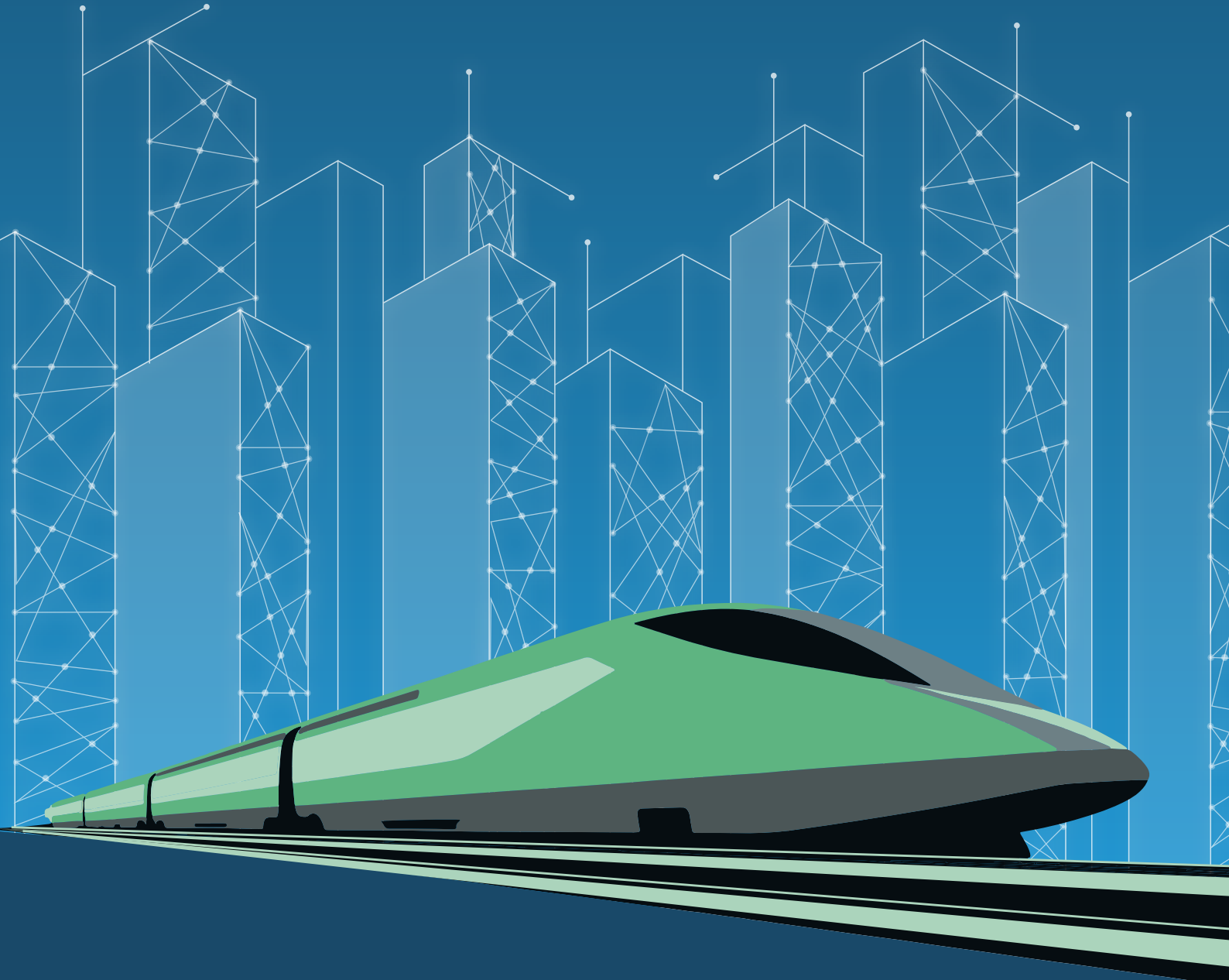


The journey toward AI-enabled railway companies

UIC



February 2024



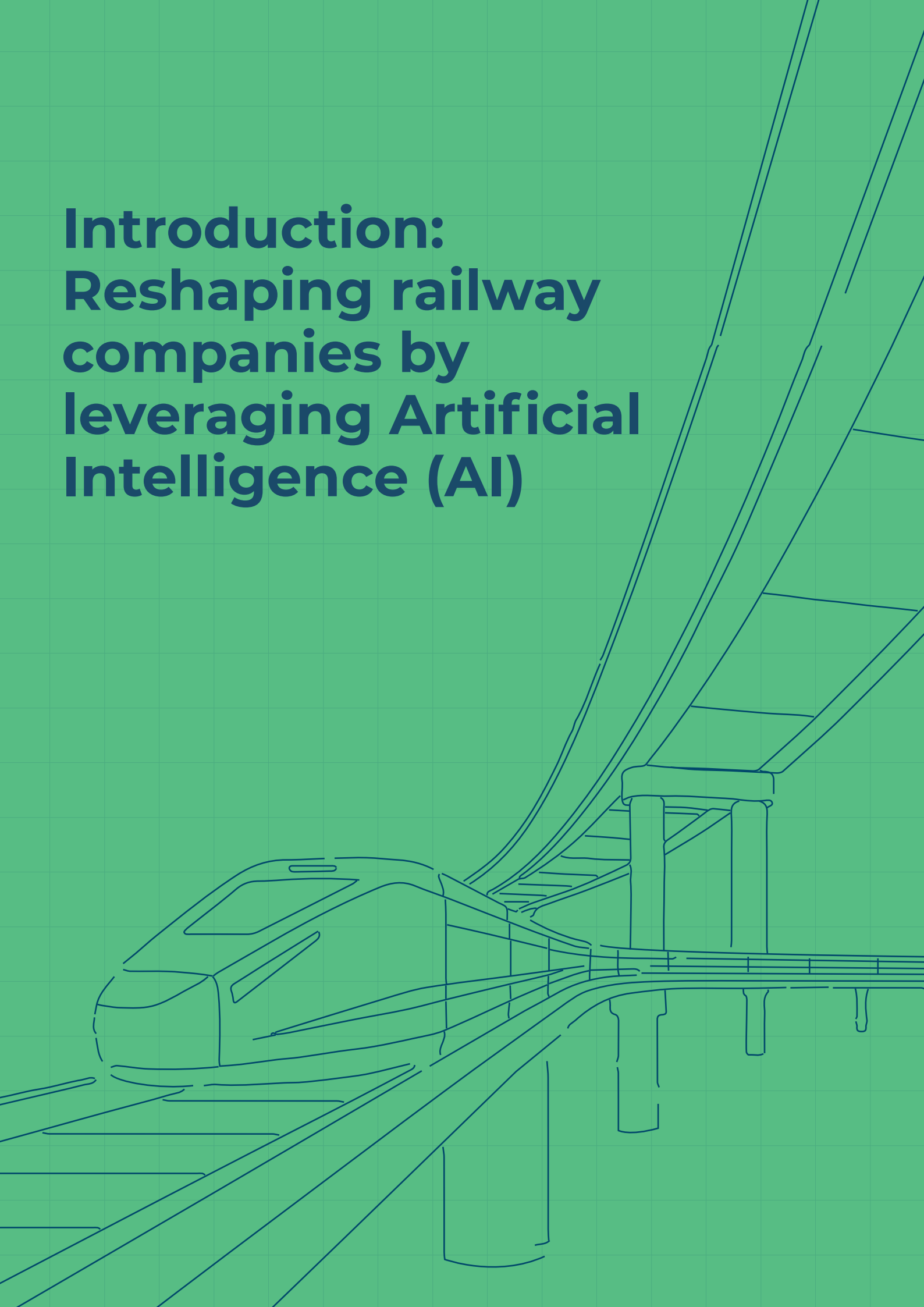
INTERNATIONAL UNION
OF RAILWAYS

This report is a result of a collaborative effort between the UIC and McKinsey & Company. It has been led by Marc Guigon, passenger director at UIC; Philippe Lorand, senior advisor at UIC; Michele Gesualdi, project manager and advisor at UIC; and Michel Leboeuf, consultant for UIC. We would like to thank the members of the Intercity and High-Speed Committee and McKinsey & Company for their support and contribution to the research, with special thanks to Leo Melnikov, Raphaëlle Chapuis, and Marwan Dupuis.

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Introduction: Reshaping railway companies by leveraging Artificial Intelligence (AI)



Today, railway companies have the potential, and the opportunity, to harness the power of rapidly evolving artificial intelligence (AI) technologies to improve the ways they plan and deliver services.

AI capabilities have accelerated due to three forces over the past few decades: tumbling costs of data storage and processing, rapidly expanding data availability, and improved data storage and modelling techniques. Generative AI (gen AI) in particular has been building momentum since 2017 and hit an inflection point at the end of 2022 when applications such as ChatGPT became publicly available.

It's no surprise then that AI adoption has surged across industries. In 2023, McKinsey's annual global survey on the state of AI revealed that one-third of respondents said their organizations regularly use gen AI in at least one business function, and 60 percent of organizations that have adopted AI are also using gen AI. Additionally, 40 percent of those reporting AI adoption at their organizations say their companies expect to invest more in AI because of advances in gen AI.¹

Gen AI can be thought of as a catalyst opportunity for railway companies to consider the application of AI technologies, including advanced analytics. Gen AI is important beyond specific use cases because of its ability to rapidly convert massive amounts of unstructured data into structured datasets. This is particularly powerful for railway companies

with copious amounts of physical documentation and in cases where data accessibility has been a roadblock for wider adoption of AI. Gen AI also represents the opportunity to accelerate the development of digital solutions, including AI, in a context where it is challenging to acquire and retain digital talent.

This report examines the adoption of AI and gen AI in the rail industry and identifies use cases that have been deployed, or have the potential to be deployed, at scale. Robotics has been excluded from the scope of study which focuses on the application of machine learning and deep learning.

Historically, the rail industry has often been slow to adopt technology and digital solutions. Railway companies that contributed to the research for this report indicated that this hesitancy may have been driven by many reasons, including:

- **Limited data availability and quality**, including siloed data infrastructure that can complicate building solutions at scale
- **Regulatory considerations**, including who owns data, what can be done with it, and what that process would look like
- **Lack of standardization and low levels of digital maturity** that make it hard to capture economies of scale with digital solutions
- **Concerns over skills loss**, especially where changes are required to support AI-enabled ways of working

¹ "The state of AI in 2023: Generative AI's breakout year," McKinsey, August 1, 2023.

Recent evolution in digital and analytics could enable accelerated AI adoption. Areas of advancement include an increase in equipment that is connected by design (e.g., new rolling stock) and accelerated time-to-market for data and analytics applications (e.g., using low-code/no-code development platforms).

AI has the power to significantly transform the way railway companies plan and deliver services across the value chain. Industry efforts have focused on use cases that target key business priorities, such as on-time performance, passenger experience, safety, and operational performance. Railway companies could also explore new use cases that are emerging alongside rapidly evolving technology, for example, leveraging AI across support functions like HR, legal, and finance.

Delivering on the promise of AI is not easy. Most of the railway companies surveyed or interviewed for this report have not deployed use cases at scale yet. Successful deployments were characterized by investment in dedicated capabilities and talent, and the definition of clear objectives—aligned with business priorities—which helped focus investment on a few game-changing use cases. While transformative, AI can bring a new set of risks that should be addressed from the beginning. Accordingly, organizations looking to adopt AI would do well to prioritize strong data governance and robust cyber security.

If this seems daunting it is worth remembering that railway companies do not need to act alone. They can leverage support from a robust ecosystem including technology providers, the academic community, and original equipment manufacturer (OEM) partners to realize AI's potential.

What are AI and generative AI?

Artificial intelligence (AI) refers to a machine's capacity to execute cognitive functions associated with the human mind including perceiving, reasoning, learning, problem solving, interacting with an environment, and exercising creativity.¹ AI is a broad term that covers topics including natural language processing, computer vision, machine learning, and deep learning. Daily uses for AI include unveiling insights, predicting outcomes, simulating strategies, and providing optimal

recommendations. AI can be differentiated from other data and analytics approaches through its ability to learn patterns directly from data.

Generative AI (gen AI) is a system that takes unstructured inputs and produces unstructured outputs. Language is one type of unstructured data. But others include images, video, product designs, even molecular models. Its multifunctional capabilities encompass classification, editing, summarizing, synthesis, and the generation of new content.

¹ "An executive's guide to AI," McKinsey, 2020.

Research methodology



This research was conducted in the context of the OPTIN project PAS689 at the request of the members of the Intercity and High-Speed Committee to explore the use and development of AI in the rail industry focused on high-speed activities. It should be noted that it is impossible to isolate the role of AI in high-speed rail from the full range of rail activities as AI encompasses and enhances all rail activities and businesses. Most of the use cases and observations in this report, therefore, can be applicable to all activities of passenger rail. While the focus is on passenger rail, the principles and some use cases could apply to freight rail, too. This study was led by the International Union of Railways (UIC) in collaboration with McKinsey & Company.

The research focused on collating AI best practices from leading railway companies and OEMs. This included identifying investments in domains and use cases, assessing the value at stake, and determining the main challenges to adoption and the key capabilities required to accelerate implementation. Some gen AI use cases were noted in the research and interviews as part of the investigation into AI. Gen AI was not defined as the preliminary focus of the study, and given the maturity of the gen AI use cases at that time, most of the gen AI use cases discussed in interviews are not industry specific.

