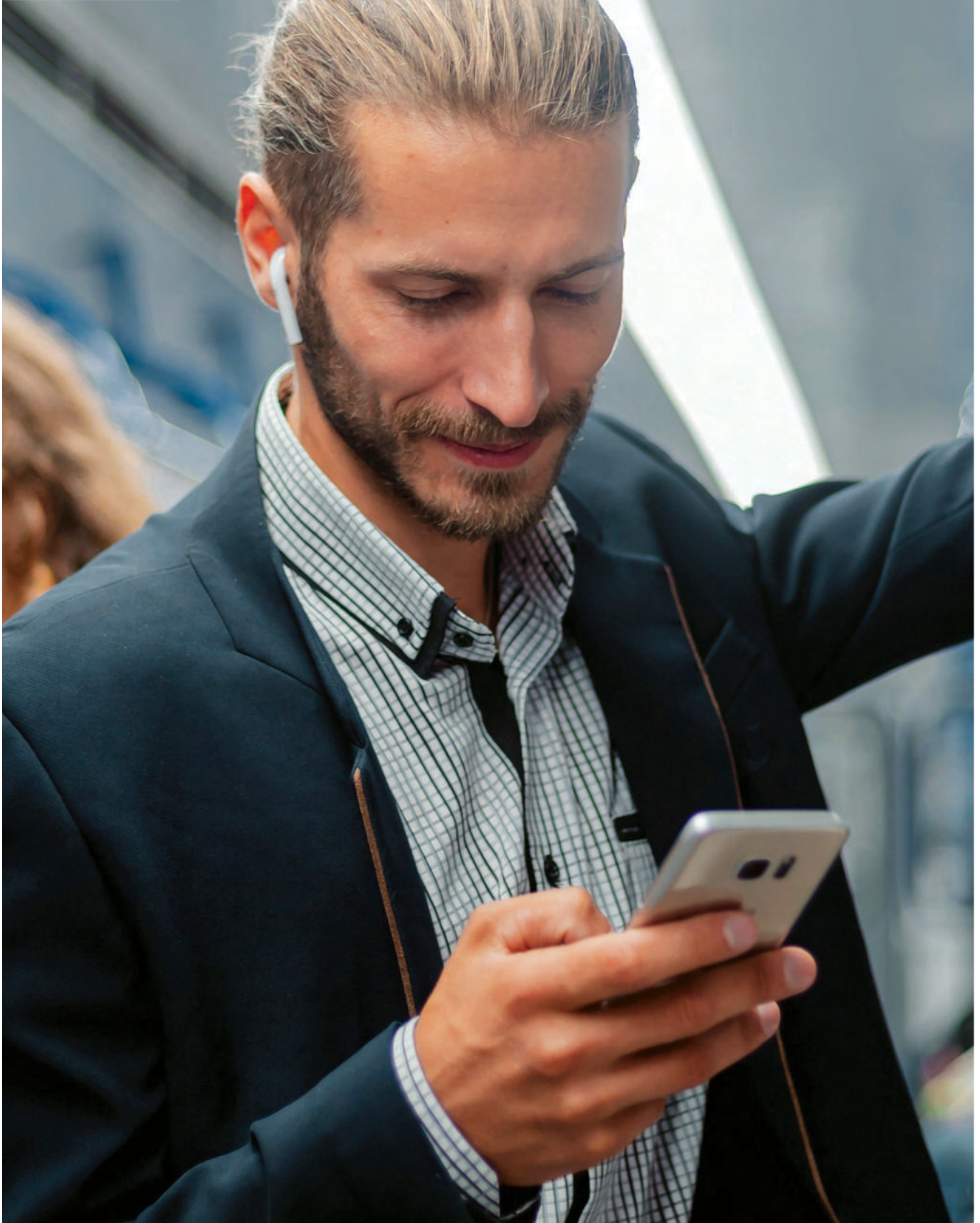




CONNECTIVITY INSIGHTS 2024



CONTENTS

ON-TRAIN INTERNET CONNECTIVITY SURVEY 2024	Page 4
EMERGING AND DEVELOPING CONNECTIVITY TRENDS	Page 12
TAKING PASSENGER SATISFACTION TO THE NEXT LEVEL	Page 20
LEVERAGING CONNECTIVITY FOR SAFETY & OPERATIONAL EFFICIENCY	Page 28
ICOMERA, EQUANS & BOUYGUES: PARTNERS ON THE CONNECTED JOURNEY	Page 38
CONCLUSION	Page 45
NOTES AND REFERENCES	Page 46



ON-TRAIN INTERNET CONNECTIVITY SURVEY 2024



89% of rail professionals believe that on-train Internet connectivity will be 'Important' or 'Very Important' to the overall future and development of the rail industry. This was one of the key findings of Icomera's 2024 On-Train Internet Connectivity Survey.

In H1 2024, we spoke to 343 rail industry professionals working across a wide range of roles in Europe and North America, seeking their input on the various aspects of onboard Internet connectivity for trains.

The survey collected a broad range of views on the quality, challenges, and potential improvements related to all onboard Internet-connected systems and services, ranging from passenger Wi-Fi to other, more operational- or security-focused applications like remote vehicle condition monitoring or video surveillance.

Other key takeaways from the survey include:

1. On-train Internet connectivity's role in the future of the rail industry will be multifaceted.
2. 72% of rail industry professionals are 'satisfied' or 'very satisfied' with the current Internet Connectivity provided on trains for passenger and operational applications.
3. A combination of established and emerging communication technologies will significantly enhance Internet connectivity on trains.
4. Given its importance, 87% of rail industry professionals believe there should be more investment in improving onboard Internet connectivity.

