UITP ADVANCING PUBLIC TRANSPORT

中国城市轨道交通协会 CHINA ASSOCIATION OF METROS

→ Insights

AI-Driven Smart Rail Transportation

– Advancing Intelligent, Efficient and Inclusive Rail Systems with Technology

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Disclaimer

The findings, interpretations and conclusions presented in this joint publication are based on the information and data available to the joint project team. Neither UITP nor the China Association of Metros (CAMET) shall be held liable for any use of this information. UITP and CAMET may periodically update this publication to correct errors or incorporate newlyavailable data.

TABLE OF CONTENTS

Executive Summary

Artificial Intelligence (AI) is rapidly emerging as a transformative force in the rail sector, moving beyond experimental pilot projects towards practical applications that support safer, more efficient, and more passenger-focused rail transit operations. Against a backdrop of increasing operational complexity, rising service expectations, workforce challenges, and pressure to improve cost efficiency, rail operators worldwide are exploring how AI technologies can unlock greater value from the vast amounts of data generated across their networks. The webinar "AI-Driven Smart Rail Transportation – Advancing Intelligent, Efficient and Inclusive Rail Systems with Technology", jointly organised by UITP and the China Association of Metros (CAMET) on 8 May 2026, brought together global rail experts, operators, authorities, and technology leaders to exchange experiences and discuss the evolving role of AI in rail transportation.

A central message emerging from the discussions was that the rail industry is entering a new phase of digital transformation where the challenge is no longer simply collecting data, but converting data into actionable intelligence. This report goes beyond summarising the webinar discussions by incorporating additional industry developments and analysis. It also provides a snapshot of how UITP members and CAMET members are advancing AI-driven innovation, highlighting key trends, challenges, and opportunities across the rail sector.

Across different regions and operational contexts, AI is increasingly being deployed to support predictive maintenance, optimise train operations, enhance passenger services, improve safety management, strengthen emergency response capabilities, and support more informed decision-making throughout the entire life cycle of urban rail systems. Speakers highlighted that while individual AI applications have existed for several years, recent advances in large language models (LLMs), multimodal AI, digital twins, intelligent agents, and machine learning are creating new opportunities to integrate intelligence across entire rail systems.

A key requirement for successful deployment is the integration of railway-specific knowledge, as rail operations involve complex technical systems, strict safety requirements, and established operational procedures that general-purpose AI tools cannot fully address. At the same time, operators are increasingly adopting predictive approaches, using AI to forecast passenger demand, optimise service planning, detect anomalies, and support maintenance before failures occur, leading to improved operational efficiency and reduced manual workload. Asset management has emerged as one of the most mature application areas, where sensor technologies, machine vision, digital twins, and predictive analytics enable real-time monitoring and early intervention to improve reliability and reduce costs.

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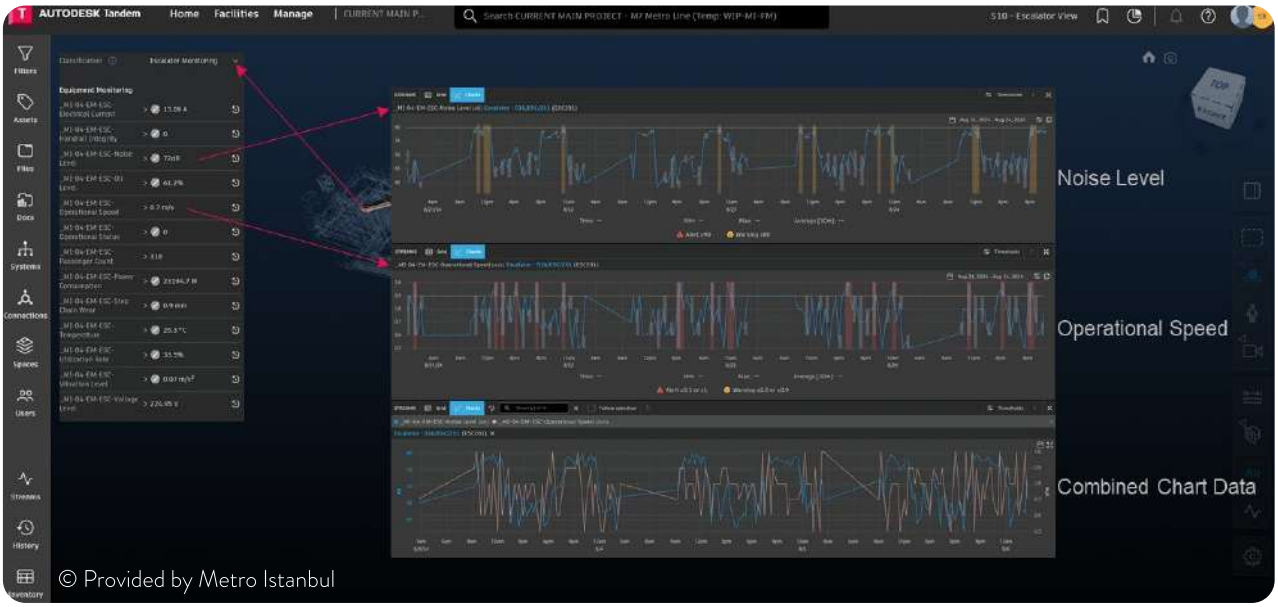
Beyond operational efficiency, AI is also enabling more responsive and inclusive passenger services, including intelligent customer support, real-time passenger information, crowd management, and smart station management, thereby improving service quality and responsiveness to evolving passenger needs. However, the webinar also emphasised that AI implementation is not solely a technological challenge, as success depends on strong data governance, workforce capabilities, and collaboration across operators, suppliers, and research institutions. Ultimately, the long-term value of AI will depend not only on technological advances but also on the ability of rail organisations to build the governance, skills, and partnerships needed to translate innovation into tangible operational and passenger benefits.