The conclusions in this report are based upon:

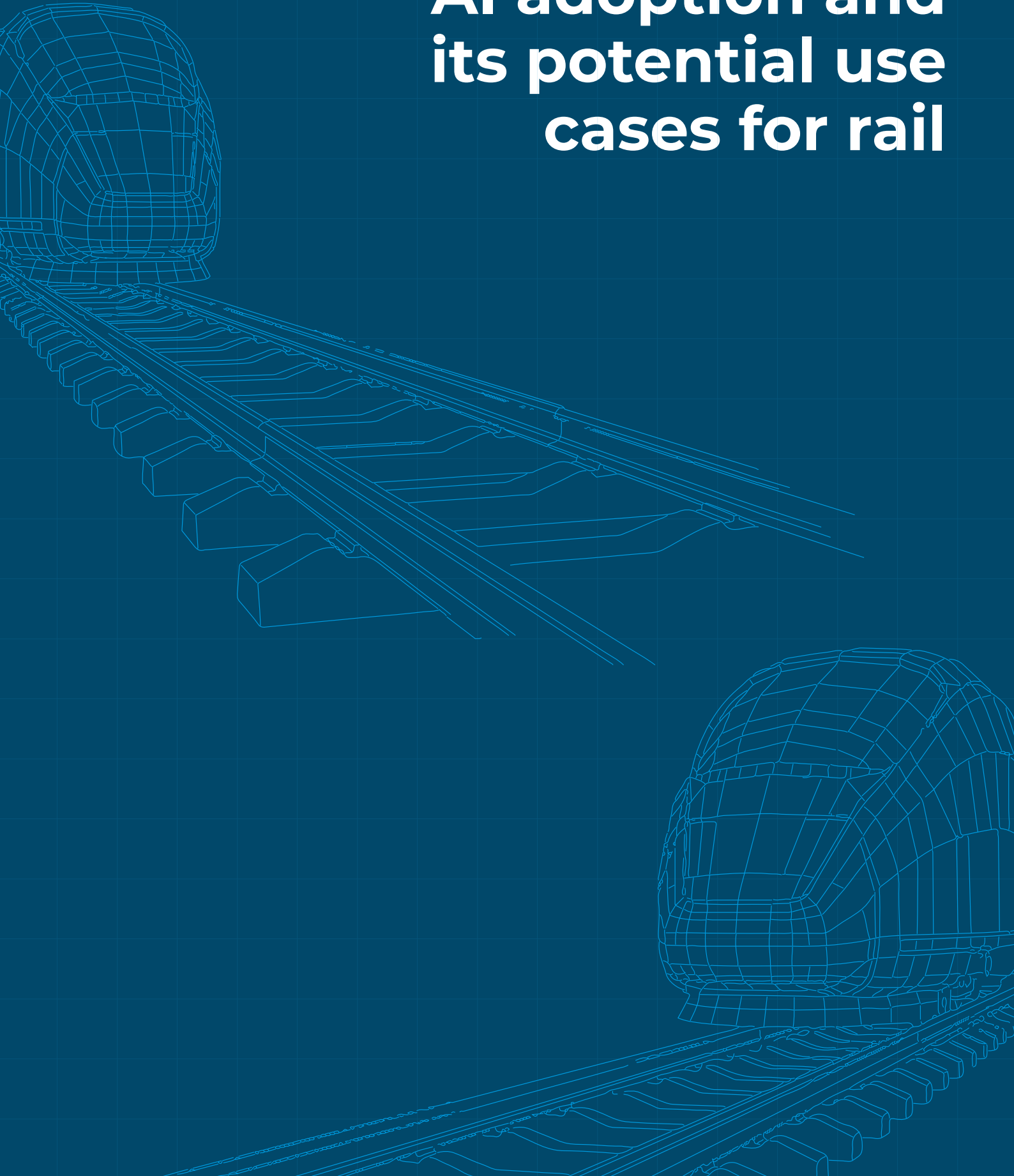
- Analysis of various railway companies' AI implementations, based on public data, annual reports, and company presentations
- Analytical research covering AI and gen AI's potential for the global economy
- A survey of 11 railway companies across Europe and Asia, conducted between June and November 2023
- Deep-dive interviews with 15 selected leading railway companies and OEM vendors, worldwide, held between June and November 2023
- UIC reports, including "Artificial intelligence, case of the railway sector: State of play and perspectives," UIC, March 2021

The research reviewed the following aspects of how railway companies have applied AI:

- Use cases implemented, and the total size of the impact
- Level of maturity of different use cases across railway companies
- The role of the ecosystem (OEMs, system integrators, software providers) in AI implementation

The report identifies AI use cases that have been deployed, or have the potential to be deployed, and examines how AI adoption could add value across the rail sector.

AI adoption and its potential use cases for rail



To understand industry-wide potential for AI adoption, the research for this report began with a review of many available AI and gen AI applications that railway companies could implement or have already begun to implement. Through interviews and analysis of railway materials, more than 100

AI use cases were identified across all areas of business activities: railway undertakings, infrastructure management, passenger experience, and support functions. Exhibit 1 summarizes the key areas of potential for railway companies looking to leverage AI.

Exhibit 1

AI has potential to support a range of business activities, across the rail value chain

Group ¹	Description	Domains ²
1 Railway undertakings	Activities that are directly and indirectly related to delivering the final railway product (ie, the travel experience)	<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">1. Operations and crew scheduling and planning</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">2. Crew training</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">3. Onboard operations and services</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">4. Train station related operations</div> </div>
		<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">5. Irregular & operations</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">6. Safety</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">7. Rolling stock maintenance</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">8. Rolling stock procurement and inventory management</div> </div>
2 Infrastructure management	Activities that are directly and indirectly related to the infrastructure needed to deliver the final railway product	<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">9. Network planning & optimization</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">10. Network construction & investment³</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">11. Network maintenance</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">12. Network procurement & inventory management</div> </div>
		<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">13. Network slot allocation and traffic management</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">14. Stakeholder & management</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">15. Rail safety</div> </div>
3 Passenger experience	Customer-facing activities related to the operations of the railway company	<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">16. Marketing and pricing</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">17. Booking and ticketing services</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">18. Customer railway journey & passenger information</div> <div style="border: 1px solid green; border-radius: 10px; padding: 5px; width: 20%;">19. In-station additional revenue</div> </div>
		<div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">20. Customer care</div>
4 Support functions	Essential non-operational activities	<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">21. HR</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">22. Finance</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; width: 20%;">23. IT</div> </div>

- Domains with high potential for innovation and digitization
- Use cases discussed during interviews and being developed

1. Corporate functions such as finance, IT, people and culture, and real estate management are other domains, and are deprioritized here.
 2. Autonomous trains and Automatic Train Operation technologies are also deprioritized here.
 3. Rail infrastructure companies outsource the building of infrastructure to contractors that were not included in the survey. However, AI can still be leveraged for design and construction, such as in the reduction of CO₂ emissions.

Industry efforts are focused on AI use cases across several domains all of which are directly tied to four KPIs:

- **On-time performance** is a key driver of ridership, as well as a source of revenues and penalties in contracted services, and is supported through scheduling, capacity management, real-time operations, and maintenance
- **Customer engagement** determines passenger experience before and during travel, driving a railway company's ability to compete with other methods of transportation
- **Safety** is always prioritized by railway companies—use cases around maintenance and passenger flow management have a direct impact on safety
- **Operational performance** can be further enhanced by automation and the adoption of gen AI; use cases such as a maintenance co-pilot, faster document access, understanding complex documentation, training, and onboarding are examples of how AI is changing service delivery

These KPIs are aligned with the top four criteria that passengers across geographies use when choosing their mode of transport. UIC's 2022 report, *Boosting passenger preference for rail* identified these as price, safety, reliability, and convenience.

While the range of potential applications of AI for railway companies is expansive, for most companies interviewed, AI is only an emerging trend—few companies have implemented AI at scale with success. The interviews revealed that around 25 percent of companies have implemented multiple use cases at scale, while others range from early development to pilot projects (Exhibit 2). This demonstrates that there is significant potential for AI applications, and, with time, adoption will likely increase.

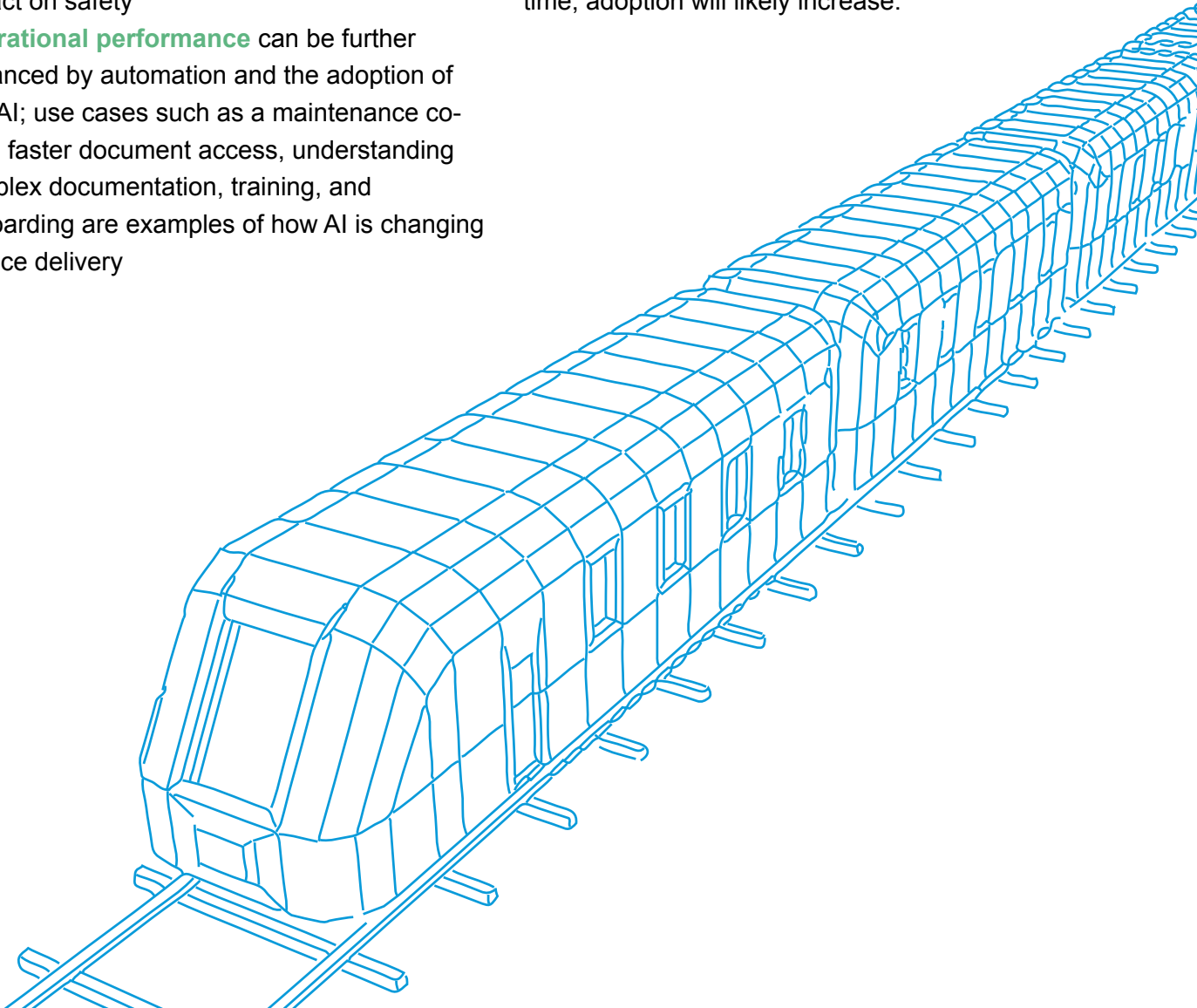
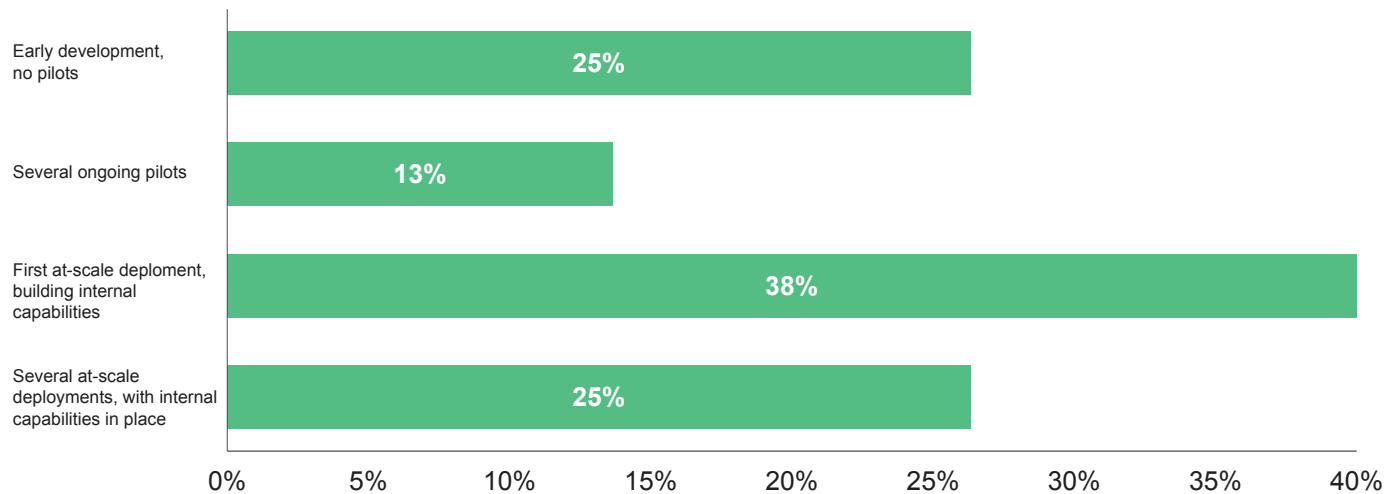


Exhibit 2

Railway companies are at different stages of engaging with AI

The proportion of companies engaging with AI, and the level of deployment



Source: UIC survey of 11 railway companies across Europe and Asia, June to November 2023

There are several railway companies with dedicated strategies and the required capabilities to implement AI use cases at scale. These companies have several attributes in common. They have:

- Dedicated research and development teams or partnerships with universities to this effort
- Established cultures of innovation and investment in partnerships to develop new technology
- Developed capabilities to implement use cases
- Taken business-driven approaches, rather than solely relying on IT departments to drive development

While there are hundreds of potential use cases, interviews revealed that industry AI efforts have been tailored to building solutions for around 20 specific use cases, particularly those that target the aforementioned KPIs. Some of these use cases have already been worked on and developed by railway companies for several years, leveraging various data and analytics methods. Over time, and through continuous improvement, these use cases have evolved to use AI algorithms over other data analytics methods.

Overall, use cases vary in terms of the maturity of the technology and their adoption by the rail industry. They are spread across the following four stages of maturity, from most to least mature:

- 1 **At-scale deployment.** This category includes use cases that are in the process of being fully deployed in the field as well as those already deployed and capturing impact. These are mature use cases from a technology standpoint and have already been refined and improved several times. Overall, six use cases were identified as having reached this level of maturity.
- 2 **Pilot stage.** These use cases have already shown ability to drive impact through proofs of concept and are currently being implemented with a subset of users for iterative improvement before being deployed at scale; six such use cases were identified.

