

# FP5 TRANS4M-R

Transforming  
Europe's Rail Freight

## D29.8

### Live-Demo of Video Gates showing process optimization in a German yard

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## 1 Executive Summary

Deliverable D29.8 of the FP5 TRANS4M R project comprises the successful execution of the live demonstration of Intelligent Video Gates (IVGs) for process optimisation in a German yard. This report forms part of the deliverable and serves to document and evaluate the demonstration conducted at the Nürnberg site. The main part of the deliverable was performed as the live demo.

The objective of this deliverable is to assess how IVGs, as part of Europe's Rail digitalisation strategy, can optimise and partially automate freight processes such as maintenance order management.

The live demonstration served as a central component of this assessment, designed to provide participants with a first-hand understanding of the IVG technology, its operational principles, and its integration into yard processes. The event combined a concise theoretical introduction with a real-time presentation of the system in operation.

During the live session, participants observed freight wagons passing through the IVG system while data, e.g. UIC wagon number, images of the different perspectives of the wagon and the timestamp of the passing wagon, were automatically captured, processed, and analysed. This direct observation allowed attendees to follow the complete digital workflow: from data acquisition to automated analysis and integration into maintenance processes, leading to make the system's functionality and benefits tangible.

In addition to showcasing the new digital process, the demonstration illustrated the transition from traditional manual inspection procedures to the IVG and Artificial Intelligence (AI) supported workflow. The comparison clearly demonstrated the advantages of the new approach, including greater operational efficiency, improved accuracy, and higher levels of automation in data handling and process management.

The demonstration confirmed that IVGs can reliably generate a digital footprint of freight operations and can be successfully embedded into yard processes. They enhance efficiency, accuracy, and transparency while supporting predictive maintenance and cross-border interoperability.

The Nürnberg showcase thus provides a concrete example and roadmap for further deployment and standardization across Europe. It demonstrates that IVGs are not only technically mature but also ready for large-scale implementation as a cornerstone technology for the digitalization of European rail freight.

### Keywords:

## 2 Abbreviations & Acronyms

AI	Artificial Intelligence
CMS	Condition Monitoring Systems
D29.8	Deliverable 29.8 (specific report within project FP5-TRANS4M-R)
FP5	Flagship Project 5 (within Europe's Rail)
IVG	Intelligent Video Gate
EU-Rail JU	Joint Undertaking (Europe's Rail Joint Undertaking)
MAWP	Multi-Annual Work Programme
OCR	Optical Character Recognition
RFID	Radio-Frequency Identification
SAP	Systems, Applications and Products in Data Processing (maintenance/ERP system)
TRANS4M-R	Transformation for Rail Freight (project acronym)
UIC	International Union of Railways (Union Internationale des Chemins de fer)
WP	Work Package

### 3 Background

The present report forms part of Deliverable D29.8 *“Live Demonstration of Video Gates showing Process Optimization in a German Yard”* within the framework of the Flagship Project FP5 TRANS4M-R, as described in the Europe’s Rail Joint Undertaking (EU-Rail JU) Multi-Annual Work Programme (MAWP). The deliverable itself consists of the successful implementation of the live demonstration in Nürnberg, while this report is just an addition to document and evaluate its execution and outcomes. It builds on the conceptual and specification work carried out in previous project tasks (Kordnejad et al. 2024, pp. 13–14).

The overarching context of this deliverable is the digital transformation of rail freight operations using intelligent checkpoints, with a specific focus on Intelligent Video Gate (IVG) systems in Germany. These systems represent a key technological enabler for automating wagon identification, inspection, and data integration at railway checkpoints across Europe. By combining Optical Character Recognition (OCR), high-resolution cameras, sensors, and interoperable IT interfaces, IVGs and also artificial intelligence replace time-consuming and error-prone manual inspection procedures with standardised, digital, and automated workflows.

Deliverable D29.8 is dedicated to the live demonstration and assessment of the IVG systems installed in Germany which took place at the Nürnberg shunting yard. Unlike earlier deliverables, which focused on requirements and specifications (Kordnejad et al. 2024, pp. 68–69), this report documents the tangible results presented to participants during a live demonstration under real operating conditions. It highlights how IVGs are already embedded into yard and maintenance ordering processes and how they contribute to process optimization, and overall efficiency improvements (Kordnejad et al. 2024, pp. 109–110).

The results of the live demo are analysed in this report from several perspectives. The real-world performance of the IVG system with respect to data capture, reliability, and integration into existing workflows was demonstrated. Furthermore, the demonstration provided evidence of its impact by contrasting conventional manual inspection procedures with the new digitalized processes supported by IVGs. Finally, the lessons learned offer guidance for future deployment, harmonization, and large-scale rollout of checkpoint technologies across Europe. In doing so, this deliverable directly contributes to the technical enabler *“Standardised European Railway Checkpoints at borders and other operational stop points”* of the MAWP (revised version June 2025), which aims to modernize freight operations, enhance cross-border interoperability, and reduce manual interventions through scalable, high-readiness digital solutions (MAWP, 2022, p. 158).

## 4 Objective/Aim

This document has been prepared to document the plan and execution of Task 29.8 within Work Package 29 (WP29) of the Flagship Project FP5, Task 29.8: “DBC will have a Live-Demo of Video Gates showing process optimisation in a yard”, which results in this report D29.8.

In contrast to previous deliverables which describes installation, test plan or use cases, D29.8 focuses on the practical execution, the live demonstration of Intelligent Video Gate (IVG) systems that have already been installed and are in use in Germany. This report is a documentation and addition to the execution of the live demo which took place in Nürnberg yard on the 16<sup>th</sup> of September 2025.

D29.8. also contributes and is part of an overall demo of checkpoints within task 29.2, *“Demonstration and evaluation of the installed checkpoints”*. In addition to that those tasks contribute to task 33.5 *“Showcase of Standardised European Railway Checkpoints”* where the goal is to showcase the benefits of IVG systems in improving reliability, efficiency, and transparency in cross-border rail freight. In this way, deliverable D29.8 provides evidence and lessons learned that are transferable to subsequent WPs and to the Europe-wide roll-out of automated checkpoint technologies.