Key insights

This section presents the key insights emerging from the current deployment and exploration of artificial intelligence in the rail sector. It synthesises practical experiences and application trends across different operators and regions, highlighting how AI is moving from isolated pilot projects towards integrated, system-wide capabilities. The focus is on understanding not only where AI is being applied, but also how it is reshaping operational practices, organisational structures, and decision-making processes within rail systems.

The insights are organised into four main areas reflecting the most significant domains of impact identified across case examples and discussions. These include the use of AI for operational efficiency and decision-making, the development of knowledge-based AI systems tailored to railway-specific requirements, the increasing maturity of predictive operations and asset management approaches, and the growing emphasis on human-centred AI that supports workforce productivity and enhances rather than replaces human expertise.

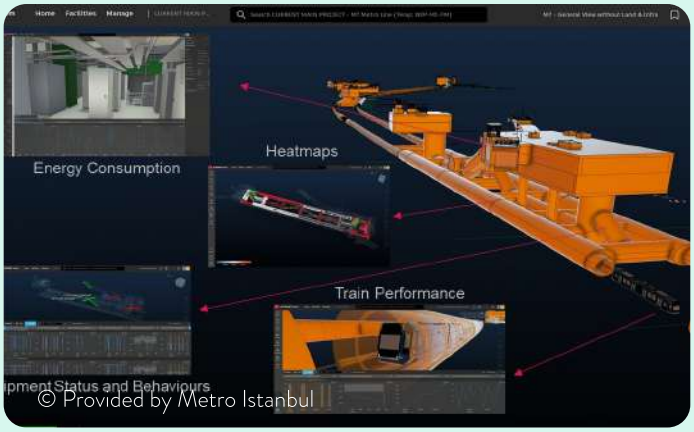
These themes illustrate a broader transition in the rail sector from data-driven experimentation to intelligence-driven operations. They also highlight the enabling conditions required for successful implementation, including data quality, domain knowledge integration, digital infrastructure, organisational readiness, and cross-sector collaboration.



AI for Operational Efficiency and Decision-Making

AI is increasingly helping rail operators move from reactive decision-making towards predictive and data-driven operations. By analysing large volumes of operational, passenger, maintenance and infrastructure data, AI systems can identify patterns, forecast future conditions and support more informed operational decisions. Applications range from passenger demand forecasting and crew scheduling to fault prediction, maintenance planning and service optimisation.

