21 May 2026

EIM Position Paper

6G and the Future of Digital Rail Operations

Executive Summary

The European railway sector stands at a critical juncture in its digital transformation. Infrastructure managers (IMs) are in the midst of planning the deployment of the Future Railway Mobile Communication System (**FRMCS**), the 5G-based successor to GSM-R that will underpin rail operations for decades to come. At the same time, the telecommunications industry is advancing rapidly towards sixth-generation (6G) network technologies, which the EU is funding through the "Smart Networks and Services Joint Undertaking" (**SNS JU**).

This position paper sets out EIM's views on the role of 6G in the future of rail digital operations and the conditions under which 6G can genuinely serve IMs' business needs in the coming years.

The central message is one of evolutionary ambition: EIM does not seek disruption but progressive enhancement. 6G must be designed to complement and extend FRMCS, not to displace it prematurely. Coverage, reliability, resilience and interoperability remain the non-negotiable foundations of any railway communication system. Within those constraints, however, 6G offers genuinely transformative capabilities: integrated sensing, AI-native network management, more precise positioning and terrestrial-satellite integration that could fundamentally change how to monitor, maintain and operate rail networks.

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1. The EIM Perspective on Connectivity

IMs operate one of Europe's most safety-critical and capital-intensive systems. Their assets (tracks, bridges, tunnels, level crossings, signalling equipment, power systems and stations) extend across tens of thousands of kilometres and must function reliably under demanding physical conditions, from high-density urban corridors to remote rural lines and deep underground environments. Communications are not a peripheral concern for IMs: they are a fundamental enabler of safe operations, efficient maintenance, and the progressive automation that the European railway policy agenda demands.

FRMCS is grounded in the 5G standard and incorporates railway-specific mission-critical extensions. FRMCS is embedded in the CCS Technical Specification for Interoperability (**CCS**

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TSI) of the EU Agency for Railways and thus carries the force of European law across the Single European Railway Area.

This regulatory and operational context shapes how IMs approach the question of 6G. Unlike consumer markets, where technology cycles of five to seven years are manageable, railways operate infrastructure with design lives of 20 to 30 years and communication systems that must guarantee interoperability across borders, across operators and across generations of rolling stock. Any engagement with 6G must therefore start with an understanding of these constraints and of the investment commitments already made in the ERTMS and those that will be made for FRMCS deployment in the coming years.

2. The Case for Early Engagement

Precisely because of these long cycles, the time to engage with 6G research is now. The lessons of the GSM-R to FRMCS transition are instructive: deeper railway involvement in telecom standardisation from the outset would have avoided many of the compatibility challenges, cost overruns and deployment delays that followed. EIM is determined not to repeat that experience.

EIM therefore calls on the European Commission, the SNS JU and the 6G-IA to incorporate rail as a vertical priority in 6G research programming.

The Association 6G-IA and EIM signed an MoU in 2025 and held two joint workshops in 2025 and 2026. These are important steps in establishing this structural dialogue.

3. From FRMCS to 6G: Evolution, Not Replacement

EIM's fundamental position on the relationship between FRMCS and 6G is one of evolutionary continuity and future proofness. IMs have invested, and continue to invest, substantially in FRMCS's future infrastructure and onboard equipment. The 6G ecosystem must therefore be designed so that FRMCS can progressively adopt 6G features as the standard matures, without requiring wholesale replacement of deployed infrastructure.

This requires clear commitment from the telecommunications industry and standardisation bodies (i.e. 3GPP and ETSI) to the principle of **backwards compatibility and modular migration**.

The architectural features that make FRMCS fit for purpose, i.e., software-defined networking, network function virtualisation, service-based architecture, hybrid private/public network operation and support for multiple data communication bearers, including satellite, are also foundational principles of 6G design.

4. 6G Capabilities of Strategic Relevance to Infrastructure Managers

Within the broad landscape of 6G innovation, EIM identifies several capability areas of particular strategic relevance to IMs' digital operations.

A) Integrated Sensing and Communications (ISAC) is arguably the most transformative 6G capability for the rail sector. By embedding environmental sensing directly within the communication layer, ISAC would allow the same radio infrastructure that carries operational communications to simultaneously detect obstacles on the track, monitor the structural condition of bridges and tunnels, identify intrusions into the operational zone, and provide real-time situational awareness across the network.

