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Intro & Overview

Executive Summary

In today's connected world, with increased urbanization, global population growth, complex supply chain networks, and interconnectivity, railway businesses are facing more challenges than ever before. Railways are strained to accommodate an increase in demand and also must jostle for position as a preferred mode of transport against car, airplane, and barge. Global warming motivates governments to impose emission goals and restrictions, adding yet another pain point for railways. The COVID-19 pandemic has also brought major unforeseen challenges to the railways sector. Due to travel restrictions, social distancing regulations, and regional "lock downs," railway operators have experienced passenger declines, leaving them wondering what the path forward looks like.

Luckily, profound technology innovations, specifically those made around Artificial Intelligence, have found their way into the railways industry. By incorporating "smart" technology solutions throughout railway systems, operators and OEMs can optimize data output to provide new services to passengers and decrease operating costs.

Artificial Intelligence (AI) solutions, such as obstacle detection or video analytics, will help propel the railway industry into the new digital age and turn visions of a seamless autonomous network into a reality. Intel and ADLINK are working tirelessly to develop AI solutions that help rail operators and solution providers address their challenges, save on operating costs, and improve their passenger experiences. Intel and ADLINK understand that technology is not a fix-all solution, however, but rather a tool that is integrated into current operations to augment other business practices.

This eBook is intended to show how Artificial Intelligence can be incorporated into railway operations to improve the railway experience and to showcase the many use cases that exist. We hope that rail operators and solution providers, in particular, will find this eBook useful in developing pragmatic solutions to support their railway operations.



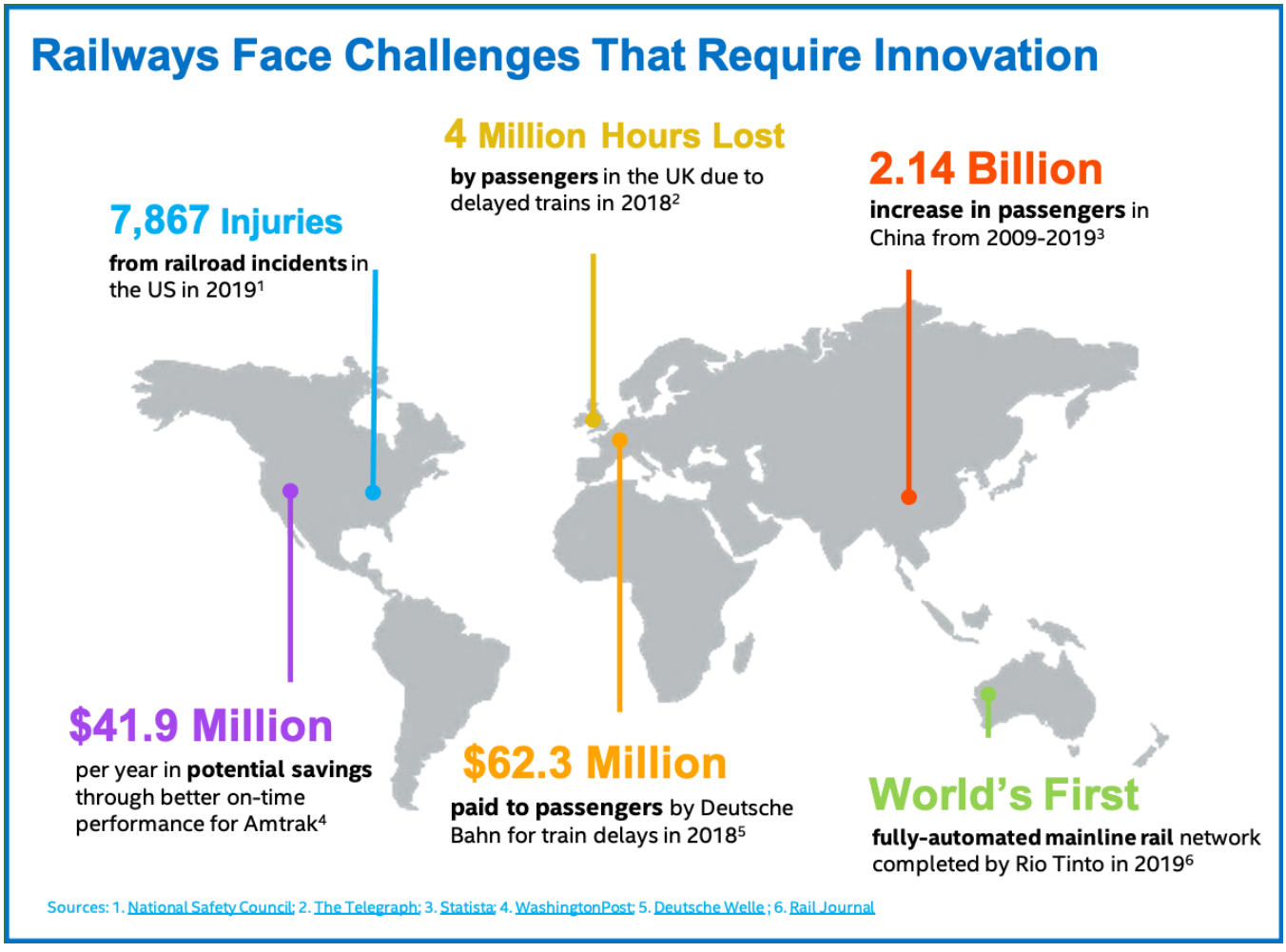
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Current State of Railways

Rail's Role in Transport

The global transportation industry drives our everyday lives. It enables us to get to and from work everyday, see loved ones, and explore new places. Public transport is indispensable, especially in urban centers, where much of the population relies on it to get to and from work. An estimated three out of four people in the European Union live in urban areas (up from 50% in 1950), and this number is projected to grow to over 80% by 2050.[1] This rapid urbanization, along with a rise in global population, is putting pressure on the transportation industry to innovate and discover new ways to increase throughput, alleviate congestion, and improve sustainability.

An increasingly important piece of this transportation story, in both passenger transport and freight logistics, will be the railways market. While the COVID-19 outbreak has impacted the passenger rail industry, causing an estimated 35% drop in passenger traffic for 2020, the market is expected to grow to $252.1 bn by 2024 (up from $225.7 bn in 2019).[2] The rail freight market is expected to incur less significant losses from the pandemic and rebound to $114.3 billion in 2023.[3]



1 "Railway Technical Strategy Europe 2019" (PDF)
2 "Covid-19 hurts global rail market growth"
3 "Rail Freight Global Market Report 2020-30: Covid 19 Impact And Recovery"

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Trends & Forces Impacting Railways

Railways play an integral role in both the global supply chain and in passenger transport. For commuters, railways offer a more safe and reliable mode of transport and allow passengers the luxury of relaxing or working along their journey. For the supply chain, rail freight plays an important role in transporting bulk commodities across countries as it is more cost effective than trucking and faster than barge shipping.[4] With the industry evolving continuously, operators need to take into account several factors that are influencing this evolution.

Transportation Ecosystem

Increased Competition to Provide Preferred Mode of Transport

Despite this promise of future growth, the rail market has faced major setbacks over the years due to increased external competition. The transformation of global supply chains has raised customers' expectations for faster, cheaper, and more flexible delivery, causing rail freight to directly compete against road transport. Because rail freight emits less emissions than other modes of transport, is more cost-effective than trucking for some commodities, and provides shorter lead-times than sea transport, the industry remains differentiated and preferable.

When it comes to long-distance passenger transport, railways must compete against road transport, which offers attractive door-to-door services, and air travel, which offers significantly shorter travel times. However, railways are improving their intercity transport and multimodal connections while advancements in high-speed rail have reduced long-distance travel times and enhanced train comfort. That being said, rail still has work to do to better differentiate itself and stave off alternative modes of transport.

Consolidation of the Market

In recent years, the railways market has seen major consolidation. In early 2019, Japanese multinational Hitachi completed a takeover of the Italian rail transportation service provider Ansaldo STS.[5] In November, 2018, Wabtec Corporation agreed to combine its operations with GE Transportation.[6] More recently, the European Commission has approved Alstom's acquisition of Bombardier Transportation in July 2020.[7] This trend towards consolidation has greatly increased competition among top rolling stock OEMs, which will help decrease costs for operators and increase innovation.

Technology

Digitalization

Emerging digital technologies, such as IoT, 5G, artificial intelligence, big data, cloud computing, and blockchain are propelling a digital revolution within railways. Digitalization provides new visibility into asset and operational performance, enabling operators and OEMs to optimize their processes, reduce operating costs, and augment the passenger experience. In addition, passengers are increasingly demanding improved multi-modality between rail and other modes of transport. Similarly, rail freight customers want real-time insight into the state of their cargo.

Data Security

With the combination of increased digitization and a connected rail network comes the risks and exposure of integrating new technologies with legacy systems. In the United States in February, 2018, the Colorado Department of Transportation's (CDOT) computer network was hacked, with the attackers demanding Bitcoin in exchange for keys to decrypt data. CDOT did not pay the ransom but they did incur $1.7 million in costs from the attack.[8] A connected rail network poses real threats of hacking and thus operators and rolling stock OEMs will need to integrate cyber-security expertise into their ecosystems in order to ensure passenger safety and secure rail assets.