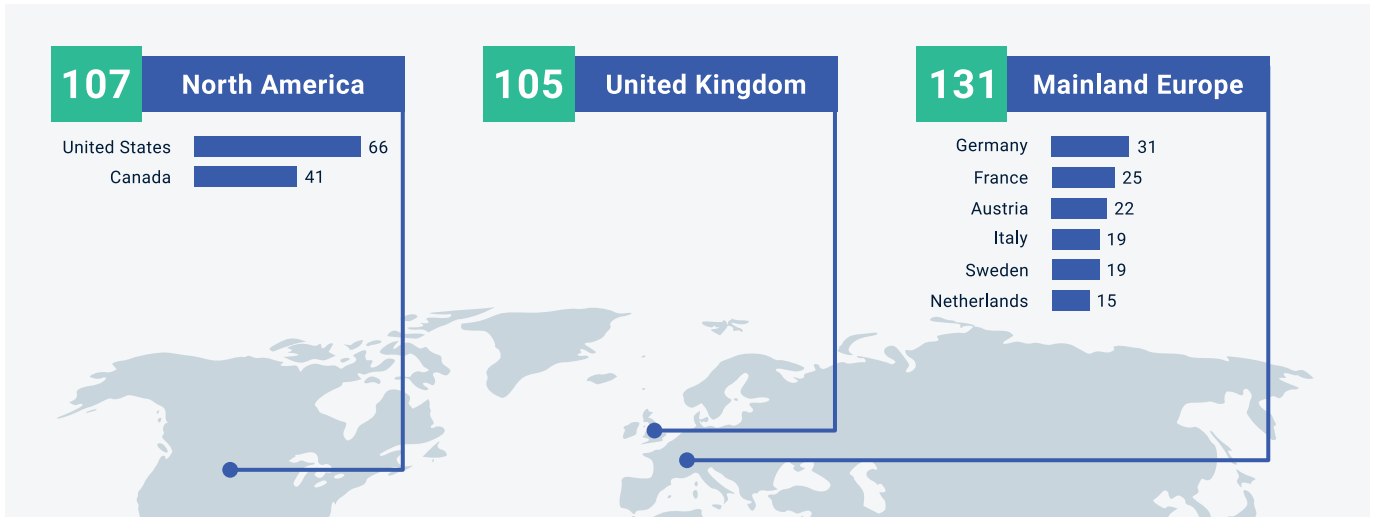
This year Icomera is celebrating its 25th anniversary and the survey answers we received may have looked very different in 1999, when the concept of Internet on-the-go was in its infancy. The term 'Wi-Fi' had just been coined, the first 3G roll-out wouldn't arrive until 2002, and even 4G networks were ten years away.

But in Gothenburg, Sweden, four pioneering students were developing "multicellular aggregating technology", creating the fastest, most reliable Internet connection possible for a moving vehicle and, in the process, Icomera was born.

Icomera deployed the rail-industry's first commercial onboard passenger Wi-Fi service with Swedish rail operator SJ in 2003. In the years since, onboard connectivity has evolved from a luxury consideration to an essential service and Icomera has become a global company, providing wireless connectivity to the vehicles of many of the world's leading transport operators, connecting millions of Wi-Fi users and tens of thousands of trainsets, trams, buses and coaches around the globe every day.

SURVEY OVERVIEW

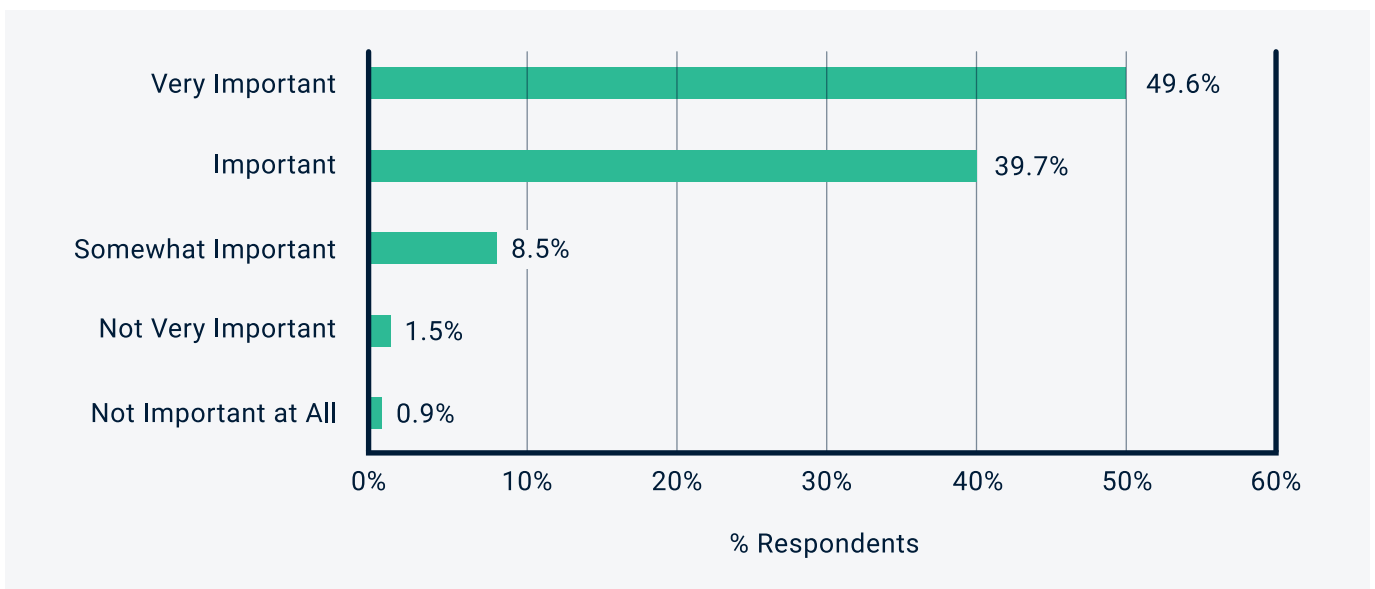
RESPONSES BY REGION / COUNTRY



QUESTION

How important do you believe on-train Internet connectivity will be to the overall future and development of the rail industry?

- **49.6%** of respondents believe that on-train Internet connectivity will be 'Very Important' and **39.7%** 'Important'.
- Of the remaining respondents, **8.5%** felt it was 'Somewhat Important' and **2.4%** 'Not Very Important' or 'Not Important at All'.



1. ON-TRAIN INTERNET CONNECTIVITY'S ROLE IN THE FUTURE OF THE RAIL INDUSTRY WILL BE MULTIFACETED

While passenger Wi-Fi has historically been the most obvious application for 'Internet on board', and understandably receives a greater share of attention from the general public, those working across the rail industry take a broader view.

When asked to give their opinion on what roles on-train Internet connectivity could play in the future of the rail industry, the benefits for the Passenger Experience were most frequently recognized (by 64% of respondents), followed by Operational Efficiency (60%), and Safety and Security (40%).

The only regional deviation from this order was in mainland Europe, where Passenger Experience and Operational Efficiency opportunities were both recognized by 53% of respondents. 65% of North American professionals specifically highlighted the potential impact of connectivity on operational efficiency, more than any other region. Respondents from the UK were more inclined to emphasize the importance of connectivity for safety and security (47% of UK respondents).

At Icomera, we see a growing proportion of the Internet connectivity we are delivering to trains being used by Internet-of-Things (IoT) applications for remote monitoring and data analytics, improving the safety and operational efficiency of rail operations.

Combined with the passenger services we support, we are ensuring confidence from origin to destination, making every journey more time-efficient for passengers, and more cost-effective for rail operators.