The overarching aim of this deliverable is to demonstrate the performance of IVG systems in real operational environments and to show their contribution to the digital transformation of rail freight processes. The objective was therefore not only to demonstrate the technological maturity of IVGs but also to show how they enable process optimization, partial automation, and higher levels of interoperability at European scale.

The live demonstration led by DB Cargo is the core of this deliverable. Conducted at the Nürnberg shunting yard, the demonstration illustrates how IVGs are already embedded in daily operations and how they transform the workplace. The IVG in Nürnberg was used as a representative example for all other installed IVGs in Germany and demonstrates what is possible at a single location, but also throughout Germany and even in the future in Europe. Traditional manual workflows, where employees walked along the train, recorded wagon damages paper based and manually this was shown in contrast to the new digital workflow, in which high-resolution cameras, OCR, AI-supported diagnostics, and seamless Systems, Applications and Products in Data Processing (SAP) integration digitalise and partly automate the tasks. The demonstrator also shows how job descriptions change: instead of performing repetitive manual tasks with a lot of unnecessary walking time, employees work digital and supervise digital systems, validate automated outputs, and act on anomalies identified by the software.

In addition to documenting the live demonstration, this deliverable has a broader strategic purpose. It assesses the integration of IVGs into maintenance IT systems, including their interoperability with other digital systems and their role in maintenance

ordering. It also considers the organizational and legal framework conditions, such as data management, rights ownership, and GDPR compliance. These insights are directly linked to the objectives of WP29, which target the development and validation of standardised checkpoint solutions for rail freight.

In summary, the aim of this deliverable is to document the plan and execution of the live demonstration of IVG systems in Germany, showing their role in process optimization at yards. Through this deliverable, WP29 progresses from theory and design towards practice and validation, confirming the role of IVGs as a cornerstone technology for the digitalisation and standardisation of European rail freight checkpoints.

#### 4.1 Task Description

*“DBC will have a Live-Demo of Video Gates showing process optimization in a yard”*, task 29.8 started in project month 13 (July 2023) and will end in month 42 (December 2025) the outputs of this task are included in this document and have been shown live in a yard on the 16<sup>th</sup> of September 2025.

Task 29.8 is not divided into subtasks. However, it is a subtask of the entire WP29 and gives input to Task 29.2. For this reason, the following table is not based on subtasks but on the content of the live demonstration.

	Task definition from GA (Task 29.8)	Output of deliverable
	DBC will have a Live-Demo of Video Gates showing process optimization in a yard.	<ul style="list-style-type: none"> <li>• Live Demonstration at the shunting yard in Nürnberg on the 16<sup>th</sup> of September 2025</li> <li>• Report D29.8</li> </ul>

## 5 Basis for the Execution of the Live Demonstration

This chapter provides the theoretical foundation for the live demonstration. It first introduces the Intelligent Video Gate (IVG) technology and then explains how process optimization is achieved through the transformation of employees' working environments.

### 5.1 Railway Checkpoints in Germany and the Use of Artificial Intelligence

Germany plays an important role in the deployment of IVGs as part of the wider European effort to digitalise rail freight operations. In cooperation with DB InfraGO (earlier: DB Netz) DB Cargo has already installed 13 IVGs at eight strategic marshalling yards: Hagen, Kornwestheim, Mannheim, Maschen, Munich, Nürnberg, Seddin and Seelze (Kordnejad et al. 2024, pp. 29–30). These locations were carefully selected on the basis of a network-wide location concept with the explicit goal of reaching approximately 95 percent coverage of DB Cargo's wagon fleet (Kordnejad et al. 2024, pp. 30).

The fundamental requirements for an Intelligent Video Gate (IVG) in railway transport encompass both technical and operational aspects aimed at improving the efficiency of workshops, terminals and marshalling yards. An IVG could replace manual physical inspections and data collection, accelerating operations and reducing dwell and processing times for trains, trucks, and intermodal loading units (Kordnejad et al. 2024 pp. 13–14, 109–110). High-resolution imaging enables detailed inspections and data integration with operations to support planning and decision-making, thus increasing overall operational efficiency.

In Germany, the video gates are positioned at the hump in marshalling yards, ensuring that every wagon passes the system for the maintenance inspection (Kordnejad et al. 2024, pp. 29). This design is particularly well-suited to bottleneck points in the rail network, where flows of freight can be reliably captured and monitored (Kordnejad et al. 2024, pp. 30).



Figure 1: Locations of DB Cargo's IVGs installed in Germany

The schematic structure of a video gate in Germany consists of a steel frame with two vertical beams and a crossbar. Nine cameras are mounted at different heights and positions to capture the wagon from all relevant angles.