4 "Top 4 benefits of rail freight"
5 "Hitachi completes Ansaldo STS takeover"
6 "Wabtec completes successful merger with GE Transportation"
7 "EC approves Alstom's Bombardier Transportation acquisition"
8 "How SamSam ransomware took down CDOT and how the state fought back — twice"

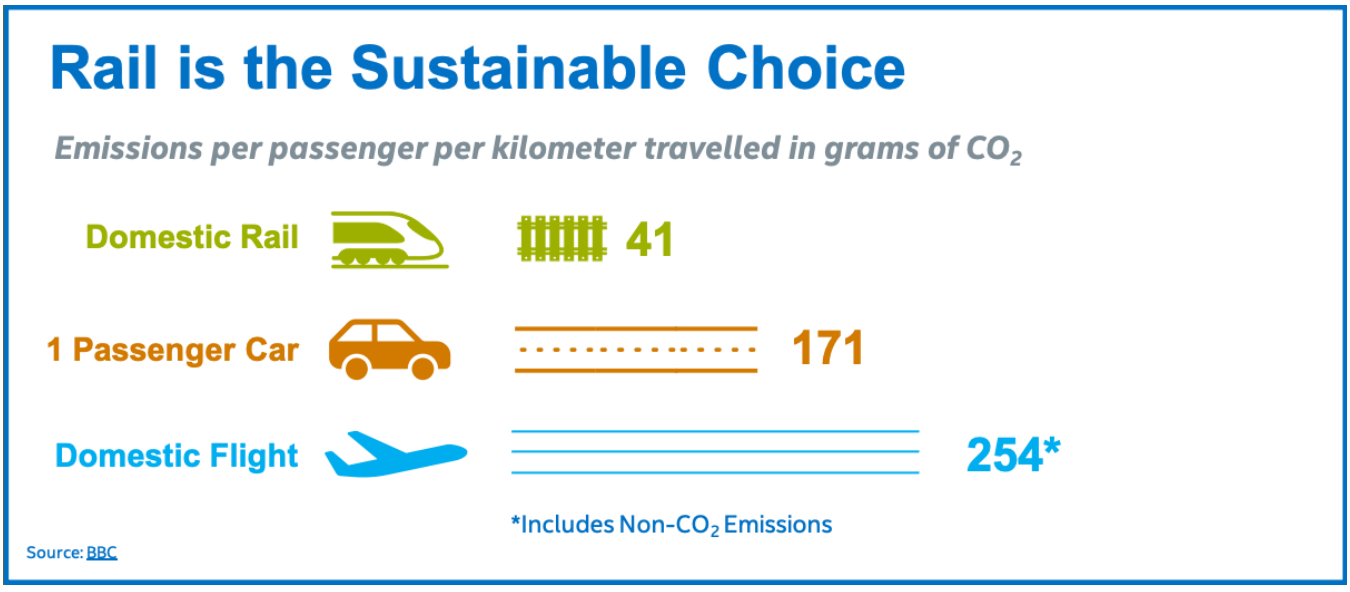
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Customer

Sustainability

Emissions regulations and other environmental regulations are pressuring all transportation systems to become greener. Luckily for rail, it is widely considered the greenest mode of mass transport. Urban rail is 7 times more energy efficient per passenger than car travel in cities, and high-speed rail is 3.4 times less polluting than air transport.[9] The environmental benefits of rail over other modes of transport is encouraging both municipalities and governments to invest in improving railway systems and promote rail transport.[10]



9 "Rail 2050 Vision"
10 "Rail 2050 Vison"

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Urbanization & Increased Traffic

A growing global population, increased urbanization, and a combination of the above forces is expected to drive growth for both passenger and freight rail. Rail ridership grew by roughly 800 billion passenger kilometers from 2018-2019[11] and while the COVID-19 pandemic has caused severe ridership declines, the market is expected a full recovery by 2023.[12] In order to handle this increased traffic, operators must improve track capacity and introduce new lines.

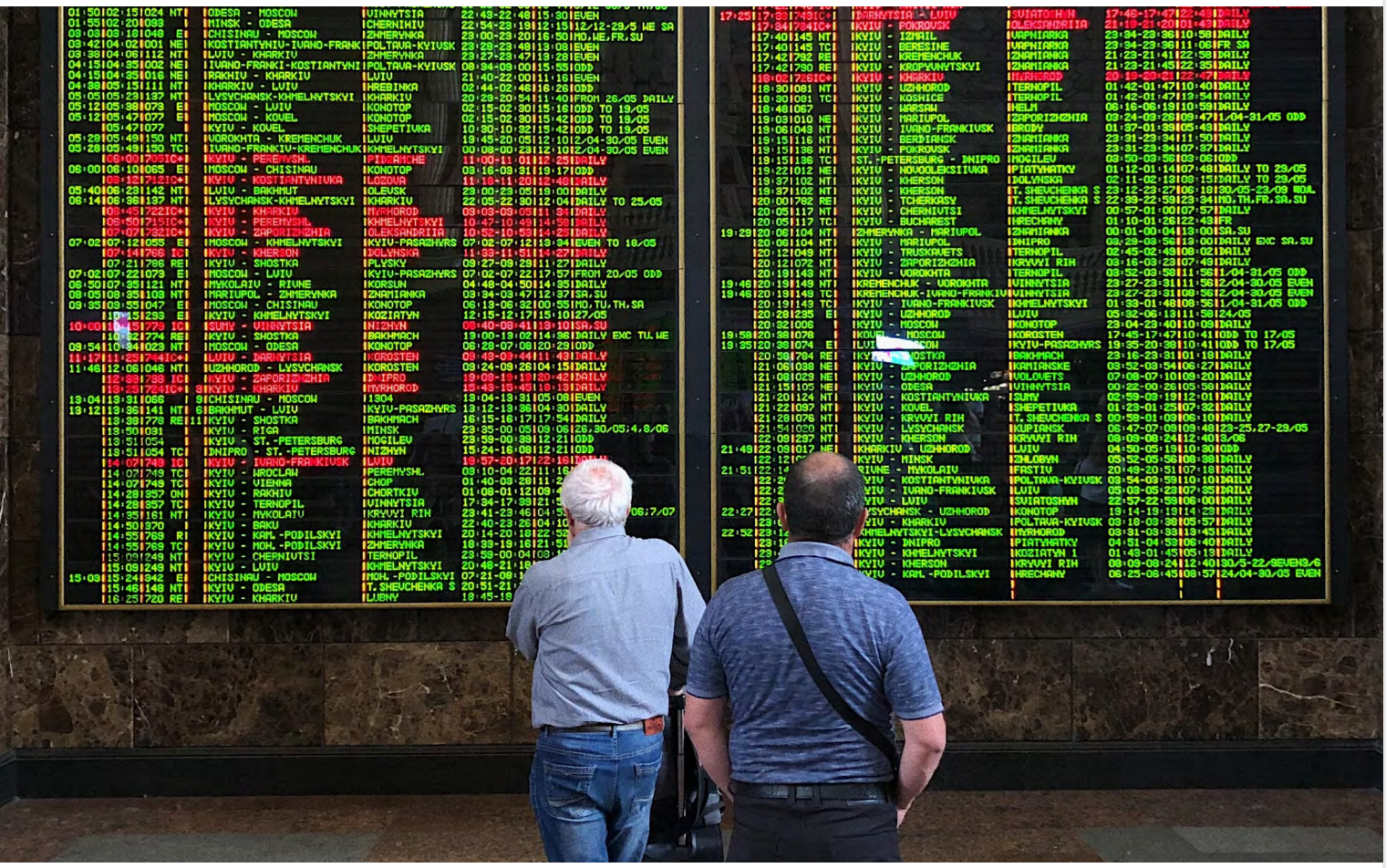
Business Challenges

Rail operators are faced with a complex set of challenges that span their entire operations. Though there are regional differences across the globe and across rail systems, there are several thematic challenges that operators are grappling with today.

Customer Facing

Passenger Experience

Maintaining a robust passenger experience is essential for rail operators in today's travel environment. The aviation industry has seen flight prices continually decrease over the years with the number of flights increasing. Additionally, with the emergence of ride-sharing and other public services such as eScooters & eBikes, urban travelers have a surplus of transport options. To maintain competitiveness, operators must make rail an attractive travel option through services including improved visibility of train schedules and occupancy, as well as in-station and on-board connectivity.



11 "Rail 2050 Vision"
12 "Covid-19 hurts global rail market growth"

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Train Punctuality

A key aspect of a rail operator's reputation is the punctuality of their trains. The Spring 2020 National Rail Passenger Survey, which reports on customer's satisfaction with rail travel in the UK, shows that punctuality is the biggest single influence on satisfaction with a service.[13] As such, operators give serious consideration to anything that improves train punctuality. Passengers rely on rail to get to their destination on time, and failure to meet those standards can leave passengers looking for other modes of transport. Additionally, many operators receive fines from transport authorities if they do not meet punctuality standards.

Safety

The safety of their operations is essential to a rail operator's success. While relative to other modes of transport rail is quite safe, a single accident or incident has the potential to damage an operator's reputation. Operators need to improve the safety of their network, including both in-station and on-board trains. Additionally, engineers are at risk when performing track maintenance, so it is imperative for operators to maximize safety protocols to protect their employees.

Operationally Focused

Operational Efficiency & Cost Reduction

Operating a rail service costs a lot of money. While maintenance costs are extremely expensive in themselves, rolling stock downtime inhibits an operator's ability to maximize its profits. Other expenses include labor and energy costs as well as facilities maintenance. High maintenance and labor costs often contribute to an organization's inability to achieve their overarching goals and ambitions.

Effective Integration of Digital Technologies (e.g. AI)

Modern rail transport has been around since the early 1800s, and while infrastructure and rolling stock is constantly renovated & replaced, there remain legacy assets throughout the system. In addition, rolling stock has a long shelf-life, and retrofitting the cars is time intensive and expensive. Implementing new digital technologies into operations requires relevant personnel training to ensure that new technologies are effective and optimally integrated with legacy systems, assets, and data. While the task may seem daunting, digital integration results in continuous improvement of operations and cost reductions.



13 "National Rail Passenger Survey, 2020"

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COVID-19 Pandemic

The COVID-19 pandemic has brought new challenges to the global railway industry. In May, 2020, the US reported a 70% decrease in public transit usage compared to January levels, and the UK reported a 77% decrease.[14] Additionally, the industry is expecting a drop of almost 35% in the number of long-distance, regional, and urban passengers in 2020 due to COVID-19 and associated social distancing regulations.[15] The combination of stay-at-home/safer-at-home orders and the new "work from home" trend have contributed to these declines in passenger numbers. Passenger numbers are expected to rebound to pre-pandemic numbers soon, but until then rail operators are tasked with figuring out how to bring back passengers while minimizing the risk of spreading the virus throughout the railway system.