2. RAIL INDUSTRY PROFESSIONALS ARE 'SATISFIED' OR 'VERY SATISFIED' WITH THE CURRENT INTERNET CONNECTIVITY PROVIDED ON TRAINS FOR PASSENGER AND OPERATIONAL APPLICATIONS

Our survey reveals that the rail industry is, on the whole, satisfied with the current state of on-train Internet connectivity. This does contrast with other surveys that focus purely on passengers' perceptions of onboard Wi-Fi services. For example, a recent survey by Uswitch found that only 55% of users reported 'Good' or 'Excellent' experiences on even the best on-train Wi-Fi services.¹

This discrepancy between the views of rail industry professionals and their passengers may be due to a combination of factors:

- Firstly, the industry professionals were asked to take operational applications into account when assessing the current state of on-train Internet connectivity. These often require less bandwidth than passenger Wi-Fi services and so more often perform in-line with expectations.
- Secondly, there is greater general awareness amongst rail industry professionals of the challenges involved in providing connectivity to and from a moving vehicle compared to passengers who, as paying customers, simply expect their Wi-Fi to work.

Satisfaction is a moving, evolving target. Icomera has seen the average data consumption per passenger Wi-Fi session more than double in the last five years, testing the limits of previous generation technologies at every stage of the connectivity pipeline.

With both passenger and operational applications becoming more data intensive over time, the current satisfaction scores will only decline if the underlying technology is not developed and deployed to meet future needs.



QUESTION

In your opinion, what roles could on-train Internet connectivity play in the future of the rail industry?



64%

Enhance the Passenger Experience

64% of industry professionals believe that on-train Internet connectivity has a role to play in further enhancing the passenger experience.



60%

Improve Operational Efficiency

Almost as many (60%) recognize its value in improving operational efficiency, providing remote access to live train sensor data for predictive maintenance for example.



40%

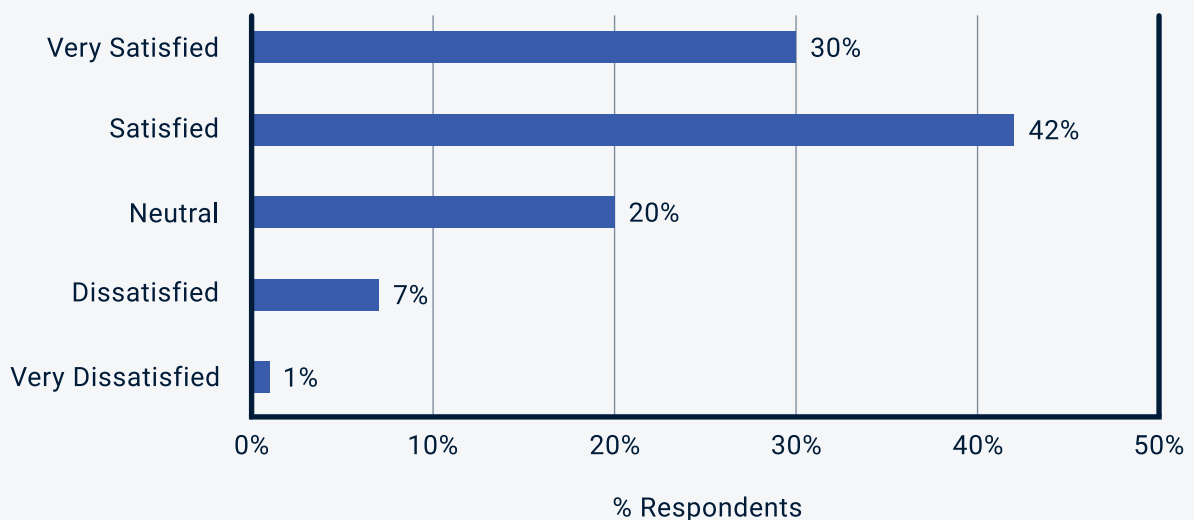
Augment Safety & Security Measures

Additionally, 40% see its utility in augmenting safety and security measures, through applications such as digital video surveillance.

QUESTION

How satisfied are you with the current Internet connectivity provided on trains, either for passenger or operational applications?

- **30%** of respondents reported being 'Very Satisfied' and **42%** 'Satisfied.' **20%** took a neutral stance.
- Dissatisfaction was relatively low across all regions, with only **7%** expressing they were 'Dissatisfied' and **1%** 'Very Dissatisfied' overall.



3. A COMBINATION OF COMMUNICATIONS TECHNOLOGIES WILL SIGNIFICANTLY ENHANCE INTERNET CONNECTIVITY ON TRAINS

The quality of an on-train Internet connection is highly dependent on the coverage and capacity of the communication networks along the route. When asked which emerging or established communication technologies could most significantly enhance Internet connectivity on trains, industry professionals placed cellular networks first (62% of respondents), followed by satellite constellations (56%) and then private trackside networks (29%). All regions included in the survey followed this order, with the exception of the United Kingdom, where the potential of commercial cellular networks and satellite Internet were both recognized by 63% of those surveyed.



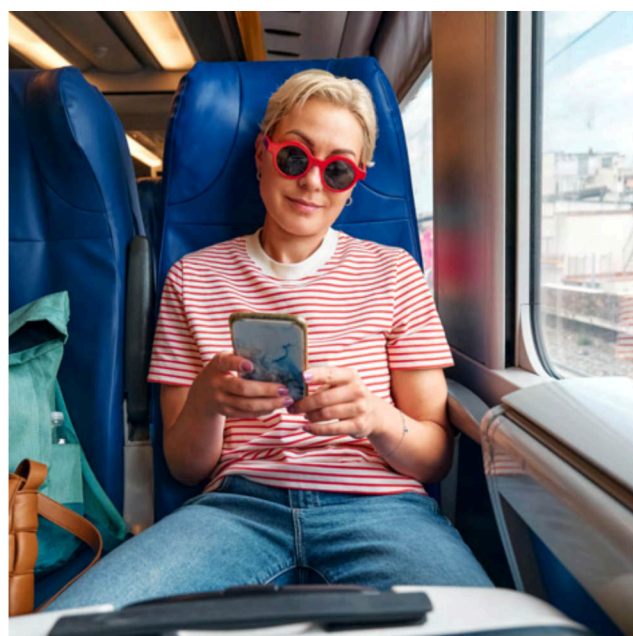
Today on-train Internet connectivity is largely delivered through cellular networks. The general preference for utilizing current cellular network technologies is due to their widespread deployment and continual evolution, for example, the 5G rollout, while the strong interest in satellite Internet, especially LEO satellites, suggests an awareness of their potential to offer high-speed connectivity, particularly along routes that traditional cellular networks may not cover effectively. The lower interest in private trackside networks still reflects recognition of their potential to offer enhanced data throughput in rural locations or in challenging environments such as tunnels, albeit with the understanding that such networks can be more costly and time-intensive for a rail operator or infrastructure owner to create and maintain.