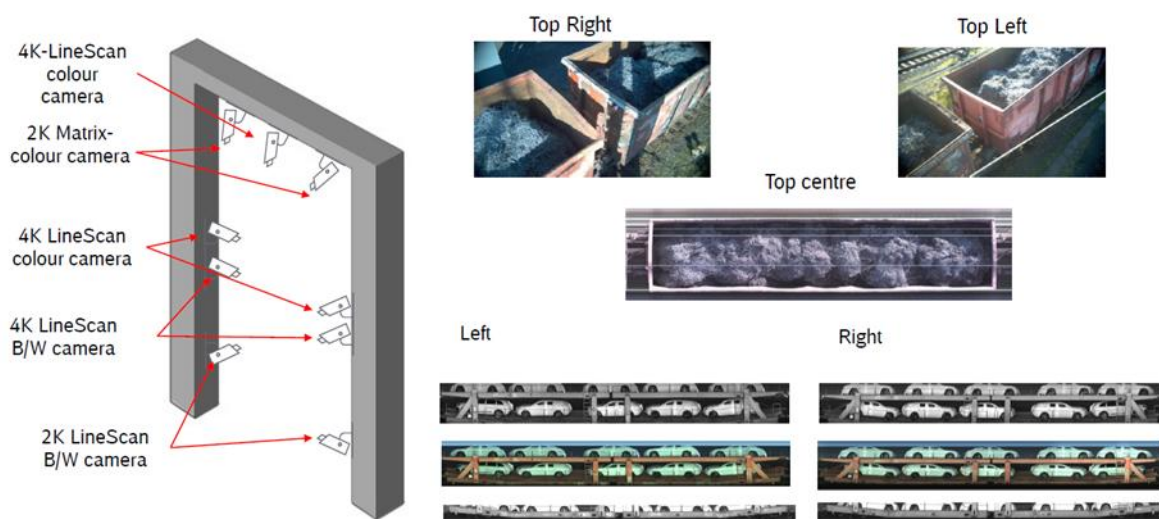


Figure 2: Standardized IVG of DB Cargo installed at 13 locations in Germany

The perspectives include:

- A black-and-white side view of each wagon side (4K),
- A colour side view of each wagon side (4K),
- A detailed view of the bogie area on both sides (4K),
- A top view of the entire wagon (4K), and
- Several angled top-side (oblique) views from both sides (2K).

The cameras which capture the wagon are matrix and line scan cameras. Images produced by line-scan are then stitched together to produce a complete view of the wagon, which forms the basis for automated analysis. OCR technology is used to read the International Union of Railways (UIC) or European Vehicle Number of each wagon, while Radio-Frequency Identification (RFID) scanners provide a secondary layer of verification (Kordnejad et al. 2024, pp. 29–30). This dual system ensures robustness, even when dirt, damage, or lighting conditions make optical recognition difficult.

The data collected is not limited to static identifiers. By combining cameras with sensors, such as laser scanners, and wayside monitoring systems, IVGs can also record train composition, measure speed, and detect anomalies such as damage to the wagon floor or irregularities on the tarp. (Kordnejad et al. 2024, pp. 35–37). This aligns with Europe's broader strategy of integrating wayside monitoring and condition monitoring systems (CMS) into digital freight corridors.

A defining feature of the German checkpoints is the integration of artificial intelligence. Machine learning models are trained on thousands of labelled images under different conditions. As a result, the AI can correctly diagnose identifiers even when numbers are partially obscured, wagons are dirty, or lighting is poor. Importantly, this process is iterative: the more data collected during daily operations, the more accurate the models become.

From an organizational perspective, the construction of the German IVGs was strongly supported by collaborative projects under Shift2Rail and later Europe's Rail (EU-Rail). The first prototypes were developed and tested under the Fr8Rail program, in cooperation with DB InfraGO (earlier: DB Netz) and suppliers such as LMT/Visy. Since then, DB Cargo has expanded the system into a nationwide network (Kordnejad et al. 2024, pp. 29–30). The operational benefits are clear: automated identification reduces manual effort, minimises errors, and accelerates inspections, while AI-based anomaly detection supports predictive maintenance and lead into a more efficient rail system.

In summary, the German network of railway checkpoints represents one of the most advanced applications of IVGs in Europe. By combining multi-perspective imaging, RFID verification, and artificial intelligence, the system generates a comprehensive digital footprint of freight trains. This not only ensures reliable identification of wagons, cargo, and damages but also supports logistics efficiency, regulatory compliance, and cross-

border interoperability. The integration of IVG data into broader monitoring and management systems paves the way for a fully digital and automated rail freight ecosystem across Europe.

## 5.2 Transformation of the Workplace

The introduction of IVGs represents far more than the installation of a new technical device, it fundamentally transforms the workplace and the daily routines of employees in rail freight. The shift from manual to digital and, in the near future, to fully data-driven workflows illustrate how job profiles are redefined and how human roles evolve alongside technological progress.

In the past, wagon inspection and maintenance ordering were characterised by manual procedures. Employees had to physically walk along each damaged wagon, often distributed across various tracks at the marshalling yard, under challenging weather and lighting conditions. Information was written down on paper forms and later transferred into IT systems, which created duplication of work and lot of time, what is not efficient (steps see Figure 3).

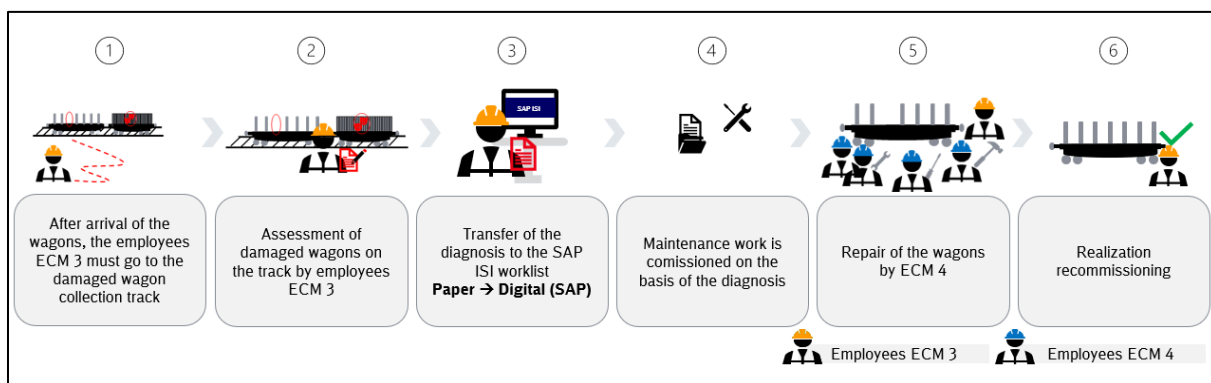


Figure 3: Manual, old, maintenance ordering process (Fr8Rail IV D2.3, 2022)

Any damage had to be noted manually, sometimes accompanied by hand-drawn sketches or photographs taken with personal devices. The accuracy of the process relied heavily on the experience and attention of the individual employee. Human error, inconsistent documentation, and gaps in data quality were common. Moreover, cross-border information sharing was limited, since procedures and formats differ from one country and operator to another (Kordnejad et al. 2024, pp. 113–117).