Operators across the globe are doubling down on their sanitization practices, instituting mask mandates, and finding creative ways to enable social distancing. And while these measures play an important part in combatting the spread of the virus, another significant aspect of bringing passengers back is ensuring that they feel safe. Obviously, if passengers do not feel comfortable riding trains, at least some will choose not to use them, regardless of the sanitization practices and the ability to social distance. Thus it is vital for operators to improve their communication mechanisms with passengers and provide additional services to help regain passenger trust in the safety of railway travel during a pandemic.

While the short term effects of the COVID-19 pandemic may seem concerning, the market is expected to bounce back and become even stronger than before. Some government bailouts of airlines have stipulated that they cannot compete with rail on short journeys. As travel restrictions ease across the globe, domestic regional travel will benefit before longer distance travel.[16] Furthermore, the European Commission has pronounced 2021 "the European year of rail," promoting railways as a low-carbon form of passenger and freight transport.[17] In Singapore, the government plans to increase the size of the railway network by over 50% by 2030, indicating their continued investment in rail.[18] And in Japan, driverless bullet trains will be tested in the fall of 2021.[19] The integration of new digital technologies into railway operations will help propel railways past the COVID-19 pandemic and future-proof the industry from ensuing crises.

14 "Rail and the Effects of the COVID-19 Pandemic"
15 "Covid-19 hurts global rail market growth"
16 "Covid-19: could the pandemic bolster international rail travel?"
17 "Promoting Sustainable Mobility: Commission proposes 2021 to be the European Year of Rail"
18 "Ministry of Transport: Trains"
19 "JR East to test driverless shinkansen bullet trains in 2021"

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Digitized Railways

Railways' Future Is Tied to Digitization

Railways need to innovate to stay competitive and digitalization will increasingly play a key role.

From 2014 to 2018, the overall length of the European rail network had decreased 0.1%, while the network usage increased by 3.5%.[20] Operators are feeling pressure to accommodate an increase in demand within the constraints of a limited network. By incorporating innovative emerging technologies into the existing operating fabric of the railway ecosystem, a connected digitalized railway network will help operators maintain their competitiveness by reducing operating costs, improving rail safety, and enhancing their passengers' experiences.

A digitized railway leverages available data and new technology across the rail ecosystem from the stations to the on-board experience to the control room. Operators can utilize data to gain valuable insight into asset and operational performance, allowing them to optimize their internal processes and maintenance practices. Through innovative communication technologies, including computer vision, a digital railway has the opportunity to increase network capacity and train speed, helping operators maximize passenger throughput and drive additional profits.

Digital railways greatly improve the passenger experience by providing new services and insight into rail operations. Improved in-station and on-board Wi-Fi and connection services allow passengers to remain connected while on the move, enabling them to work from anywhere or to enjoy entertainment streaming services. Technology can be leveraged to provide real-time train scheduling information, allowing passengers to make necessary changes and to better prepare for the future. Freight operators can gain real-time localization data of locomotives and cargo to provide customers with up-to-date asset information, improving customer loyalty and satisfaction.

Passengers rely on a safe and secure rail network, and with aging infrastructure and increased usage rates, the risks and consequences of accidents are higher than ever. Digital solutions give operators the peace of mind that their network is safe and secure for both passengers and employees. New sensing technologies and analytic capabilities help identify potential threats before they happen, whether they be infrastructure faults or security threats in stations. The combination of digital technologies, furthermore, are being deployed to enable an autonomous network that removes the possibility of human error. Digital rail solutions have tremendous potential to revolutionize the industry and propel it to be the transport of choice for passengers and freight.



20 "Eighth Annual IRG-Rail Market Monitoring Report"

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The Future of Smart Rail



1. Entering a Station

- Facemask Detection & Thermal Monitoring
- Touchless Hand Sanitizing Stations
- Access Control

2. Check-In

- Touchless Kiosks for Ticketing/Bag Check
- Automated Fare Collection

3. Navigating

- Wi-Fi
- Digital Signage for Navigating
- Passenger Information Systems
- Video Security



4. Boarding a Train

- Seat Availability
- People Counting
- Platform Screen Doors
- Automated Fare Collection

5. In-Cabin

- Digital Ordering
- Air Quality Monitoring
- On-Board Wi-Fi

6. Train Control & Maintenance

- Predictive Maintenance
- Object Detection
- Automatic Train Operation
- Scheduling Optimization



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Applications of Digitized Railways

While use cases span the entire railways ecosystem, this segmentation highlights use cases that are actually deployed and/or the aspect of the rail system that the use case addresses. Onboard solutions are deployed on a train, while station use cases include applications that are deployed in stations, as well as in the train control centers or depots.

Onboard

Passenger Information System

Passengers always want greater visibility and information regarding the status of their train and trip. Using sensors and vision systems, operators can gain real-time insight into the occupancy of their trains to provide better services to their passengers. These services include informing passengers of where unoccupied lavatories are, which carriages are first class, and which carriages are less crowded. This real-time information can greatly improve customer satisfaction while also providing valuable passenger data to the operator.

Predictive Maintenance

Predictive maintenance for tracks and rolling stock can generate significant cost savings to an operator, helping to reduce asset downtime and optimize maintenance processes. Sensors can be applied to high risk assets, such as train doors, pantographs, or wheel sets to detect abnormalities and avoid operational breakdowns or failures. Additionally, rolling stock can be utilized to monitor track and wayside health to optimize those maintenance processes. This real-time asset health data provides operators greater visibility into their assets and is a key aspect of understanding overall asset efficiency and reducing unexpected incidents.

Obstacle Detection

Viewed as an integral step in the move towards autonomous trains, obstacle detection utilizes machine vision to detect obstacles on or near a track. Obstacles can be anything from humans and animals to obstructions caused by landslides or severe weather. Multi-sensor obstacle detection systems can provide valuable information in the condition of rail lines and greatly improve safety of operations.

Geolocation

Currently, railway tracks are split up into different “blocks” that detect when a train is in a block with the use of ground equipment. Block signals notify oncoming trains whether or not a block is safe to enter. With this system, however, the exact location of a train is not known. By using geolocation, control towers will be able to see the exact location and speed of a train. While geolocation is an advancement on the path to autonomous trains, in the near term it can help increase current capacity on tracks, decrease travel times, and increase safety on trains.

5G & Wi-Fi

Because railways are competing with air travel and road transport, an enhanced passenger experience becomes essential to bring in customers. On top of that, the COVID-19 pandemic has only accelerated the already increasing work from home movement. Operators need to provide fast & reliable on-board Wi-Fi to incentivize travelers to continue to use rail transport. Using 5G technology will give passengers a lightning fast Wi-Fi, boosting productivity as well as allowing passengers to enjoy streaming entertainment.

5G connections will also help enable improved connectivity and help lower latency between sensors at the network edge. Sensor data and other information relevant for predictive maintenance, obstacle detection, geolocation, and train-to-train communications can be transferred and shared within seconds, helping improve safety and real-time visibility into operations. Using 5G communications, operators can reduce the space between trains, ultimately maximizing throughput on current infrastructure.

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In-Station

Automated Fare Collection

Through the use of sensing beacons and vision systems, operators can automatically collect ticket fares of passengers as they pass through stations. This can eventually remove the need for ticket barriers in metro systems, ultimately improving passenger flow through stations and reducing bottlenecks. This technology can also be deployed in trains, removing the need for on-board ticketing.

Platform Video Analytics

Utilizing CCTV for platform video analytics has a multitude of benefits for railway operators. First and foremost, video analytics can be used to help improve the safety and security of a train station. Operators can monitor passenger behavior and use biometric indicators to spot people of interest, suspicious behavior, or abandoned bags. Furthermore, video can detect when passengers slip and fall onto tracks or monitor the behavior of children to reduce the likelihood of a lost child or other accident. Operators can leverage video analytics to monitor the flow of passenger traffic through stations to improve station planning and operational decision making.

Platform Screen Doors

Another method for helping to increase passenger safety within train stations is Platform Screen Doors (PSDs). Operators have long used employees to monitor stations, but as stations become increasingly more crowded, PSDs can act as another line of defense. PSDs help to prevent people from falling on tracks, getting too close to moving trains, or committing suicide or homicide. Other benefits of PSDs include reducing cluttering on the track as well as improving climate control by sealing out the tunnel.

Passenger Information Systems & Digital Signage

Similar to onboard Passenger Information Systems, in-station information systems utilize train occupancy data to inform passengers when a train is full and to provide alternative route or train options. Additionally, operators can leverage digital signage and mobile applications to provide passengers with real-time scheduling changes and train delays. Digital signage can also display station layouts to customers as well as information on retail options, lavatories, and advertisements. With the use of beacons or other sensing technology, operators can provide mobile wayfinding for passengers to navigate through stations to get to connections on time, improving customer satisfaction and optimizing passenger flows.

e-Ticketing & Self-Service Kiosks

E-Ticketing services are increasingly becoming a standard passenger expectation. E-tickets allow for contactless payment of tickets and can further enable Automated Fare Collection systems. Additionally, for passengers that wish to have a physical ticket or who do not have a mobile device, self-service kiosks enable efficient and fast ticket purchases. Kiosks can be utilized for self-service ticketing as well as for retail purchases and provide operators with valuable data-driven customer insights.

5G & Wi-Fi

The digital age has increased customers' expectations of a connected world and the ability to always be online. With one millisecond of latency and multi-Gbps download speeds, 5G offers passengers fast speeds and reliable connections, allowing them to stay connected on the go. 5G also allows passengers to download tickets with up-to-date pricing and allows operators to deliver valuable real-time information to passengers right on their mobile devices.