By taking a hybrid approach and intelligently utilizing a range of different connectivity technologies together in tandem, transport operators will be best placed to gain maximum value well into the future.

4. RAIL INDUSTRY PROFESSIONALS BELIEVE THERE SHOULD BE MORE INVESTMENT IN IMPROVING ONBOARD INTERNET CONNECTIVITY

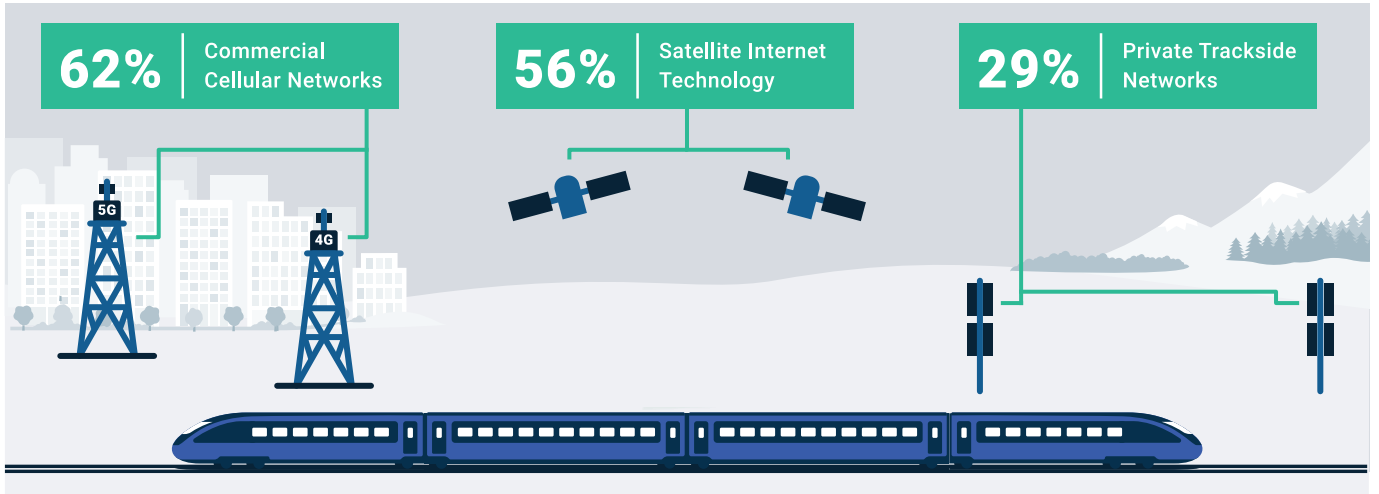
Given the importance of on-train Internet connectivity amongst rail professionals has been established across other answers in our survey, it should come as no surprise that a significant majority - 87% of respondents - support increased investment in this area.

Writing in the New Statesman, Daniel Susskind, an economist at Oxford University and King's College London, conservatively estimated that an investment in passenger Wi-Fi would yield five times the economic value in return.² And as we have already discussed, passenger Wi-Fi is just one application served by the connection to and from the moving vehicle – Susskind's estimate does not consider the value of improving the safety and operational efficiency of a rail network, which would only strengthen the business case.



QUESTION

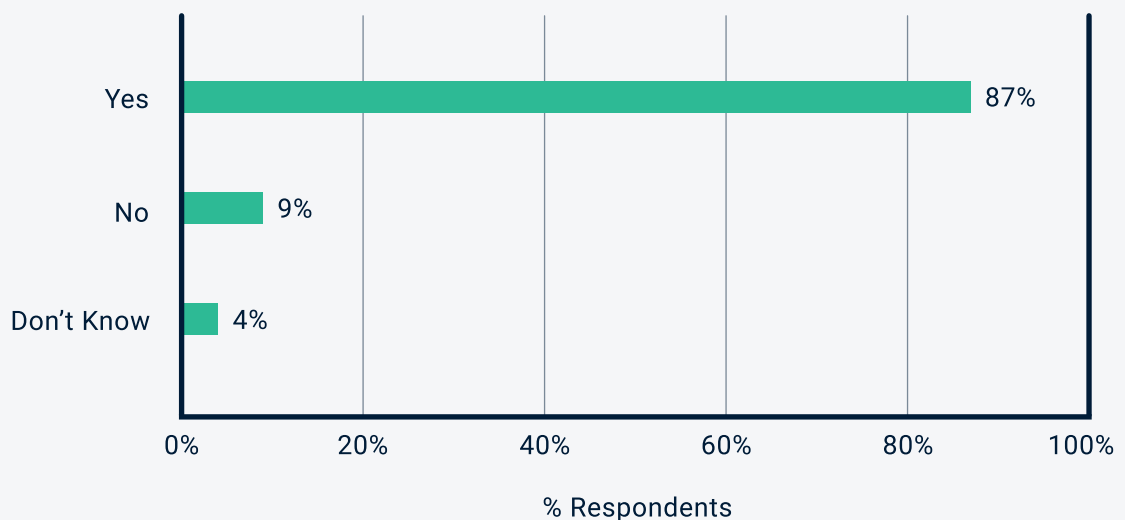
Which communication technologies do you believe could most significantly enhance Internet connectivity on trains?

