Europe's Rail

FP6-FutuRe

Cost effective regional lines

Flagship Project FP6 – FUTURE

Delivering innovative rail services to revitalise capillary lines and regional rail services

Final Event

November 4-5th, 2026

Founded by the European Union. Views and opinion expressed are however those of the author(s) and do necessarily reflect those of the Union. Neither the European Union nor the Granting Authority can be held responsible for them. This project has received funding from the European Union's Horizon Europe's research and Innovation program me under Grant Agreement No 101101962

Antitrust statement

FP6-FutuRe
Cost effective regional lines

While some activities among competitors are both legal and beneficial to the industry, group activities of competitors are inherently suspect under the antitrust/ competition laws of the countries in which our companies do business.

Agreements between or among competitors need not be formal to raise questions under antitrust laws. They may include any kind of understanding, formal or informal, secretive or public, under which each of the participants can reasonably expect that another will follow a particular course of action or conduct. Each of the participants in this initiative is responsible for seeing that topics which may give an appearance of an agreement that would violate the antitrust laws are not discussed. It is the responsibility of each participant in the first instance to avoid raising improper subjects for discussion, notably such as those identified below.

It is the sole purpose of any meeting of this initiative to provide a forum for expression of various points of view on topics

(i) that are strictly related to the purpose or the execution of the initiative,

(ii) that need to be discussed among the participants of the initiative,

(iii) that are duly mentioned in the agenda of this meeting and

(iv) that are extensively described in the minutes of the meeting.

Participants are strongly encouraged to adhere to the agenda. Under no circumstances shall this meeting be used as a means for competing companies to reach any understanding, expressed or implied, which restricts or tends to restrict competition, or in any way impairs or tends to impair the ability of members to exercise independent business judgment regarding matters affecting competition.

As a general rule, participants may not exchange any information about any business secret of their respective companies. In particular, participants must avoid any agreement or exchange of information on topics on the following non-exhaustive list:

Prices, including calculation methodologies, surcharges, fees, rebates, conditions, freight rates, marketing terms, and pricing policies in general;

any kind of market allocation, such as the allocation of territories, routes, product markets, customers, suppliers, and tenders;

production planning; marketing or investment plans; capacities; levels of production or sales; customer base; customer relationships; margins; costs in general; product development; specific R&D projects;

standards setting (when its purpose is to limit the availability and selection of products, limit competition, restrict entry into an industry, inhibit innovation or inhibit the ability of competitors to compete);

codes of ethics administered in a way that could inhibit or restrict competition;

group boycotts;

validity of patents;

ongoing litigations.

The challenge: regional lines need a different cost model

Today's Regional Lines

- ❑ Essential function as **green transport**
- ❑ Feeder lines for passengers and freight traffic connecting remote locations with other transport services and the Single European Railway Area (**SERA**)

Main Barrier

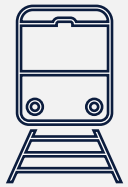
Mounting pressure on these lines on account of **increasing costs** of investment and operation that threat viability

Challenges

Make regional lines viable through:



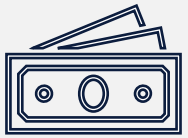
Improving **competitiveness**



Reinforcing the **role** of rail



Meeting Evolving **Customer Needs**



Reducing **Costs**



Sustainable and **resilient** transport

The WP4/WP9 response: simplify the asset, strengthen the connection

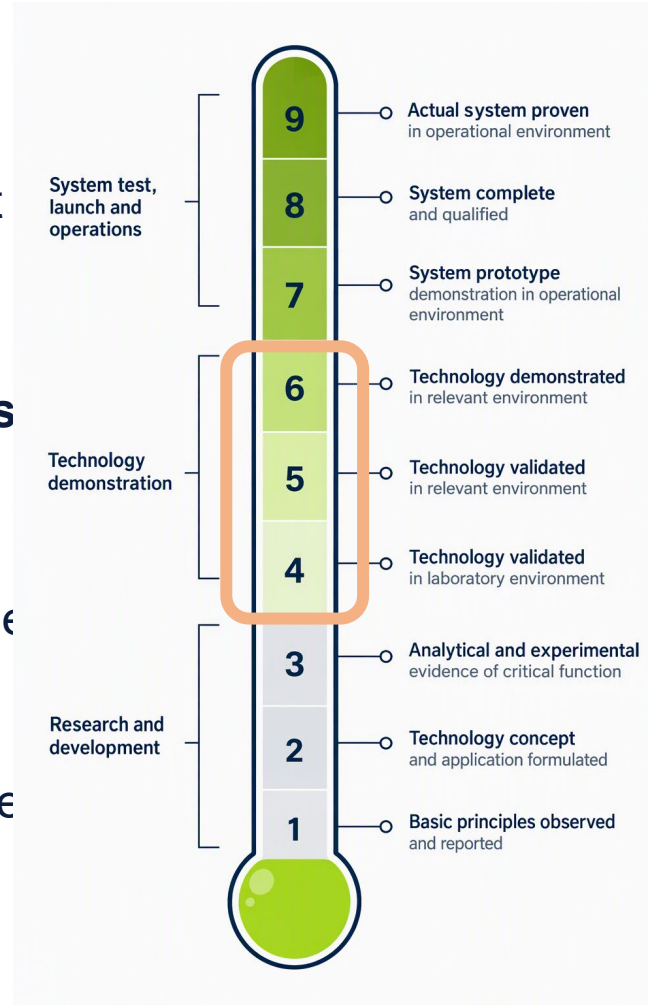
Conventional railway assets depend heavily on **cabling, grid connections, civil works and site-based maintenance**—cost drivers that are particularly significant on low-density regional lines.

Lever arms for improvement:

Installation and maintenance effort - Energy dependency - Connectivity gaps

Our answer:

- Cost-efficient, energy self-sufficient, wireless enabled wayside assets such as level crossings and switches including a communication prototype with trackside enabling control and operation of wayside assets;
- Adapted Communication System demonstration providing the ability to work with heterogeneous communication networks, including public ones from mobile network operators;
- A SWOC concept to integrate additional capabilities such as autonomous operation of wayside elements;



Relevant socioeconomic and energy KPIs

KPI		What was measured or assessed?	Reference/baseline	Project target
1	Total cost of ownership	Overall reduction of the Total Cost of Ownership (CAPEX and OPEX) of the CCS system, while maintaining or increasing the present safety level.	Economic model	Expected **decrease by targeting 25%**
2	CAPEX reduction	Reduced the CAPEX of radio network and allowing for higher savings due to the utilization of public radio network in low density lines	Telecom infrastructure cost per km and Mbps	At least **15% reduction** against the specified baseline figures.
3	System availability	Increased system availability due to reduced trackside asset failure and more reliable CCS (average delay minutes per assets and signalling failures)	Availability model	Increased availability compared to baseline considering EN 50126.
5	CAPEX+OPEX	Combined annualised infrastructure cost	Conventional grid-fed assets (100% grid energy)	At least **30% of operating energy supplied by batteries.**

Relevant socioeconomic and energy KPIs

KPI		What was measured or assessed?	Reference/baseline	Project target
8	Reduced wayside-asset OPEX	Maintenance interventions and total intervention time, including logistics, diagnosis, replacement and reconfiguration/testing.	1.5 interventions per asset per year and 0.5 hours per intervention.	At least **30% reduction** against the specified baseline figures.
9	Trackside energy performance	Contribution of locally supplied/stored energy to asset demand, with grid supply as the reference.	Conventional grid-fed assets (100% grid energy)	At least **30% of operating energy supplied by batteries.**
12	Improved asset energy efficiency	Similar to KPI9	Conventional grid-fed assets (100% grid energy)	At least **15% of operating energy supplied by batteries** under the item criterion.