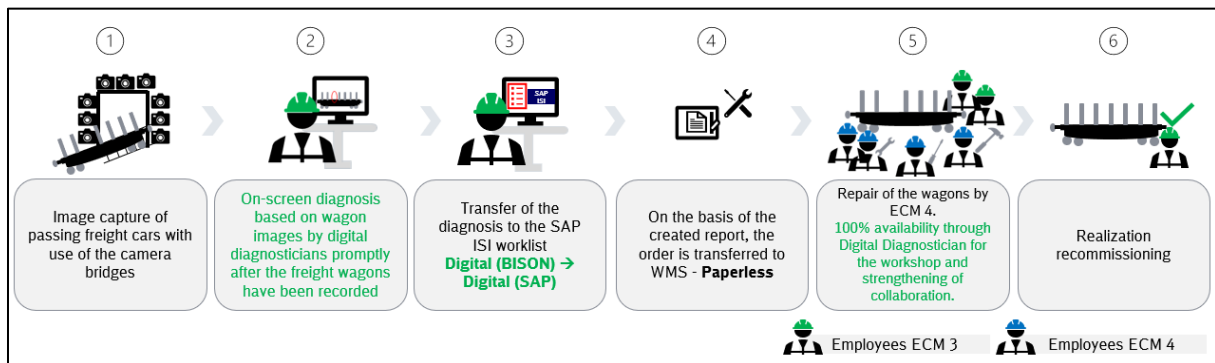


Figure 4: Transformed maintenance ordering process at DB Cargo (Fr8Rail IV D2.3, 2022)

With the implementation of IVGs, this situation has been transformed. The systems use high-resolution cameras, OCR, and AI-based analytics to automatically gain images and information of the wagons (DB Cargo AG, 2023). This generates information which can be used on screen, digitally, which is instantly integrated into yard IT systems such as SAP for maintenance ordering (Kordnejad et al. 2024, pp. 109–110). As employees work with damage codes defined by the GCU, the automatically generated damage information is likewise classified according to the GCU damage codes. This information is combined with timestamps and images of the passing wagon. Instead of spending long hours on repetitive data collection, employees can use real time data for the inspection of damages and validate the automatically generated results. The role of the employee has shifted from manual and paper-based procedures to a fully digital supported work, even with the support of AI and analysing findings (steps see Figure 44).

Looking into the future, the workplace will continue to evolve. Artificial intelligence models are continuously retrained with operational data, which means IVGs will become increasingly capable of identifying complex defects such as damages in floors, wholes in tarps, or brake pad issues. Integration with other monitoring technologies—such as hot-box detectors, wheel impact load detectors, or acoustic bearing monitors—will create a holistic monitoring environment, producing a “digital twin” of the rail freight system (Kordnejad et al. 2024, pp. 35–37, 119–123). In such a setting, employees will act less as manual inspectors and more as supervisors of interconnected systems, data analysts, and decision-makers. They will be responsible for interpreting diagnostic data, ensuring compliance with safety regulations, and coordinating corrective actions.

This future role demands new qualifications. Employees will require not only technical know-how to operate and maintain the equipment, but also digital literacy to interpret automated outputs and understand data flows. Training programs and cultural change management will therefore be essential. Staff acceptance will remain a critical success factor: only if employees trust the systems and see them as supportive tools rather than replacements will the full potential of IVGs be realized (Kordnejad et al. 2024, pp. 113–117).

In summary, the transformation of the workplace follows three clear stages. First, the past was marked by manual, labour-intensive workflows with high error potential. Second, the present demonstrates the advantages of digitalised processes, where inspectors supervise automated systems and focus on validation and interpretation. Third, the future points towards intelligent, integrated, and data-driven operations in which staff take on analytical, supervisory, and strategic roles. The live demonstration at Nürnberg made this transition tangible and showed how the workplace of the future in rail freight is already beginning to take shape today.

## 6 Live Demonstration

The following section outlines the content and focus of the live demo including location, participants, agenda and execution.

### 6.1 Location and Participants

The live demonstration took place on 16<sup>th</sup> of September 2025 at the German shunting yard in Nürnberg. This location was chosen for several reasons.

First, Nürnberg hosts the first Intelligent Video Gate (IVG) installation in Germany, where the initial considerations, adjustments, and implementation activities for the technology began. In addition, the site offered excellent accessibility, allowing participants to reach all destinations of the demonstration conveniently without the need for a car.

Participants included representatives of the Europe's Rail Joint Undertaking, EU-Rail project managers, project partners, and coordinators.

### 6.2 Objectives and Context

The goal of the live demonstration day was to provide a comprehensive understanding of the process steps involved in digital wagon inspection in the maintenance ordering process. Participants observed both the transition from manual to digital workflows performed by employees on site and the technology that enables this transformation.