3 **Proof of concept (PoC).** These use cases (five in total) are currently being tested for their ability to deliver value.

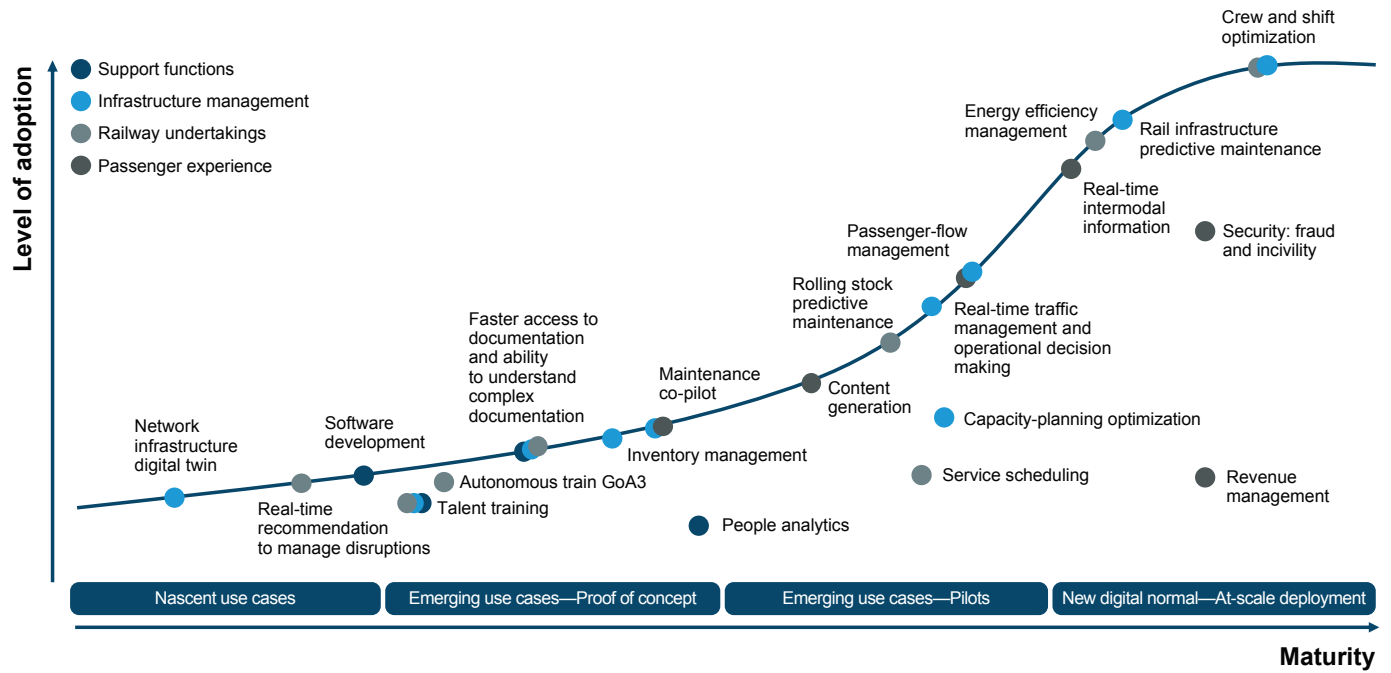
4 **Nascent.** The emergence of new technological capabilities, including gen AI and digital twins, is expanding opportunities for railway use cases while accelerating the possibilities of existing use cases. Railway companies are in the early stages of identifying and exploring these use cases to meet their needs.

Interviews also helped to identify the level of adoption of the use case. Exhibit 3 plots the most common use cases in terms of maturity and adoption. Use cases higher up on the curve are likely to have been adopted by all the major railway companies. Use cases lower down have been adopted by fewer companies.

In some instances, use cases are identified as being mature but not yet deployed at scale—often when the use case was pioneered in an adjacent industry that helped mature the technology. Take, for example, revenue management systems used in the airline industry. The technology and use case are mature, but the level of adoption in rail is relatively low as reservation systems work differently in each industry.

Exhibit 3

Research identified roughly 20 AI use cases, at different maturity levels, being applied by railways



Source: UIC survey of 11 railway companies across Europe and Asia, and 15 interviews with railway companies and OEM vendors, worldwide, June to November 2023

The rest of this chapter examines AI and gen AI use cases, across stages of maturity, according to the four groups of business activities: railway undertakings; infrastructure management; passenger experience; and support functions.

Railway undertakings

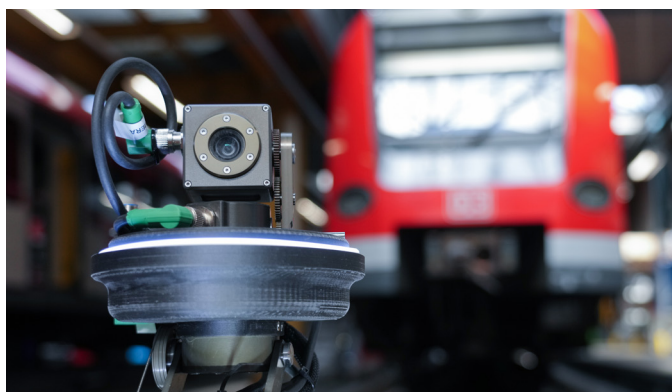
Railway undertakings are companies or entities responsible for operating and managing railway services, including the provision of train transportation. The most mature use cases focus on shift planning and energy efficiency while other uses cases include rolling stock predictive maintenance, service scheduling, autonomous trains, and real-time disruption management.

Use cases deployed at scale

Crew and shift optimization: Around 40 percent of railway companies interviewed have adopted AI solutions to optimize crew planning and shift planning. This allows them to generate staffing schedules that allocate personnel effectively for coverage while also controlling for employee experience (such as employees’ working-hour preferences) leading to a schedule optimized for safety and resilience. This use case has been deployed across all business units that work in shifts including train drivers, onboard staff, and maintenance operators. In some instances, adoption has generated a 10 to 15 percent optimization in shifts as well as reductions in labor costs.

Energy efficiency management: AI-based platforms to optimize energy consumption already exist at scale—for example, for energy grid management or building energy management—but have only started to scale for railway companies in recent years. These technologies focus on reducing energy consumption by optimizing routing, maintenance, and operation of trains. For example, VIA Rail Canada tested and implemented EcoRail, an AI-enabled software that offers driving recommendations to locomotive engineers (for example, when to accelerate or brake).² The SNCF³ and Deutsche Bahn⁴ both announced similar eco drive systems in an effort to further reduce energy consumption. The resulting decrease in energy consumption for such systems is expected to be between 10 and 15 percent.⁵

Use cases in pilot phase



Digital maintenance in Deutsche Bahn Munich Steinhausen S-Bahn plant

Rolling stock predictive maintenance: Rolling stock reliability is a key driver for overall service reliability. An optimized maintenance cycle can also achieve higher passenger numbers while minimizing the number of required cars. Half of

the railway companies interviewed use predictive maintenance for rolling stock. The focus has been on assets with the highest criticality and highest probability of failure, while the greatest pain point has been access to relevant data. The arrival of newer rolling stock—such as assets that are connected by design—is gradually helping railway companies to overcome this challenge. Railway interviews confirmed UIC research that depending on the type of rolling stock and the type of component, predictive maintenance has enabled a 15 percent increase in reliability, a 20 percent reduction in maintenance costs, and a 30 percent reduction in train breakdowns. In Germany, Deutsche Bahn is testing a tool on regional trains to forecast wheelset maintenance in an effort to support better maintained, higher quality, and safer vehicles for passengers.⁶

Service scheduling: Around 30 percent of railway companies interviewed say they are pursuing pilots to integrate optimization algorithms that support service scheduling. These algorithms assess customer demand, determine priority paths and schedules, and run scenarios to define the optimal output within constraints such as station capacity, workforce availability, and profitability. Some railway companies are adding their own in-house solutions and additional layers of intelligence on top of commercial products. For example, Deutsche Bahn is using AI and big data to calculate train arrivals and departures, drawing on real time and historical data (such as timetables or network signaling systems) to predict movements. This enables the railway to intervene and share updates directly with passengers.⁷

² "VIA Rail Canada extends AI pilot for emissions reduction," *Railway Technology*, November 25, 2022.

³ "Our commitment to energy sobriety," National Company of the French Railways (Société Nationale des Chemins de fer Français) press release, December 8, 2022.

⁴ "How train drivers save energy," Deutsche Bahn, accessed December 2023.

⁵ "VIA Rail Canada extends AI pilot," November 25, 2022.

⁶ "Artificial Intelligence at DB," Deutsche Bahn, accessed December 2023.

⁷ Ibid.

This approach can improve scheduling precision, capacity utilization, on-time service, and customer experiences.

Use cases in PoC

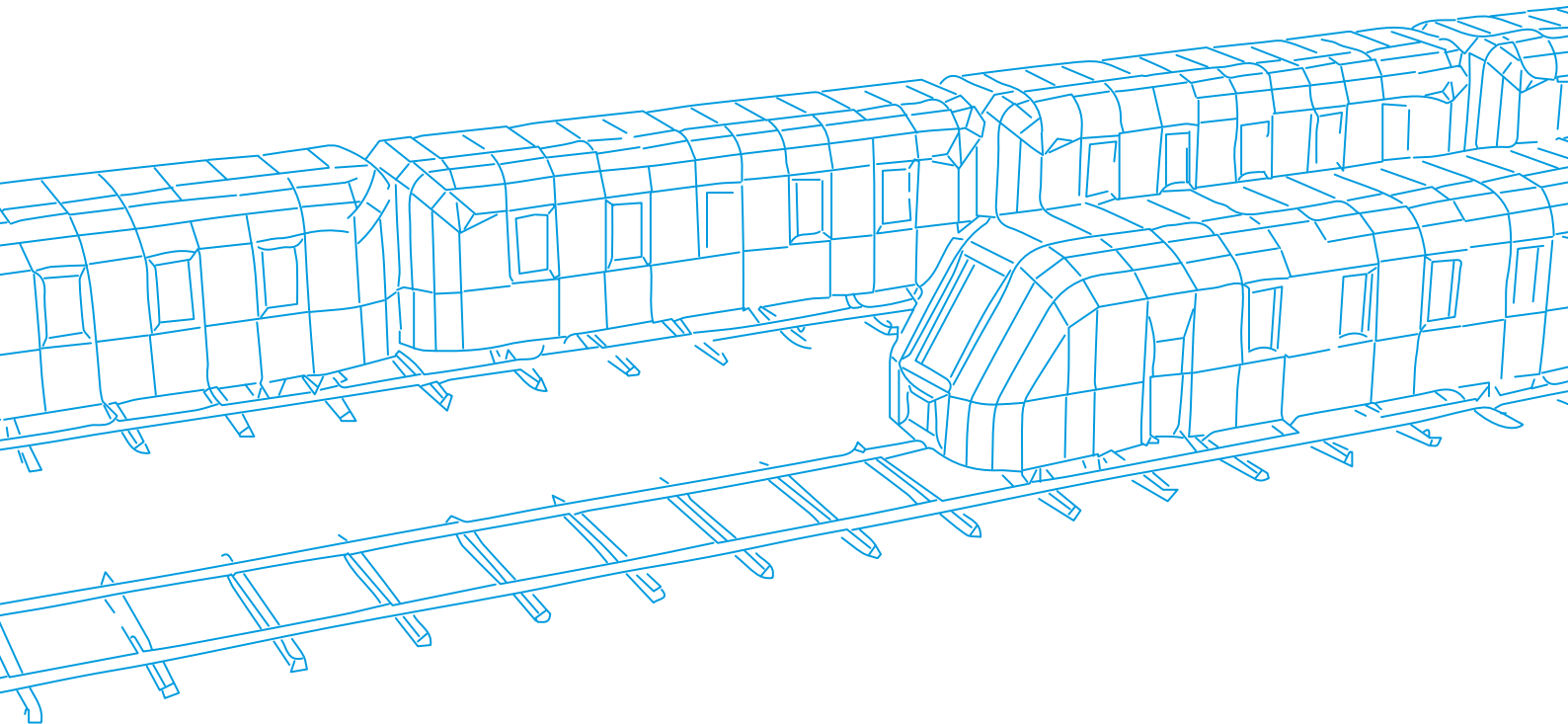
Autonomous trains, specifically GoA3⁸:

Several railway companies (20 percent of those interviewed) are exploring the potential of semi-autonomous and driverless trains through PoCs to automate train processes and transform railway systems. These GoA3 trains are intended to improve capacity and efficiency, driving a 30 percent increase in passenger capacity, a 30 to 45 percent reduction in energy consumption, as well as reductions in labor costs. In 2019, China launched the world's first fully autonomous high-

speed railway from Beijing to Zhangjiakou, with a top speed of 350 kph. This advance played a vital role in connecting Beijing to the suburbs during the 2022 Winter Olympics.⁹

Nascent use cases

Real-time recommendations for managing disruptions: 10 percent of railway companies interviewed are pursuing AI-powered digital twins of real-time operations to accommodate irregular operations and improve customer experiences. This solution could drive faster and stronger decision making during periods of disruption, thereby potentially minimizing the impact on cost, passenger experience, and employee experience.



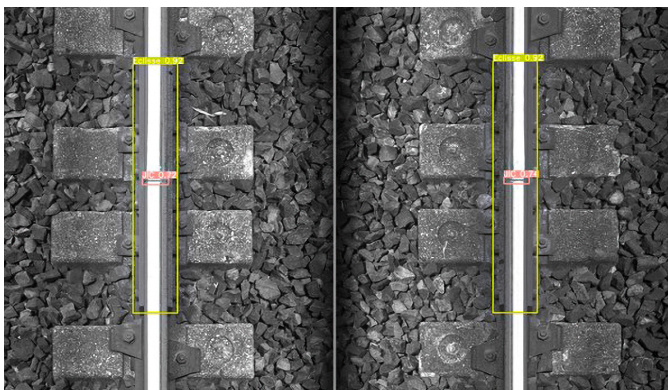
⁸ Grade of Automation (GoA) level 3 and corresponds to level 3 and level 4 of automated driving according to the Society of Automotive Engineers (SAE).

⁹ "The Beijing-Zhangjiakou high-speed railway launched its 350km/h smart carriage yesterday," Xinhua News Agency, December 31, 2019.