Requirements and architecture for wayside assets

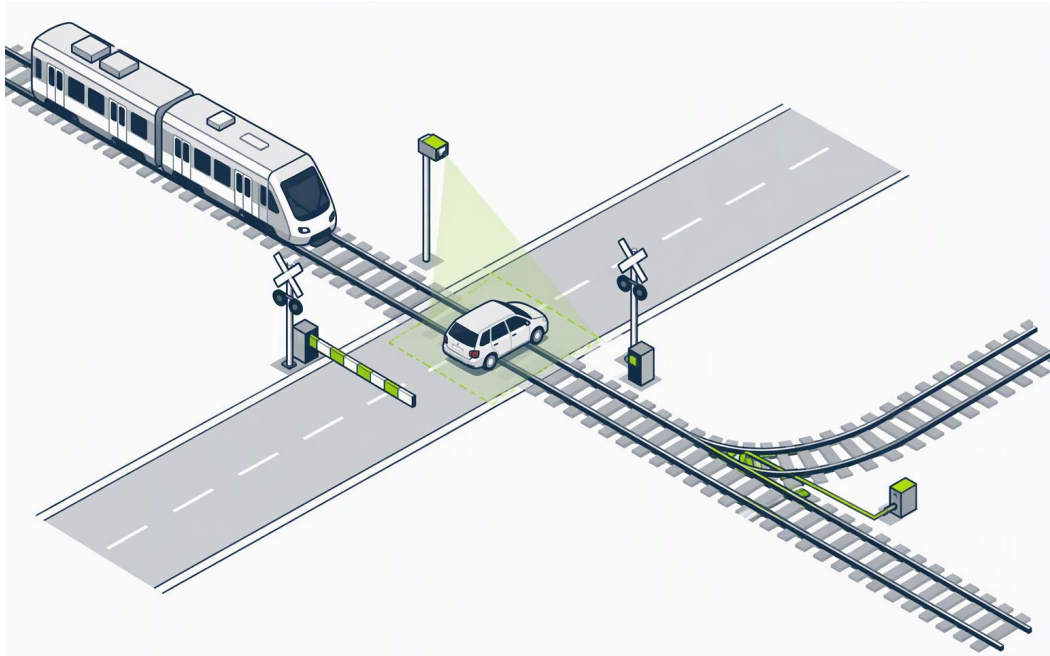
THE NEED: cost-effective wayside assets, in an harmonised regional rail

Wayside assets represent a major cost factor in construction, expansion and operation of regional lines. Accordingly, the innovation is focused primarily on **reducing Total Cost of Ownership**, rather than simply adding functionality.

Three types of assets are considered:

- **Level crossings**
- **Switches**
- **Level-crossing obstacle detection (LCOB)**

The requirements translate the needs of regional rail into wayside assets that are **cheaper to deploy and operate, more flexible in their energy and communication arrangements, easier to maintain, and capable of supporting safe operation.**



AI-generated conceptual visualisation

Requirements and architecture for wayside assets

THE SOLUTIONS: cost-effective wayside assets, in harmonised regional rail

- **Wireless connection between controlling entity and object controller**: Targets cabling, civil-work and maintenance costs, particularly in greenfield deployment.
- **Object controller close to field devices:** Allows the local field-device connection to remain wired while wireless is concentrated on the longer-distance connection where wired implementation is more costly.
- **Hybrid/local energy supply:** Allows renewable energy to be prioritised, batteries to provide backup, and grid dependency to be reduced or, for selected configurations, removed.
- **Remote diagnosis and maintenance:** Supports fewer physical maintenance interventions, shorter intervention times and consequently the project's OPEX-reduction objective.
- **Technology-independent LCOB requirements:** The obstacle-detection requirements are deliberately defined around the required function rather than one sensor technology, allowing different technologies or combinations to be used.
- **Configurable switch design:** Supports adaptation to different track gauges, turnout geometries and operating configurations instead of requiring one fixed implementation.

The requirements were then **iteratively updated using feedback from the WP9 demonstrators**.

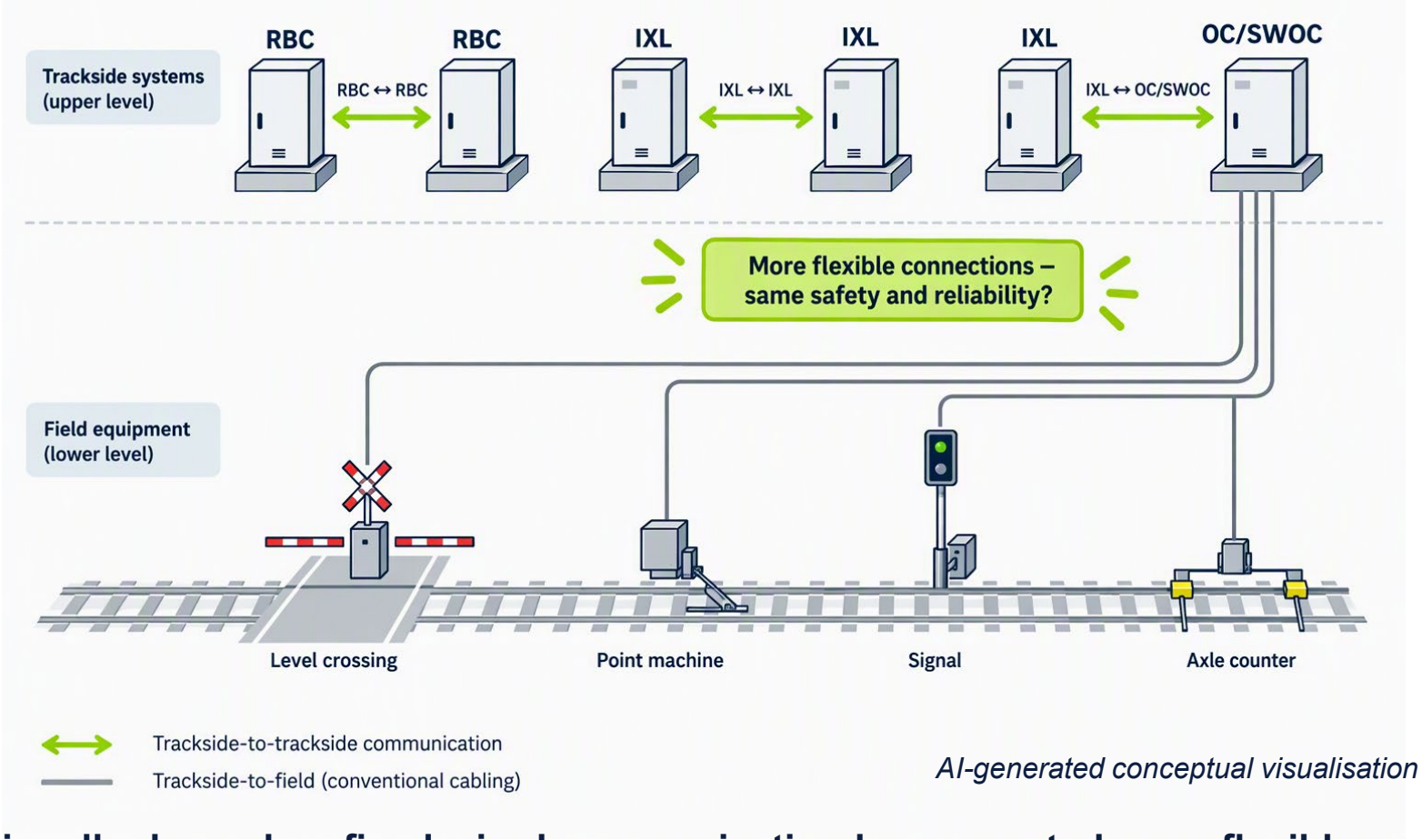
Requirements and architecture for wireless communications

THE NEED: making regional railway signalling more economically viable without compromising its operational and safety needs.