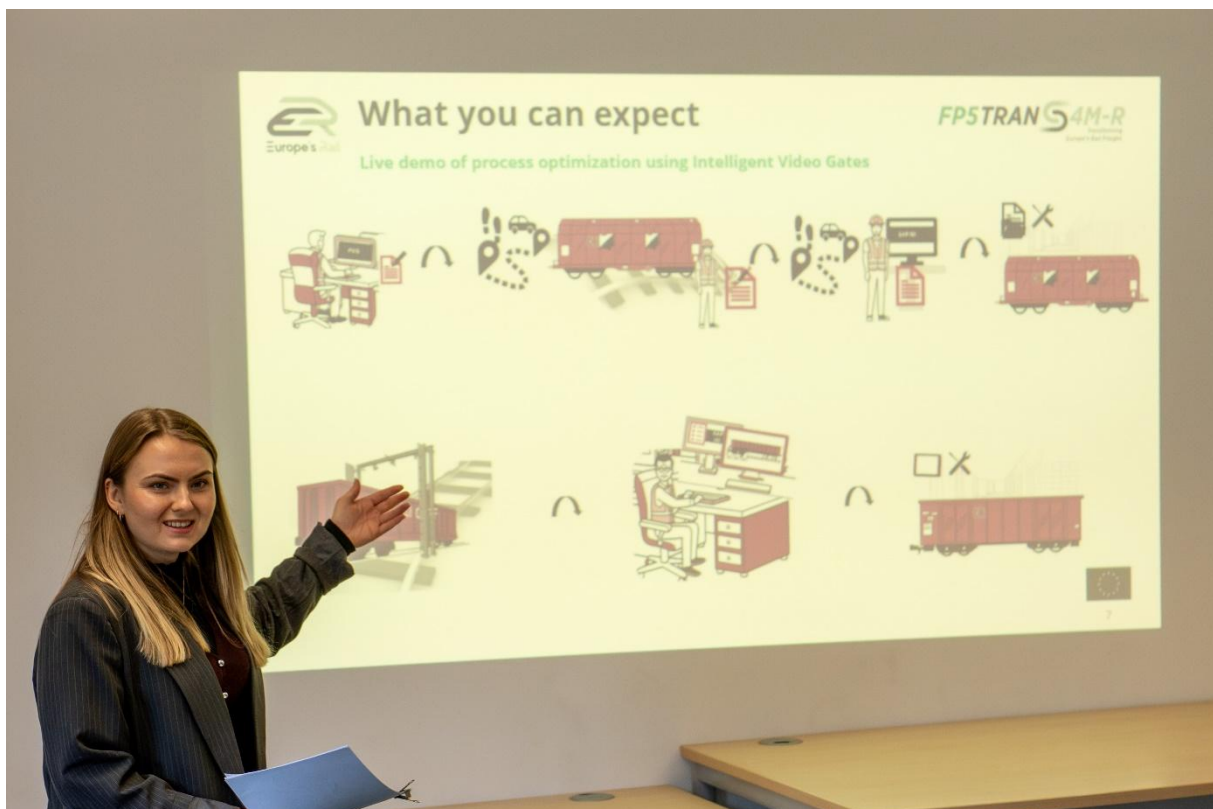
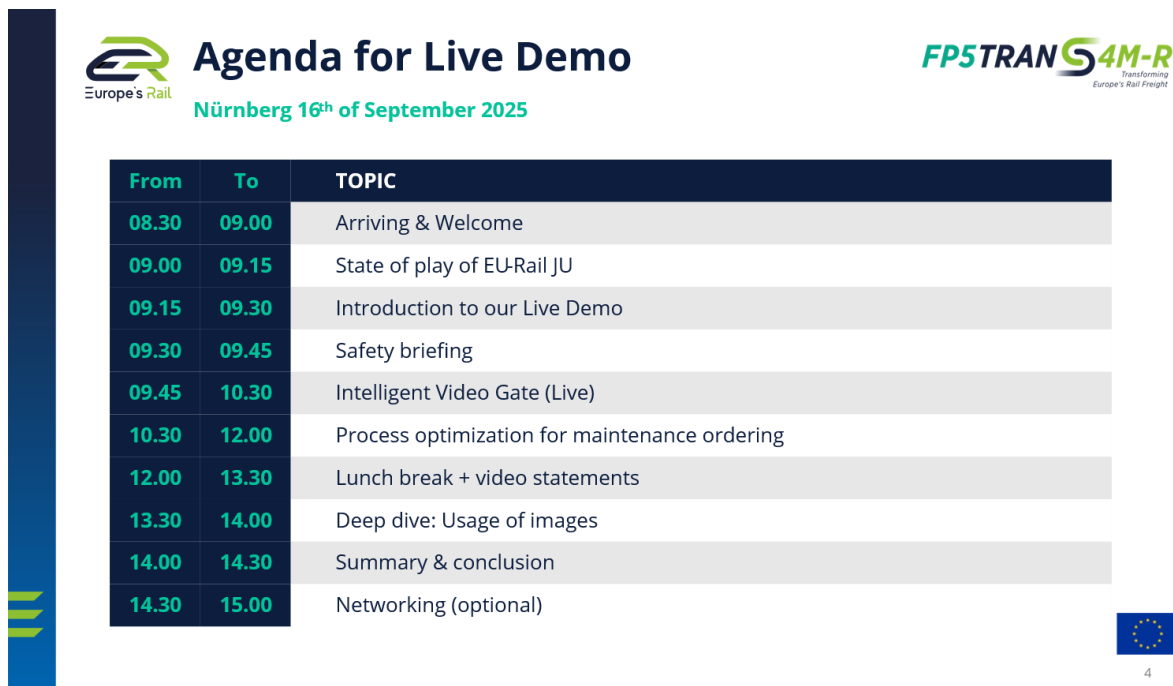


Figure 5: Introduction of the live demo at Nürnberg yard (Acker, 2025)

Moreover, the demonstration was contextualized within the broader project framework: its classification within the Grant Agreement, its linkage to the EU-Rail programme, and its continuity with the predecessor project Shift2Rail were presented.

### 6.3 Agenda and Opening Session

The event began with a formal welcome and an introduction to the day's agenda. Following a short presentation on the organisational framework and intended objectives, the agenda covered the current state of play of the EU-Rail Joint Undertaking, a safety briefing for movement within the yard, and an introduction to the checkpoints and IVG system. It also included an overview of operational processes before the introduction of the IVG technology and how these processes have evolved since its implementation.



The slide features the logos for Europe's Rail and FP5TRAN S4M-R at the top. The title is 'Agenda for Live Demo' with the date 'Nürnberg 16<sup>th</sup> of September 2025'. A table lists the agenda items with their respective start and end times. The slide also includes a small European Union flag in the bottom right corner.

