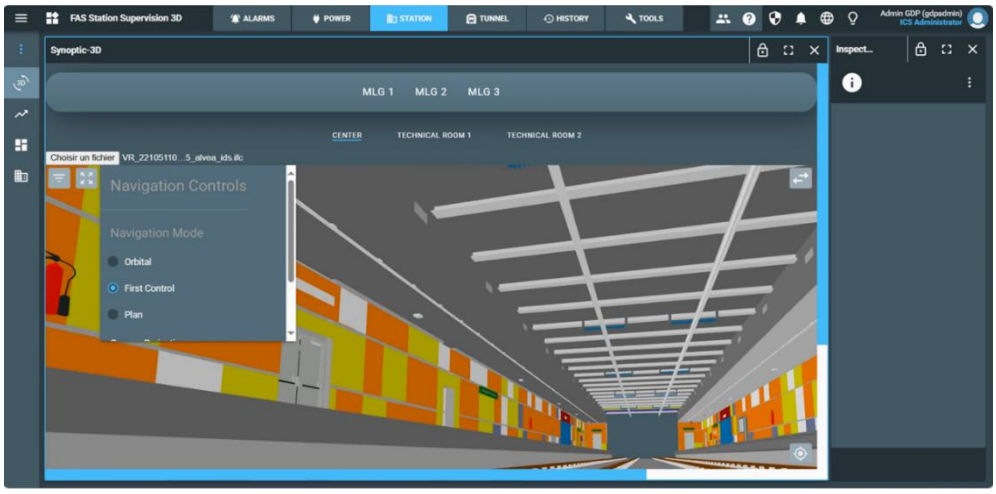
CLUSTER E - DIGITAL INNOVATIONS FOR RAILWAY INFRASTRUCTURE MANAGEMENT AND MAINTENANCE

Introduction

This document provides an overview of the most advanced digital technologies currently being developed within the FP3-IAM4RAIL project to improve the management and maintenance of railway infrastructure. It highlights how innovative approaches—ranging from enhanced use of BIM and Digital Twins to new methods for analysing infrastructure conditions and supporting certification processes—are transforming asset supervision, inspection activities and decision-making. The ultimate goal is to enable a more efficient, safe and reliable railway system through better data integration, increased automation and more accurate, real-time understanding of assets.

BIM and data-oriented services for station supervision and maintenance



3D view of part of Malaga - María Zambrano Train Station BIM model

The project is supported by the Europe's Rail Joint Undertaking and its members.

Within the FP3-IAM4RAIL project, the use of Digital Twin technologies to streamline Asset Management represents a key objective of Cluster E. One of the most promising approaches is the adoption of BIM models to support and enhance the configuration of Asset Management Systems (AMS), ensuring greater consistency, accuracy and interoperability of asset-related data.

To enable this, the project explored the capabilities of BIM files for station supervision and maintenance, defining a dedicated BIM Execution Plan (BEP) that specifies how models should be produced to be directly usable for AMS configuration and for the automatic extraction of 2D representations from 3D views. A dedicated analysis tool was also developed to verify BIM files and detect missing or inconsistent information when models do not follow the BEP requirements. In parallel, initial experiments were carried out to integrate a BIM viewer into the Asset Management environment.

For demonstration purposes, a section of the Málaga station model provided by ADIF was used to validate the approach and identify the adjustments needed for full BEP compliance. A preview of these intermediate results will be presented at InnoTrans 2024, where a Virtual Reality experience will allow users to explore the 3D BIM model of Málaga station and related equipment data. Work on interfacing the BIM model with the Digital Twin components of the station Asset Management System will continue in the coming months.

Track condition data fusion in Point Clouds web platform data requirements, architecture and data collection report

The integration of track condition data within 3D point clouds plays a central role in enabling remote inspection and verification of railway infrastructure. This approach supports safer and more efficient planning of maintenance and renewal activities by allowing experts to assess the surrounding environment without the need for physical presence on the tracks, thereby reducing operational risks and improving the quality of decision-making.