Infrastructure management

In the context of the railway industry, infrastructure management encompasses planning, operation, and maintenance of the physical and organizational components of rail networks, including tracks, stations, and signaling systems, to ensure efficient and sustainable railway operations. At-scale use cases are focused on predictive maintenance for rail infrastructure with other use cases spanning capacity planning, real-time traffic management, inventory management, maintenance co-pilots, and network infrastructure digital twins.

Use cases deployed at scale



SNCF assesses rail track condition with an automated image analytics system AIDO that uses image streams from track inspection wagons

Crew and shift optimization: As for railway undertakings, better crew planning and shift planning has helped to generate the optimal schedule for safety and resilience.

Rail infrastructure predictive maintenance:

All the major infrastructure managers interviewed are using predictive maintenance to prioritize and schedule maintenance work for assets with the highest criticality and highest probability of failure. The use case has been deployed over a long period of time and often relies on trains specifically equipped to measure tracks and detect any sign of upcoming failure. There are several levels of maturity, with more mature solutions leveraging both internal and external data sources to predict and identify the most optimal cycle (for example, taking into account the weather conditions when defining maintenance frequency for interlockings). In Switzerland, Swiss Federal Railways is automating maintenance inspections by using AI to review photographs from a specialty train with cameras to spot any potential rail defects.¹⁰ In Austria, ÖBB is using data from internal sources, as well as lidar data gathered by maintenance vehicles, to better monitor the areas surrounding the tracks, so as to spot trees that may become dangerous, for example.¹¹ It is UIC's observation that, typically, predictive maintenance for rail infrastructure can drive a 15 to 25 percent reduction in unplanned downtime, a 15 to 30 percent reduction in maintenance costs, a 100 percent (or more) increase in failure-capture capacity, and a 20 percent reduction in delays per service— all supporting on-time performance.

¹⁰ Peter Tsankov, "SBB adopts AI to improve railway maintenance," *Medium*, March 3, 2021.

¹¹ "From data to predictive maintenance at ÖBB," *Railtech.com*, August 17, 2021.

Use cases in pilot phase

Passenger flow management: Effective passenger flow plays a crucial role in enhancing railway station management and safety. AI-based systems can be used to analyze passenger movement patterns, predict peak travel times, and dynamically adjust staffing or direct passengers to less crowded areas in real time. These systems may use sensors, surveillance cameras, and machine learning algorithms to optimize passenger flow, reduce bottlenecks, and enhance overall station security. This improves the overall passenger experience and contributes significantly to the overall security and operational efficiency of the railway station.

Capacity planning optimization: Around 25 percent of railway companies interviewed are working on increasing their network capacity and solving for the most favorable and robust schedule by optimizing capacity planning. Infrastructure managers are leveraging deep learning to identify the best use of network capacity given operator needs, maintenance needs, and external factors. In Germany, Deutsche Bahn uses AI-powered data visualization called “Peak Spotting” that can identify upcoming capacity utilization peaks on long-distance trains and at stations. This supports interventions, such as dispatching high-capacity trains to solve bottlenecks.¹² UIC notes that capacity planning optimization can drive a 7 to 9 percent increase in network capacity.



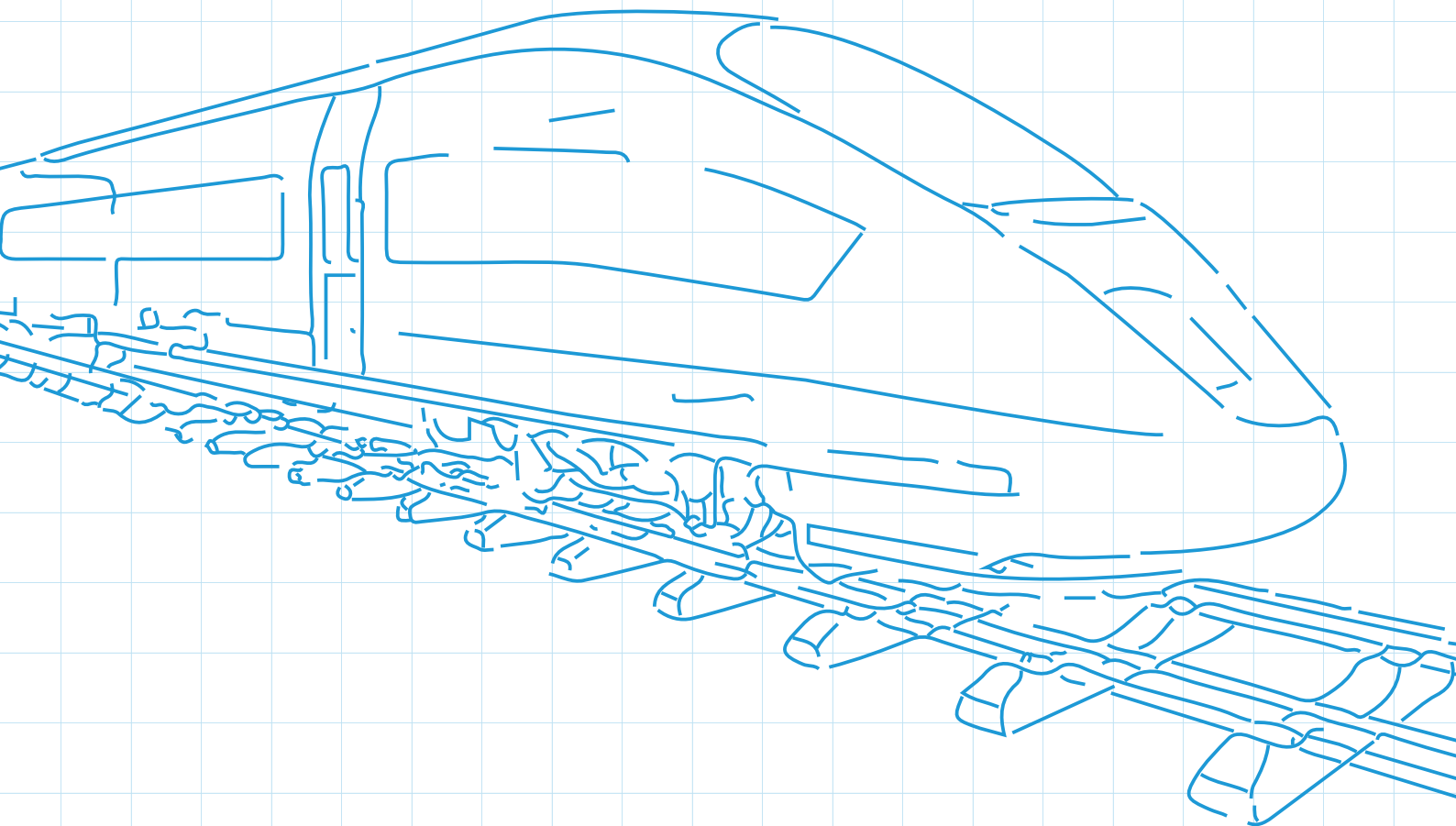
SNCF's cockpit and bidirectional assistant (CAB) project aims to provide decision support when monitoring real-time information and quickly finding a recovery solution in case of an incident

Real-time traffic management: 60 percent of infrastructure managers interviewed say they use AI to determine efficient routes, enabling better coordination and overall reduction in traffic disruptions through centralized and automated traffic management in real time.

This approach can include creating a series of rules to address path conflicts that factor in elements such as the frequency of service. This allows predictive and proactive planning for delays to minimize disruptions and communicate impact with customers, driving increases in network capacity, improving on-time performance, shortening delays, and elevating passenger experience. Deutsche Bahn leverages AI for regional trains for more efficient traffic management during disruptions by flagging issues (such as a delayed departure due to a group boarding a train) and providing options with anticipated outcomes to dispatchers.

¹² “Artificial Intelligence at DB,” Deutsche Bahn, accessed December 2023.

“Around 25 percent of railway companies interviewed are working on increasing their network capacity and solving for the most favorable and robust schedule by optimizing capacity planning.”



AI can also flag potential issues and provide options before they occur. These capabilities reduce waiting times; in one example the railway was able to compensate for an eight-minute delay on one line.¹³ AI technologies are also being used to optimize routes and the cost of transportation for end-to-end intermodal journeys for freight logistics. A similar approach could be replicated for passenger intermodal journeys.

Use cases in PoC

Inventory management: 20 percent of railway companies interviewed reported preliminary interest in integrating advanced analytics and machine learning to forecast demand for inventory and optimize their supply levels accordingly. This is anticipated to improve inventory accuracy, shorten lead times, reduce excess inventory, and boost working capital.

Maintenance co-pilot: A small number of companies interviewed are exploring gen AI's potential for supporting maintenance technicians in the form of a maintenance co-pilot. A maintenance co-pilot can ingest equipment manuals and assist technicians by diagnosing problems quickly and

providing instructions on the technical procedure needed. This support can increase efficiency, decrease costs, and help solve for talent retention or attraction. Beyond the execution of the maintenance itself, gen AI can help prepare and organize the interventions. In Japan, West Japan Railway Co. is using image capturing and AI to determine how many maintenance workers will be needed for snow clearance work.¹⁴

Nascent use cases

Network infrastructure digital twin: Several railway companies interviewed (10 percent) are considering using AI to support the design and construction of infrastructure projects, including regeneration. An AI-powered digital twin can optimize railway design for efficient operations as well as optimizing the actual project construction to combat cost and deadline overruns which are common to infrastructure projects. Based on experiences across industries, it is anticipated that leveraging this use case could drive a 10 to 15 percent saving in capital expenditure through design optimization and reduce project overruns by six to 18 months.

¹³ "Artificial Intelligence at DB," Deutsche Bahn, accessed December 2023.

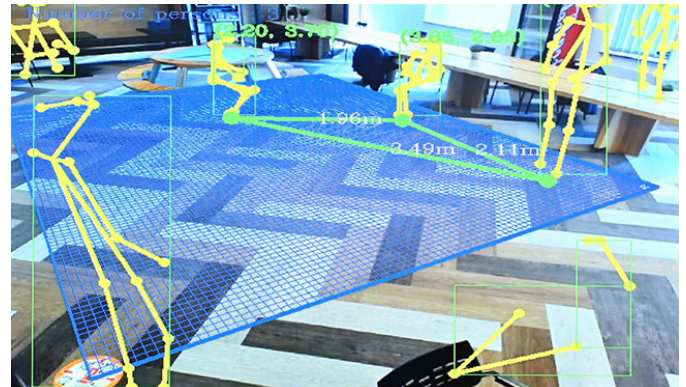
¹⁴ "Japan Railway turning to AI to combat problems with snow," Kyodo News, January 26, 2020.

Passenger experience

Passenger experience in the railway industry refers to the overall satisfaction and comfort of individuals using train services, encompassing aspects such as service quality, convenience, amenities, and customer interactions. At-scale use cases focus on revenue management, security, and real-time intermodal information; other use cases include passenger flow management and content generation.

Use cases deployed at scale

Revenue management: While many railways use rule-based revenue management, advanced AI-based solutions have been implemented by about 5 percent of the railway companies interviewed. One of the prerequisites for adopting a revenue management solution is to have a reservation-based system in place that leverages dynamic pricing based on the origin-destination, time of day or the day of the week, and the level of demand. The approach consists of leveraging advanced algorithms and machine learning to analyze historical demand and sales trends to forecast demand and identify optimized pricing strategies. Models can have more sophistication, such as including benchmarks with competitor prices. For a European railway company, this approach to revenue management drove a 3 to 8 percent increase in revenue as well as an increase in the number of customers by ensuring that pricing is set to match demand.



Infrabel solution for AI-based social distance control, photographer Benjamin Brolet, copyright Infrabel

Security (fraud and incivility prevention):

25 percent of companies interviewed indicated they have pursued the use of artificial vision and predictive algorithms that support security. This use case has been deployed over a long period of time, with an iterative approach to refine algorithms and use cases. For instance, in Belgium in early 2020, Infrabel leveraged such technology to ensure employees were maintaining social distancing and wearing masks to slow the spread of COVID-19.¹⁵ More recent developments have focused on supporting decision making around where and when to deploy security teams to cover the hundreds of network stations and trains most effectively and to intervene before an issue occurs. Railway companies indicated that this approach has driven a 10 percent reduction in security costs, reductions in fraud, increases in ridership, and improvements in customer experience.

¹⁵ Francois Lenoir and Clement Rossignol, "Belgian rail tests sensors to keep workers apart during COVID-19," *Reuters*, May 25, 2020.

Real-time intermodal information: 40 percent of railway companies interviewed report leveraging AI to provide transparency, for instance, by recommending intermodal journeys to passengers including real-time updates to offer a seamless end-to-end journey spanning rail and other transport methods. This approach has driven a 10 to 15 percent increase in customer satisfaction and supports customer engagement, according to the railways interviewed for this report.

Use cases in pilot phase

Passenger flow management: Seamless embarkation and disembarkation are essential parts of passenger experience, and many railway companies are trying to optimize these processes. For example, in France, Thales group introduced its distributed intelligent video analytics (DIVA) system that, in real time, indicates crowd density and guides passengers to avoid crowded places via platform displays.¹⁶ Moreover, predictive modeling of passenger flow can help railway undertakings manage flow through preventive action, especially during peak hours or peak seasons. This can mitigate risks such as overcrowding or overcapacity of the network. Passenger flow management is a key component of safety management in stations.



Deutsche Bahn - Digital Avatar interactive system

Content generation for passengers: 40 percent of railway companies interviewed report using AI to generate personalized passenger communication and provide real-time updates to improve customer experience. In Germany, Deutsche Bahn developed SEMMI, an AI-based interactive voice response system that can interact directly with customers—either as a digital avatar, a voice over the phone, or a physical robot.¹⁷ In the Netherlands, NS uses AI to personalize its marketing activities to reach customers.¹⁸ Content generation for passengers is reported to drive increases in conversion rates, a 5 to 15 percent reduction in marketing costs, increases in ticket sales, and a 15 percent increase in issue resolution rates.

¹⁶ "Thales introduces real-time crowd management solution for railway stations," *Railway Technology*, March 23, 2021.

¹⁷ "Artificial Intelligence at DB," Deutsche Bahn, accessed December 2023.

¹⁸ "Innovations," *Annual report 2022*, Dutch Railways (Nederlandse Spoorwegen), 2022.