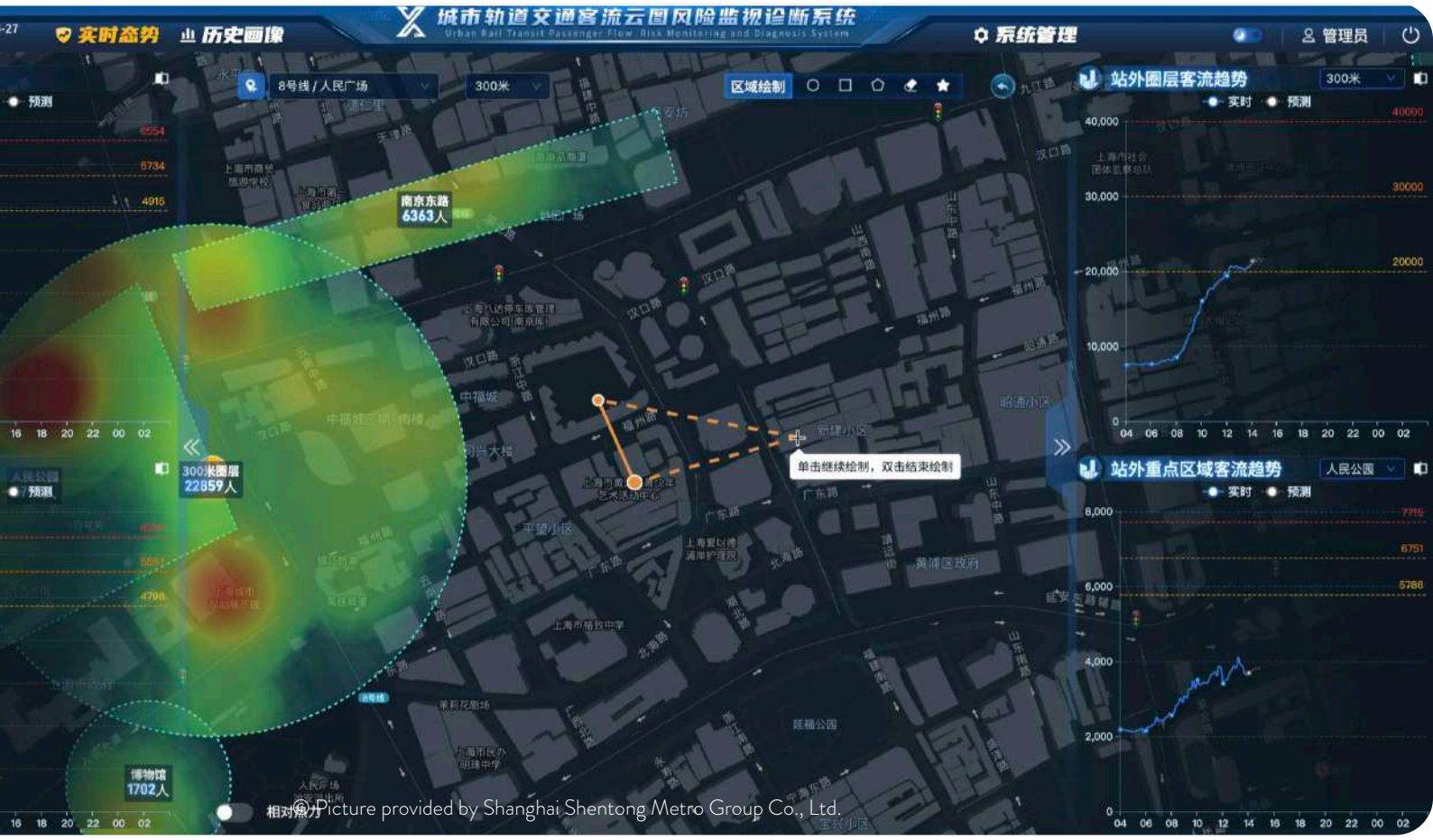
The ability to process information in real time enables operators to improve efficiency, reduce operational risks and optimise resource allocation. However, successful implementation depends on data quality, interoperability, staff capabilities and trust in AI-generated recommendations. As several speakers highlighted, AI should be viewed as a decision-support tool that augments human expertise rather than replacing it.



Case Study: Shanghai Metro – AI-Driven Passenger Flow Forecasting

Shanghai Shentong Metro showcased how AI is being used to forecast passenger flows and provide early warning of potential congestion risks. By integrating multi-source passenger flow sensing, simulation modelling, and travel-chain reconstruction, the system can issue congestion risk warnings up to one hour in advance, with forecasting accuracy exceeding 95% and a significant reduction in false alarms.