Conventional communication relies heavily on electrical and fibre-optic cabling. Deployment, civil works and maintenance of this cabling as important cost factors, particularly for regional lines.

Two main communication domains:

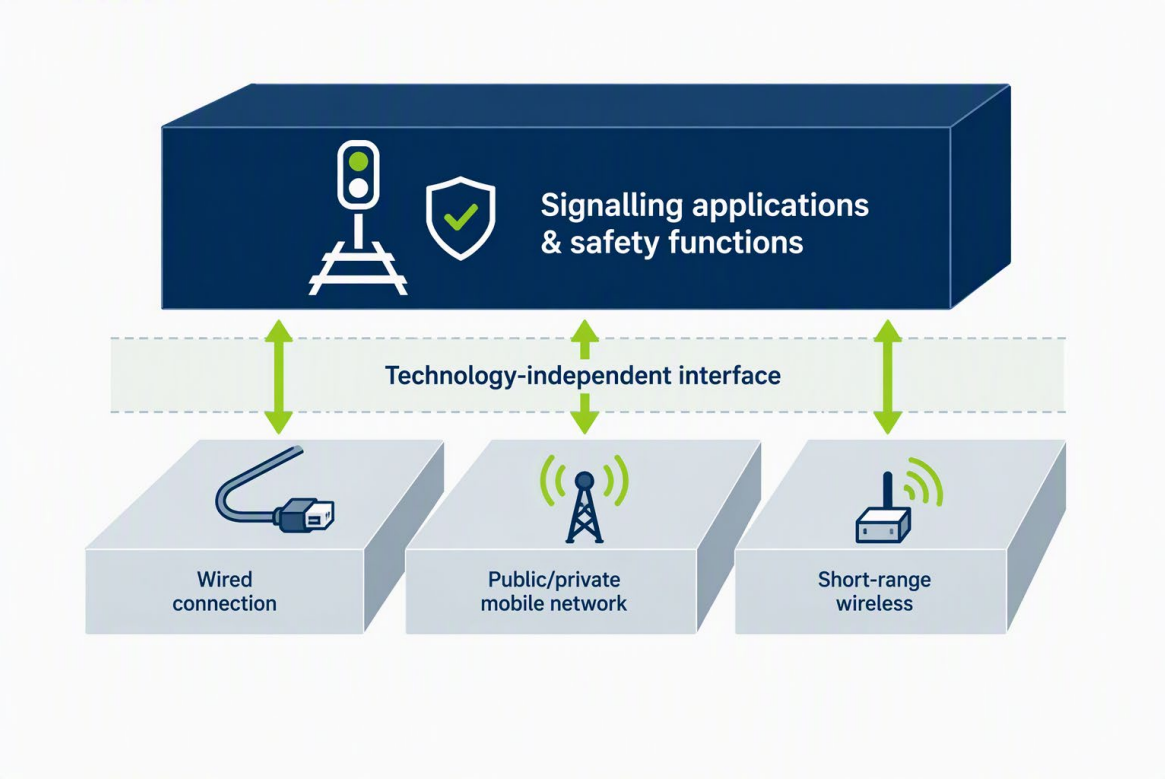
- **Trackside-to-trackside**
- **Trackside-to-field**



AI-generated conceptual visualisation

How can signaling devices that traditionally depend on fixed wired communication be connected more flexibly and economically, while retaining the reliability, safety and interoperability needed by railway signaling?

Requirements and architecture for wireless communications



THE SOLUTIONS:

- **decouple the signalling application and its safety functions from the underlying communication network**, allowing the transmission system to use suitable wireless technologies while transparently carrying the signalling information.
- An architecture that does **not prescribe one specific radio technology**. Depending on the deployment, it can use public or private mobile networks or shorter-range technologies.
- The physical communication architecture is ultimately envisioned as a suitable combination of **wired and wireless channels**, with the objective of optimising CAPEX and OPEX while maintaining reliability and safety.
- the use of **OC/SWOC concepts close to the field equipment**. In the proposed architecture, Smart Wayside Object Controllers can provide local control of field devices while communicating wirelessly with other elements of the signalling architecture

SWOC-based multi modal level crossing

(SWOC= Smart Wayside Object Controller)

Challenge: modernise level crossings without importing main-line cost and complexity

Cost-efficient

Reuse existing assets where compatible, reduce cabling and civil works, and support incremental upgrades.

Safe & interoperable

Keep railway protection authoritative and align the solution with CCS and Europe's Rail System Pillar architecture.

Connected & adaptable

Support G1/G2, greenfield/brownfield and informative services for road users and pedestrians.

MODULAR + SCALABLE | STANDARD INTERFACES + WIRELESS COMMS | REMOTE DIAGNOSTICS | LOW-POWER OPTIONS | MULTI MODAL SERVICES

Design rationale

Select only the functions needed at each crossing, while preserving a common architectural framework and upgrade path.

SWOC-based multi modal level crossing

A modular platform combines only the capabilities required at each level crossing.

ARCHITECTURAL RESPONSE

1 — Configure through modularity, do not overbuild

Combine modules such as cloud, CCS/MDC, and field functions according to local needs.