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Adjusting to a Post-COVID-19 'New Normal'

The COVID-19 pandemic has brought new challenges and considerations to railways that had previously received little attention. Operators need better insight into train usage and occupancy, and they need to improve the cleanliness and sanitization of their networks. As such, COVID-19 has propelled operators to accelerate some initiatives that were already ongoing prior to the outbreak, while in other cases, new initiatives have emerged. For instance, touchless solutions, like e-ticketing, were starting to be adopted prior to the pandemic, but COVID-19 has accelerated the need for these solutions. Alternatively, new applications have arisen, such as Facemask and Thermal Detection.

Facemask Detection

Operators across the globe have mandated mask wearing in stations and on trains due to the COVID-19 pandemic. However, compliance is not always adhered to, and passengers sometimes forget to put a mask on. Operators can leverage CCTV systems to detect mask usage in stations or trains. Having employees manually check for masks can be expensive and leaves room for error, whereas utilizing facemask detection will ensure compliance and can reduce labor costs in the long-term.

Seat Availability

To give passengers a greater sense of safety and confidence, operators can increase visibility into the train occupancy and seat availability. By using sensors, beacons, or vision systems, operators can provide passengers real-time seat availability data. Knowing that a seat is available in a specific carriage that is not crowded can give passengers the peace of mind that the likelihood of disease transmission is minimal.

Disinfecting Robots

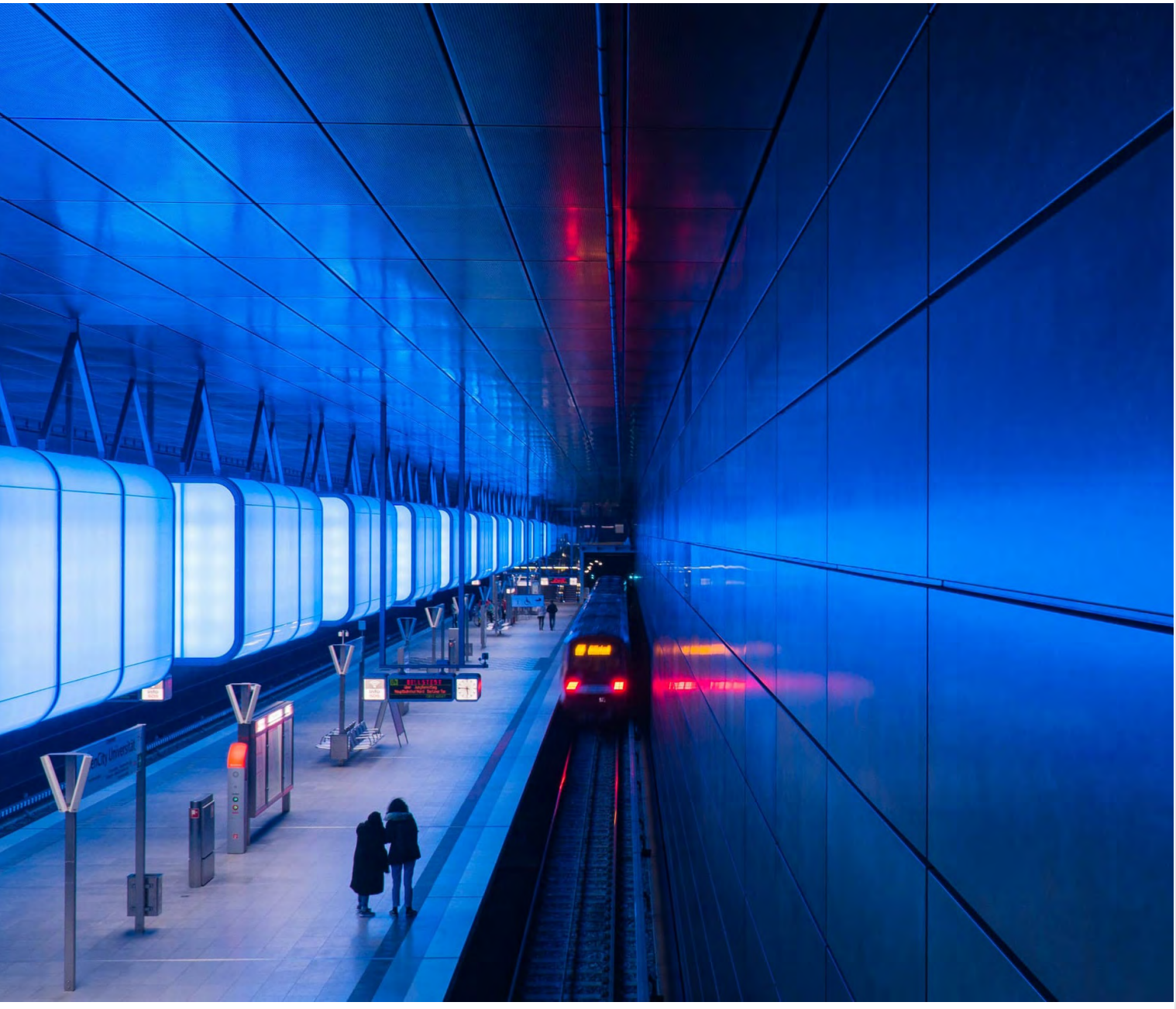
COVID-19 has heightened cleaning practices throughout society, and public transportation is no exception. Businesses are doing everything they can to sanitize high-touch surfaces and improve air ventilation to help reduce the

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spread of the virus. However, many of these cleaning practices are done manually. Deutsche Bahn doubled their number of traveling cleaning staff in May of 2020, and other operators have reported increasing cleaning practices since COVID-19 as well.[21,22,23] Operators can leverage technology to help with their cleaning efforts, such as with dis-infecting robots that can be deployed to spray disinfectants automatically throughout a facility.

Thermal Monitoring

Having a fever was widely considered an early indicator/symptom of COVID-19. And while new information has shown that individuals can be asymptomatic carriers of COVID-19, a fever is still a strong indicator of having the virus. Operators can leverage thermal detection cameras to identify individuals throughout the railway network who have elevated temperatures. These scanners can be used to screen individuals entering a railway station, entering a train, or to monitor other entry points throughout the system. Not only can it help limit the likelihood of an infected person entering the network, but it can give passengers the peace of mind that the operator is doing all they can to limit the spread of the virus.



21 "Deutsche Bahn launches a hygiene and cleaning campaign"
22 "IRJ IN-BRIEF – Covid-19: Passengers value cleaning"
23 "'Every train scrubbed every night': public transport has never been so clean"

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AI & Future Outlook

Harnessing the Power of AI for Better Railways

The emergence of innovative new technologies is the underlying enabler of digital railways and most of the afore-mentioned use cases. These technologies include Internet of Things (IoT), Artificial Intelligence (AI), Cloud, 5G, and edge computing. The advancements in these areas are driving the rapid expansion of the digital railways market which is forecasted to grow from $50.0 billion in 2019 to $74.8 billion by 2024 for a compound annual growth rate of 8.4%.[24] Among these foundational technologies, AI will play an especially pivotal role in propelling this growth.

Though AI was first coined by Alan Turing in the 1950s, the technology is just now becoming widespread and available across industries thanks to more powerful, efficient and less expensive processors. As AI improves its accessibility and capabilities, its importance and applicability is finally being realized by customers. A survey from the Economist Intelligence Unit found that nine out of ten business executives in both the private & public sector described AI as important to solving their organizations' strategic challenges.[25] Governments recognize its importance as well. In 2018, the European Commission issued a communication, Artificial Intelligence for Europe, which increased the Commission's annual investments in AI by 70% to reach €1.5 billion for the period 2018-2020.[26]

Global business is honing in on the use of AI in daily operations, and the railway industry is no exception. Thanks to smart sensors and increased connectivity, railway systems are producing more data than ever before, and operators are now facing a data deluge. AI is an essential component of efficiently unlocking the value of this influx of data and directing that value to aide operators in addressing many of the aforementioned challenges. AI harnesses the power of data, analytics, and cloud to improve the passenger experience, rail operations, asset maintenance, and safety and security, resulting in increased customer satisfaction and revenues and decreased costs.

The applications of AI are quite expansive and often benefit multiple aspects of a rail network. For example, using predictive maintenance to improve operational practices also decreases the likelihood of asset failure and a subsequent accident, further improving the safety of a rail line. Optimizing train timetables with AI systems based on mobility demand relieves operators of a cumbersome time-consuming process and improves the passenger experience by increasing train punctuality. Operators can also leverage AI to predict train-delays, adjust timetables accordingly, and finally communicate this information to passengers so they are able to adjust their schedules as well. Some of the more prominent AI use cases are presented below.



24 "Digital Railway Market by Offering... Global Forecast to 2024"
25 "INTELLIGENT ECONOMIES: AI's transformation of industries and society" (PDF)
26 "Shaping Europe's digital future: Artificial Intelligence"

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How AI Is Being Leveraged Throughout Rail

Scheduling Optimization

With the influx of digitalization in society, customers' expectations have shifted from traditionally fixed schedules to an agile, on demand, and transparent transport system.[27] AI algorithms can help enable this reality by utilizing multiple data sources to predict demand and to better inform train scheduling and management. Benefits of AI-enabled scheduling optimization include reduced overall travel time, including waiting times, and improved customer satisfaction.

Asset Intelligence & Predictive Maintenance

AI algorithms make up the backbone of predictive maintenance capabilities. By leveraging the multitude of data points coming from rolling stock components, operators can utilize AI to predict when a component will fail, allowing them to fix the issue before it arises. Some asset failures, like a wheel bearing or train door malfunction, can cause a train to be taken out of operation for maintenance, reducing fleet availability and capacity. AI-enabled predictive maintenance eliminates these occurrences and the need for time-intensive root cause analysis, leading to reduced maintenance costs, faster repair, and increased fleet mobility.