The platform has already delivered tangible operational benefits. According to the presentation, the peak-section load factor on line 10 was reduced from 94% to 78%. The system also helped address nearly ten operational risk points at ten stations, including Xinzhuang Station and Yishan Road Station. In addition, the accuracy of operational alerts was significantly improved, with the false alarm rate reduced from 30% to 5%. Beyond congestion forecasting, the platform supports operational planning, capacity allocation, and disruption management by enabling operators to anticipate passenger demand and implement proactive interventions before issues escalate.



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Case Study: Qingdao Metro – Intelligent Operations through AI Agents

Qingdao Metro exceed 4.4billion yuan in 2024, with labour cost accounting for over 60% of the total. To address the continue operation pressure, Qingdao Metrodeployed a network-wide AI framework combining large language models, intelligent agents and operational knowledge systems. The operator has identified more than 530 AI application scenarios covering transport organisation, passenger service, maintenance, emergency management and enterprise administration and so on 23 categories. Through deployment on Metro Line 6, AI-supported operational systems have contributed to improved reliability, faster emergency response and significant efficiency gains across multiple business functions. Organisational optimisation drives >30% efficiency & cost savings, about ¥100M annually.

Knowledge-Based AI for Railways

As AI becomes more widely adopted across the rail sector, operators are increasingly recognising that technology alone is insufficient to deliver reliable and operationally relevant outcomes. While recent advances in large language models (LLMs) have demonstrated impressive capabilities, railway operations involve highly specialised engineering knowledge, operational procedures, safety requirements, and regulatory frameworks that are often not reflected in general-purpose AI models.

More critically, the cross-stage business semantic connection along the AI perception-decision-execution chain still relies on manual intervention. This constitutes a core bottleneck restricting the release of AI technical effectiveness in urban rail transit, and significantly dilutes the technical value of artificial intelligence.

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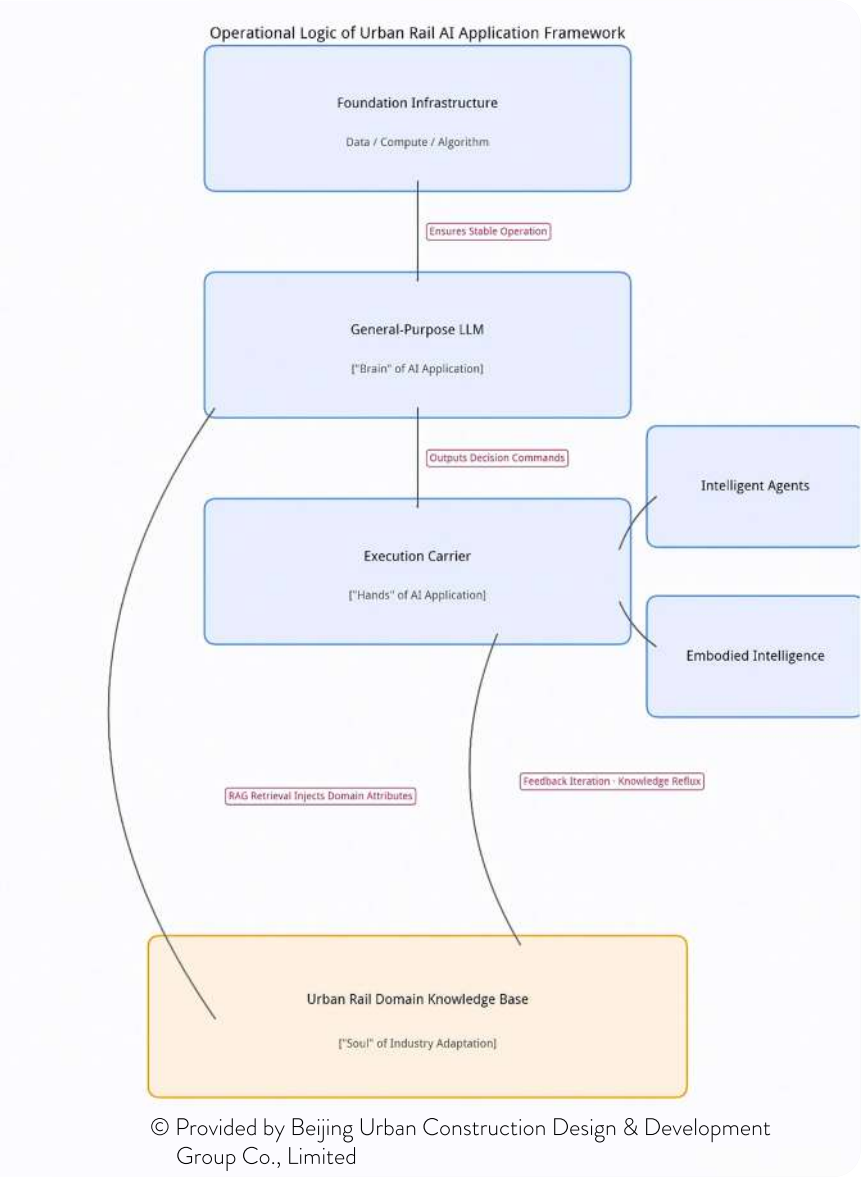
As a result, a growing industry focus is emerging around the development of railway-specific knowledge systems that can improve the accuracy, reliability, and explainability of AI applications, fully embed the knowledge base into the entire perception-decision-execution chain, and ultimately form a stable and efficient human-machine collaboration model.