To achieve this, a web-based platform was developed to combine multiple data streams in a single, interactive environment. The system brings together track and overhead line condition data, high-resolution point clouds, digitalised railway assets and geo-referenced contextual information such as orthophotos, digital terrain models and cadastral maps. The platform architecture was designed with strong requirements for scalability, modularity, configurability, usability and flexibility—ensuring it can operate both in cloud-based and on-premises installations.

For demonstration purposes, around 50 kilometres of high-speed line were selected with the support of Rete Ferroviaria Italiana. Track geometry and overhead line condition data were collected using the Diamante 2.0 high-speed diagnostic train, while additional mobile surveying data were acquired through MERMEC's airborne and train-borne systems. This

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integrated dataset enabled the project to demonstrate how merged digital information can support more efficient workflows in asset assessment and planning.

Track condition data fused inside the point cloud

Dedicated MERMEC vehicle for the Digital Twin

High-speed Diamante 2.0 diagnostic train

Blockchain for certification management

The development of the Digital Conformity Framework represents an important step in the digital transformation of railway conformity assessment within the Europe's Rail Joint Undertaking. The goal is to make certification processes more efficient, transparent and secure by enabling their execution within a trusted virtual environment.

The current certification workflow used by Rete Ferroviaria Italiana (RFI) involves several stakeholders responsible for project implementation, infrastructure operation and maintenance, and technical standard compliance. Each plays a key role in ensuring that railway assets meet the required safety and interoperability criteria.

Within the FP3-IAM4RAIL project, the VCF introduces a new digital approach built on secure and controlled data exchange through a Federated Data Space, enabling trusted partners to

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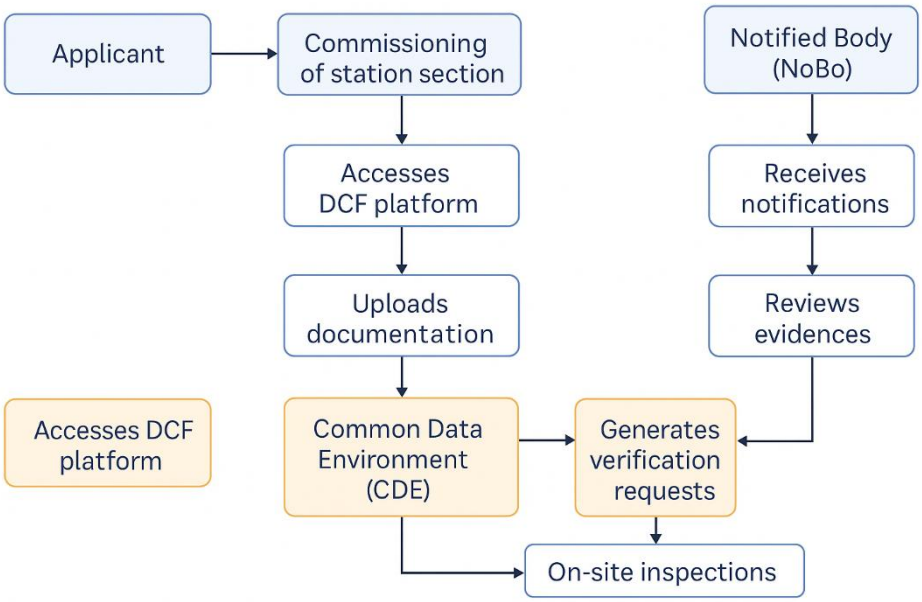
share information while maintaining full ownership and governance of their data. To ensure traceability and integrity across the entire certification lifecycle, blockchain technology is employed as a core component of the framework. Its immutability and transparency make it possible to verify every action associated with a certificate, greatly enhancing trust and auditability.

The project assessed different blockchain models, comparing public and private networks. While private blockchains offer stronger control and confidentiality, public blockchains provide higher transparency and resilience. For the demonstrator, the use of a public blockchain was selected as the most suitable option to ensure integrity, verifiability and trust among all involved stakeholders.

Through this combined approach, the VCF aims to establish a more reliable, efficient and future-proof certification ecosystem for the railway sector.