2 — Safety boundary

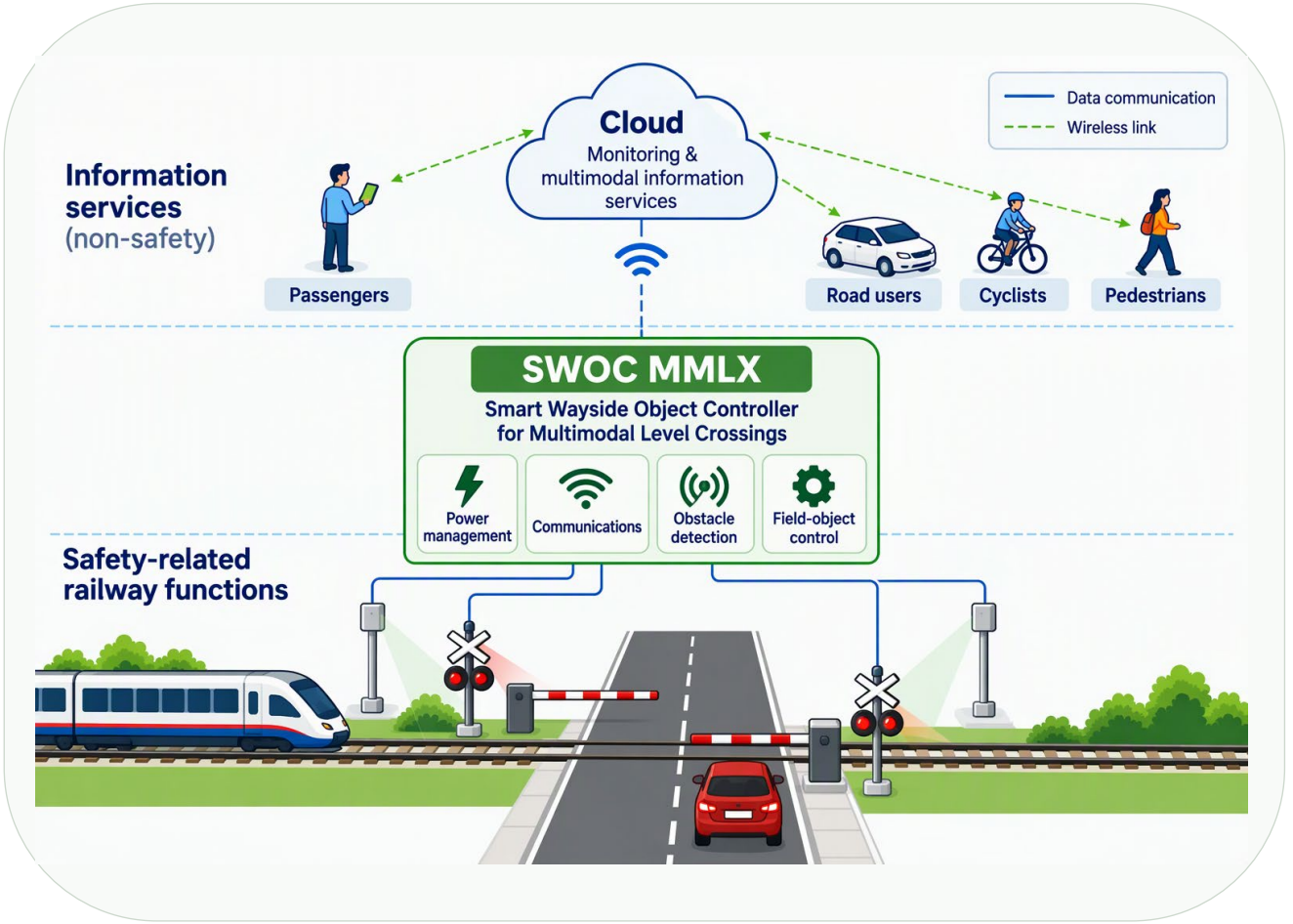
Railway signalling keeps its actual safety integrity level; cloud information for non-railway users is advisory.

3 — Reuse European results

FP6 extends the Shift2Rail SWOC baseline with cloud connectivity and multimodal information services.

4 — Reduce installation costs

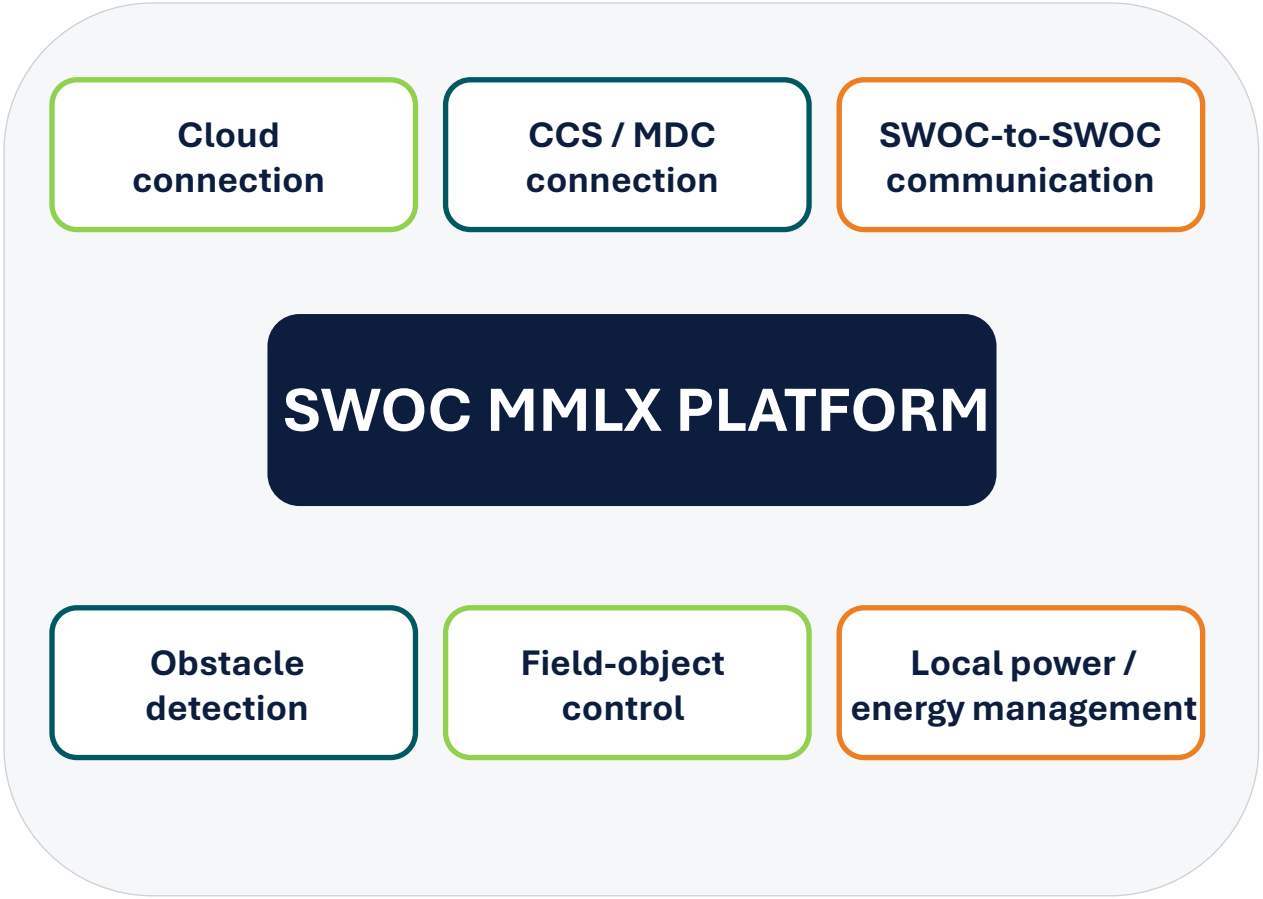
Wireless links can reduce long-distance cabling and associated civil works where suitable.



Architectural consequence: tailored deployment today, with a common upgrade path for tomorrow.

SWOC-based multi modal level crossing

A common SWOC platform is configured through functional modules for each local context.



1 Tailored deployment

Minimal configuration for a simple crossing; richer functions where operational needs justify them.

2 Incremental migration

Reuse compatible brownfield assets and add modules without replacing the full system.