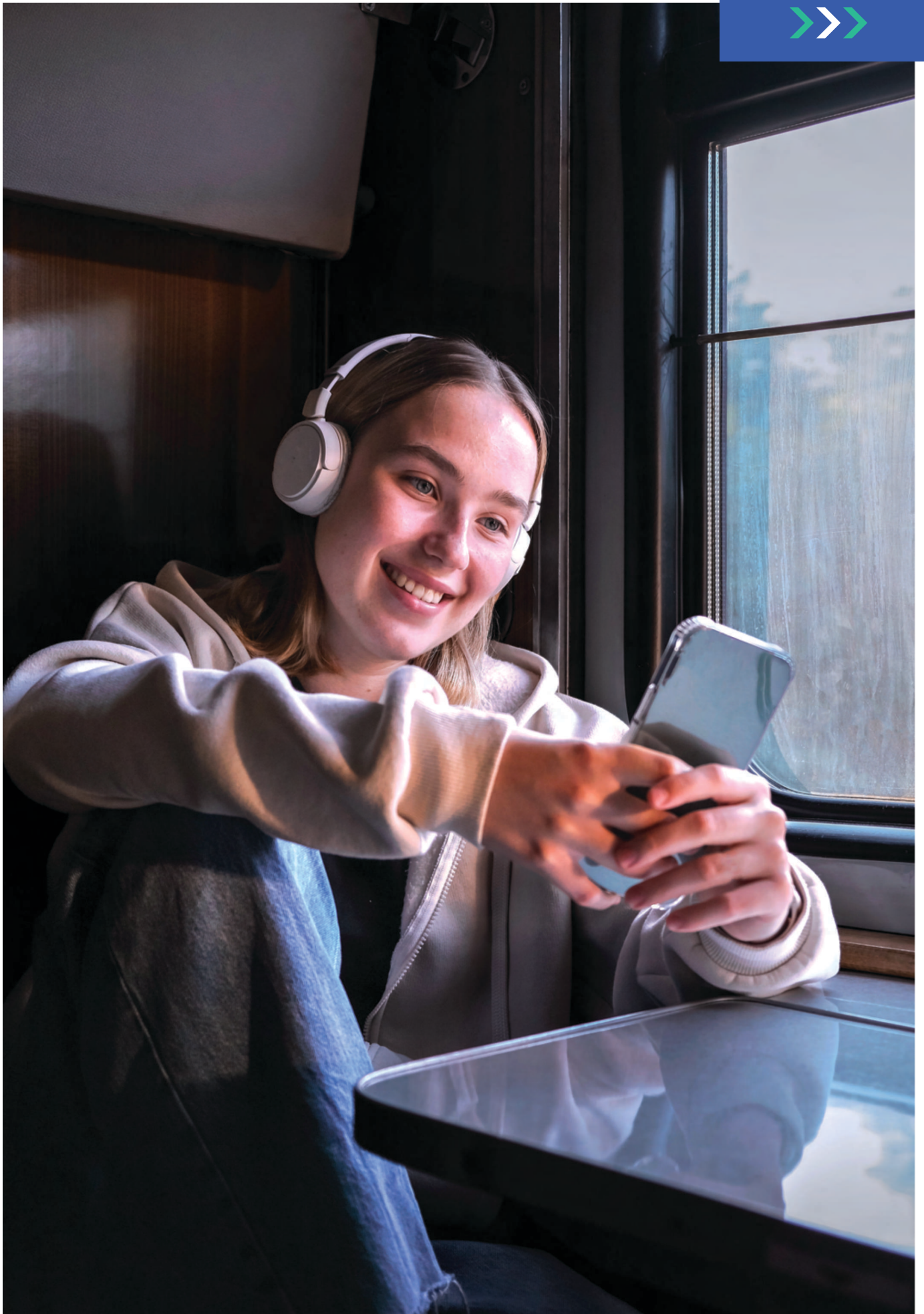


QUESTION

Do you believe your company/organization should invest more in improving onboard Internet connectivity?

- A significant majority (**87%** of respondents) support increased investment in improving onboard Internet connectivity.
- The remaining **13%** either do not see the need for more investment (**9%**) or are unsure (**4%**).



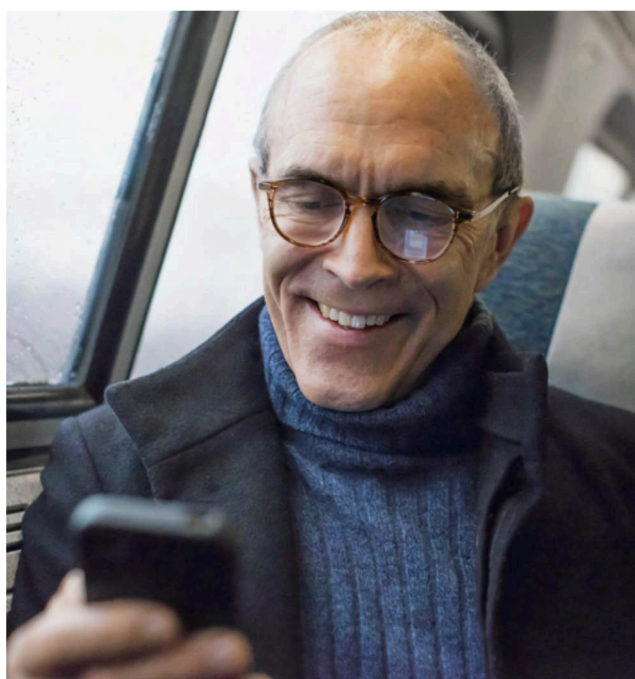


Over the coming years the transport industry will have to contend with multiple factors that will influence the way we travel, from post-pandemic behavioral changes, climate change and threats arising from global conflicts, to aging populations and the blurring of boundaries between the physical and digital worlds.

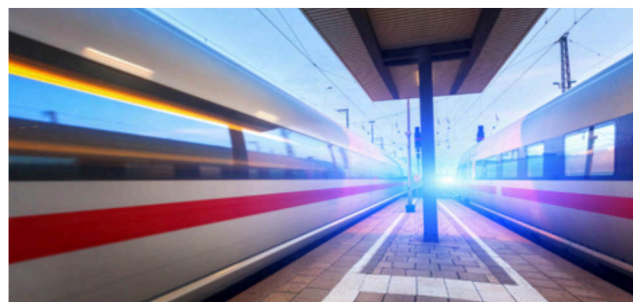
In order to best serve society in the face of these developments, the transport industry needs to simultaneously pursue three objectives to attract passengers and meet the increase in demand that comes from shifting society's travel habits further towards sustainable, green mobility:

1. Catering for the evolving needs of business and leisure commuters, regardless of age or disability
2. Offering a safe environment that guards against physical and cyber threats to individuals and to wider infrastructure
3. Achieving the above in a cost-effective and resilient way that also allows the industry to adapt to rapidly changing environmental, societal, and economic needs in the future.

Clearly, investments that can deliver against all three of these objectives should be prioritized, and onboard Internet connectivity is one such investment.



With an increasing number of onboard devices or systems requiring connectivity, the increasing value of the data they generate, and the increasing importance of its timely availability, ensuring the reliable and secure transmission of the data that all these systems generate and utilize, to and from the moving vehicle, is key.



THE ESSENTIAL ROLE OF ON-TRAIN INTERNET CONNECTIVITY

Our survey results paint a clear picture: On-train Internet connectivity is seen as a pivotal element for the evolution of the rail industry by the people who will be responsible for overseeing it. This sentiment reflects the increasing digitalization of all aspects of transportation and the need for robust, consistent connectivity for both passenger and operational applications.