Case Study: Collaborative Development of Railway AI Knowledge Systems in China

One of the key barriers to AI adoption in urban rail transit is the absence of structured industry knowledge. Railway operations rely on highly specialised engineering expertise, operational procedures, safety requirements, and regulatory frameworks that are often not adequately represented in general-purpose AI models, limiting their reliability and practical application in rail environments. Without access to specialised railway expertise, general-purpose large language models may generate inaccurate responses or «hallucinations» when addressing highly technical operational and engineering questions. Rather than developing entirely new railway-specific foundation models, he argued that the industry should focus on building comprehensive knowledge bases and integrating them with existing AI models through technologies such as Retrieval-Augmented Generation (RAG), knowledge graphs, and intelligent agents. This approach enables AI systems to access verified industry knowledge while maintaining flexibility, scalability, and compatibility with rapidly evolving foundation models.



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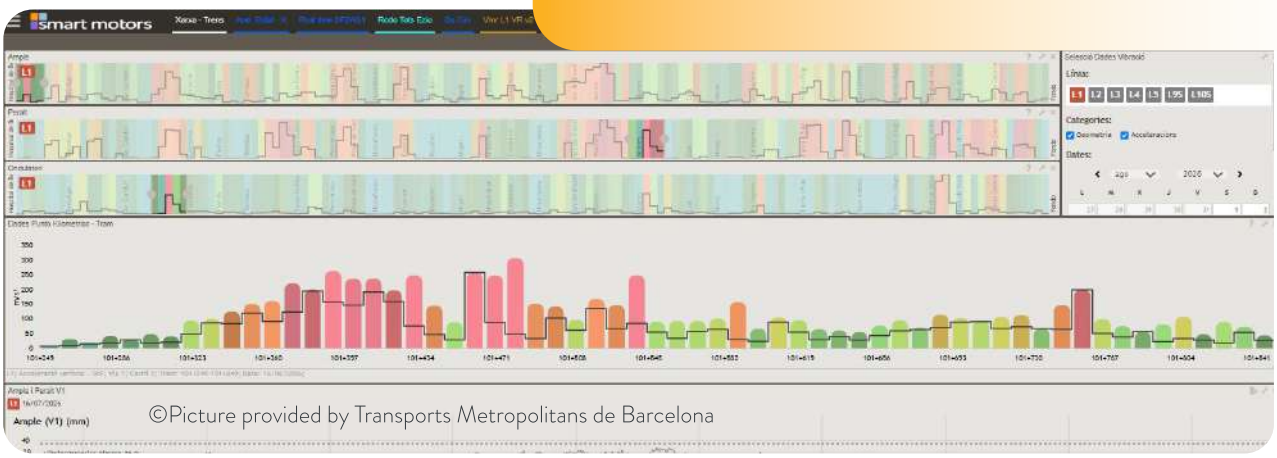
To address this challenge, Chinese urban rail operators have increasingly adopted a collaborative approach to AI research and development. Significantly, the consortium has grown from 71 member organisations at its establishment in 2025 to more than 100 participating organisations, demonstrating strong industry commitment to collective innovation. Through joint investment and knowledge sharing, consortium members are developing common standards, datasets, evaluation frameworks, and AI application guidelines, creating a shared foundation that can accelerate AI deployment across the wider railway sector.