Support functions

Support functions include essential nonoperational activities such as HR, finance, communication, IT, and procurement that contribute to the overall efficiency and effectiveness of railway undertakings and infrastructure managers. Most use cases are still nascent or in pilot phases, such as people analytics, talent training, software development, and using gen AI to quickly access and understand complex documentation.

Use cases in pilot phase

People analytics: 25 percent of firms interviewed are pursuing people analytics PoCs using advanced analytics and algorithms to reimagine the talent acquisition pipeline and improve employee development and retention. This is intended to combat industry challenges in workforce diversity and talent attraction through defining common characteristics of successful hires, identifying churn drivers, and determining opportunities for development and advancement. Some railway companies have used this approach to better understand workforce preferences and improve experiences. For example, one company used people analytics to address high churn for drivers.

Talent training: 10 percent of railway companies interviewed are conducting PoCs leveraging gen AI to analyze training effectiveness and develop on-demand personalized training materials to improve employee development.

Faster access and understanding of complex documentation: 40 percent of railway companies interviewed are starting to leverage gen AI to quickly understand and glean insights from complex business documentation such as legal documents, contracts, and manuals. For example, such gen AI use cases can support train drivers, maintenance technicians, customer care agents, and legal teams.

Nascent use cases

Software development: Gen AI can greatly assist in software development by automating various tasks throughout the development process. It can generate code snippets or entire programs, detect and fix bugs, automate testing, suggest code refactoring improvements, provide natural language processing capabilities for understanding documentation and code comments, facilitate collaborative development through intelligent code review assistance, and offer domain-specific assistance tailored to the railway industry. The direct impact of AI on productivity in software engineering encompasses a 20 to 45 percent decrease in annual spending on activities such as generating initial code drafts, code corrections, refactoring, root-cause analysis, and generating new system design.¹⁹ It is important to remember, however, that gen AI should complement human developers rather than replace them, as it accelerates certain tasks and complements human creativity and expertise.

¹⁹ *The economic potential of generative AI: The next productivity frontier*, McKinsey, June 14, 2023.

Using AI: The size of the prize



AI is transforming companies' operating and business models, across industries and around the world. In 2023, McKinsey found that gen AI's impact on productivity could add trillions of dollars in value to the global economy, increasing the impact of all artificial intelligence by 15 to 40 percent. This figure includes between \$2.6 trillion and \$4.4 trillion in gen AI use-case impact alone.²⁰

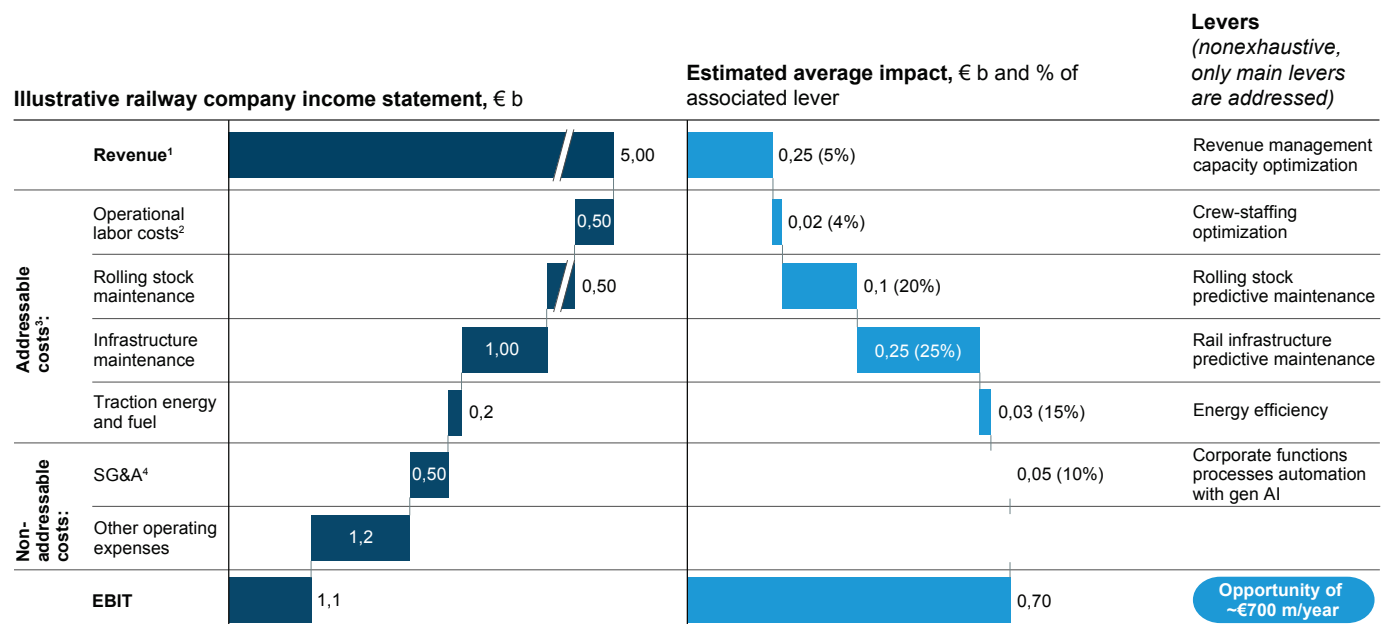
For railway companies, analysis indicates that AI can change the way services are planned and delivered, with the potential to unlock an estimated \$13 billion to \$22 billion in impact a year, globally.

This value represents hundreds of potential AI use cases across rail's value chain, from infrastructure planning to operations and customer engagement, as well as in core corporate functions. AI can support railway companies to better invest, build, plan, and deliver efficient services and meet passenger needs. To illustrate, for a €5 billion rail company, AI could deliver around €700 million a year in value (Exhibit 4).²¹ This includes increasing revenue through revenue management solutions and infrastructure capacity use cases, as well as optimizing labor, maintenance, and corporate costs.

Exhibit 4

AI could present an opportunity of around €700 million a year for a €5 billion company

Based on the cost structure of European railway companies



1. Revenue can be generated by ticket sales or subsidies.
2. These include wages for train drivers, on-board train staff, in-station staff, and traffic-management staff.
3. Infrastructure and rolling stock costs can often be separated if a railway company does not own infrastructure.
4. Selling, general, and administrative expenses.

Source: Annual reports; expert interviews; UIC

²⁰ The economic potential of generative AI: The next productivity frontier, McKinsey, June 14, 2023.

²¹ Different business models exist for the rail industry. While the baseline may vary, the saving percentages are likely to remain similar as use cases can be applied across all types of rail activities.

“AI can support railway companies to better invest, build, plan, and deliver efficient services and meet passenger needs.”

AI adoption has the potential to add value through use cases across the rail sector.

Infrastructure planning and building

AI technology can support smarter infrastructure investment decisions, including:

- Optimizing investment decisions, including identifying what, where, and when to invest to maintain infrastructure in a good state of repair and expand capacity as needed
- Designing projects to foster efficiency, address design questions such as the need for electrification or the type of material to use, and assess scenarios such as single track versus double track, or high-speed versus conventional rail, to identify an optimal design to meet needs while minimizing costs
- Planning construction, developing the optimal building schedule, and proactively identifying risks to meet deadlines and avoid cost overruns. This is particularly useful in the context of regeneration work often delivered while trying to minimize the impact on operations. In the United Kingdom, a

generative scheduling solution was used for a 3.37 km railway viaduct project. The schedule of work had already been developed over three years in earlier phases, but with the AI solution the team was able to generate dozens of schedule options in just minutes. They could also run scenarios to determine efficiency opportunities. By optimizing the sequences, resources, and calendars for the viaduct, the team was able to shorten the construction period by four months which helped to add a buffer to the schedule to minimize the risk of delays.²²

Railway undertakings

AI technology can improve scheduling and real-time operations to deliver more effective service and boost customer engagement.

Scheduling

AI can support railway undertakings and infrastructure managers to plan their operations, including:

- Optimizing infrastructure capacity, with the goal of maximizing commercial service while ensuring enough capacity for maintenance purposes, and meeting regulations and safety guidelines
- Defining the optimal service to match passenger needs while minimizing the need for additional resources
- Optimizing resource and talent schedules, accounting for preferences while minimizing costs

²² Alice Technologies, “Align JV optimizes HS2’s Colne Valley viaduct construction sequencing and resources with ALICE,” blog entry, accessed December 2023.

AI can support rail schedulers by rapidly simulating scenarios, optimizing for several parameters at the same time such as safety, costs, service levels, and customer and employee experience.

Real time operations

During service delivery, AI can support informed decision making, including:

- Proactively recognizing and flagging safety concerns to operators to support effective responses
- Optimizing responses to unforeseen events and identifying the next best course of action to mitigate impact, including how to manage competing priorities
- Adapting schedules and plans in real time to allow for effective management of any consequences of irregular operations

Customer engagement

Railway companies can leverage AI to engage directly with passengers to improve their experience, both when planning trips and taking them. Applications include clear service announcements and personalized communication content. AI could be used in a few primary areas, such as:

- Optimizing pricing for reservation-based systems and tailoring prices to anticipated demand based on historical trends
- Defining the right service to meet the needs of passengers, including accounting for common transfers between routes and options for fast-track trains

- Providing the right information at the right time, whether as personalized marketing before a trip or updates during a trip such as anticipated impact of delays

Maintenance

For rolling stock and rail infrastructure, AI can support more efficient operations alongside maintenance by minimizing disruptions and costs. AI could be leveraged in three primary areas:

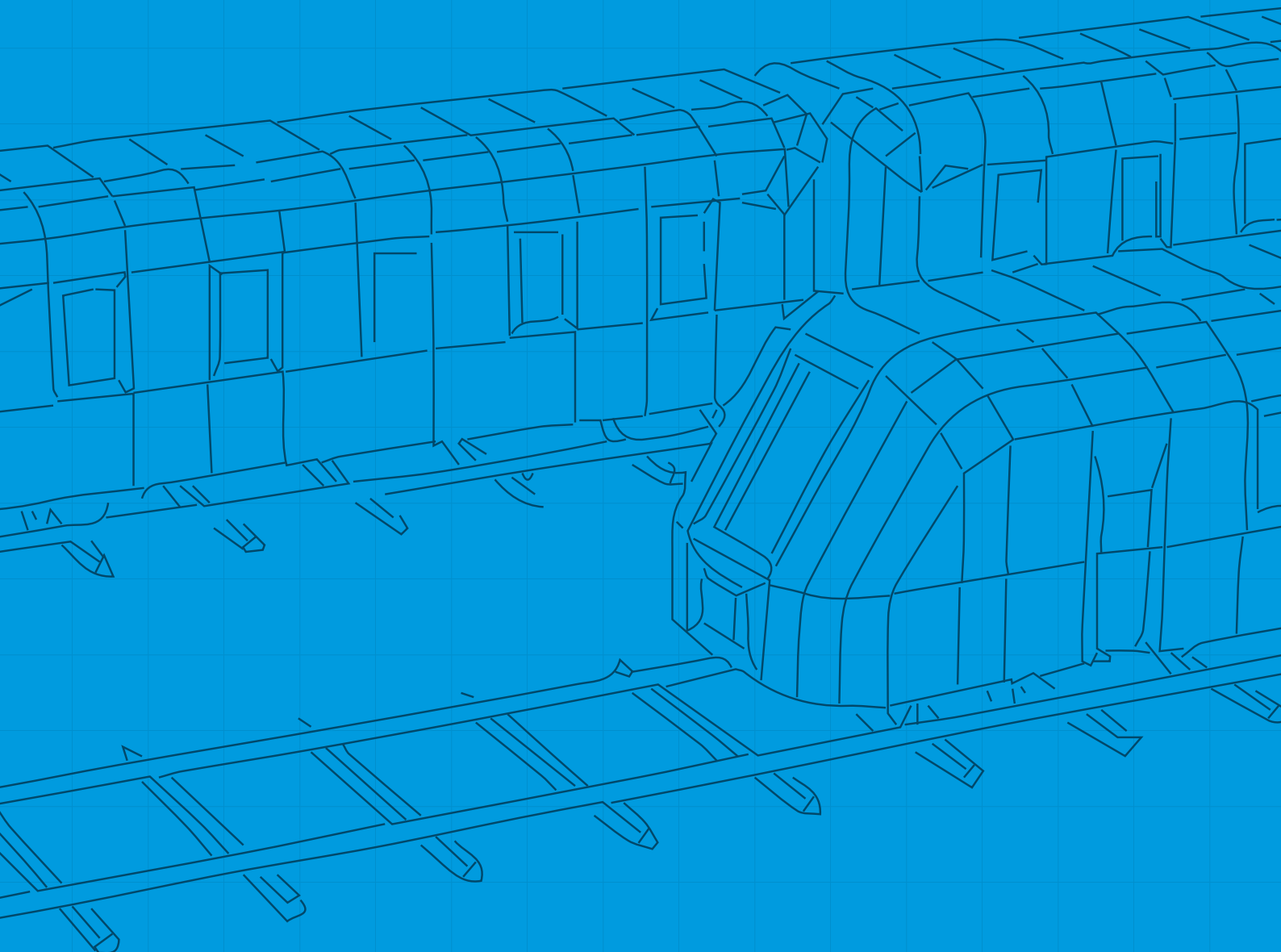
- Defining the optimal maintenance plan, accounting for asset use and its condition
- Defining the optimal maintenance schedule to ensure assets are in a good state of repair while maximizing maintenance capabilities
- Actively supporting maintenance teams to prepare for and deliver maintenance services in a timely manner; gen AI co-pilot use cases are changing the game through the ability to provide contextualized and detailed instructions

Corporate functions

Like other industries, railway corporate functions could benefit from using AI to automate processes, allowing resources to focus on value-added activities. Across HR, legal, and finance, AI can support in a few ways, including:

- Synthesizing large documents to pull out relevant information for employees
- Optimizing talent recruiting, such as through drafting job descriptions and identifying trends in successful hires
- Generating personalized training content for employees to support their development and advancement

Implementation: Recipes for success



Many AI use cases can be successfully designed and deployed at scale within 12 to 18 months to realize value. While the possibilities and value of AI are clear, the journey to become a data-driven company, fully integrating advanced analytics and AI use cases in ways of working and operating can be challenging. In fact, over 60 percent of companies across industries experience a stall at some point on their digital transformation journey.²³

A notable example of AI implementation in the rail industry is China's success with the Beijing–Zhangjiakou intercity railway. Digital technologies and AI were applied from the design stage of the line down to its day-to-day operation (see sidebar,

“Case example: The Beijing–Zhangjiakou intercity railway”). Many railway companies—often relying upon infrastructure, rolling stock, and operations inherited from decades ago—may have challenges to overcome to achieve similar results.