3 Future-ready interfaces

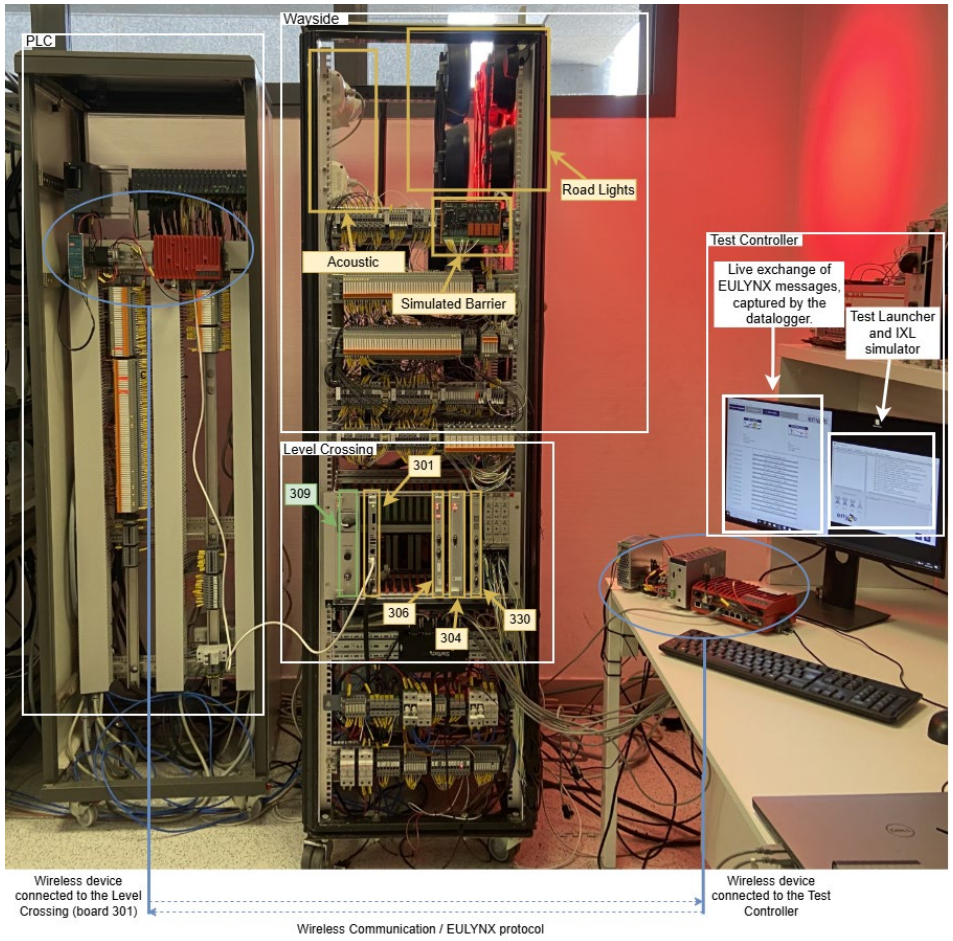
A common framework supports interoperability, scalability and later upgrades.

Result delivered: a common reference architecture with requirements; and migration framework for configurable multimodal level crossings.

WP9 R&D Area 1

Wayside Assets

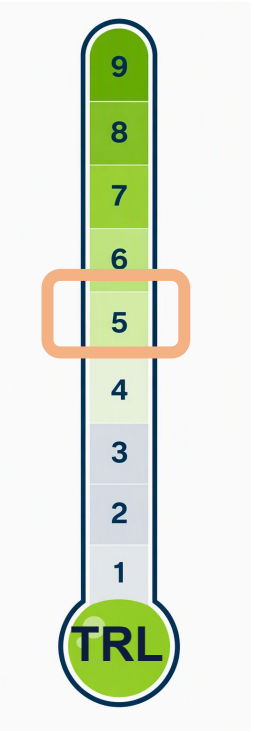
Demonstration focus 1: wireless and energy-efficient railway assets



The demonstrators established the core functional feasibility of **a standardised, remotely diagnosable level crossing and point machine controllers and uninterrupted operation during tested energy-source transitions.**

Environment: A controlled laboratory environment representing regional railway operation: real controller hardware and software, simulated interlocking and field equipment, and a local wireless network. The crossing followed ADIF's configuration.

→ **Achieved TRL: 5** - functional demonstration in a representative controlled laboratory environment.



Learnings: The core functions can be integrated and exercised in a representative controlled environment.

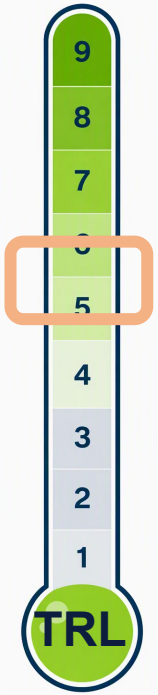
Demonstration focus 1: Energie self-sufficiency



A locally powered, grid-independent energy module for regional wayside assets, combining photovoltaic generation, short-term battery storage and long-term hydrogen storage. The design addresses **a level crossing and a switch with switch heating.**

Demonstrator provided measurement-informed evidence for grid-independent wayside power.





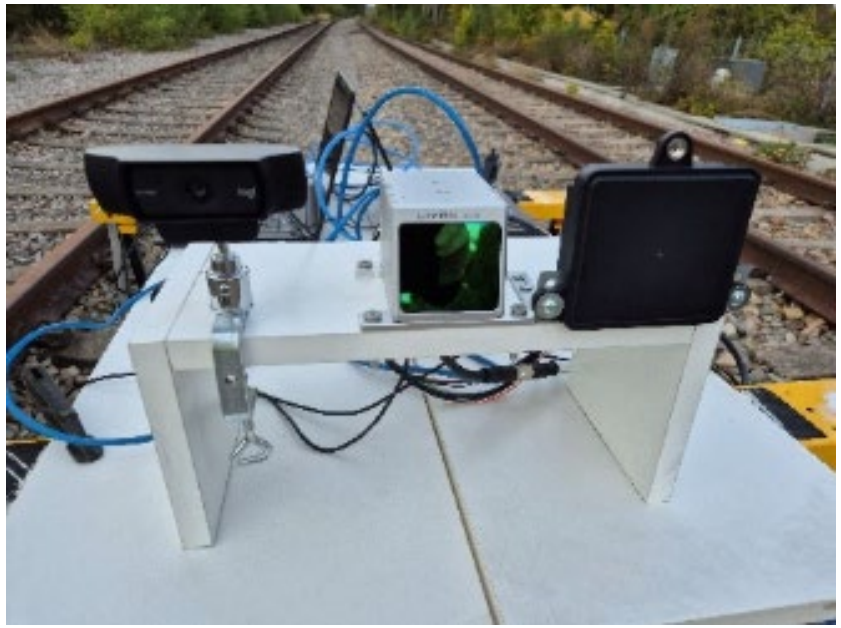
Learnings: The initial simulation supported continuous supply. Physical measurements revealed severe degradation of the installed fuel cell. An updated simulation indicated that its remaining 3–3.5 kW output could still support the crossing and heated switch, provided photovoltaic capacity and battery capacity were sufficient. The report states that the installed battery already has the necessary capacity for that revised case.

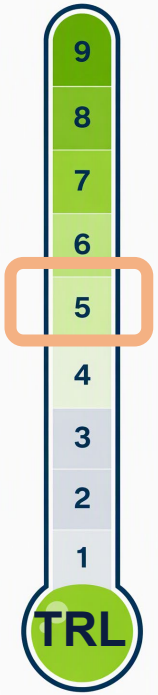
Demonstration focus 2: Obstacle detection

Aim: Obstacle detection system LCOB aims at **detecting whether obstacles are present in a level crossing area and provide that status to the level-crossing/signalling system.**

Testing environment: Tests were conducted in Italy using in a test yard and, for the fog test, a dedicated test tunnel. Other test cases also use simulated/controlled rain and snow conditions. Measurements were collected at a test rail in **Tortuna, Sweden:** a closed double-track area with a dummy level crossing, a single-track live unguarded level crossing.