Automated Fare Collection (AFC)

One way to enable Automated Fare Collection systems in railways is through intelligent biometric identification. By leveraging CCTV systems in station and onboard trains, operators can identify passengers and charge them their ticket fare without a ticketing gate. This system can greatly decrease overcrowding issues at train stations by eliminating rush-hour queues at ticketing gates.

Video Security

2,500 petabytes of data was generated daily by new video cameras in 2019, up from 500 petabytes in 2014.[28] This extraordinary increase in video data can be felt across industries including railways. AI-powered video analytics can help operators and OEMs cope with this increase in data, turning it into valuable insight and improve security systems. AI algorithms transform traditional CCTV systems into intelligent CCTV systems that can detect suspicious behavior on trains or in train stations, spot train vandalism, or detect passengers that attempt to bypass ticketing gates. These added capabilities not only improve security systems, detecting potential threats before they occur, but also relieve operators of constantly monitoring security feed, freeing up employees to perform other tasks.

Obstacle & Intrusion Detection

Animals, humans, and vehicles crossing a track, or debris along a track, pose a serious threat to the safety of a train. Not only that, but accidents cause can cause extreme damage to trains and interrupt the normal operations of a railway system, resulting in abundant financial losses. New machine vision technology leverages AI to detect obstacles or intrusions along a railway and alerts train operators of such threats. Additionally, it is important for camera systems to detect moving objects, such as an animal or pedestrian, that are near the track so operators can act accordingly.

Automatic Train Operation (ATO)

AI plays a large role in allowing ATO. AI technology is needed to calculate optimized speed and trajectories based on track capacity, weather conditions, and timetable planning. AI-video analytics are capable of triangulating a train's exact location and communicating this back to train control and to other trains in the network. AI enabled obstacle and intrusion detection capabilities are also necessary to identify potential hazards along a track and react accordingly. An AI-enabled ATO rail network allows operators to increase capacity on rail lines, reduce energy consumption of trains, enhance ride comfort, and improve timekeeping.

27 "Artificial intelligence in rail: Hype or reality?"
28 "Meeting the Challenges of Storing IP Video Surveillance Content" (PDF)

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Deutsche Bahn Leverages AI for Remote Monitoring Challenge

Acoustic Infrastructure Monitoring (AIM)[29]

Deutsche Bahn, the national rail operator in Germany, is a leader and pioneer in technology adoption for Europe. They are continuously looking for ways to improve the quality and capacity of their rail operations, improve their customer service, and improve the efficiency and transparency of their processes. For this, Deutsche Bahn's technology and innovation arm, DB Systel, has taken advantage of AI technology.

Challenge

Mechanical assets such as escalators, lifts, energy converters, and other common train components receive high levels of wear and tear and are prone to malfunctions. Consequently, they need to be monitored frequently.

Solution

DB Systel developed Acoustic Infrastructure Monitoring (AIM), a system capable of monitoring the condition of mechanical systems acoustically. AIM uses machine learning and artificial intelligence to recognize imminent disruptions and deviations from the normal operating state and alerts plant operators.

Benefits

- Improved visibility into asset health
- Immediate alerting and event reporting of abnormalities
- Reduced maintenance and repair costs
- Increased availability/reduced downtime of mechanical assets

29 "Acoustic infrastructure monitoring: Problems are lent a digital ear"

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AI's Pervasiveness Throughout Rail

Asset Intelligence & Predictive Maintenance

By understanding legacy data, AI-enabled analytics predict asset failure leading to preemptive maintenance

Scheduling Optimization

AI algorithms consider multiple data sources to predict demand and develop optimal timetables.

Automatic Train Operation

AI technologies are essential for ATO, calculating optimal speeds and trajectories, geolocating a train, and detecting nearby trains and obstructions



Video Security

AI enabled security systems take traditional security systems and turn them into intelligent ones that can help detect suspicious/abnormal behavior

Obstacle & Intrusion Detection

AI enabled machine vision detects and alerts train drivers and train control centers of obstructions on tracks or nearby a track

Automated Fare Collection

AI enables intelligent biometric identification that automatically charges passengers ticket fees

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Future of AI & Rail

While the benefits of AI within railways are already apparent, AI's future evolution and continued improvement opens endless possibilities for rail operators. Autonomous trains are becoming a reality. Automatic Train Operation has been widely used on metro lines for decades, but great advancements in digital signaling and communication capabilities is allowing for its use on mainline networks where different train types running on different routes share the same infrastructure.[30] The difficulties of running different trains across different operators on the same infrastructure requires open communication and data sharing between operators and the trains themselves. And as such, precise, real-time data and decision making is needed. AI will play an integral role here through its ability to understand multiple data sources and make safe and efficient decisions. AI will help enable a seamless autonomous transportation network that will result in shorter travel times for passengers.

Even as unforeseen events introduce new challenges to the railway industry, operators can leverage AI to combat these challenges and introduce new value-adding features for passengers. The COVID-19 pandemic has introduced the importance of social distancing, and passengers may feel uncomfortable navigating a cabin looking for a seat. Instead, operators can utilize intelligent video analytics to spot unoccupied seats and convey this information to passengers in real-time. Similarly, operators can leverage video analytics in stations or onboard trains to spot passengers or employees who do not comply with mask ordinances.

Lastly, the future of transportation will be an integrated multimodal industry, where different modes of transport are no longer siloed but seamlessly integrate with one another. Passengers will be able to open their phone, plug in a destination, buy a single ticket, and travel to their destination in the most efficient manner given current traffic and weather conditions. A multimodal transportation industry allows passengers to seamlessly transition from one mode of transport to the next through a single interface. AI algorithms will be able to recommend the fastest, most comfortable, and most scenic method of travel depending on a passenger's preference.

AI is not a standalone "fix-all" technology, and has certain shortcomings. For example, Autonomous Trains use AI-enabled machine vision to recognize their surroundings, but robust reliable communication networks are needed to relay this information. Additionally, AI systems are fueled by data. Not just the quantity of that data, but the quality, integrity, and legality of its use are all important inputs as well. That being said, the future of rail has the potential to blossom into a cost effective, energy efficient, seamless passenger voyage, and the application of AI will be crucial along this journey.



30 "Automatic Train Operation takes to the main line"

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AI-Enabled Obstacle Detection Drives Safer Railways

Challenge

Although the world's rail systems safely transport millions of passengers to their destinations every day, real risks remain, and the consequences can be serious. Derailment accidents, terrorist attacks, and other dangers are unfortunate occurrences that railways systems and operators must anticipate and prepare to mitigate.

A European railway customer had developed a railway obstacle detection recognition system to help improve the safety of their trains and mitigate potential accidents. The customer's requirements were substation, however. Their system relied on a combination of optical radar, digital cameras, and a host of sensors to identify railway failures or other obstacles by leveraging AI-based processing algorithms. The graphics processing load for this application was immense.

Solution

ADLINK's cutting-edge AVA-5500 AI-enabled Video Analytics (AVA) platform met the challenge. The system's powerful AI processing and software support helped the railway customer optimize their applications according to their needs. Thanks to the AVA-5500's EN50155-certified Extreme Rugged construction, it was also ready for immediate deployment where the railway obstacle recognition system would operate.

Boasting a 6th Gen Intel® Core™ processor, ADLINK's offering also uses latching-type connectors for enhanced security, convenience and time-to-market benefits. Without latching connectors, cable connections require hot glue to maintain ruggedness, which is far from ideal.



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Building with ADLINK & Intel

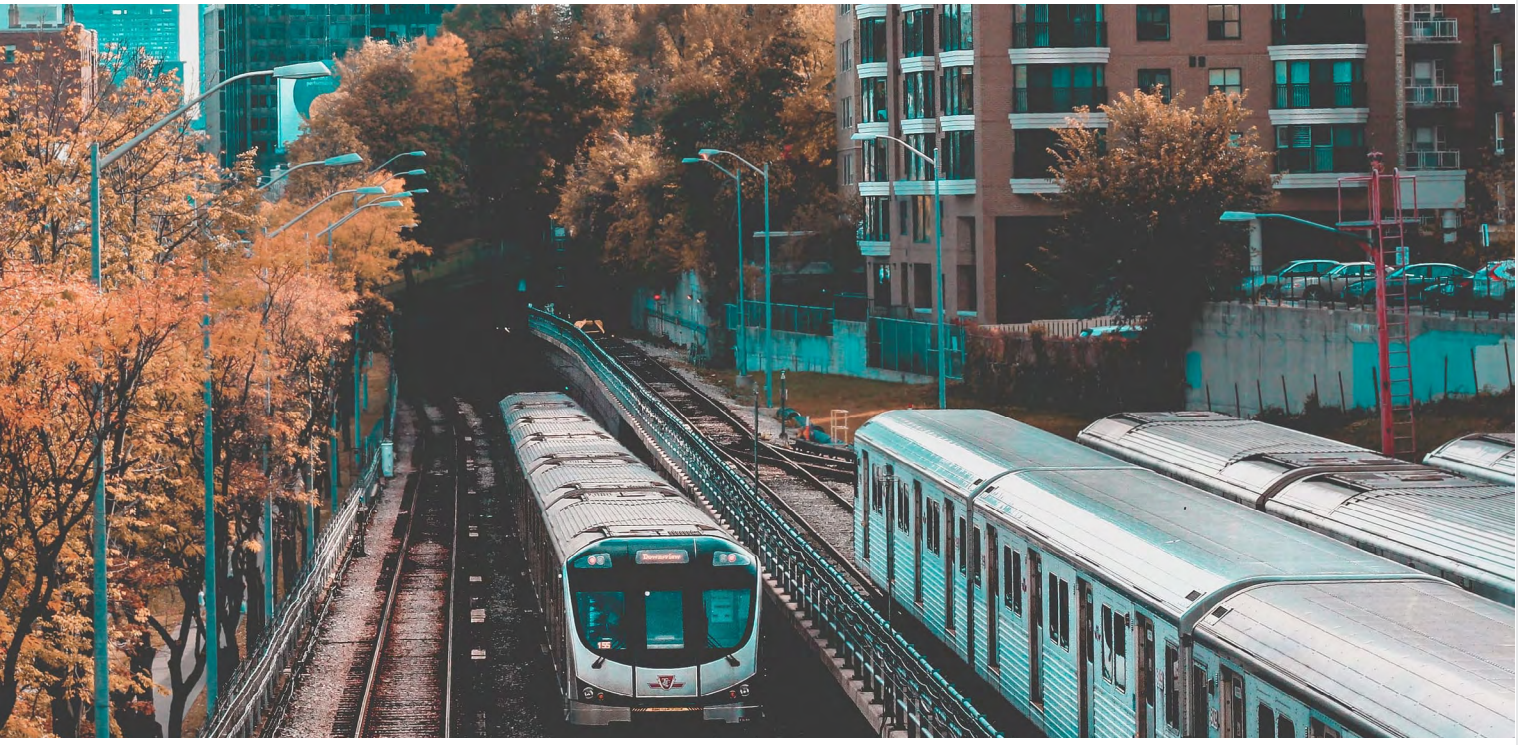
Enabling Digital Railways

ADLINK is working with Intel and partners across the globe to develop, test, and deploy the technology solutions that will enable a smarter, safer, and efficient railway ecosystem. Together, ADLINK and Intel can create flexible configurations for varying application requirements that can withstand the harshest of environments. With Intel technologies, ADLINK develops rugged computing equipment deployed in railcars, terminals, and other critical areas to help OEMs and operators reduce costs and improve safety.