Railway companies can take inspiration from data-driven companies in adjacent industries. What these companies have in common is that they put six building blocks in place that are key to a successful digital and data transformation: strategic roadmap, talent, agile operating model, technology, data, and adoption and scaling.

²³ “How to restart your stalled digital transformation,” McKinsey, March 6, 2020.

Case example: The Beijing–Zhangjiakou intercity railway

Zhangjiakou was chosen to co-host the 2022 Winter Olympics and was also a key hub for connecting the wider region around northeast Beijing. The development of a rapid transit system was necessary to reduce the travel time from the capital to Zhangjiakou.

The intercity railway was launched in December 2019, after less than five years of construction, reducing the transit time between the two cities from just over three hours to 47 minutes, with a top speed of 350 kph.

AI was leveraged end-to-end to develop this high-speed rail line. Key innovations included advanced AI applications in construction (like safety-risk identification and drone-based progress control), equipment (including autonomous high-speed trains and intelligent EMUs), and operations (such as multilanguage ticketing services). These innovations enhanced the Beijing–Zhangjiakou line and set a precedent for further applications on other routes like the Beijing–Xiong’an and Fuzhou–Xiamen high-speed railways.¹

¹ “Beijing-Zhangjiakou high-speed railway opens,” Xinhua News Agency, December 30, 2019; Input collected by UIC from Chinese railway companies.

Challenges faced by railway companies in the journey to become more data-driven

While there has been initial success proving the value of prioritized use cases, railway companies may face challenges in using AI to deliver better and more efficient services to passengers. These challenges span areas including data availability and quality, regulatory considerations, lack of standardization and digital maturity, concerns over skills loss, and difficulty in demonstrating the business case for AI applications.

Data availability and quality

Data is the fuel of any digital and analytics transformation. Most railway companies have three characteristics in common that hold back the full potential of digital and analytics: siloed legacy IT systems, assets that might not be connected by design due to their longer life cycle (for example, 1970s rolling stock was not connected by design), and processes that are still manual. For instance, rolling stock predictive maintenance use cases have been discussed for years but are still not largely deployed. The main challenge is access to the data to be able to run the analysis. New fleets are likely to help unlock more use cases.

Companies need relevant, high-quality data to develop AI use cases. Railway companies can invest in their data architecture, ensure that fit-for-purpose data governance and standards are in place, and work closely within the industry ecosystem to access the data they need. This issue needs to be addressed beyond the scope of

a single railway company. Data sharing between stakeholders and OEMs, for instance, or between infrastructure managers and operators could unlock some use cases.

Regulatory considerations

Globally, regulation around data privacy and data usage for AI is a topic often in the headlines. Regulation is evolving at a fast pace to protect personal data (such as GDPR in Europe)²⁴ to clarify data ownership in a connected world (for example, the EU Data Act passed in 2023)²⁵ or to promote the growth and innovation of AI while prioritizing safeguards and security, including for individual privacy. In the United States, the Biden administration issued the Executive Order on Safe, Secure, and Trustworthy Artificial Intelligence in October 2023²⁶ and the European Union is working on an EU AI act to ensure better conditions for the development and use of this innovative technology.²⁷ In China, the Interim Measures for the Management of Generative Artificial Intelligence Services was established in 2023.²⁸

Given this evolving regulatory landscape, some risk-averse railway companies are likely to act with caution before pursuing the opportunity to develop some use cases. This complexity can explain the slow adoption of some use cases that are mature from a technological standpoint.

Railway companies will need to put robust data governance and security measures in place to ensure data is only used for proper processes and outputs, in line with regulations.

²⁴ "What is the GDPR, the EU's new data protection law?" GDPR.eu, accessed December 2023.

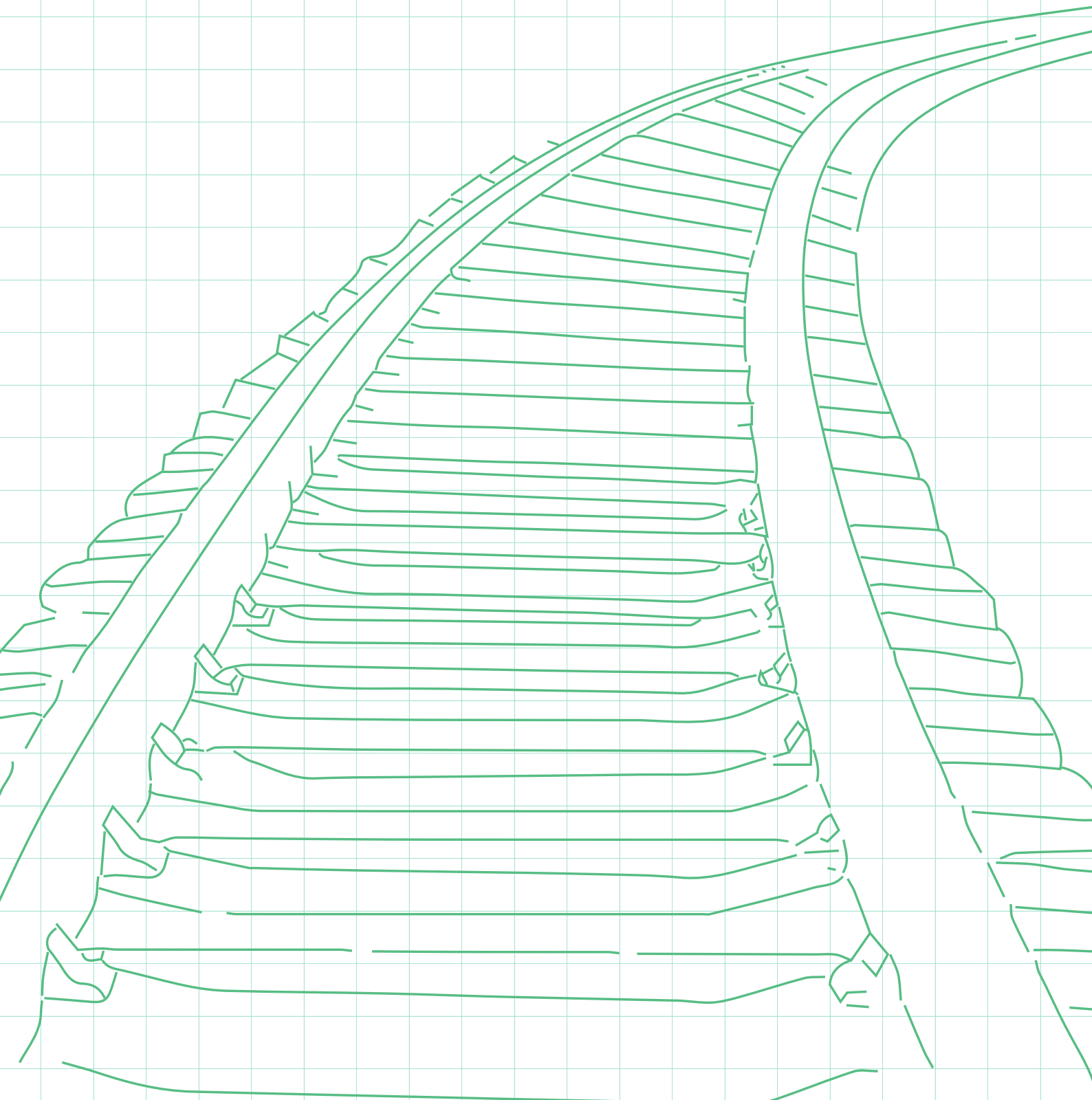
²⁵ Pieter Haeck, "Europe's new data law, explained," *Politico*, June 28, 2023.

²⁶ "Fact sheet: President Biden issues executive order on safe, secure, and trustworthy artificial intelligence," White House press release, October 30, 2023.

²⁷ "EU AI Act: First regulation on artificial intelligence," European Parliament press release, December 19, 2023.

²⁸ "China: Generative AI measures finalized," Library of Congress, July 19, 2023.

“Data is the fuel of any digital and analytics transformation.”



Lack of data standardization

The global railway community (railway companies, authorities, and third-party vendors) currently has limited standardization when it comes to an industry-specific data taxonomy and data collection, preservation, and transmission among parties involved. When it comes to full-scale digital and AI transformation, this lack of data standardization means that companies are having to reinvent the wheel instead of sharing best practices. Consequently, there are uncapped economies of scale and missed opportunities for reuse. As an example, in the airline industry, IATA's New Distribution Capability (NDC) standard can be considered best practice for data transmission. It enhances communication between airlines and travel agents and is open to any third party to implement and use.

Concerns over skills loss

Gen AI can improve productivity across industries. While this will impact some roles more than others, it will likely change ways of working for almost everyone. Research led by McKinsey shows that in the United States, 30 percent of the hours worked today could be automated by 2030.²⁹ Based on these insights, customer service and office support jobs are likely to be more impacted than other functions within railway companies.

In railways, some emerging gen AI use cases are intended to supplement the work of employees and to improve efficiency and passenger

experience. As the existing skilled workforce ages, it represents an opportunity to accelerate the ramp-up of a new workforce. At the same time, concerns have emerged over younger employees not understanding the skills behind solutions if AI is supporting their work. For example, there are worries that a maintenance co-pilot could inadvertently lead to a loss of maintenance skills.

While these use cases support employee experience and enable efficiency, they do not necessarily replace workers themselves. Including human-in-the-loop validation means solutions are overseen and checked by experts. This can also guardrail against the risk of AI providing an incorrect or erroneous answer. Internal processes can limit solution autonomy to ensure operators continue to drive decision making. These new ways of working require training and upskilling to ensure users are engaging with systems successfully.

Risk-averse culture

The rise and acceleration of gen AI comes with risks, including interpretability, privacy issues, malicious use, and unfairness due to bias. Although not alone in this position, railway companies are generally risk averse when it comes to technology.

This reinforces the need to set up the right governance from the beginning, including new roles such as risk and compliance related to the use of data, and to upskill and inform the workforce about the risks of AI.

²⁹ *Generative AI and the future of work in America*, McKinsey Global Institute, July 26, 2023.

Difficulty in demonstrating the business case and need for change

Proving the value of AI use cases, and measuring concrete impact, can be difficult as technical solutions often necessitate large process changes. This is complicated by the fact that railway companies are often large organizations that require time to roll out changes.

Given this, it is important that KPIs are put in place to ensure impact is being accurately measured and communicated to build support for solutions.

Quick wins and momentum building can aid the beginning of large transitions, overcome resistance to change, and support the longer journey.

Six components that can help to implement AI at scale

Organizations interested in harnessing the power of AI, and those continuing to innovate with AI at an enterprise level, can focus their efforts on six key components (Exhibit 5).

Exhibit 5

Railways can focus on getting six elements right to unlock the power of AI at scale

1. Strategic roadmap

Strategic decisions: Identify and prioritize domains and use cases addressing the most important value pools first.

Core elements: Define the vision and value at stake, the future state vision, and the roadmap for the journey, including funding, resourcing, and vendor commitments.

2. AI-specific roles and skills

Strategic decisions: Define which roles should be sourced internally, externally, or through partners and vendors.

Core elements: Define the business and technical talent needs, mapped to the strategic roadmap.

3. Operating model

Strategic decisions: Adopt an agile way of working, defining how best to engage users and the use-case ecosystem, and defining the desired level of centralization.

Core elements: Train talent in agile ways of working and define where AI capabilities should sit.

4. Technology

Strategic decisions: Choose between open-source or vendor solutions, as well as technology partners within ecosystems.

Core elements: Define requirements for technology that meets use-case needs, while establishing a scalable foundation for later use.

5. Data management

Strategic decisions: Decide which internal and third-party sources to prioritize, identify whether data sources should be centralized, and define a data governance strategy.

Core elements: Define business and technical talent needs, mapped to the strategic roadmap.

6. Adoption and scaling

Strategic decisions: Identify internal change agents who will drive success, craft an engaging change story, upskill stakeholders, and define impact-tracking methodology.

Core elements: Ensure collaboration between technology and business teams, embedding end-user engagement throughout development. Design a comprehensive rollout approach and end-to-end processes, scaling alongside a company-wide culture and mindset shift.

While this framework can be applied across industries, there are a few elements that rail companies can strive to get right to unlock AI at scale.

Strategic roadmap

Aligning with the senior leadership team on the potential of AI is the most fundamental component to get right and should always come first.

- **Core elements to get right:** Define the vision and quantify potential financial and nonfinancial benefits of use cases, as well as a future state vision and roadmap for the journey. This requires commitment to funding and resourcing the roadmap, and considering potential partners and vendors to engage for the transformation.
- **Strategic decisions and design choices:** Identify and prioritize domains and use cases addressing the most important value pools first.
- **Common challenges:** Few railway companies have developed strategic roadmaps that support business priorities for AI implementation. Many use cases have been pursued on an ad hoc basis (often driven by a research department or by the business directly) rather than by following a clear vision articulated at enterprise level.

AI-specific roles and skills

Ensuring the right skills and capabilities are in place is critical to support AI innovation and execution.

- **Core elements to get right:** Define the business and technical talent needs, linked to the strategic roadmap, to ensure the right skills and capabilities are in place at the right time.
- **Strategic decisions and design choices:** Define which roles are best sourced internally, hired externally, or accessed through partnerships and vendors.
- **Common challenges:** Many railway companies are state owned and may face the additional challenge of competing directly with the private sector for technical talent. Railway companies will need to define a value proposition to attract and retain new talent and could also leverage their existing talent pool by reskilling the workforce to meet changing needs.

Operating model

Bringing technology, business, and operations closer together to deliver value.

- **Core elements to get right:** Define the appropriate positioning and organizational model to maximize AI adoption and impact while building reusable capabilities across the business.
- **Strategic decisions and design choices:** Position resources with AI skills across the organization, define how best to engage users and the use case ecosystem to ensure needs are met, and define the relevant level of centralization.
- **Common challenges:** Railway companies are typically complex organizations with a large number of distinct and differentiated business units, making it challenging to define the right level of reuse and centralization that avoids duplication of effort but drives innovation where it is most needed.

Technology

Putting in place the right platform and tools is essential for innovation.

