INTERNATIONAL UNION
OF RAILWAYS

Digital transformation of railway

Challenges and Opportunities

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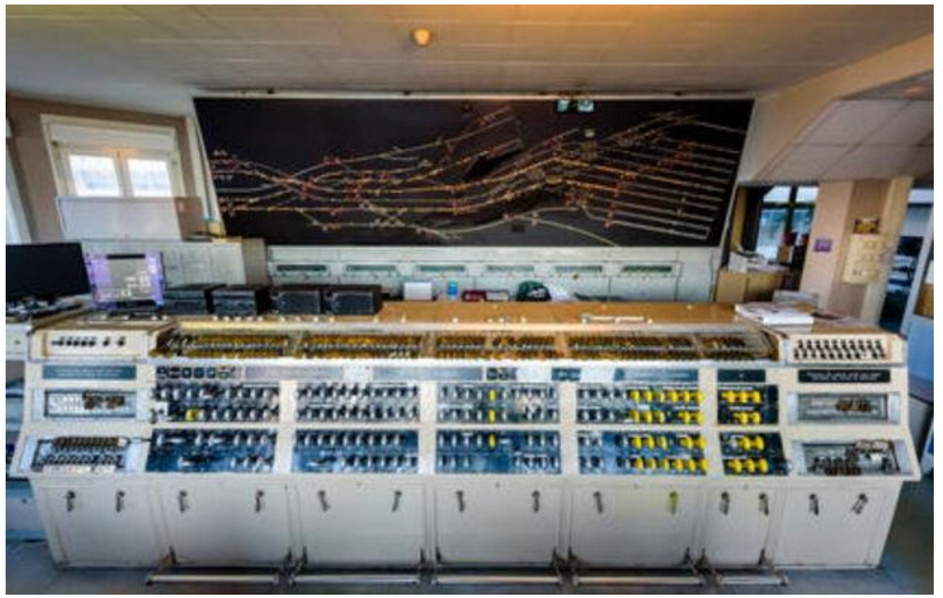
150+ years of innovation

19th-century mechanics, 20th-century signalling, 21st-century connectivity

Railways: Where Past and Future Run on the Same Track

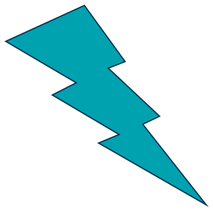
- Technology in most railways spans decades
- A mix of long-term lifecycles, attachment to availability and reliability and controlled evolution



Credit: SNCF/Sylvain Cambon

Railways are Diverse

Analog
GSM-R
FRMCS



Diesel
Flavors AC, DC
Hydrogen

ETCS
National flavors
(TVM, ASFA, LZB,
…)

Operating Rules
- National
- Harmonized

Track Gauges

… and many more

A System of Systems — and Stakeholders

No one builds the railway alone

Passengers

Goods

Infrastructure Managers

Railway Undertaking

European Union

National Regulations

Telecom

Rolling Stock

Signaling

Civils

Standards

Regulation is the railway's operating system.

