies but not yet the adaptation and focus to resilience. By embedding resilience in the digital rail ecosystem, it secures this critical transport asset for EU citizens and businesses, providing the foundation for sustainable, secure, and recoverable transport services.

Europe's railways must remain operational under any disruption.

Flagship Initiative 4: High-speed rail

What we mean

Europe's high-speed system must evolve beyond today's fragmented architecture, integrating next-generation digital and clean technologies within a single European framework. As a fully integrated pan-European high-speed rail innovation initiative, the flagship unifies the design, deployment, and operation of next-generation high-speed systems within a harmonised European architecture. It ensures unmatched interoperability across borders.

The initiative builds on the achievements of Europe's Rail Joint Undertaking, notably on aerodynamics, traction systems, TMS and cybersecurity, and will pioneer harmonised pre-deployment corridors serving as early implementation pilots for pan-European high-speed expansion:

This work covers:

- These corridors will test new technologies – including ETCS L2-only operations, predictive maintenance, and EU capacity management – under real conditions, ensuring safe, reliable, and cost effective scaling.
- Through harmonised corridors implemented as early pre-deployment pilots, the initiative will reduce travel times between major EU capitals, create seamless multimodal links, and strengthen Europe's industrial and technological sovereignty in high-speed mobility. It also addresses key socio-economic objectives: balancing the benefits of high-speed connectivity while mitigating territorial exclusion through integrated planning and ensuring equitable accessibility to all EU regions.

Executing the mission: outputs, impacts, and resources

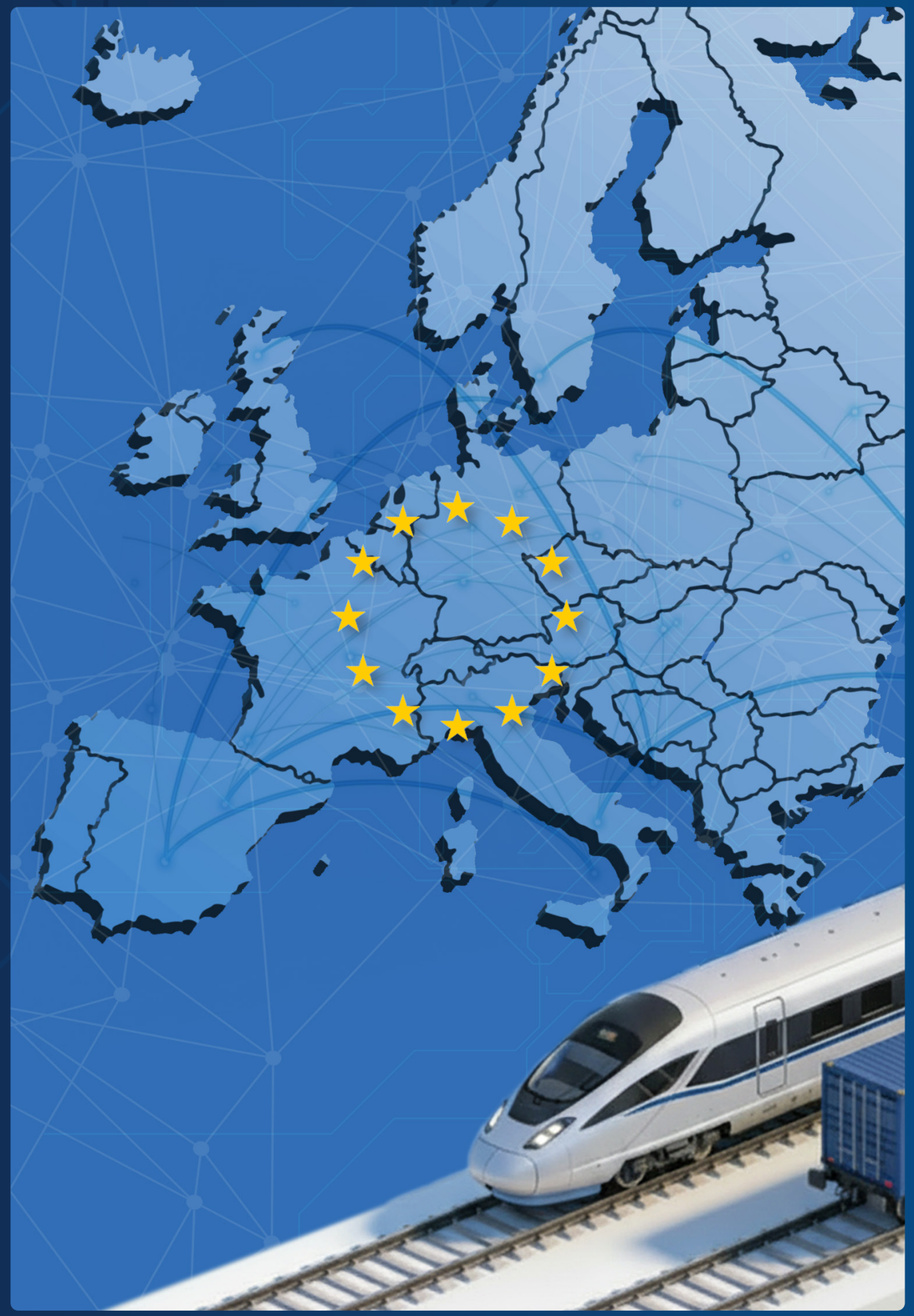
Building on the achievements of the Shift2Rail and EU-Rail JUs, the work of a new Joint Undertaking would contribute to making rail a more attractive transport option for both passengers and freight operators, supporting the EU's broader climate and mobility objectives while ensuring the sector's long-term competitiveness.