To enable groundbreaking railway applications featuring AI capabilities, railway organizations need technology solution providers who they can trust to partner with to develop the railways of tomorrow. With over 20 years of experience designing and manufacturing powerful and reliable computer systems, ADLINK delivers a comprehensive portfolio of modules and systems optimized for the transportation industry to deliver performance, reliability, and ruggedness. Understanding that railway systems can be subjected to hostile environmental conditions, ADLINK and Intel solutions can be trusted to unluck the power of valuable data without compromising quality.

While ADLINK boasts an impressive portfolio of cost-effective commercial off-the-shelf (COTS) components able to withstand punishing environmental conditions, the ADLINK and Intel partnership is ready to work with their customers to develop customizable solutions for any requirement. Understanding that no two organizations are alike, and that COTS may not solve unique challenges, ADLINK is able to provide turnkey systems that meet compliance requirements. ADLINK can work with clients from the start of a project all the way through completion, assisting with design, working closely with customers during prototyping and production phases, and ultimately meet project deadlines to a customer's needs.

With experience developing solutions in adjacent markets and a vast network of partners across industries, ADLINK's AI solutions can be scaled to other industries to meet the needs of customers. ADLINK's AI-enabled Video Analytics Platform can be utilized for railroad intrusion and hazard detection, but can also be leveraged for video surveillance in airports or safety monitoring on an oil rig.



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Developing Digital Solutions with ADLINK

Rugged Fanless Railway Platforms

AI-Enabled Video Analytics Platform

ADLINK AI-enabled video analytics platforms are comprehensive and versatile solutions and bring AI and the IoT to the railway industry. These platforms have real-time video analytic capabilities suitable for a range of applications such as railroad hazard detection/rail inspection, surveillance and intrusion detection, and passenger information systems. All these applications are enabled through ADLINK's ruggedized hardware suitable for the most demanding of requirements and environments.

Driver Machine Interfaces (DMI)

ADLINK's portfolio of driver machine interfaces reliably deliver critical train information for drivers to monitor operations, conduct diagnostics, manage broadcasting, and control subsystems in real time, no matter how challenging the operating environment. ADLINK's components are encased in a highly resilient chassis that performs in the harshest of environments. When it comes to rail signaling and train control, ADLINK DMIs offer exceptional I/O flexibility, storage capabilities, and connectivity.

Data Collection Systems (DCS)

ADLINK data collection systems are deployable in existing racks for secure collection and storage of critical data that facilitates train operating monitoring, driver performance evaluation, and post-event investigation. Through ADLINK's DCS, operators can manage data reliably, yielding improved operational efficiency and more safety.

CompactPCI Solutions

The nature of mass transit, particularly railways, puts a tremendous strain on computer systems and can be a vexing challenge for embedded designers. Continuous operation for up to 100,000 hours, use in often unforgiving environmental conditions, and extreme vibration are just some of the issues with which technology in the transportation industry must contend. Regulatory requirements constrain system design further, and passenger comfort and safety are also important.

ADLINK's CompactPCI rugged transportation solutions tackle all challenges faced by railway organizations. ADLINK's railway systems are EN 50155 compliant and meet global railway industry requirements for onboard train management and wayside control systems, remote video surveillance and monitoring, broadband Internet access systems, and a broad range of passenger information and entertainment systems. ADLINK's support for COTS and open systems is evident in our CompactPCI systems for railways and transportation, as ADLINK maintains an extensive selection of high-speed, scalable, and low-cost products.

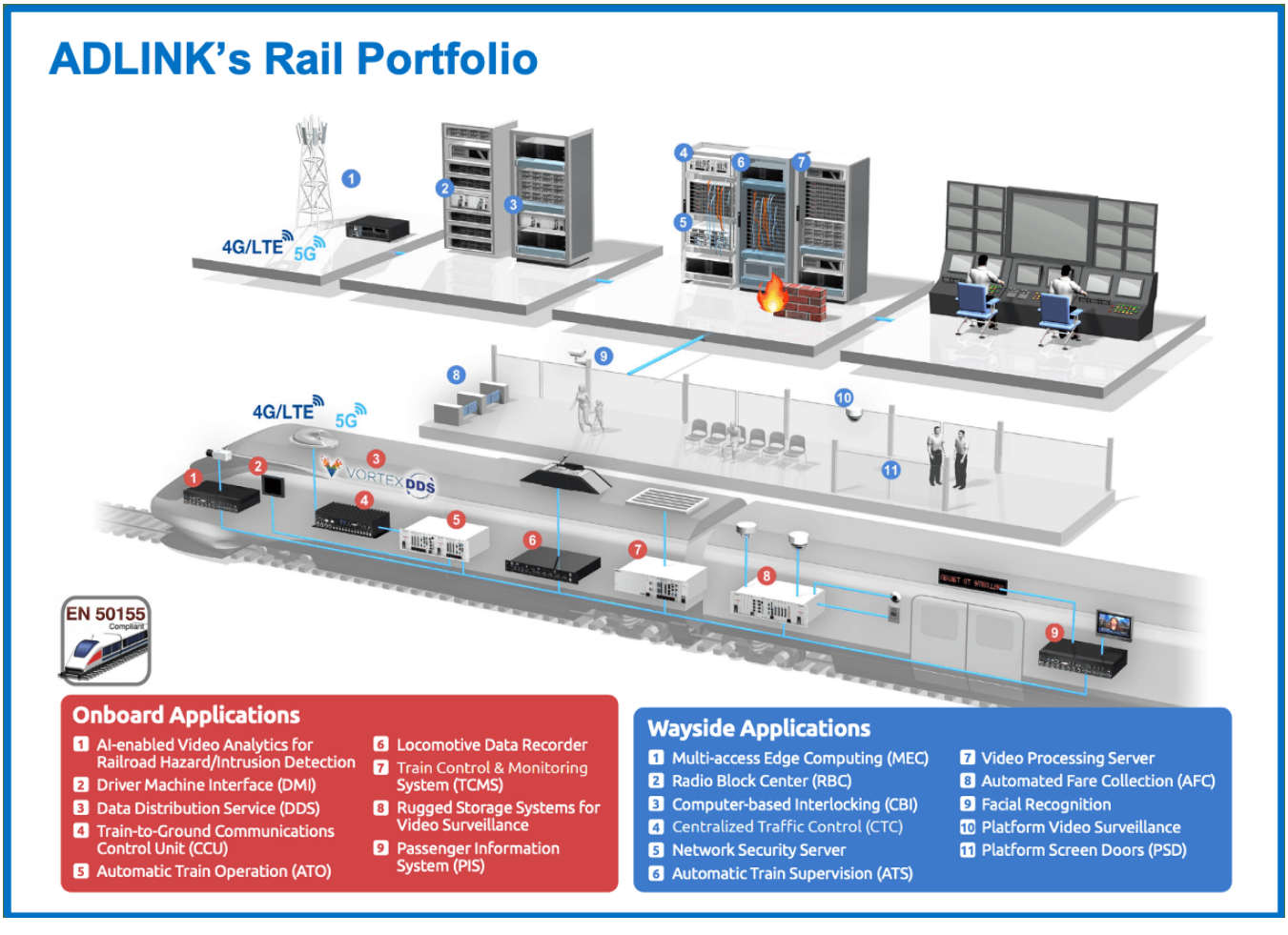
The ADLINK CompactPCI ecosystem encompasses top of the line blades, enclosures, backplanes, switches, power supplies, and peripheral cards. The CompactPCI portfolio is differentiable from other architectures through its dual form factors—3U and 6U Eurocard—which gives it broad plug-and-play capability with other devices. Additionally, this flexibility gives users and integrators the freedom to combine select CompactPCI components with complementary COTS hardware. Lastly, the hot swap capability of CompactPCI allows boards to be swapped in and out of systems without turning off power, which is especially advantageous in applications where downtime cannot be tolerated such as railways.

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Networking Solutions

Modern networking infrastructure continues to evolve, becoming both more powerful and more complex. Although COTS hardware tends to be sufficient for many situations, choosing a networking partner like ADLINK can provide distinct advantages in specific feature implementations as well as project scalability. For example, a large cloud provider with very specific hardware needs could join forces with a partner to build thousands of servers according to precise needs, saving the cloud provider time and money.