Availability

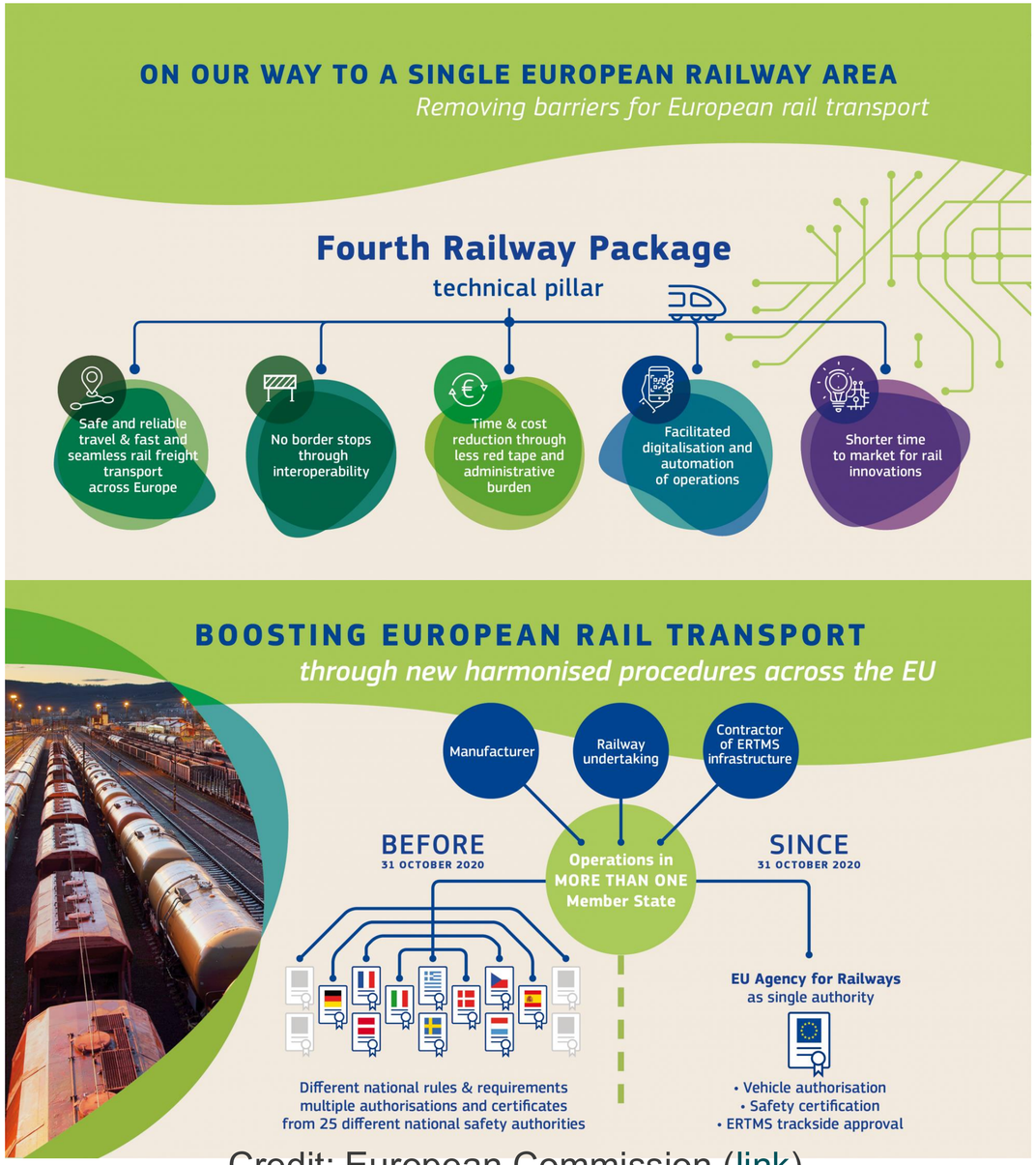
Safety

Interoperability

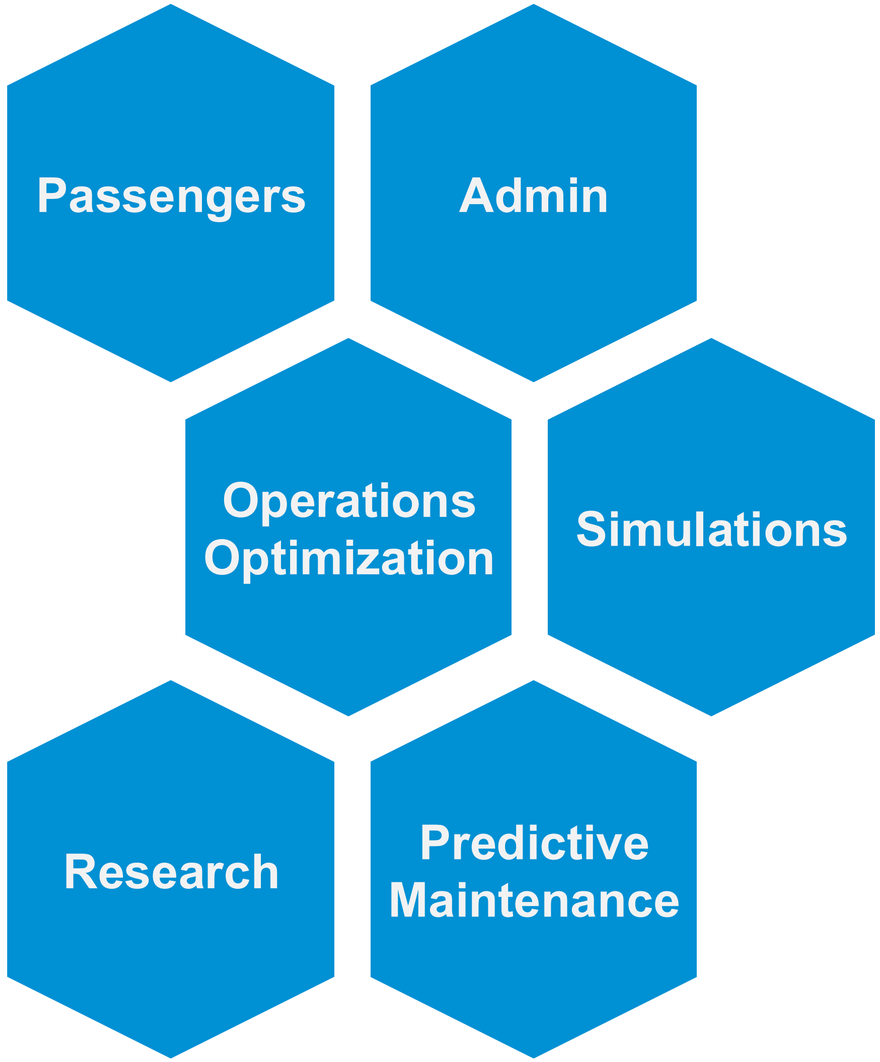
Certification

Standards

Digital transformation of the railway domain



Credit: European Commission (link)



Railway, Innovation, Digitalization

- Railway innovation: **evolution** rather than revolution
- Digitalisation: a **shift** in architecture and mindset
- Innovation driven by **connectivity**
  - From train to ground
  - Weaving data, connectivity, and intelligence into the railway fabric

The GSM-R success story

- GSM-R started taking over from analog radio at the end of 90s…
- … and is planned to be supported at least until 2035
- Based on 2G+ (GSM/GPRS), operated on more than 130,000 km in Europe and 210,000 km worldwide
- Reliable, supporting critical applications (like voice and ETCS)…
- … but becoming obsolete and limited in its support of new digital needs

Credit: dsm99 on Flickr (CC-BY-SA 2.0)

FRMCS

Future Railway Mobile Communication System

Three basic building blocks

- 5G
- Around harmonized spectrum (n100, n101)… and more (MNOs, NTNs)
- 3GPP MCX

Specifications and standards

- 5 UIC key documents
- Complemented by ETSI TC RT standards…
- … and other international standards (3GPP, IETF, …)