Integrated use case overview.

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Automatic track visual inspection by drones

The integration of drone-based visual inspections into the Digital Twin lifecycle is a key contribution to the objectives of Cluster E. This work is led by AZD Praha, the sole Europe's Rail member from Czechia. Traditionally focused on signalling and control systems, AZD Praha has expanded its role since 2016 by becoming an Infrastructure Manager for two regional lines north of Prague, which now serve as dedicated testbeds for railway innovation. This allows new concepts for modern asset management to be developed and validated directly on operational infrastructure.

Drone docking and charging station

Within this use case, AZD defined the system architecture for unmanned visual inspections and developed both hardware and software components to support a fully integrated workflow for remote data acquisition. The architecture centres on Digital Twins of key railway assets—including switches and point machines, signals, balises, trackside equipment and track elements such as rails, sleepers and fasteners. These models are designed to integrate BIM data, real-time diagnostics from signalling systems, visual information from drone missions and maintenance records. Both periodic and event-triggered inspections contribute marked-up visual data to the Digital Twin, enriching asset condition knowledge over time.

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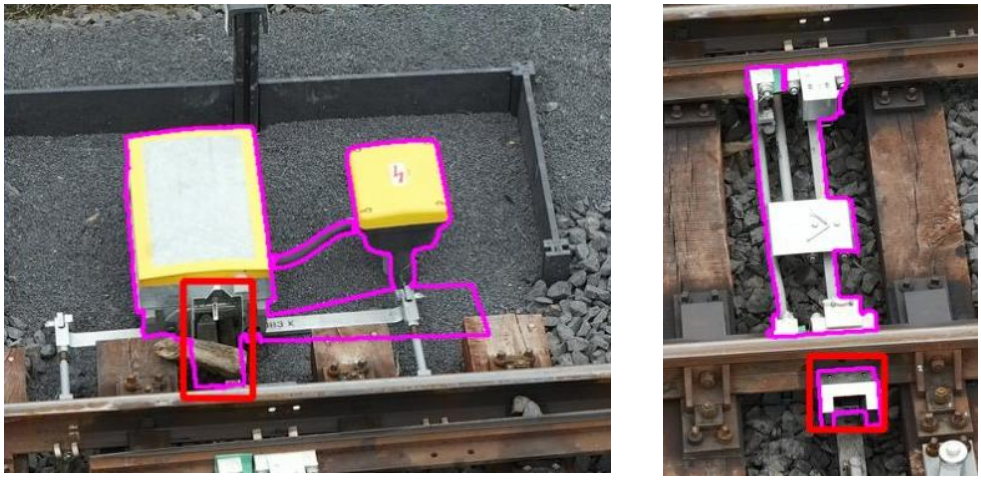
The hardware ecosystem includes an on-board computer with 5G connectivity, automated wireless charging solutions, docking stations for drone operations and a fleet of industrial-grade drones equipped with high-resolution cameras and LiDAR sensors. These components are now being assembled and tested in preparation for a demonstrator deployment next year. On the software side, AZD is developing tools such as precise optically guided landing, a web-based dashboard for remote fleet supervision, LiDAR data processing modules and a dedicated server for storing and accessing Digital Twin information.



Anomaly estimate boxes in 2 confidence levels (red H, yellow L)

Accompanying textual output can be machine read

During spring and early summer 2024, AZD conducted test surveys at the Libčeves station on the Čížkovice–Obrnice line, refining the operational settings required for high-quality data capture. The resulting imagery enables the creation of detailed photomaps and 3D models of the track and surrounding assets. With the data collection workflow now consolidated, software tools have been adapted to process the captured images and point clouds according to project needs.

Continuous exchanges within the Work Package and the broader FP3-IAM4RAIL community, played a crucial role in defining a shared understanding of Digital Twins for this context and in shaping the Key Performance Indicators used to assess progress.