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Case Study: Transports Metropolitans de Barcelona (TMB) – Building a Digital Knowledge Ecosystem through DAVANA

Transports Metropolitans de Barcelona (TMB) provides an example of how organisational knowledge can be integrated across operations to support digital transformation and AI adoption. The DAVANA digital ecosystem is a data and knowledge platform designed to connect information from multiple departments, infrastructure systems, and operational processes within a unified environment. Rather than treating AI as a standalone technology initiative, the platform forms part of a broader strategy centred on data integration, organisational knowledge management, and data-driven decision-making.

The DAVANA platform consolidates information from operations, maintenance, customer service, infrastructure management, and business systems, enabling the organisation to generate automated insights and support operational decision-making. By breaking down traditional departmental data silos, the platform provides a common source of information that can be used to improve service reliability, optimise maintenance planning, enhance asset management, and support more informed management decisions.

A key message from TMB was that data alone does not create value. The true benefit emerges when data can be transformed into actionable intelligence and embedded directly into operational workflows. Through DAVANA, AI and advanced analytics are used not simply to process large volumes of information, but to deliver practical recommendations and decision support for frontline staff and management teams.

The TMB experience highlights an important lesson for the rail sector. Successful AI deployment depends not only on algorithm development but also on the ability to organise, connect, and govern organisational knowledge. By establishing a digital knowledge ecosystem, operators can create the foundation required for future AI applications while ensuring that insights generated by AI systems remain relevant, trustworthy, and operationally useful. The case demonstrates how integrated data and knowledge architectures can serve as a critical enabler of intelligent rail operations and long-term digital transformation.

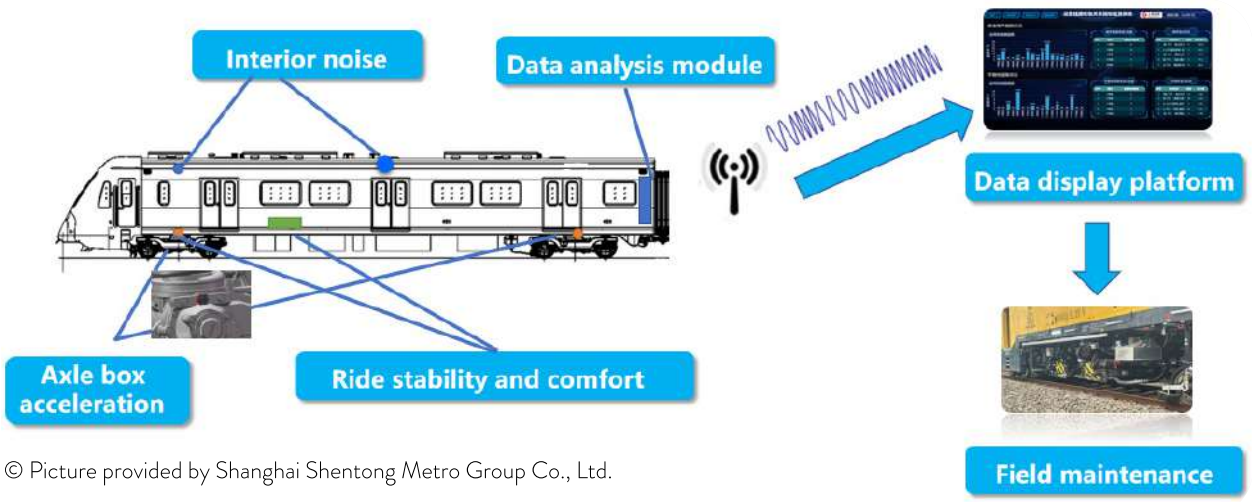
Predictive Maintainance and Asset Management

Predictive maintainance and asset management have emerged as some of the most mature applications of artificial intelligence in the rail sector. By combining machine learning, digital twins, sensor technologies, and advanced analytics, operators are increasingly able to detect anomalies, forecast failures, optimise maintenance schedules, and improve asset performance before disruptions occur. This represents a significant shift away from traditional reactive and time-based maintenance approaches towards more proactive and condition-based management.

The benefits are substantial. AI-supported monitoring systems can improve asset reliability, reduce maintenance costs, optimise resource allocation, and minimise service disruptions. By continuously analysing data from infrastructure, rolling stock, energy systems, other subsystems, and operational activities, operators gain greater visibility into asset health and network performance. Several speakers demonstrated how predictive technologies are already being applied across rail systems worldwide to support more efficient and resilient operations.