As a networking partner, ADLINK can work closely with networking equipment providers (NEPs) or communication service providers (CSPs) and remove barriers often associated with platform production. Experience with coordinating worldwide distribution hubs, strong command of international supply chains, and top-tier service/support centers are all distinct strengths ADLINK leverages as it forms NEP and CSP partnerships. Additionally, thanks to its international footprint, ADLINK can adeptly manage certification processes to conform with major global standards, so companies won't suffer compliance difficulties as solutions ship internationally. Customization flexibility and heavy investment in R&D keeps ADLINK at the forefront of networking partner innovation, leading the way forward with emerging technologies, including edge computing and video analytics.



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Next Generation LDARS

Challenge

Instead of relying on the traditional “black box” approach of recording and storing event data locally, and then retrieving it in a lab as part of an after-event investigation, a U.S.-based company sought to develop a live event recording system capable of streaming data to the cloud.

However, the company’s improved LDARS system clearly required more CPU resources than its legacy LDARS PC/104 computing platform could provide. Moreover, the LDARS system constituted only a fraction of the train’s complete onboard Positive Train Control (PTC) system, and their next generation solution couldn’t expand beyond the legacy system’s total footprint. In short, the company needed higher performance while maintaining a fanless design (for dust resistance) without exceeding thermal and power thresholds.

Solution

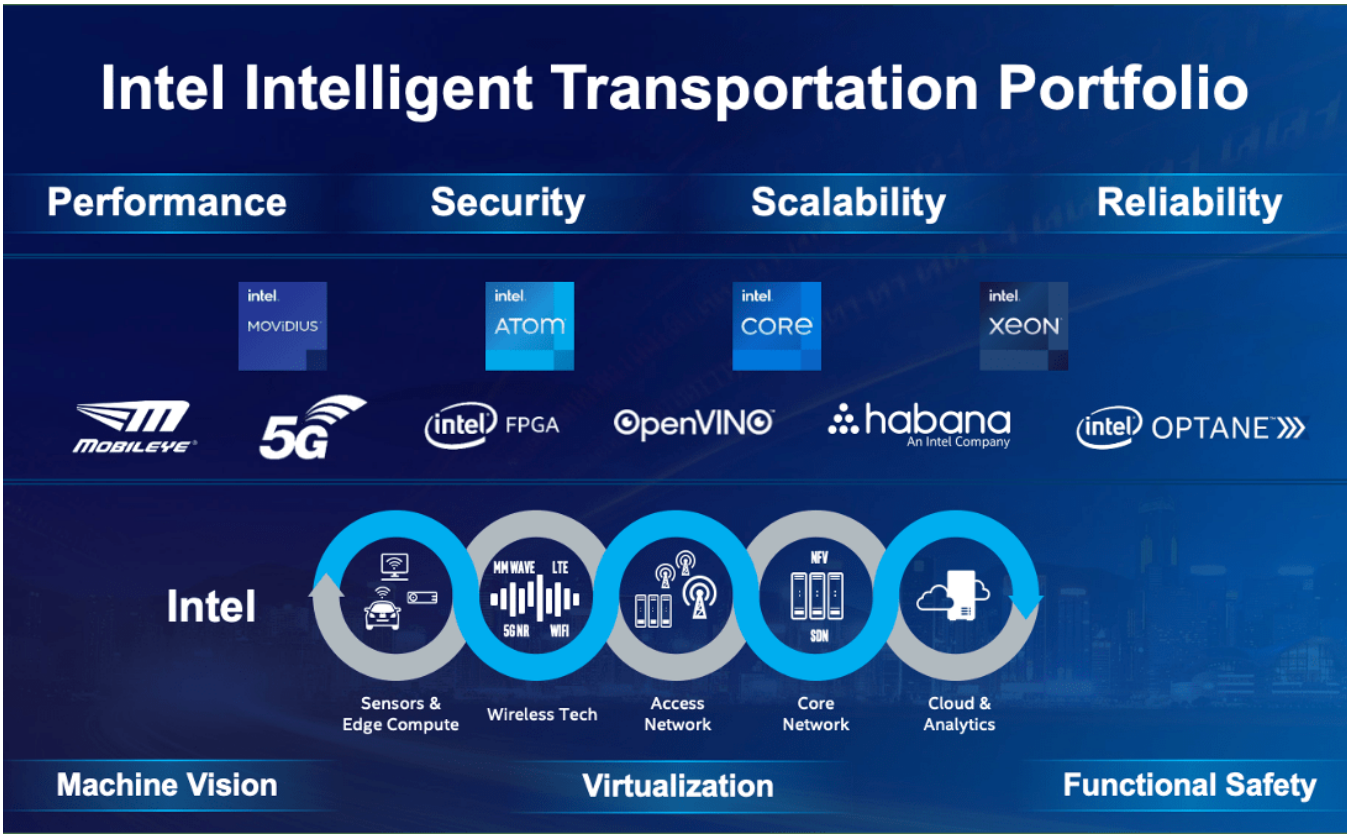
ADLINK provided the initial solution for the new LDARS system and also supplied its eventual successor. At first, the company selected ADLINK’s CoreModule-920, which featured a 3rd Gen Intel® Core™ or Xeon® processor and fast I/O connections, but then the LDARS company migrated to ADLINK’s CM4-SL2 PCI/104-Express single board computer. Boasting a 6th Gen Intel® Core™ processor, ADLINK’s offering also uses latching-type connectors for enhanced security, convenience and time-to-market benefits. Without latching connectors, cable connections require hot glue to maintain ruggedness, which is far from ideal.



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Developing Digital Solutions with Intel

For decades, Intel has been at the forefront of technology research, innovation, and development ranging from advanced compute, storage, and networking technologies that power many of the world's data centers to advanced innovations and designs for emerging technologies and platforms such as autonomous driving vehicles and 5G communications. At every step, Intel takes a deeply integrated approach with technology to provide a strong set of compatible solutions, platforms, products, technology innovations, and architectures to complement one of the world's most dynamic set of ecosystem partners.



Intel® Compute Technologies

As railways connect more infrastructure to the cloud, they're seeing a greater need to place high-performance compute at (or near) the Edge to perform predictive analytics and AI using data from sensors, cameras, and other sources. This can help reduce latency, improve near real-time responses, and relieve demand on network bandwidth for performance-hungry tasks like vision. Solutions based on Intel® platforms deliver high performance at the Edge. Railways can use Intel® platforms with specialized technologies to consolidate multiple systems into one while leaving enough room to add new functionalities as needed.

Intel is helping IoT innovations get to market faster, reducing solution complexity, and defining how to derive actionable intelligence more quickly and securely. Intel® Compute technologies are hardened to support today's IoT scenarios for railways.

Intel® Artificial Intelligence

Intel has the industry's most comprehensive suite of hardware and software technologies that deliver broad capabilities and support diverse approaches for AI—including today's AI applications and more complex AI tasks in the future. Intel's AI portfolio helps customers enable AI model development and deployment at any scale from massive clouds to tiny Edge devices, and everything in between. Intel is leading the next wave of AI with new products designed to accelerate AI system development and deployment from cloud to Edge, offering the broadest and deepest spectrum of solutions in the industry.

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Intel® Movidius™ Myriad™ Vision Processing Unit (VPU)

Intel's next-generation Intel® Movidius™ is designed for Edge media, computer vision, and inference applications. The technology incorporates unique, highly efficient architectural advances that are expected to deliver leading performance—more than 10 times the inference performance as the previous generation—with up to six times the power efficiency of competitor processors.

Additional technologies supporting AI include:

- **Intel® Xeon® Scalable processors:** powerfully designed to handle the broadest range of AI workloads including deep learning.
- **Intel® FPGA**: Near real-time, programmable acceleration for deep learning inference workloads.
- **Intel® Vision Accelerator Design products**: Based on Intel® Movidius™ VPUs and Intel® Arria® 10 FPGAs, the Intel® Vision Accelerator Design products provide powerful, deep, neural network inference for fast, accurate video analytics to meet the demands of computer vision applications at the Edge and to enable solution providers and their customers to take advantage of a wide spectrum of video analytics-based use cases.

Computer Vision with Intel® Distribution of OpenVINO™ Toolkit

The **Intel® Distribution of OpenVINO™ Toolkit** is a comprehensive toolkit for quickly developing multiplatform applications and solutions that emulate human vision. Based on Convolutional Neural Networks (CNNs), the toolkit extends Computer Vision workloads across Intel® hardware, maximizing performance. Railway organizations can accelerate and deploy CNNs on Intel® platforms with the Intel® Deep Learning Deployment Toolkit that's available in the OpenVINO™ toolkit and as a stand-alone download. Together with the new Intel® DevCloud for the Edge, OpenVINO addresses a kexy pain point for developers—allowing them to try, prototype and test AI solutions on a broad range of Intel processors before they buy hardware. The OpenVINO™ toolkit:

- Enables CNN-based deep learning inference on the Edge.
- Supports heterogeneous execution across computer vision accelerators—CPU, GPU, **Intel® Movidius™ Neural Compute Stick**, and FPGA—using a common API.
- Speeds time to market via a library of functions and preoptimized kernels.
- Enables development and optimization.

Intel® 5G

Intel is a leader in driving network transformation and enabling Edge compute that's needed to bring 5G to life. Intel is transforming purpose-built networks to become more agile, flexible, and scalable with Software Defined Networking (SDN) and Network Function Virtualization (NFV)—setting the stage for 5G.

For Intel's communications service provider customers, the work is already underway as Intel lays the foundation for 5G and transforms its communications infrastructure to SDN. This enables more seamlessly connected, powerful, and intelligent 5G-ready networks in comparison to previous networks that were hardware-based. Leading service providers around the globe have made incredible progress in advancing SDN and NFV with solutions across the core network.

With the move to 5G, Intel-powered networks help railway organizations become AI ready–with the compute power to handle networking, cloud, and AI workloads. Transformed networks with powerful computing resources at the Edge enable operators and cloud providers to intelligently deliver highly personalized services for railways today and in the 5G future.