From	To	TOPIC
08.30	09.00	Arriving & Welcome
09.00	09.15	State of play of EU-Rail JU
09.15	09.30	Introduction to our Live Demo
09.30	09.45	Safety briefing
09.45	10.30	Intelligent Video Gate (Live)
10.30	12.00	Process optimization for maintenance ordering
12.00	13.30	Lunch break + video statements
13.30	14.00	Deep dive: Usage of images
14.00	14.30	Summary & conclusion
14.30	15.00	Networking (optional)

Figure 6: Agenda of the live demo at German shunting yard

The discussions further addressed areas where improvements were needed and where potential for optimisation was identified. This progression from challenge to purpose (see Figure 7) reflects a paradigmatic shift in the role of technology as an enabler of optimisation. Rather than serving merely as a tool for problem-solving, technology increasingly acts as a catalyst for systemic improvement and innovation. Through the integration of data analytics, automation, and intelligent systems, technological advancement transforms complex operational challenges into purposeful strategies that enhance efficiency, adaptability, and long-term sustainability.

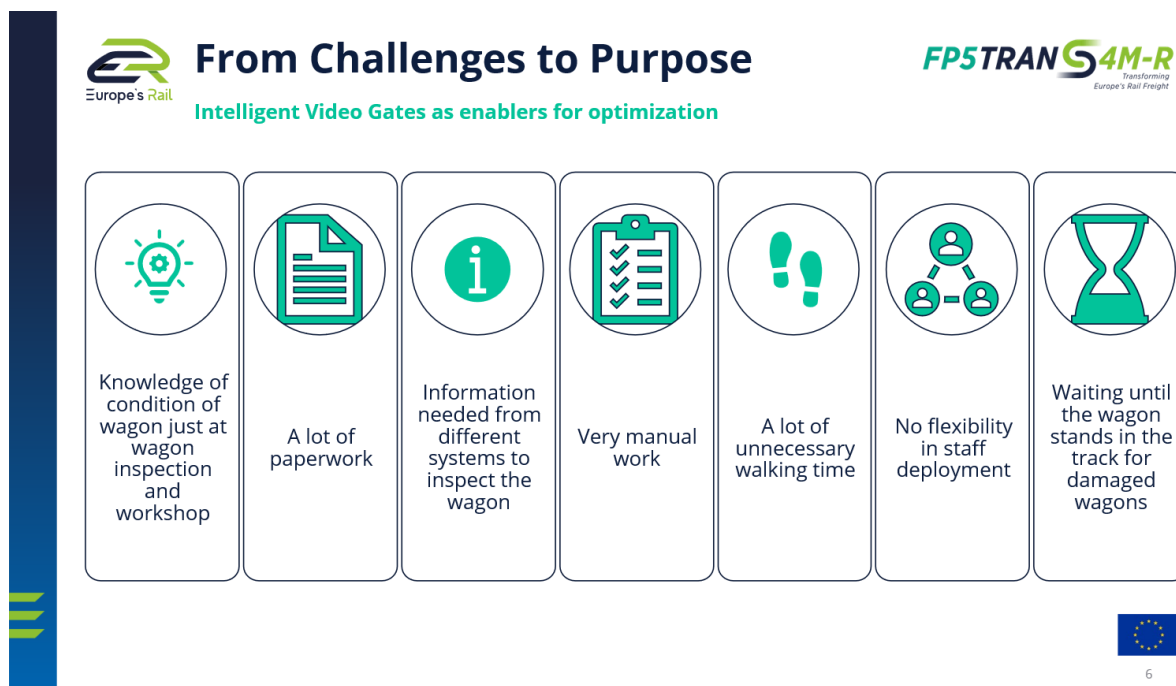


Figure 7: The challenges at the beginning of the project shown at the live demonstration

## 6.4 Technological Demonstration

The second part of the event focused on technological innovations. In addition to presenting the IVG system itself, several smaller yet significant developments were highlighted. The project's European scope was emphasised as a sign of transferability and scalability across rail networks.

The contributions of the project team and partners were formally recognised, underlining the collaborative nature of the initiative.

A central highlight was the on-site demonstration of the Intelligent Video Gate. After distributing personal protective equipment, participants examined the installation directly. Technical explanations covered system functionality, data transmission and volume, and integration opportunities with other systems.