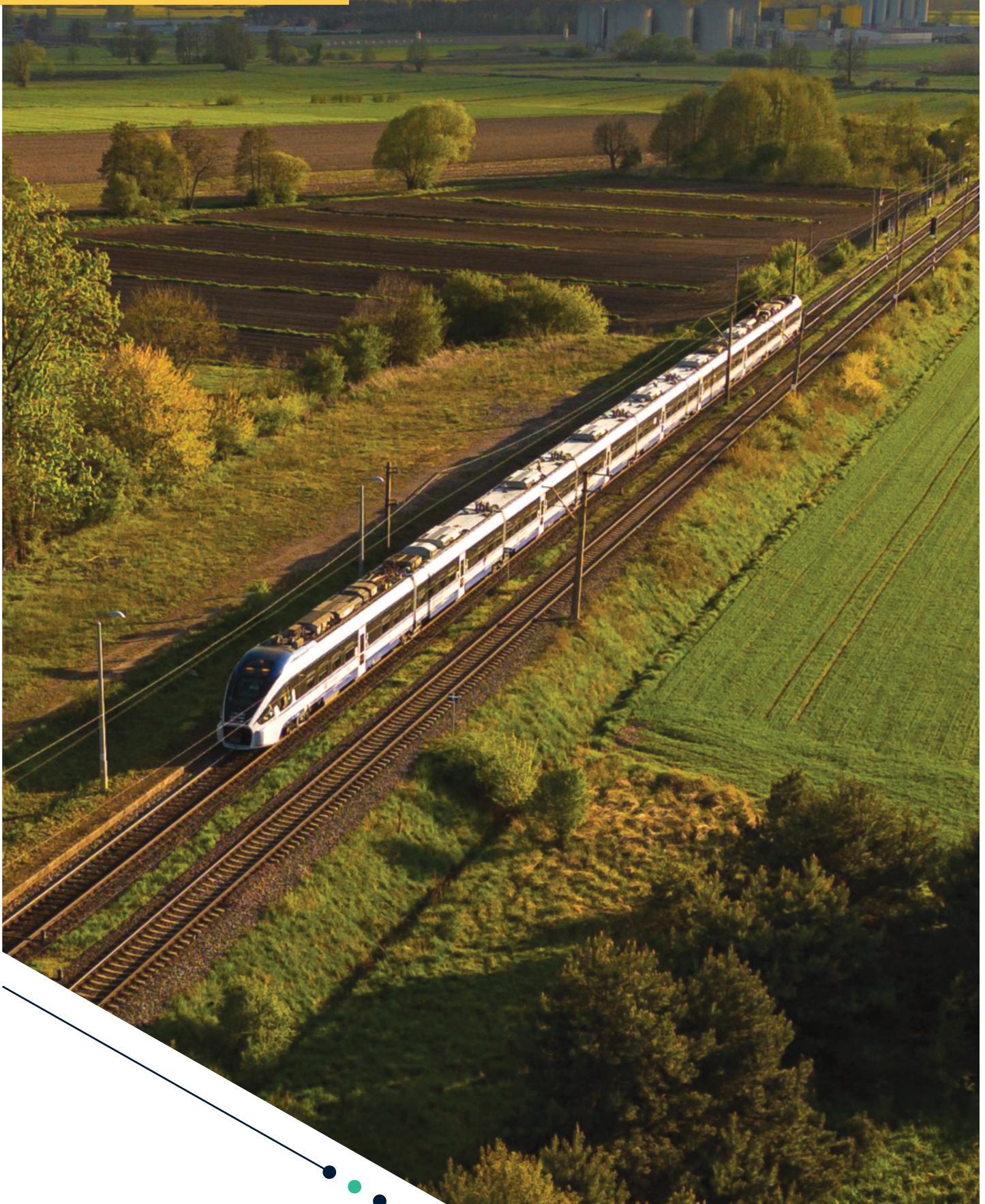
Looking ahead, the rail industry must navigate various challenges and opportunities. By prioritizing investments in onboard Internet connectivity, the industry can meet these challenges head-on, ensuring sustainable growth and improved service for passengers and operators alike.

As Icomera celebrates its 25th anniversary and the transformation from the early days of onboard Wi-Fi to today's multifaceted connectivity landscape, we have compiled the remainder of this report to explore the expanding role of connectivity in supporting the industry's pursuit of its overarching goals, and the new technologies and innovations that will be adopted along the way.





PART TWO





EMERGING AND DEVELOPING
CONNECTIVITY TRENDS



EMERGING AND DEVELOPING CONNECTIVITY TRENDS



Technological advancements are undoubtedly having an ever-growing impact on the world. But when it comes to public transport and onboard connectivity specifically, their influence might be a little less clear.

Technologies such as satellite, Wi-Fi 7, edge computing, and artificial intelligence (AI) are being deployed to help deliver increased value at every step of the connectivity pipeline, bringing ever more reliable performance, alongside enhanced data management.

SATELLITE TECHNOLOGY: A HYBRID STRATEGY

The recent emergence of Low Earth Orbit (LEO) constellations has reignited interest in satellite technology as an interesting option for transport operators to consider.

Harnessing satellite connectivity alongside cellular and trackside networks can help address the connectivity challenges faced in different geographic locations. This ensures that moving vehicles have access to the fastest and most reliable connection possible, improving overall service performance.



Satellite networks are particularly valuable in scenarios where vehicles traverse long stretches of rural or remote areas with no existing cellular or fibre infrastructure. These regions, often referred to as “not-spots,” pose challenges for uninterrupted connectivity. By leveraging satellite technology, not-spots can be effectively covered, providing seamless connectivity throughout the journey.

However, it's important to note that ground-based network infrastructure often offers data transmission with a lower cost base compared to satellite technology. In many urban environments, the aggregation of cellular 5G and LTE-A networks will provide sufficient connectivity, while dedicated private trackside networks can offer enhanced data throughput in rural locations or in challenging environments such as tunnels.

Given the value and limitations of different communications technologies, optimum connectivity is best achieved by leveraging a combination of two or more technologies together using aggregation.

By combining the advantages of different technologies across different geographic locations, transport operators are well placed to deliver seamless connectivity throughout a vehicle's journey.



TAKING ADVANTAGE OF WI-FI 7

Wi-Fi 7, also known as the IEEE 802.11be or EHT (Extremely High Throughput) standard, marks a significant technological step change; its introduction will deliver far better performance in high-density environments, making it perfectly suited for Wi-Fi on public transportation.