→ TRL achieved: 5





Learnings:

- Multisensor obstacle detection is technically promising
- Sensor diversity matters
- Processing/fusion is as important as sensor selection

KPIs for wayside assets

KPI	Project target	Wireless energy efficient LX	🎯	Wirelesss energy efficient point machine	🎯	Longterm energy storage	🎯	Obstacle detection	🎯
KPI8 — Reduced wayside-asset OPEX	At least 30% reduction against the specified baseline figures.	qualitative support through remote diagnostic capability	~	qualitative support through remote diagnostic capability	~	no measured OPEX contribution in this phase; further cost-benefit work is envisaged.	~	No measured contribution	~
KPI9 — Trackside energy performance	at least 30% of operating energy supplied by batteries.	demand-versus-supply assessment concludes above 30%, using measured controller demand and calculated solar/battery supply	✓	demand-versus-supply assessment concludes above 30%	✓	100% battery-supplied energy in simulation	✓	No measured contribution	~
KPI12 — Improved asset energy efficiency	At least 15% of operating energy supplied by batteries	the sizing assessment concludes above 15%..	✓	the sizing assessment concludes above 15%..	✓		✓	No measured contribution	~

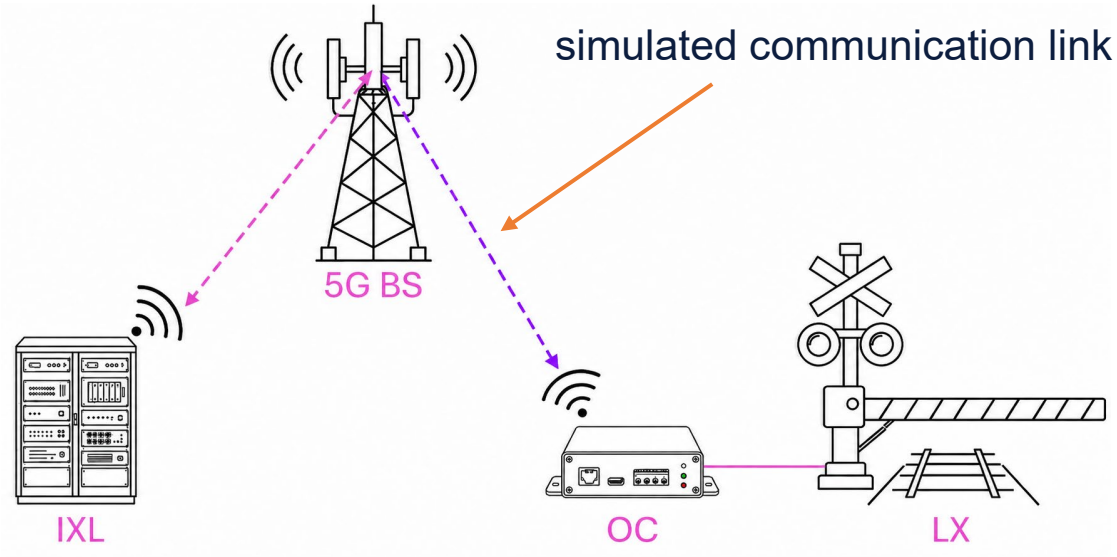
WP9 R&D Area 2

Wireless communications

Focus topic 1: Performance of wireless communications

Simulations

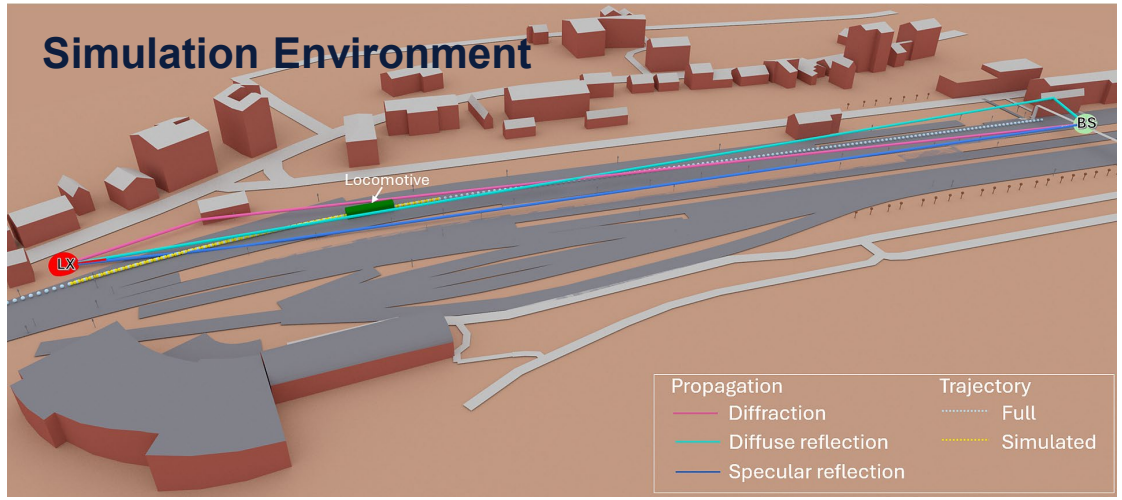
- Analysis of performance of wireless communication link between 5G base station (BS) and object controller (OC) connected to level crossing (LX) in an urban regional railway scenario
  - EULYNX messages used for communication
- Site-specific radio channel (ray-tracing model) using SIONNA RT
- Comparison of model with measurements to validate the channel model
- Evaluation of the wireless communication link reliability (5G NR link-level simulation) with block error rate



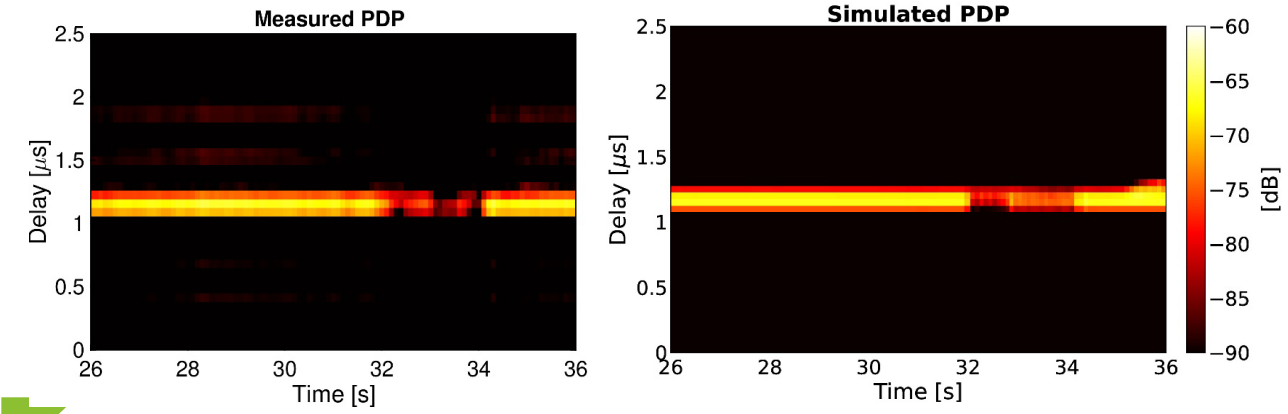
Focus topic 1: Performance of wireless communications