- **Core elements to get right:** Identify what technology is required that meets the needs of use cases while establishing a scalable foundation for later use. This includes appropriate architecture, continuous delivery, and security measures. Two approaches were observed among the railway companies interviewed. Some leverage existing platforms with embedded data and capabilities (for example, SAP or Oracle) to develop AI use cases; others develop, from scratch, a dedicated data and analytics platform using data across legacy IT systems. The solution depends on the specific use case.
- **Strategic decisions and design choices:** Choose between open source or vendor-driven solutions, and identify technology partners within existing ecosystems.
- **Common challenges:** Mitigating risk will require strong cybersecurity foundations to be in place; another challenge could be integration of legacy IT systems.

Data management

Making relevant data available is vital to address use cases.

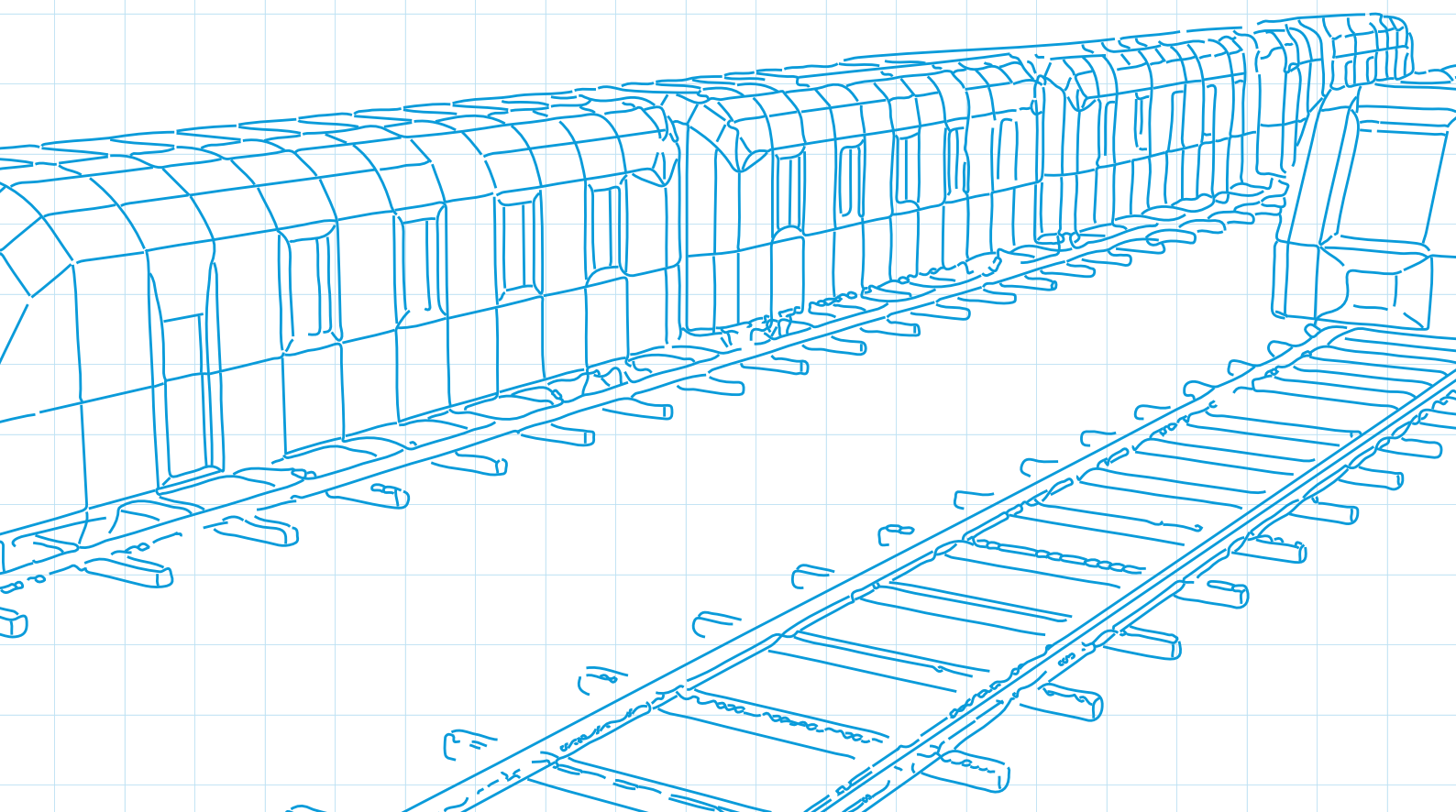
- **Core elements to get right:** Identify the data needed for use cases and build a repeatable approach to data governance with processes in place to capture, validate, and store information in a standardized and centralized infrastructure. Setting a firm-wide definition of good data ensures data quality. Set up fit-for-purpose data governance by appointing the appropriate roles like data owners and data stewards.
- **Strategic decisions and design choices:** Evaluate and decide which internal and third-party data sources should be prioritized for use, identify if any data sources should be centralized, and define a data governance operating model.
- **Common challenges:** In many railway companies, data is siloed and spread across business units and legacy systems, which complicates access. A robust data architecture and strong governance will support regulatory compliance and build confidence in use cases.

Adoption and scaling

Managing the transformation is essential for capturing the value at stake.

- **Core elements to get right:** Emphasize collaboration between technology and business teams, with end-user engagement throughout development, to ensure that the resulting tools are fit for purpose. Design a comprehensive and standardized rollout approach and end-to-end processes. Measure impact with operational and financial KPIs to ensure value is captured and recognized.
- **Strategic decisions and design choices:** Identify internal leadership and change agents who will drive the success of an AI program, craft an engaging change story and long-term communication strategy, upskill relevant stakeholders, and define the mechanism and cadence for tracking impact.
- **Common challenges:** These include an unclear understanding of the value of implementing new technology, and a lack of sponsorship or championing from senior leadership.

“There are a few approaches railway companies are following to develop the six capabilities needed to deliver on AI’s value. There is no one-size-fits-all solution for this work, as the correct approach for each railway company will depend on its maturity, resources, and ability to attract technical talent.”



Potential risks to be considered when implementing AI and gen AI use cases

There have been numerous examples of risks and ethics violations when using gen AI. It is essential for any company that integrates AI-based solutions to consider risks that can impact outputs and the value of the use case. It is even more important for the railway industry to be aware of these risks and tackle them from the start. Risks could include:

- **Impaired fairness.** Gen AI can produce content that is not clearly identifiable as AI-generated, leading to confusion or deception of users.
- **IP infringement.** Foundation models typically leverage internet-based data, leading to incidents of IP infringement (for example, copyright violations or plagiarism).
- **Privacy concerns.** Gen AI may heighten privacy concerns through the use of personal or sensitive information for model training.
- **Malicious use.** Gen AI, particularly open-source LLMs, can be leveraged to create and disseminate malicious content (such as falsehoods).
- **Security threats.** Gen AI applications may be subject to prompt injection and other vulnerabilities.

- **Performance and hallucination risk.** Foundation models may generate factually incorrect or outdated answers.
- **ESG impact.** Training and deployment of foundation models may increase carbon emissions and exceed ESG commitments.
- **Third-party risk.** Use of third-party gen AI models and tools can pose the risk that proprietary data is used by public models.

Any company working with or developing solutions based on AI should establish responsible AI principles and ethical guardrails.

Common approaches to building data and AI capabilities

There are a few approaches railway companies are following to develop the six capabilities needed to deliver on AI's value. There is no one-size-fits-all solution for this work, as the correct approach for each railway company will depend on its maturity, resources, and ability to attract technical talent. Regardless of the approach taken, there will be strategic decisions to be made around when to buy, versus when to build, for different use cases. Interviews revealed three approaches to delivering value:

Approach 1: Building robust internal capabilities with a centralized roadmap

Some railway companies with robust digital maturity have built centralized capabilities, such as research and development departments. In this approach, one business unit or function is in charge of leading AI use cases from strategy to implementation, resulting in one prioritized roadmap of use cases managed centrally for the company. It is also responsible for identifying and experimenting with the latest trends and technology, including formalized partnerships with research centers and universities to support cutting edge work.

Approach 2: Building robust internal capabilities with integrated roadmaps

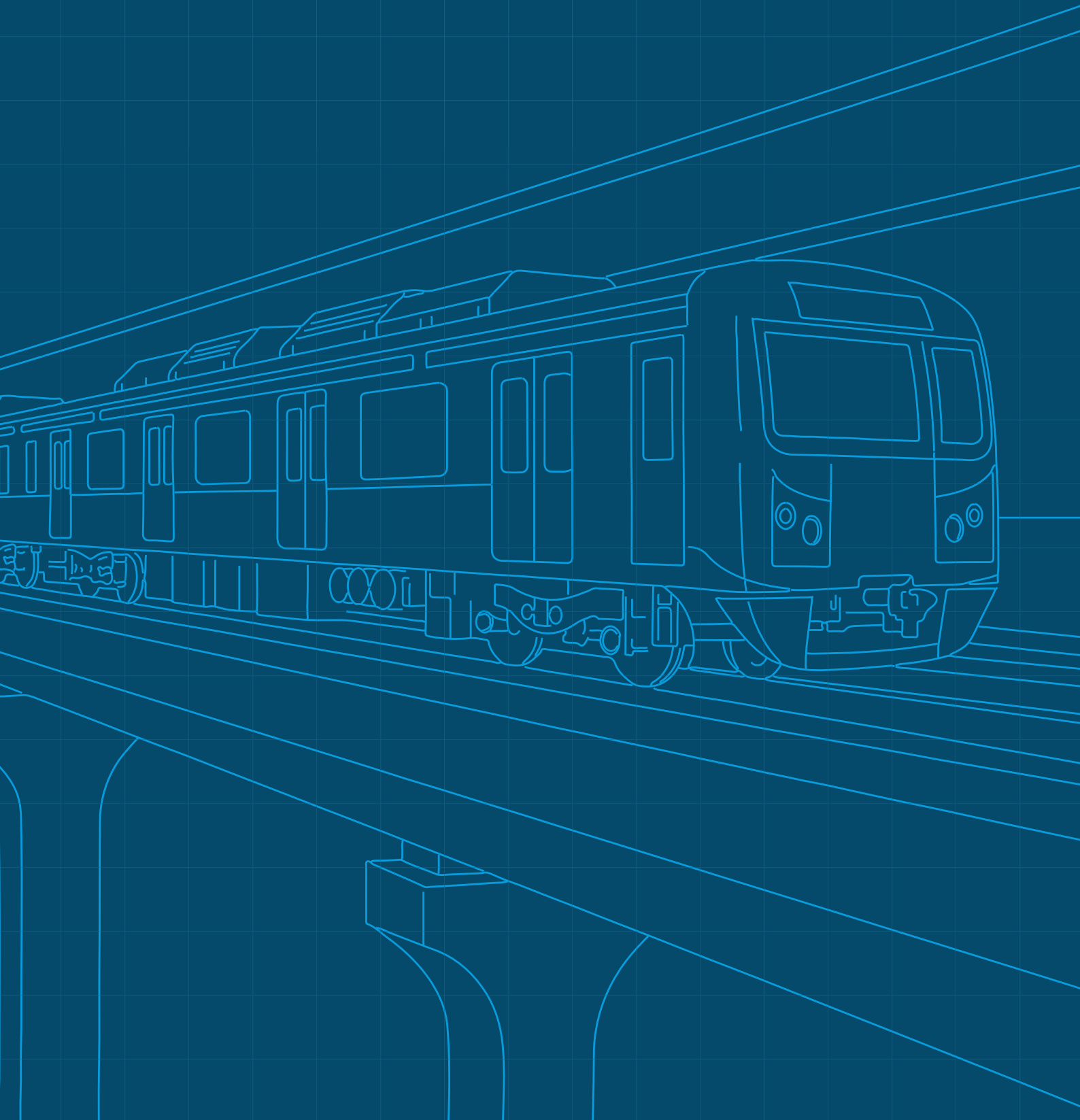
This approach mirrors Approach 1 in the centralized research and development function, but each business unit may have its own AI capabilities to develop use cases. Some critical resources might be shared but each business unit

can independently drive its own roadmap. Hence the company roadmap is the assembly of all the roadmaps from the different business units. While teams can use centralized IT systems, they are funded by business units and work closely with them. This model, also known as hub and spoke, recognizes different needs and maturities of the units driving different strategic roadmaps.

Approach 3: Leveraging ecosystem partners to deliver available solutions

For smaller and less-mature railway companies that do not have a strategic roadmap (or the requisite capabilities in skills, operating model, technology, and data), external partnerships can support them to identify opportunities and leveraging off-the-shelf solutions. These partnerships can enable rapid deployment but require capability building in parallel to ensure railway companies can manage the solution and support its evolution. This approach brings value quickly through efficient partnerships.

The role of the ecosystem

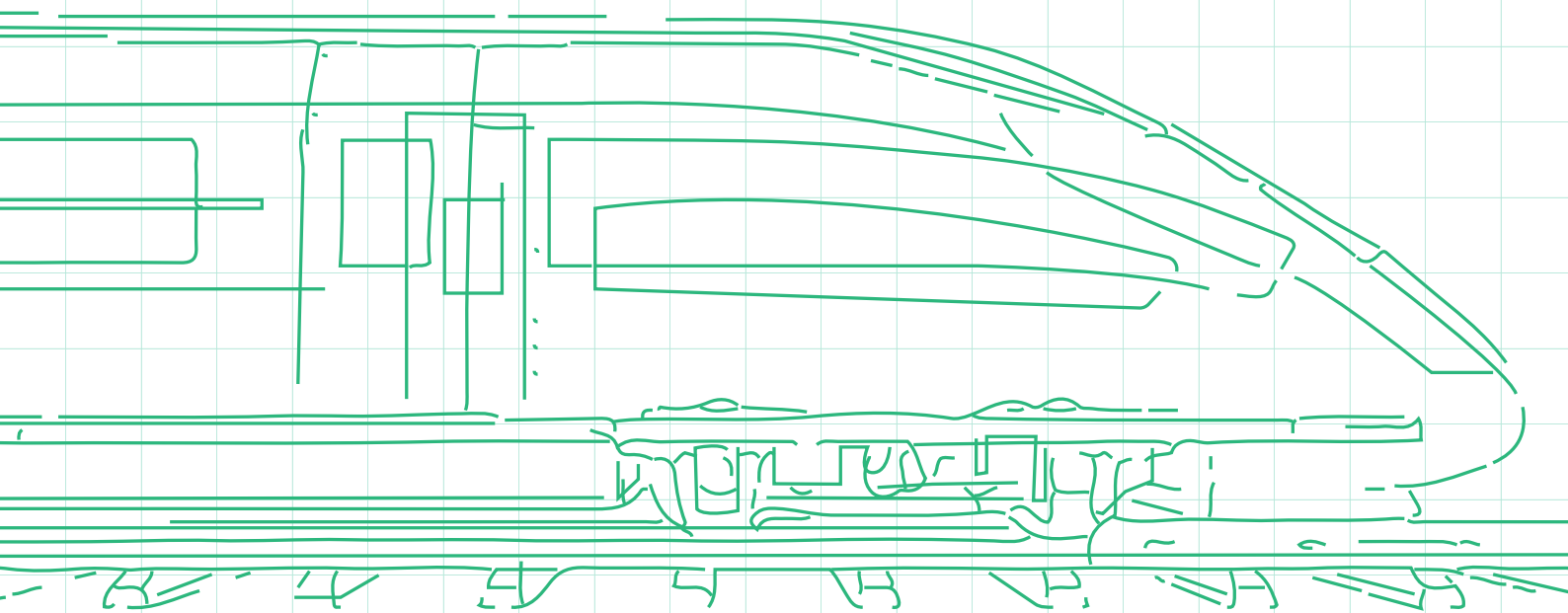


Railway ecosystem partners have an opportunity to collaborate to make AI a reality in the sector and to capture impact. Stakeholders can benefit from working together as delivering the value at stake, and building more accessible and available transport, will benefit the entire ecosystem. Also, through collaboration, talent can be leveraged across partners to develop technical solutions. Innovative financing solutions will likely be needed to make this happen.