Wi-Fi 7 introduces several intelligent functions and features which allow for far better performance:

- **Wider Channel Bandwidth:** Wi-Fi 7 more than doubles the available usable bandwidth compared to Wi-Fi 6/6E by utilizing 320 MHz channels on the dedicated 6 GHz band, resulting in dramatically higher throughput.
- **4K QAM:** Wi-Fi 7 allows data to be packed more densely compared to the 1K QAM of Wi-Fi 6/6E. Specifically, 4K QAM enables each symbol to carry

12 bits compared to 10 bits in Wi-Fi 6/6E, resulting in 20% higher theoretical transmission rates.

- **Multi-Link Operation (MLO):** Whereas previous Wi-Fi generations only establish single-band connections between devices, MLO allows devices to simultaneously send and receive data across different frequency bands and channels, delivering data at a greater speed and lower latency.
- **Preamble Puncturing:** Preamble puncturing allows you to surgically slice off only the part of a channel with interference, greatly improving network capacity and reducing congestion.

So, what do these features of Wi-Fi 7 translate to in terms of their benefits for public transportation in particular? With previous Wi-Fi standards, technology and spectrum were a limiting factor which could sometimes lead to bottlenecks. The smart features Wi-Fi 7 introduces allow for more reliable performance in crowded environments, alongside faster speeds for passenger and onboard systems.

Transport operators who embrace Wi-Fi 7 will stay ahead of the curve; not only will they be ready to deliver faster, more reliable Internet access today, but they'll also be prepared to meet the ever-increasing demands of any data-intensive applications which are introduced further down the line.

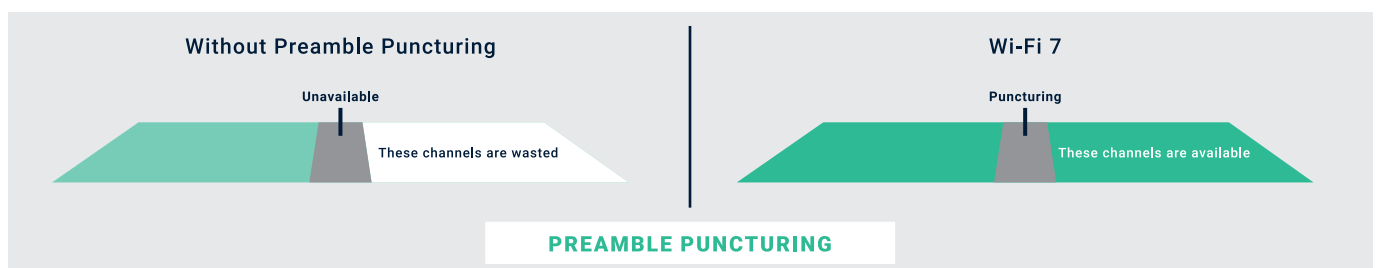
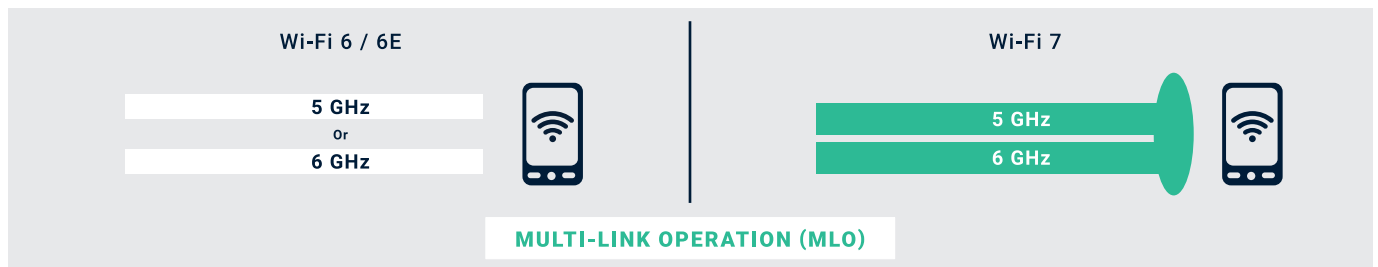
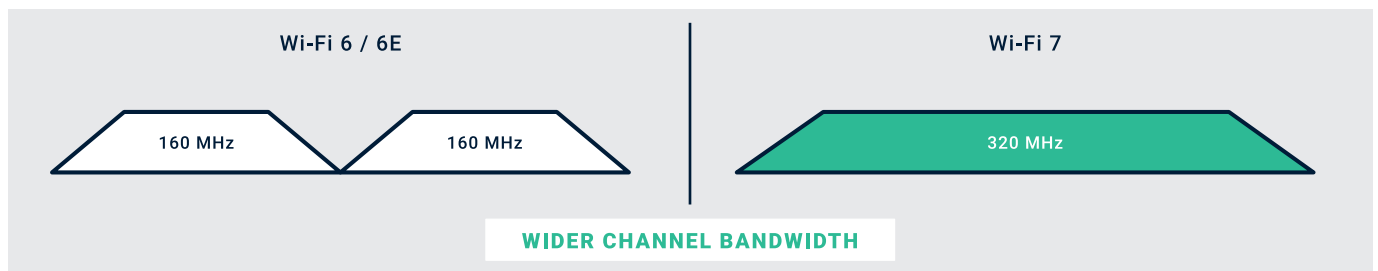


WI-FI 7: READY TO REVOLUTIONIZE THE WIRELESS LANDSCAPE

Wi-Fi 7 is capable of delivering up to 4.8x faster speeds, double the maximum bandwidth, a 20% increase in data transmission, and up to 100x lower latency than previous generations of Wi-Fi standard.

- MORE RELIABLE PERFORMANCE IN CROWDED ENVIRONMENTS**
- FASTER SPEEDS FOR PASSENGERS AND ONBOARD SYSTEMS**
- BENEFIT FROM NEXT-GENERATION TECHNOLOGY**

KEY FEATURES



EDGE COMPUTING & DATA-DRIVEN TRANSIT

Edge computing developed from the need for a practical solution to handle the ever-increasing wealth of network data in a quicker, more efficient way. With the edge computing model, computing power can be spread to the edge of the network, closer to the devices which generate the data.