Decision Support Systems for railway station asset management

Decision Support Systems (DSS) play an increasingly central role in improving the daily operation of railway stations, especially when data from multiple sources can be consolidated into a single, coherent environment. Within FP3-IAM4RAIL, this activity focuses on leveraging data centralisation to support station administrators across different time horizons—from real-time monitoring to long-term planning.

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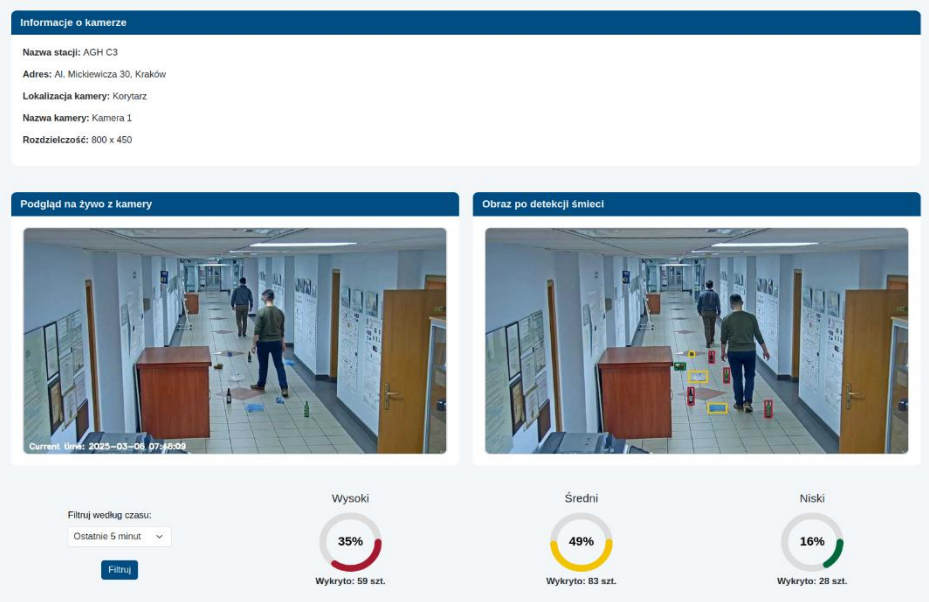
Ongoing developments include solutions for:

- automatic detection of waste or disorder through video monitoring and station digital representations, supporting faster maintenance interventions;
- enhanced maintenance planning and operational control through predictive models and intelligent scheduling;
- real-time tracking of economic KPIs to support informed decision-making;
- tools to assist in managing commercial surface leases;
- structural health monitoring of station buildings using integrated sensing and modelling.



Cleanliness monitoring and reporting

These areas are being explored by PKP S.A. and its partners, with future demonstrations planned at Łódź Kaliska station.

One of the most promising developments is the integration of BIM models into machine-vision workflows for trash and dirt detection. Drawing inspiration from simulation techniques widely used in autonomous driving, the team is experimenting with automatically generated 3D station models as training environments for computer vision algorithms. These synthetic scenarios enable the system to learn how to identify cleanliness issues before being deployed in real operational conditions.

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Similar to autonomous car training – BIM is used to create a virtual station model, where scenarios (i.e.: trash) can be tested and simulated CCTV data created

Work is also progressing on decision support tools dedicated to maintenance and motion control. Two complementary approaches are being explored. The first focuses on predictive analytics to estimate upcoming maintenance needs, enabling more accurate planning and timely interventions. The second aims to optimise the allocation of available personnel by considering not only working hours and operational constraints but also travel distances. By applying route-planning methods, the system can generate more efficient maintenance schedules and better coordinate on-site activities.

In April 2024, a survey was distributed to all consortium members to establish a shared European baseline regarding data streams, Digital Twins and related technologies used in station and wayside asset management. The questionnaire covered topics such as:

- data streams and how they are collected;
- the use of Digital Twins or equivalent digital solutions;
- BIM adoption levels;
- integration between ERP systems (e.g., SAP, IFS) and asset management processes;

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- digital asset management practices.

The results of this survey will provide valuable insights into the current level of integration across Europe and will guide future developments on how these digital solutions can be introduced and harmonised within the sector.

Europe's Rail

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