Case Study: Shanghai Metro –Wheel-Rail Intelligent Management System

Shanghai Metro has launched a Wheel-Rail Intelligent Maintenance Decision Platform, designed to enhance the service condition of infrastructure equipment, operational safety, and passenger ride comfort. The system integrates functions including perception monitoring, fault identification, defect prediction, and maintenance optimisation, enabling round-the-clock monitoring of wheel-rail matching status across the entire network. This provides a scientific basis for precise maintenance and repair interventions.



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The platform has now been deployed across all 18 metro lines in Shanghai. It achieves a prediction accuracy of over 90% for typical track defects and an anomaly warning accuracy of higher than 95%. In terms of operational efficiency, it reduces manual inspection workloads by 5,000 person-times annually, increases detection response speed by 200%, and improves defect localisation accuracy by a factor of four. Furthermore, interior noise levels in sensitive track sections have been reduced by more than 5 dB, significantly improving the overall riding experience. This application has successfully driven the transformation of track maintenance from a "planned maintenance" model to a "condition-based maintenance" approach, marking a major leap from periodic manual inspections to intelligent, round-the-clock monitoring and predictive upkeep.

Case Study: Metro Istanbul – Digital Twins for Integrated Operations

Metro Istanbul highlighted the role of digital twin technologies in supporting integrated asset management and operational decision-making. By combining BIM models, IoT sensors, SCADA systems, energy management platforms, and operational data within a unified digital environment, the operator is developing a comprehensive digital representation of its metro network.

The digital twin platform enables real-time asset monitoring, predictive maintenance, simulation of operational scenarios, and data-driven planning. Metro Istanbul estimates that full implementation could improve operational efficiency by up to 35% while reducing energy consumption and maintenance costs by as much as 25%. The case illustrates how digital twins can provide a foundation for more intelligent and sustainable metro operations.

Case Study: Dubai RTA – AI-Enabled Infrastructure Inspection and Operational Decision Support

Dubai's Roads and Transport Authority (RTA) demonstrated how AI can support both infrastructure management and operational decision-making through the deployment of its Automated Rail Infrastructure Inspection System (ARIIS). The system combines LiDAR, laser scanning, optical sensing technologies, and advanced analytics to automate infrastructure inspections and enable predictive maintenance. By continuously monitoring track geometry, rail conditions, and other critical assets, ARIIS provides early warnings of potential defects before they develop into operational risks. According to RTA, the initiative has reduced inspection time by approximately 80%, improved resource utilisation by 50%, and significantly increased the amount of asset condition data available for maintenance planning. The project illustrates how AI-supported inspection systems can enhance safety, improve efficiency, and strengthen long-term asset management strategies.

Human-Centered AI: Intelligent Agents and Workforce Productivity

While public discussions about AI are often focussed on automation, a recurring theme throughout the webinar was that the most immediate value of AI in rail lies in augmenting human capabilities rather than replacing them. Railways remain highly complex and safety-critical systems where human expertise, operational judgement, and accountability continue to play a central role. As a result, many operators are exploring how AI can reduce routine tasks, improve access to information, support decision-making, and enable employees to focus on higher-value activities.

Several speakers highlighted the growing emergence of intelligent agents as the next stage of AI development. Unlike traditional software tools that perform specific tasks, intelligent agents can retrieve information, analyse situations, recommend actions, coordinate workflows, and support operational decision-making. This evolution reflects a broader shift from AI as a passive analytical tool towards AI as an active operational assistant.

Case Study: Shanghai Metro – AI-Powered Intelligent Train Crew System

Shanghai Metro showcased its AI+ Intelligent Train Crew System, demonstrating how AI can enhance workforce productivity and support frontline staff in increasingly automated railway environments. The system combines intelligent monitoring, LLM-assisted troubleshooting, fault knowledge vectorisation, automated reasoning, and voice- and text-based interaction capabilities. By integrating operational knowledge, fault databases, and real-time system information, the platform functions as an intelligent assistant that helps train crews and operational staff quickly access information, diagnose problems, and receive decision support during daily operations.

Rather than replacing employees, the system is designed to augment human capabilities by reducing the time required for information retrieval, troubleshooting, and routine administrative tasks. Staff can interact with the platform through natural language queries, enabling faster access to technical knowledge and more consistent responses to operational issues. According to pilot data from Shanghai Metro Line 10, the deployment has generated significant productivity and efficiency gains. Driver productivity index measured internally increased from 0.591 to 0.683, representing an improvement of approximately 15.6%. Mileage statistics and reporting tasks that previously required three to four hours per day can now be completed in around 20 minutes. The operator also reported annual cost savings exceeding RMB 500,000 per line and network-wide savings of more than RMB 10 million per year.