Timeline (requirements, standards & regulation):

- MORANE 2 project (→Q3CY27)
- UIC v3.0 specifications (→Q3CY27)
- ETSI TC RT standards (→Q4CY27)
- CCS TSI 2028

Timeline (deployments)

- Commercial deployments from 2030 onwards
- GSM-R support until at least 2035

Enabler for ETCS evolution, ATO, predictive maintenance, and beyond

From connectivity to a railway digital system

- Connectivity is the **foundation**, not the destination.
- Next step: turn data flows into **actionable intelligence.**
- Unlocking new **simulation, automation, and optimisation** capabilities while also reducing **certification** hurdles
- Data enables the digital representation of the railway — the **digital twin**
- One shall not forget **cybersecurity**

A Universe Around a Train

The train is the centre — but the value is everywhere.

predictive maintenance

Virtual testing

cross-border

certification

simulation

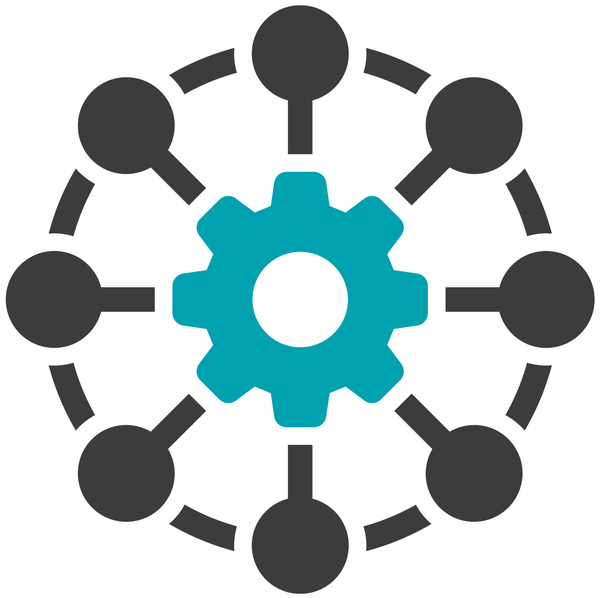
Incremental Digital Twins

- Not every use case needs full system fidelity.
- Start with simple models (assets, components) and evolve complexity.
- Build modular, composable components over time.
- Enables pragmatic deployment and manageable certification.