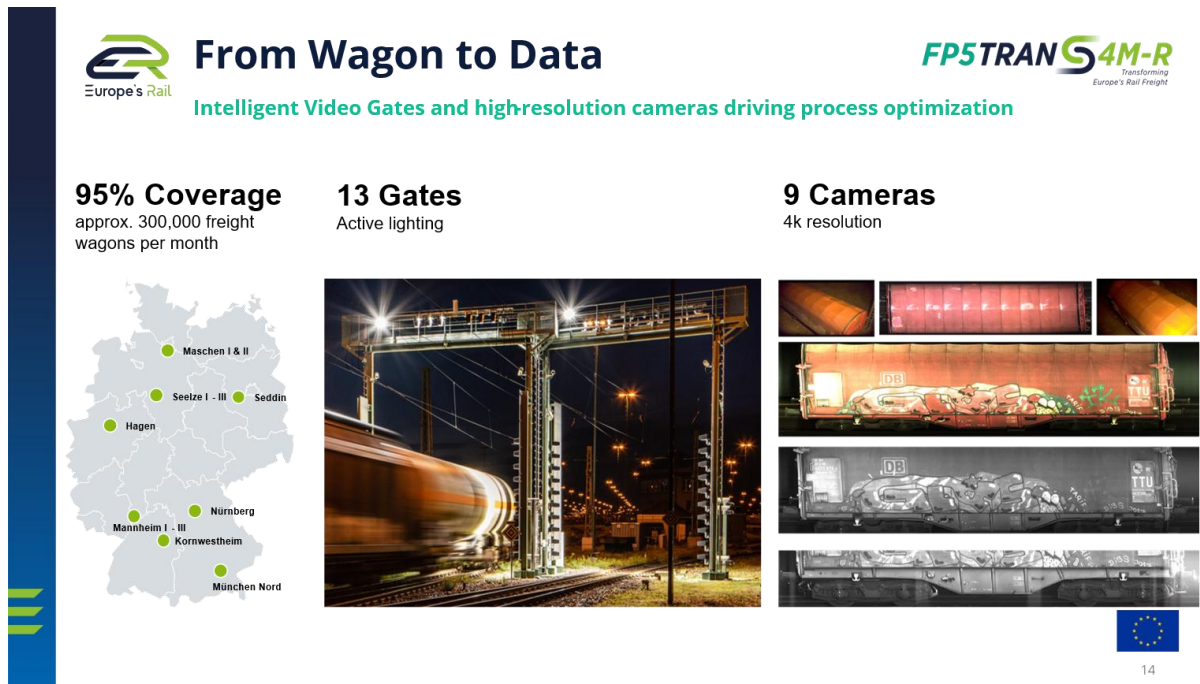


Figure 8: Distribution of IVG in Germany

The connection between the technical enabler IVG and the usage for the training of AI models was explained with some examples. The base of this work are the labels on images which DB Cargo is generating day by day as the employees are marking (annotate) damages in their daily work.

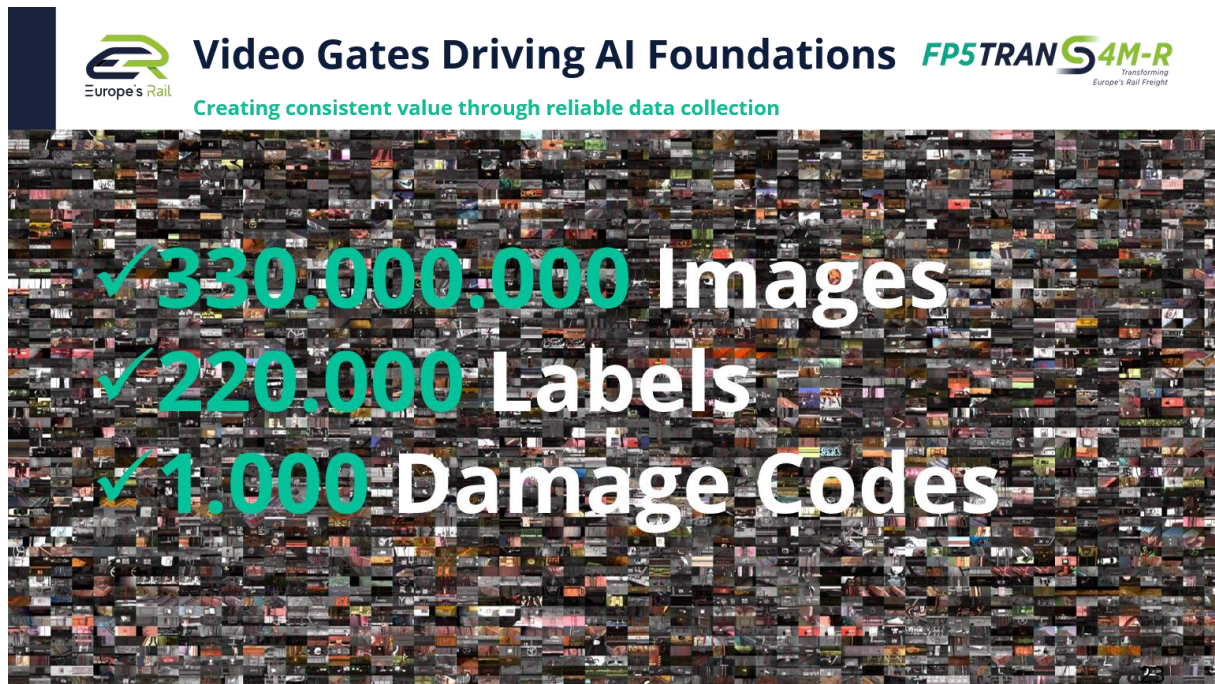


Figure 9: Data facts

The subsequent discussion addressed, among other aspects:

- *Locations of video gates:* On the humps at the yards at 8 locations (see chapter 5.1),
- *the annual number of image captures:* 10,000 wagons passing per day all over Germany, this means up to 300,000 images per day are gathered,
- *the transmission and communication infrastructure:* via LTE to an AWS cloud and from there distributed to the necessary systems, such as the maintenance ordering system which is used by the employees to do the maintenance ordering based on the generated wagon images,
- *ownership and usage rights of the technology:* Owner of the gates is DB InfraGO (earlier: DB Netz), DB Cargo obtains the images from DB InfraGO
- usage of RFID systems for freight car identification and related application scenarios.



*Figure 10: DB Cargo explaining technical details of IVG at live demo (Acker, 2025)*

Geotechnical challenges encountered during the construction phase were highlighted. Furthermore, the necessity of variable camera configurations to address country-specific use cases was outlined.

It was emphasised that the video gates in Germany have the current design due to a specific use case, namely the optimization of wagon diagnostics and the preparation of workshop orders. For this reason, video gates in other countries have a different design, as they serve a different purpose and are sufficient for their respective applications and have the necessary configurations.



*Figure 11: Participants in front of the IVG Nürnberg (Acker, 2025)*

The images show how participants at the marshalling yard were able to view the IVG and its technical details on site.

## **6.5 Demonstration of Process Optimisation**

The live demonstration at the Nürnberg yard vividly illustrated the ongoing transformation from manual to digital wagon inspection of damaged wagons. First, the conventional process flow was illustrated using damaged wagons as reference objects. Traditionally, the damage assessment process required employees to physically access the damaged wagons. Depending on the location, this could involve walking considerable distances or using a vehicle for transport.