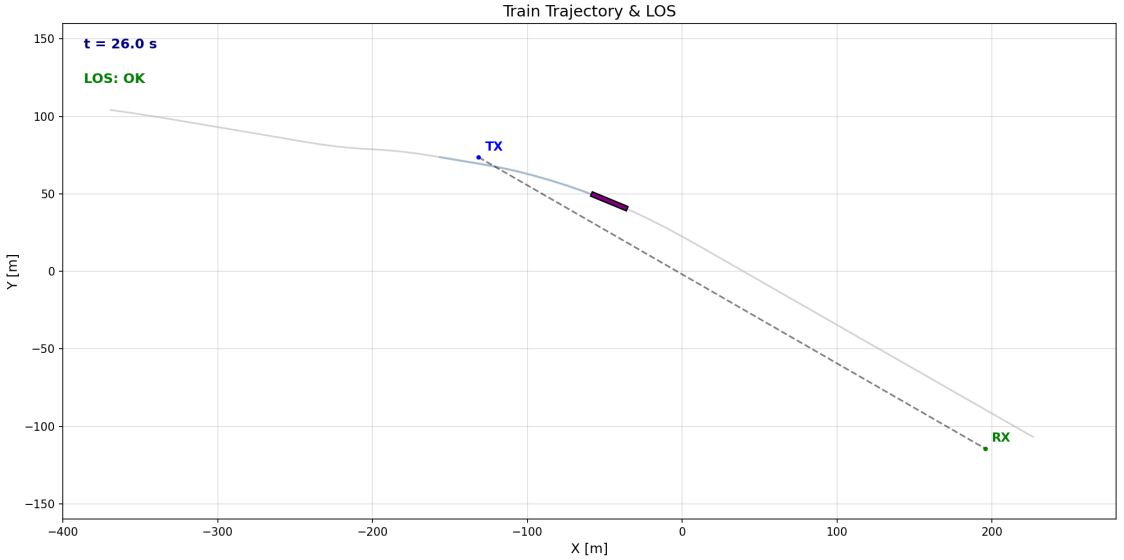
Scenario:

- OC/LX and receiver (BS) static
- Locomotive moves and blocks line-of-sight (LOS)
- Inclusion of
  - Effect of moving train on link reliability
  - Surrounding (scattering, reflection, diffraction,…)

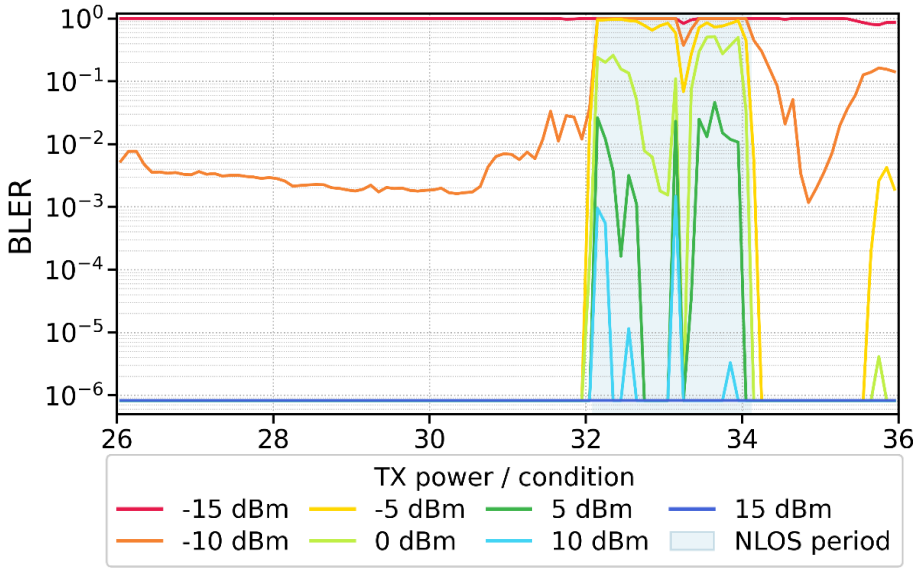


Good match between measurements and simulations





Focus topic 1: Performance of wireless communications



- Decrease in radio channel performance in non-line of sight (NLOS) period, i.e., when the train blocks direct link
- Simulation for different transmit powers; no packet loss for this scenario requires at least 15 dBm transmit power
- Method be applied to different scenarios

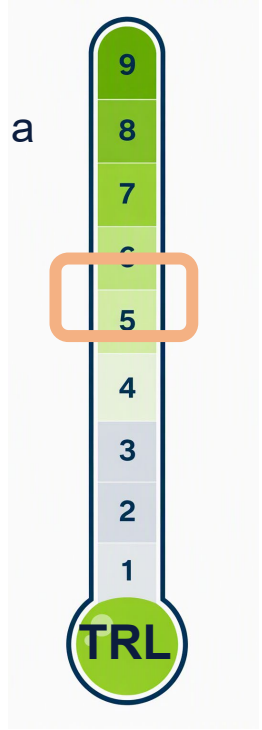
Demonstration focus 3: wireless trackside field devices



AIM: to show that a **Smart Wayside Object Controller (SWOC)** can control a remote railway field device over a **wireless connection**, while using **local energy harvesting** rather than conventional data and power cabling.

Environment: The testing took place under near-operational conditions without affecting train operations, on a regional test track in northern Czechia, with the GS Master at an existing level crossing and the GS Slave, gate signal and local power supply approximately 300 m away.

→ **Achieved TRL: 5**



Learnings:

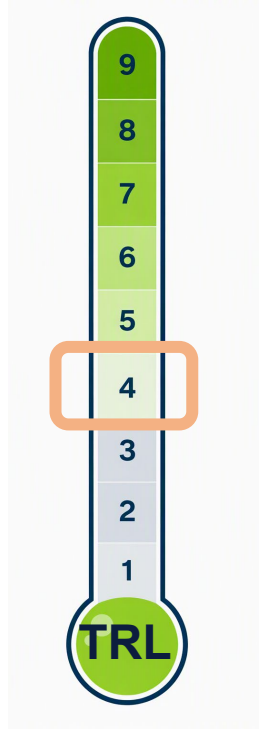
- Replacing cables is technically feasible for this application.
- Wireless connectivity needs to go together with local power.
- The principle is potentially applicable beyond gate signals.

Demonstration focus 4: adapting networks for a higher usage

Aim: Validate a dedicated **gigabit-capacity train-to-track radio network** integrated with a multi-connectivity platform, to allow reliable ATP/ETCS and ATO data communication, passenger internet access, and bulk data transfer.

Test environment: Laboratory setup representing onboard and trackside systems, centred on a dedicated 70 GHz 802.11ad radio link.

→ **Achieved TRL: 4**



Learnings: Dedicated Gigabit communications, multi-connectivity and FRMCS-oriented interfaces can be effectively integrated within a common railway communication architecture, enabling the coexistence of operational and broadband services with seamless service continuity.

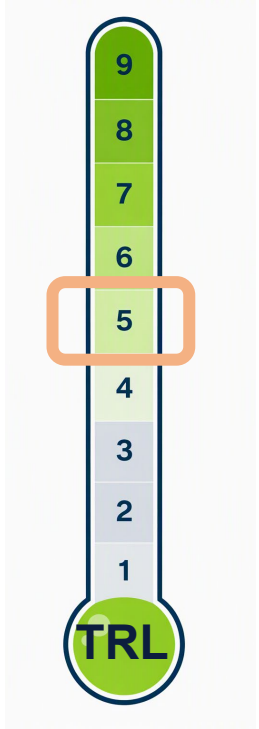
Demonstration focus 5: increasing efficiency by the use of public networks

Aim: Demonstration of a train-to-trackside **Multi-Bearer Communication Platform (MBCP)** using multiple public **4G/5G mobile networks plus satellite connectivity**, supporting vital and non-vital railway services while reducing reliance on infrastructure manager-owned telecom infrastructure.