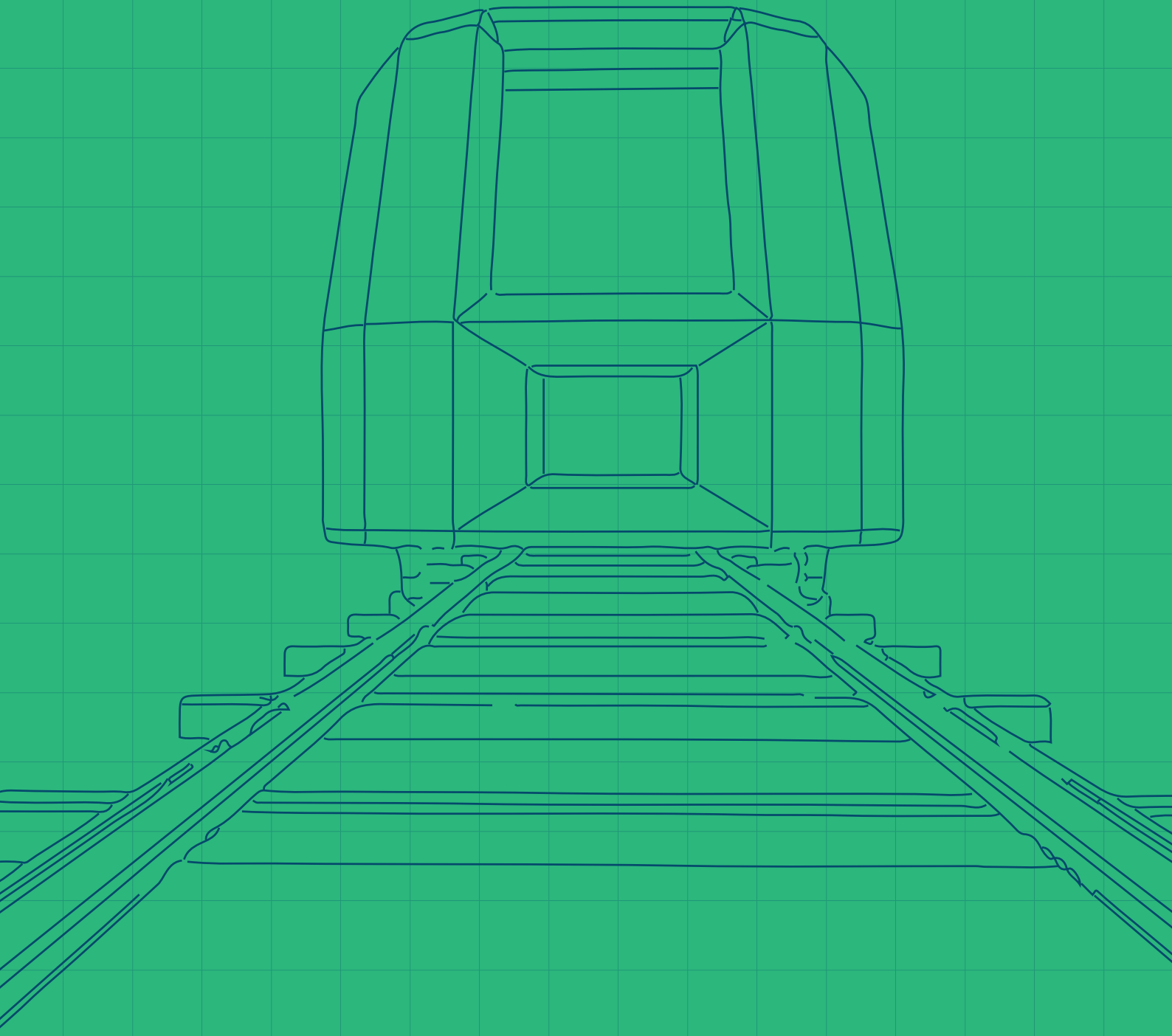
Railway companies can coordinate and collaborate with partners across the broader railway ecosystem to further this transformation toward building a data-driven industry with fully embedded AI. All partners have a role to play in this transition and in supporting more efficient and attractive railway transportation:

- **OEMs** could provide railway companies access to relevant data for use cases and continue to partner with railway companies to develop products that bring value, such as connected-by-design products and tools for smaller railway companies that may have fewer resources to invest in AI.
- **Technology firms** could continue to provide off-the-shelf and customizable solutions that can be used in a railway context to accelerate development, as well as lend talent to railway companies through formal partnerships to mitigate talent accessibility challenges.
- **Research centers** could prioritize education, innovation, and algorithm development for research relevant to railway use cases, and create formal research partnerships with railway companies to prove use-case value.
- **Policy makers** may consider supporting industry standardization and data availability to further digital capabilities.
- **UIC and similar organizations** could help to establish a standardized ontology to be used across the whole sector and shared by all stakeholders to enable seamless data connection and reduce the complexity caused by lack of data lineage and fragmented legacy systems.

“Stakeholders can benefit from working together as delivering the value at stake, and building more accessible and available transport, will benefit the entire ecosystem.”



Conclusion



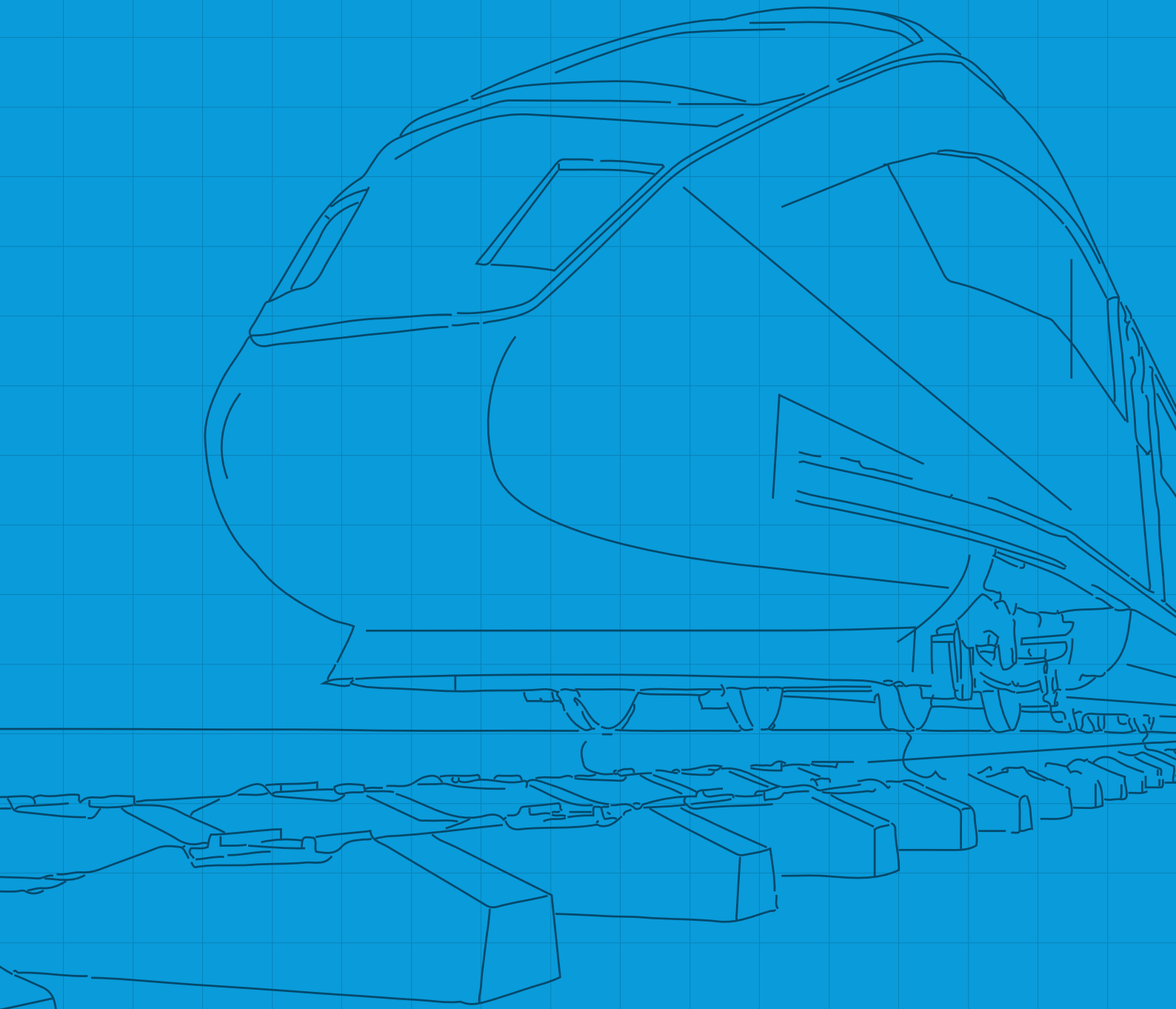
AI technology can dramatically change the way railway companies plan and deliver their services and help them to optimize capacity and improve customer experience. Early efforts have focused investment on use cases that support safety, on-time performance, and customer engagement, setting a clear path to deliver value. Beyond these initial use cases, additional opportunities are emerging alongside rapidly evolving technology.

To capture the value at stake, all stakeholders across the rail ecosystem could prioritize use cases that serve a clear need instead of developing

technology for technology's sake. Deploying AI successfully will require six components to be in place: a strategic roadmap, skills and AI-specific roles, operating model, technology, data, and adoption and change management.

Railway companies do not need to act alone. There is a wide ecosystem of partners and vendors with deep technical and business expertise to support this journey.

Glossary



Artificial intelligence (AI): This refers to a machine's capacity to execute cognitive functions associated with the human mind, including reasoning, learning, problem solving, interacting with an environment, and exercising creativity. AI is a broad term that covers many topics: natural language processing, computer vision, machine learning, deep learning.

Content generation: The process of using technology, such as artificial intelligence, to create written or visual content that is tailored to a specific audience and can be produced quickly and efficiently.

Data quality: Quality encompasses accuracy, completeness, consistency, and reliability of data to ensure the availability of reliable and trustworthy data that can be used for analysis and decision making.

Data governance: This is the overall management and control of an organization's data assets. It involves establishing policies, procedures, and processes to ensure data quality, reliability, and compliance. Data governance is crucial for ensuring that the data used for decision making is accurate, consistent, and trustworthy.

Data lake: A large storage system that holds raw and diverse data in its original format, allowing for flexible processing and analysis. It is mainly used for data exploration, advanced analytics, and business intelligence.

Data warehouse: A centralized storage system for organized data used for reporting and analysis purposes. It provides a consolidated view of data from various sources and is optimized for query performance.

Deep learning: Type of machine learning that can process a wider range of data resources, requires less data preprocessing by humans, and can often produce more accurate results than traditional machine learning approaches. In deep learning, interconnected layers of software-based calculators known as "neurons" form a neural network. The network can ingest vast amounts of input data and process it through multiple layers that learn increasingly complex features of the data at each layer. The network can then make a determination about the data, learn if its determination is correct, and use what it has learned to make determinations about new data. For example, once it learns what an object looks like, it can recognize the object in a new image.

Descriptive analytics: Summarizing and visualizing historical data to provide insights and patterns that can help in decision making.

Digital twin: A virtual replica of a physical object, person, or process that can be used to simulate its behavior to better understand how it works in real life.

Generative AI (gen AI): An AI model that generates content in response to a prompt by leveraging large language models (LLM). Gen AI's multifunctional capabilities encompass classification, editing, summarizing, synthesis, and the generation of new content.

Internet of Things (IoT): A network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and connectivity, enabling them to collect and exchange data.

Machine learning: Algorithms that detect patterns and learn how to make predictions and recommendations by processing data and experiences, rather than by receiving explicit programming instruction. The algorithms also adapt in response to new data and experiences to improve efficacy over time.

Natural language processing (NLP): A field AI focused on the interpretation and manipulation of human-generated spoken or written data, allowing computers to process and respond to written and spoken communication.

Predictive analytics: The use of data science and machine learning to provide insights and predictions about future performance and trends.

Predictive maintenance: A proactive maintenance strategy that uses data analysis and advanced technologies like artificial intelligence and machine learning to predict when equipment or machinery is likely to fail.

Structured data: Information that is organized and formatted in a specific way, making it easy to search, analyze, and process. Examples of structured data include customer information in a database or financial data in a spreadsheet.

Unstructured data: Information that does not have a predefined format or organization. It includes words, text, images, videos, and other forms of data that do not fit into a traditional database structure. Unstructured data lacks a consistent schema or data model, making it more challenging to analyze and interpret.

Virtual agents: Computer programs or artificial intelligence systems that can simulate human-like conversations with users. Virtual agents use natural language processing and machine learning algorithms to understand and respond to user queries—providing assistance or information, or performing tasks.

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