In Nürnberg, this time-consuming procedure was deliberately not reproduced during the live demo, as it would have required taking participants to the distant damaged-car collection tracks. Instead, for demonstration purposes, a damaged wagon was positioned directly in front of the workshop. In the conventional process (see chapter 5.2), employees inspected each wagon manually, identifying damages and reporting them through a step-by-step documentation procedure (see Figure 3). This approach often delayed the flow of information, which is critical for determining appropriate handling tracks and initiating maintenance actions.

In contrast to the traditional manual inspection, the digitalized workflow (see Figure 4) demonstrated at the Nürnberg yard showcased a fully digital and data-driven inspection process. As a selected freight wagon passed through the IVG system, high-resolution cameras captured detailed images, OCR extracted the UIC wagon number, and AI algorithms automatically identified and highlighted potential damages. The digital inspection results were then reviewed on screen, and the corresponding data were seamlessly transferred to SAP, where a maintenance order could be generated within minutes.



*Figure 12: Live demonstration of usage of the wagon images (Acker, 2025)*

The demonstration also offered complementary insights into the working methodology of the Digital Diagnosticians and the integration of the software into existing maintenance processes. At the newly established digital workplace, employees were able to view wagon data and imagery directly within the system. This eliminates the need for printouts or handwritten notes. Instead of physically inspecting wagons on the tracks, staff could now access all relevant information immediately at one place, directly from their workstation. During the live session, several freight wagons with varying types of damages, e.g. damaged tarps and floors, were displayed alongside the corresponding AI analyses.

For instance, one wagon that had passed through the video gate was automatically flagged by the AI for a damaged floor panel. The employee then confirmed the damage digitally and added it to the workshop order. This information subsequently supported

the downstream maintenance process: workshop staff could access the same images and damage annotations to understand the scope of required work. The workflow was verified directly in the workshop office by the master craftsman, confirming the practical utility of the digital system.

This direct comparison between the manual and digital process highlighted not only the significant benefits in efficiency and data consistency but also the evolving role of employees, from performing physical inspections on-site to managing digitally supported diagnostic processes.

The event concluded with a synthesis of the main findings and an outlook on future developments, including the forthcoming D 29.2 event.

## 7 Conclusion & Lesson Learned

This deliverable documents the live demonstration of IVGs at German shunting yards, carried out within WP29 of the FP5-TRANS4M-R project. The context of this work lies in the wider ambition of EU-Rail to digitalise freight operations and introduce standardised checkpoints that can automate identification, inspection, and data handling across Europe.

The objective of Task 29.8 was to indicate the performance of IVG systems in real operational environments and to demonstrate how they can optimise and partially automate key freight processes. The execution of the live demonstration took place at the Nürnberg yard, where the installed video gate was presented, explained, and was able to prove that it works under live conditions in the daily yard processes. Real damaged wagons in front of the wagon maintenance workshop were used and served as example objects to illustrate the difference between traditional manual inspection and the new digital workflow, which included OCR-based recognition, AI-supported diagnostics, and seamless SAP integration.

The central problem addressed is the inefficiency of conventional inspection and maintenance processes. Manual workflows are time-consuming, error-prone, and insufficiently harmonized across borders. This creates bottlenecks in marshalling yards, slows down maintenance ordering, and limits interoperability between stakeholders.

The demo combined an explanation of technical details, live demonstration under real yard conditions at TRL 8 and a presentation as well as an evaluation of the whole process as lessons learned. The demonstration began with formal presentations, followed by a safety briefing, provision of protective equipment, and a guided on-site inspection of the IVG. Technical explanations covered annual volumes of image capture, transmission and communication infrastructure, and usage of RFID. The digital workflow was showcased step by step, with Digital Diagnostics and maintenance staff illustrating how wagon image data is processed and incorporated into daily practice.

The live demo proved that IVG data can be successfully used to optimise yard processes especially the maintenance ordering process. Also, participants highlighted the added value of digital image data for predictive maintenance and operational optimisation.

At the same time, the demonstration exposed challenges that remain to be solved. From a technical perspective, recognition performance is still influenced by lighting, weather, and dirty or damaged codes. Organisationally, the integration of IVGs into diverse and often outdated IT landscapes requires significant effort, while cross-border harmonization of procedures is a huge challenge. On the human side, staff training and change management are critical: employees need to develop confidence in digital outputs and adapt to new roles in supervising and interpreting automated results.

From these challenges, several lessons learned can be drawn.

- First, hybrid solutions combining high-resolution multi-perspective imaging with AI-based recognition and RFID fallback are the most reliable.
- Second, AI models must be continuously retrained with operational data to cope with variability and ensure robustness.
- Third, embedding cybersecurity “by design” is not optional but a prerequisite for trust and acceptance. Fourth, early involvement of staff and structured requalification programs are essential to secure user buy-in.
- Finally, interoperability and harmonisation efforts at European level must run in parallel with technical roll-out, otherwise national solutions risk remaining isolated.

The best solution identified is the hybrid approach combining high-resolution multi-perspective imaging, AI-based recognition, and RFID-based verification. This increases both accuracy and resilience, ensuring reliable operation under diverse real-world conditions.

Overall, the live demonstration at Nürnberg confirmed the transformative potential of IVGs. It showed not only the technical capabilities of the system but also the organizational, procedural, and human factors necessary for successful adoption. The work contributes directly to EU-Rail objectives by providing a tested and transferable checkpoint model for large-scale deployment.

Overall, the live demonstration at Nürnberg confirmed that the Intelligent Video Gate system and the newly established job profile are already operating at TRL 8 — fully functional, productive, and no longer in a prototype phase. The system has transitioned into regular operational use, proving its maturity and robustness in daily railway processes. This achievement represents a key milestone not only for the German deployment but for the European railway sector as a whole, demonstrating that IVGs are ready for large-scale implementation as part of EU-Rail digitalisation strategy.

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