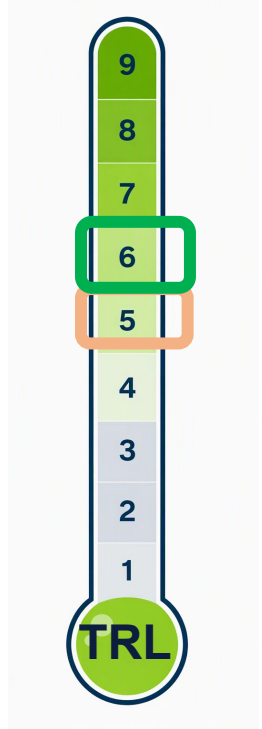
Test environment: Laboratory demonstrator, designed to reproduce a realistic regional-rail scenario with two emulated train setups and an emulated IM trackside/control-room setup.

→ **Achieved TRL: 5**

Learnings: Multi-bearer public-network connectivity combined with FRMCS/MCX functionality can support a broad set of railway voice, data and video applications in a realistic laboratory scenario, while providing communications resilience through redundant bearers.



Demonstration focus 6: G2 Regional Lines Train-to-Cloud Communications



Aim: Demonstrate a low-cost, IP-based train-to-cloud communication chain using commercial networks instead of dedicated railway telecom infrastructure, with onward sharing through Federated Data Spaces (FDS).

Test environment: Four runs aboard a Cargo freight locomotive in normal revenue service on the Jönköping–Falköping–Herrljunga corridor, Sweden. Commercial connectivity was combined with the T-Systems DIH LivingLab sandbox for FDS testing.

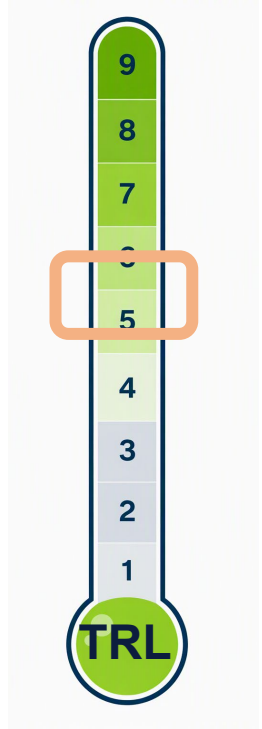
Learnings: Commercial bearers can support the demonstrated data-sharing functions. Communication-path performance must be distinguished from cloud/sandbox processing: some requests were dropped or delayed within DIH.

TRL6 demonstrated (vs TRL5 required)





Demonstration focus 7: wireless activation of a wayside asset



Aim: Show that **wireless communication, onboard localisation and virtual switching points** can replace selected conventional train-detection and command connections for level crossings, without changing their core functionality.

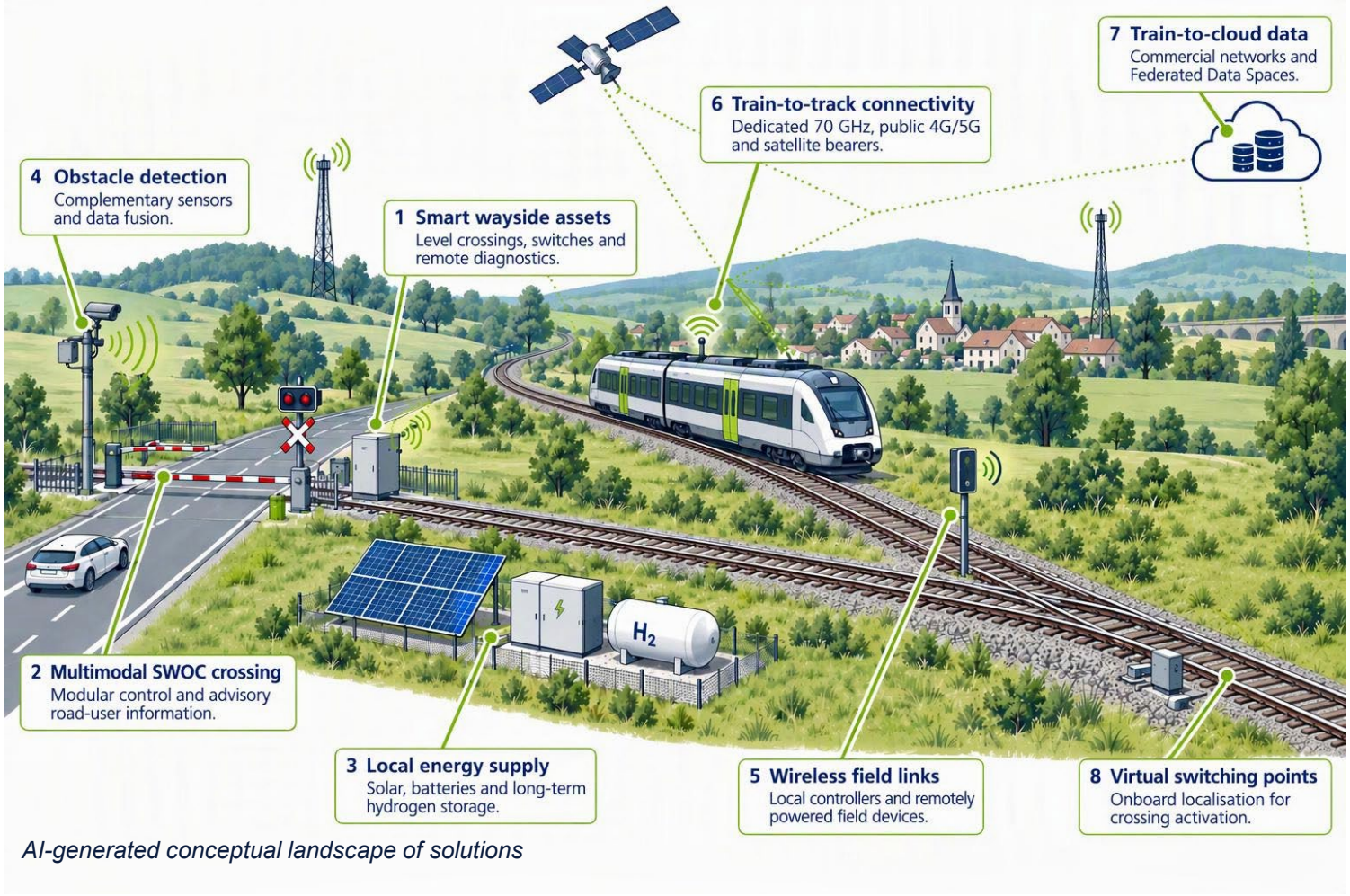
Test environment: Shadow-mode installation at **four level crossings** on the operational, single-track Süßenbrunn–Laa an der Thaya line north of Vienna. The line carries approximately **150 train movements daily**; crossing-site speed limits are **70–80 km/h**. A separately instrumented locomotive supports localisation testing.



Learnings:

- GNSS antenna position alone does not establish train-head/tail position or integrity. Complementary sensing and train identification are necessary.
- Communication performance and localisation quality both affect switching timing.

Regional rail assets: from fixed infrastructure to connected, intelligent systems



AI-generated conceptual landscape of solutions

WP9 demonstrated how wireless communication, efficient energy supply and smarter sensing can reduce the infrastructure burden of regional rail while maintaining dependable operation.

A multidisciplinary collaboration fostering European technical innovations



Europe's Rail

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