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B) AI-native network management is equally significant. IMs operate vast, geographically dispersed assets under highly variable conditions. AI-driven predictive maintenance has the potential to transform the economics of IMs, reducing unplanned interventions, extending asset lifecycles and improving service reliability. For this potential to be realised, 6G networks must support distributed AI inference at the edge, enable digital twin environments for infrastructure simulation and planning, and provide the bandwidth and latency characteristics required for real-time analytics across extended rail corridors. EIM calls for research investment in AI architectures specifically validated for safety-critical industrial applications, including the trustworthiness and explainability requirements that regulatory frameworks for railways will impose.

C) Ultra-precise positioning is a third priority area. ETCS already relies on train positioning data, and the evolution towards higher automation levels under ATO will place increasing demands on positioning accuracy and resilience. 6G's target of centimetre-level positioning accuracy, augmenting GNSS with network-based localisation, particularly in environments where satellite signals are degraded or unavailable (such as tunnels, cuttings, dense urban areas), directly addresses one of the most significant technical constraints on railway automation. Research priorities include positioning solutions that maintain accuracy at high speeds (up to 500 km/h), that function reliably in the challenging electromagnetic environments of electrified railways and that meet the safety integrity requirements of ETCS applications.

D) Terrestrial and non-terrestrial (satellite) integration addresses the coverage imperative that remains paramount for IMs. Large parts of the European rail network traverse rural and remote areas where terrestrial mobile coverage is commercially unattractive for public network operators. For these segments, satellite connectivity (e.g. EGNOS4Rail) may offer the prospect of complete, continuous coverage for mission-critical services, including failover resilience for safety applications. In addition, 6G bearers would also support rail operation in such rural and remote areas. EIM calls for research into non-terrestrial network (NTN) integration architectures that can meet the latency and reliability requirements of railway mission-critical communications, and for regulatory frameworks that ensure appropriate spectrum access and service priority for railway applications across both terrestrial and satellite components. This is also motivated by the coming Digital Networks Act[1].

5. Research Priorities and Policy Recommendations

EIM calls on the European Commission, the SNS JU and the 6G-IA to embed the following priorities in 6G research agendas and policy frameworks.

Research should prioritise railway-relevant use cases, including trackside obstacle detection, infrastructure structural health monitoring and operational zone intrusion detection, with particular attention to the system-level integration challenges of combining sensing and safety-critical communications on shared spectrum. The trustworthiness, safety certification and regulatory acceptance of AI-driven railway applications must be addressed as research priorities in their own right, not as afterthoughts to technical capability development.

[1] The Digital Networks Act | Shaping Europe's digital future

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Standardisation work should proceed on the basis that FRMCS and its successors must evolve through progressive, **backwards-compatible enhancements and prolongation of Mission Critical (FRMCS) services** within the 3GPP/ETSI framework, with railway-specific requirements formally specified and protected throughout the IMT-2030 standardisation process, with a clear focus on aiming towards **harmonised standards**.

Funding frameworks, including the next Multiannual Financial Framework and any successor to the current Horizon Europe programme, should include dedicated support for rail-telecom joint research, demonstration, and pre-deployment projects that bring together IMs, telecommunications operators, equipment suppliers and research institutions around real-world railway environments and use cases. The cost and complexity of railway certification and validation must be explicitly recognised in research funding eligibility criteria.

Finally, EIM calls for a **regulatory framework that provides long-term spectrum certainty** for railway communications across the FRMCS-to-6G transition, ensures that satellite integration serves genuine coverage obligations rather than merely commercial broadband, and establishes clear liability and service continuity obligations for public mobile network operators whose infrastructure carries mission-critical railway applications.

7. Conclusion

The transition from FRMCS to the 6G era is not imminent, but it is inevitable.

The decisions taken in the next few years in research laboratories, standardisation bodies and EU funding programmes will determine whether 6G genuinely serves rail IMs or merely adds another generation of adaptation costs to an already challenging investment landscape.

EIM's engagement with 6G-IA, following the signature of the MoU and the dialogue established at joint workshops, demonstrates that this cooperation is possible and mutually beneficial. The railway sector brings to the table a scale of deployment, a rigour of operational requirements and a clarity of societal purpose (i.e., safe, efficient, sustainable mobility) that can anchor 6G research into business value. The telecommunications community brings the technical innovation capacity that can help the rail stakeholders to realise the full potential of their networks.

EIM stands ready to deepen this partnership and to work with the European Commission, the SNS JU, ERA and all relevant stakeholders to ensure that 6G becomes a genuine enabler of the digital railway that Europe needs.

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