Case Study: TMB Barcelona – DAVANA Digital Ecosystem for Intelligent Operations

DAVANA digital ecosystem as a foundation for data-driven railway operations and decision support. Recognising that large volumes of operational data are generated across different departments and systems every day, TMB developed DAVANA to integrate information from operations, maintenance, customer service, infrastructure management, and business functions into a single digital environment.

©Picture provided by Transports Metropolitans de Barcelona

The platform serves as a central knowledge and analytics hub, enabling data from previously isolated systems to be combined and analysed in real time. By consolidating information across the organisation, DAVANA supports operational monitoring, performance management, maintenance planning, and strategic decision-making. The system transforms raw data into actionable insights that can be accessed by different departments through customised dashboards and analytical tools.

A key principle of the DAVANA initiative is that data alone has limited value unless it can be converted into practical knowledge that supports day-to-day operations. Through advanced analytics, automation, and AI-enabled capabilities, the platform helps staff identify emerging issues, evaluate operational performance, and make more informed decisions. Rather than replacing employees, the system enhances situational awareness and provides decision support, enabling teams to respond more quickly and effectively to operational challenges. The DAVANA ecosystem demonstrates how rail operators can move beyond isolated digital projects towards an integrated knowledge-based operating model.

Conclusion

The webinar demonstrated that artificial intelligence is rapidly evolving from a promising technology into a practical tool for transforming railway operations. Across diverse operational contexts and geographical regions, rail operators are increasingly moving beyond pilot projects towards the deployment of AI solutions that deliver measurable improvements in safety, efficiency, reliability, sustainability, and customer service. From predictive maintenance and digital twins to passenger flow forecasting, intelligent agents, and knowledge-based systems, AI is beginning to create value across the entire rail value chain.

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Several common themes emerged from the discussions. First, the rail industry is shifting from a focus on data collection towards the creation of actionable intelligence. Whether through predictive maintenance systems, passenger flow forecasting, digital twins, or intelligent operational assistants, AI is enabling operators to anticipate problems, optimise resources, and make more informed decisions in real time. The challenge is no longer how to collect data, but how to transform data into operational insights that support better outcomes for passengers, staff, and infrastructure.

Second, successful AI deployment depends on much more than technological capability alone. While advances in large language models, machine learning, computer vision, and intelligent agents are creating new opportunities, long-term success will rely equally on high-quality data, governance frameworks, workforce readiness, organisational change, and industry collaboration. The experiences shared by all experts from the webinars highlighted the growing importance of railway-specific knowledge architectures, digital ecosystems, and collaborative data platforms as foundational enablers of AI applications. As railway systems become increasingly complex, the ability to organise, share, and continuously enrich operational knowledge may become a key source of competitive advantage.

Third, the webinar reinforced that AI should be viewed as a tool for augmenting rather than replacing human expertise. From intelligent agents supporting train crews to decision-support platforms assisting operational controllers and maintenance teams, the most successful applications are those that combine the speed and analytical capabilities of AI with the experience, judgement, and accountability of railway professionals. Human-centred AI is therefore likely to remain a defining principle for the sector, particularly in safety-critical environments where trust, transparency, and accountability are essential.

The discussions also highlighted the importance of collaboration. The development of common standards, shared datasets, evaluation frameworks, and industry knowledge bases will be essential to accelerate innovation while ensuring interoperability, trust, and scalability. Initiatives such as the Urban Rail Transit Artificial Intelligence Joint Research Consortium, UITP's Artificial Intelligence Working Group, and other collaborative research platforms demonstrate how operators, research institutions, industry associations, and technology providers can work together to accelerate innovation while reducing duplication of effort.

Looking ahead, the future of railway AI will extend beyond individual applications towards integrated intelligent rail ecosystems where data, knowledge, assets, operations, and people are connected through digital platforms. Key priorities for the industry include expanding high-quality railway datasets, strengthening governance and cybersecurity frameworks, developing AI-ready workforces, establishing common standards, and ensuring that AI systems remain transparent, reliable, and aligned with operational needs. Organisations that successfully combine technological innovation with strong governance, workforce development, and knowledge management will be best positioned to realise the full benefits of AI and deliver safer, more efficient, resilient, and passenger-focused rail systems.

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