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Getting Started

The digitization of the railways industry has begun. Organizations across the world are embracing railways as a low-carbon emission form of transport and investing in new technologies to improve their operations to entice new customers and passengers. The convergence of AI with 5G and edge technologies will unlock new capabilities, revenue streams, and cost savings for your organization, but you need not embark on this journey alone.

Intel and ADLINK are partnering to help you along this digitization journey. They offer robust products that enable railway organizations to build AI-at-the-edge applications that strengthen capabilities and accomplish organizational goals. Together they can help you unlock the power of data to improve operational and asset efficiency, enhance your network safety, and optimize the travel experience for your passengers.

The journey to a smarter, safer railway begins with small steps. It starts with assembling like-minded leaders to create a shared vision of the future. Then, leveraging their extensive experience with many governments and railway authorities worldwide, Intel and ADLINK deliver building blocks that railway leaders can use to create and implement that future in the actual world. No matter what your priorities may be, Intel and ADLINK are ready to work with you to turn your visions into realities.

Four Steps on Your Digital Rail Journey









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1. Assess Your Current Needs and Define Future State

Determine the current status of your organization. Ask yourself, "What is and what isn't working? What are your most impactful KPIs?" Discuss where you want you to be in the future and define key performance indicators that will help you quantify success.

2. Create a Holistic Vision and Blueprint for Your Operation

Work with your team members to define a shared vision that addresses your desired outcomes. The vision should not be expressed solely as technical achievements but also as experiential improvements that technology can make possible. It is essential to build that vision with stakeholder involvement to achieve better and more diverse suggestions, consensus, and commitment.

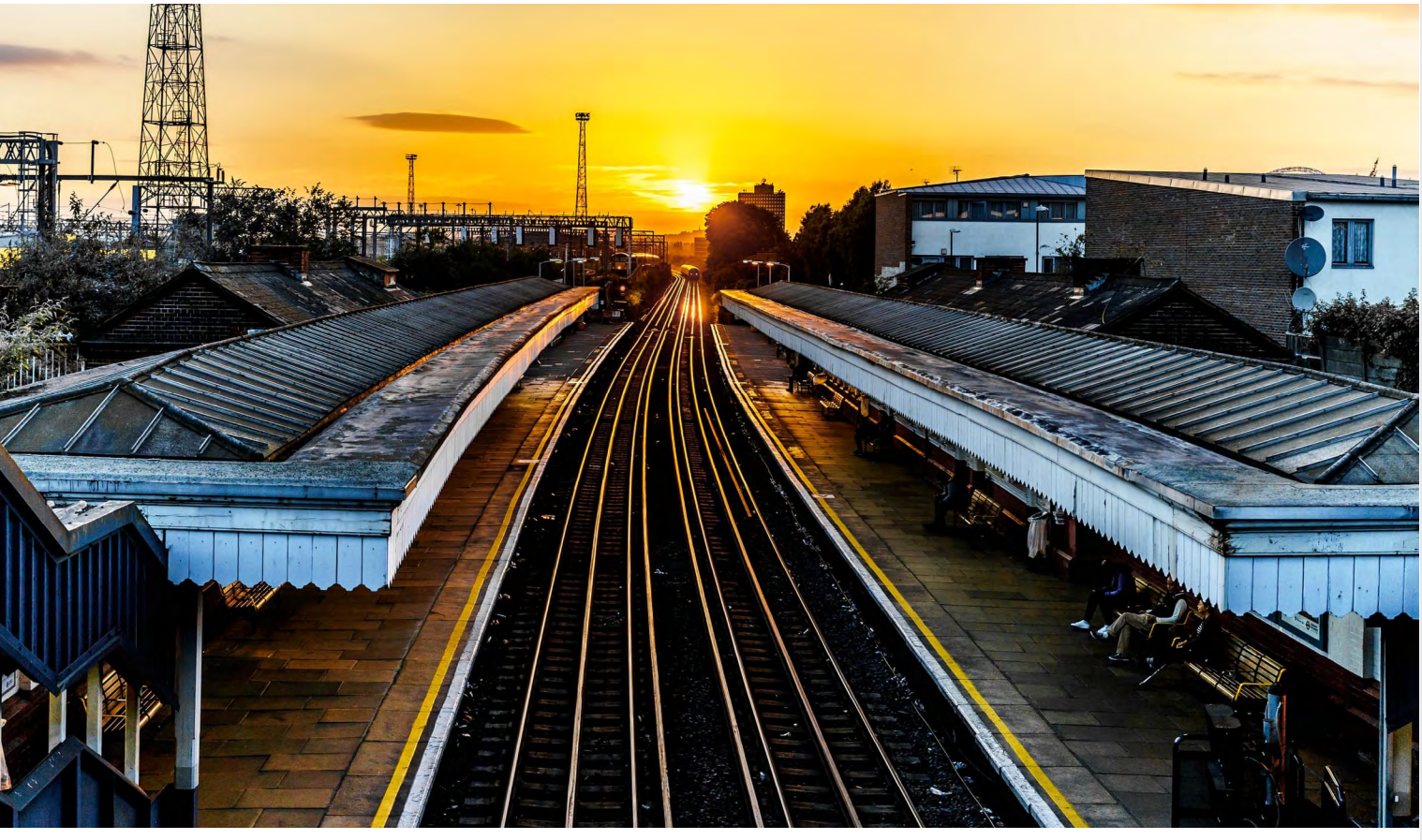
Develop a priority list and "blueprints" for the most important projects in your technical modernization plan and pipeline. How do these priorities and projects align with the "Future State" you defined earlier? Think about how you will acquire the necessary resources to execute these projects. Align with your management chain to get approval and increase visibility and transparency across teams and goals.

3. Start Small, Move Fast

Start by picking a digitalization project with high potential and a visible impact. How does this project compare to the priorities set out in step 2? Identify milestones at which you will regroup and measure progress. Validate your assumptions and track your return on investment.

4. Proliferate Learnings

Regroup after step 3. Share lessons learned, discuss what worked and what didn't, and strengthen stakeholder commitment to your shared visions. Do your current KPIs still apply? Train those that will operate and manage digital technologies at scale on best practices. Are you on a path that will help you achieve your vision? Assess, iterate, and improve.



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Resources

Enable your digital strategy from edge to cloud, from train to platform, with ADLINK.

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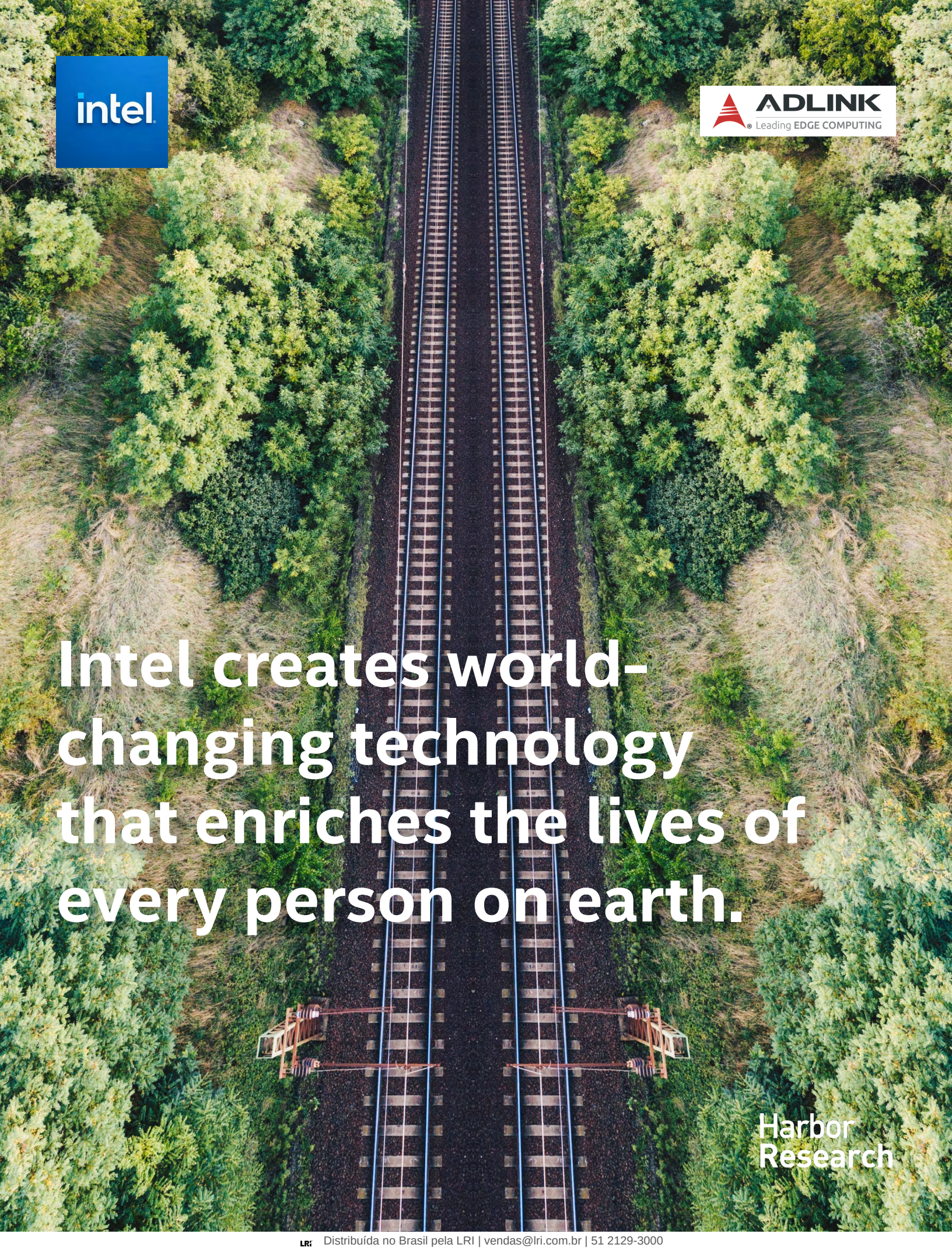
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