Interoperable Digital Twins – “Connecting the Digital Railway”

- Twins must **interoperate across systems, suppliers, and borders**.
- Common data models and standard interfaces are essential.
- Federation of twins enables system-of-systems simulation and decision-making.
- Interoperability multiplies value — beyond individual assets to network-level intelligence.

Enabling interoperable Digital Twins



- **Ontologies** to enable interoperability
- Railway data models combining
  - Railway models (**RailSystemModel**, …)
  - Models for legal registers (**ERA Ontology**)
- … and linked with international standards (**bSI IFC for BIM**, …)
- **Open** licenses, open models

Regulation shall not hinder Innovation

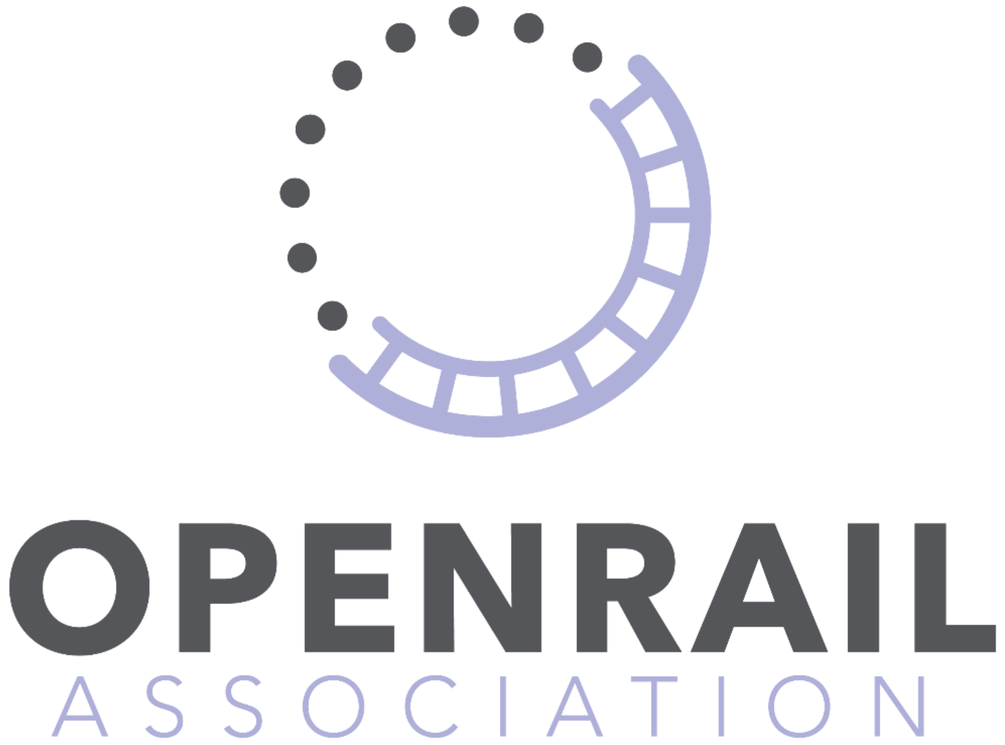
Safety is the floor, not the ceiling

- **Regulated use cases** ensure safety, trust, and compliance.
- **Open innovation** accelerates service development and operational optimisation.
- Architecture should allow **coexistence** of certified cores and open innovation layers.
- **Digital twins become platforms**, not just tools — balancing trust with agility.
- Result: a railway both **securely regulated and dynamically innovative**.

Towards a Digital Railway

- The digital journey is **evolutionary**, not revolutionary.
- Legacy, connectivity, intelligence, and ecosystem form **one continuous arc**.
- Safety-critical and open innovation **coexist and reinforce** each other.
- Digitalisation turns the railway into a **living, adaptive, collaborative system**.

OpenRail Association



The **OpenRail Association** creates an open, autonomous and collaborative innovation space.
Its mission is to promote the development of **Open Source software projects in the railway sector**, as it already exists in numerous other industrial sectors like telecommunication, automotive, or energy.

https://openrailassociation.org/

Fostering close cooperation links
with all actors in the rail transport domain

Preparing and publishing
Reports, Specifications, Guidelines, IRS

The worldwide organisation for the promotion of rail transport

200 members
on all 5 continents

Understanding the business needs
of the rail community

Developing innovation programmes
to identify solutions to those needs

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Thank you
for your attention

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