The new rail partnership 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.

- Approximately **EUR 3 billion for R&I activities**, with half (EUR 1.5 billion) coming from EU funding and half from industry contributions. 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

- Approximately **EUR 15 billion for pre-deployment activities**. 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. The estimate considers comparable efforts being made by the European Union to modernise European air traffic management, where EUR 1.3 billion of EU grants have been provided against EUR 1.4 billion of industry investments. Simplifying and modernising the future of rail does not only rely on an equivalent European Rail Traffic Management System in the future, but also on several other European standardised solutions being deployed as a system in the network.

Drawing on the European Union's past support for ERTMS through the Connecting Europe Facility, the estimate includes the investment needed for DAC, FRMCS, satellite applications, other technology game changers and possible future traffic management solutions. 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. 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.

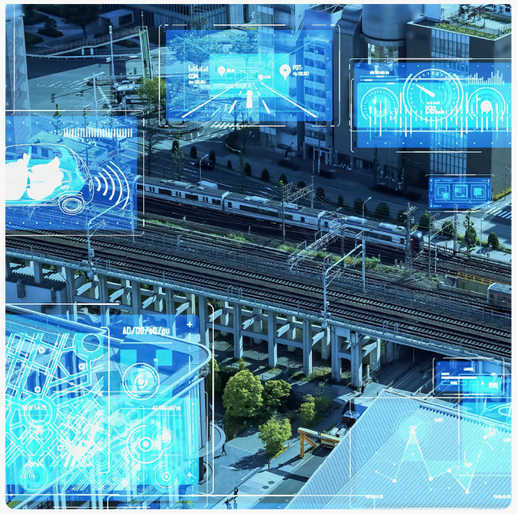


04 Conclusion

The rail sector – a cornerstone of sustainable mobility, employing 2.3 million people and generating EUR 143 billion in GDP – faces unprecedented challenges that demand equally unprecedented solutions. System fragmentation, global competition, climate change, and cybersecurity threats threaten not only Europe's transportation competitiveness but also its strategic autonomy and climate ambitions. Yet, within these challenges lies an extraordinary opportunity to transform European rail into the world's most efficient, resilient, and innovative transport system.

The case for action is unambiguous. As Mario Draghi [7] and Enrico Letta [8] both argued in their reports, and as underlined in the recent 2025 State of the European Union [9] address by the President Ursula von der Leyen, the EU must support major industrial initiatives, promote and empower investments via public-private partnerships, tackle global societal challenges and catalyse innovation at scale. The European Commission's plans to establish a European Competitiveness Fund within the next Multi-annual Financial Framework (MFF) reinforce this same ambition.

The investment required is substantial but the cost of inaction is far greater: continued inefficiency in the current fragmented system.



Meanwhile, emerging global competitors (e.g. China) already leverage their big domestic markets to develop and test innovations that they then deploy worldwide. Europe risks losing its position of technological leadership unless it acts decisively and immediately. The solution is neither solely incremental nor market-driven: it is the creation of a new European Rail Joint Undertaking.

History proves why. Transformative system change in rail innovation in Europe demonstrates clearly that coordinated, long-term, legally binding partnerships are required, which traditional contractual approaches cannot provide. Shift2Rail and Europe's Rail have proven that this institutional partnership model (Joint Undertaking) works: it delivers prototype testing activities, validates EU-harmonised solutions, and advances technologies from low TRL to commercial readiness. These achievements are made possible through stable governance, shared risk management, and unified policy-market alignment.

The new Joint Undertaking must go further and represent a fundamental evolution in European research and innovation. For the first time, it could systematically integrate pre-deployment activities as a core component, not an after-thought. Equally important, pre-deployment tackles a fundamental market failure in rail innovation by investigating solutions to align innovation costs with benefits, unlocking private investment in transformative technologies.

Four strategically-aligned Flagship Initiatives will drive this ambition of simplifying the rail system, by increased competitiveness (through cost reduction, technological sovereignty for industrial leadership), agility (through simplified systems and adaptive operational capabilities for market readiness), and resilience (through climate adaptation, cybersecurity, dual-use for strategic autonomy).

The flagship EU systemic approach links research, standardisation and pre-deployment and fits within a new rail Joint Undertaking structure. Subject to the decision makers' views, it could be co-supported by Horizon Europe for R&I and the European Competitiveness Fund for pre-deployment, creating a continuous innovation-to-deployment cycle that has never before been achieved in European rail research.

The investment required is substantial but the cost of inaction is far greater: continued inefficiency in the current fragmented system.

Implementing innovation in the market requires all actors to align and today the private members of the future Rail Joint Undertaking stand ready to commit significant resources, matching every euro of EU investment to deliver this ambition.

The evidence is overwhelming. The capabilities exist. The commitment is present. The timeline is clear.

Europe must act now to seize this moment, to deliver with the support of innovation what Europe's citizens, businesses, and strategic future require.

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

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

9 https://commission.europa.eu/strategy-and-policy/state-union/state-union-2025_en

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