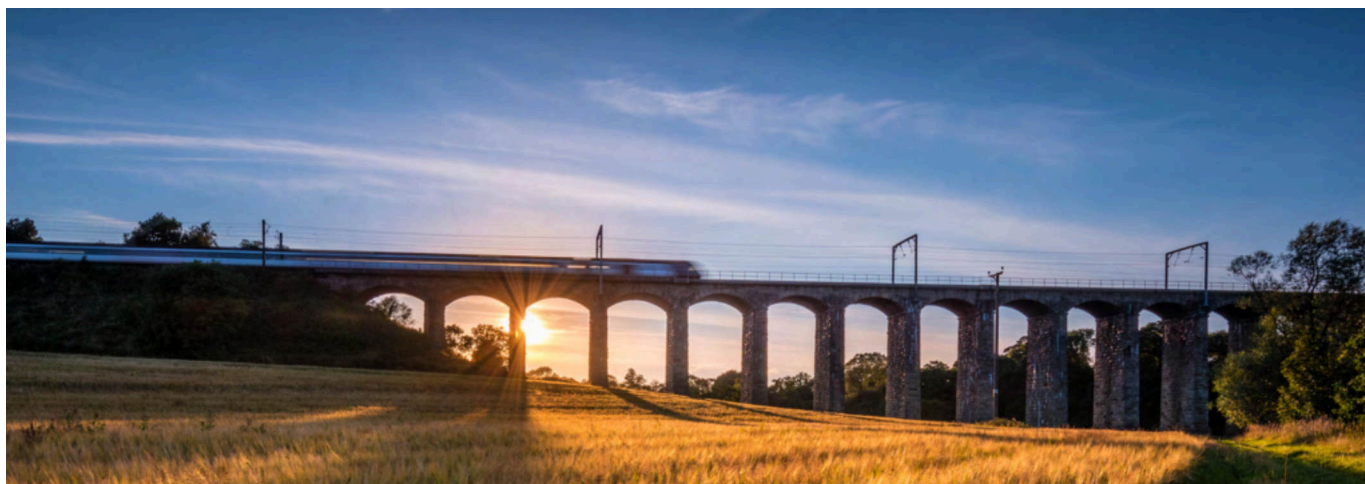
In the context of public transport, by taking advantage of edge computing in combination with fast, reliable and secure Internet connectivity, computing power can be located on the vehicle itself, extending the cloud and effectively turning a train, for example, into a rolling data centre.

Intelligently processing data locally without needing to push it off a vehicle delivers significantly improved overall system performance through:

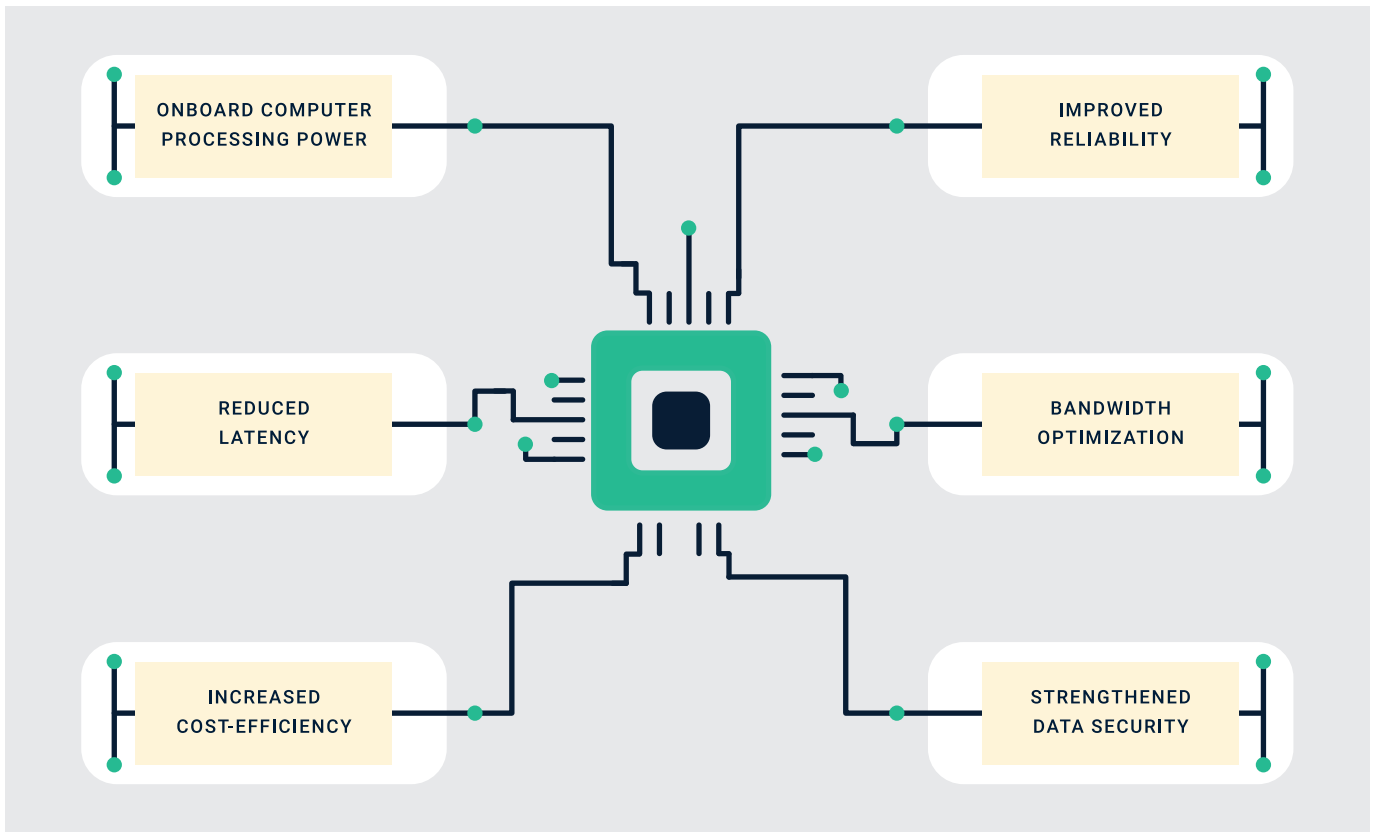
- **Onboard Computer Processing Power:** The ability for routers to perform complex computations directly within the vehicle ensures swift and efficient data analysis, reducing the reliance on external cloud-based servers.
- **Improved Reliability:** Onboard processing enables the vehicle to maintain essential operations locally, helping ensure that they always remain operational, contributing to a more dependable and resilient public transport network.

- **Reduced Latency:** In a public transport scenario, where real-time data is crucial for operations, the capacity to process data locally on the router reduces delay because not all data needs to travel back-and-forth to a cloud server.
- **Bandwidth Optimization:** Given the wealth of data generated on vehicles nowadays and the finite bandwidth available, transmitting all data generated back to the cloud is unnecessary and inefficient. To reduce the overall load on the network, it makes more sense to process data as close as possible to the source, and then determine whether it needs to be uploaded.
- **Increased Cost-Efficiency:** Edge computing can help reduce the costs associated with transmitting and storing large volumes of data in the cloud.
- **Strengthened Data Security:** Edge computing can improve network security by processing sensitive data locally rather than transmitting it back to a central server.

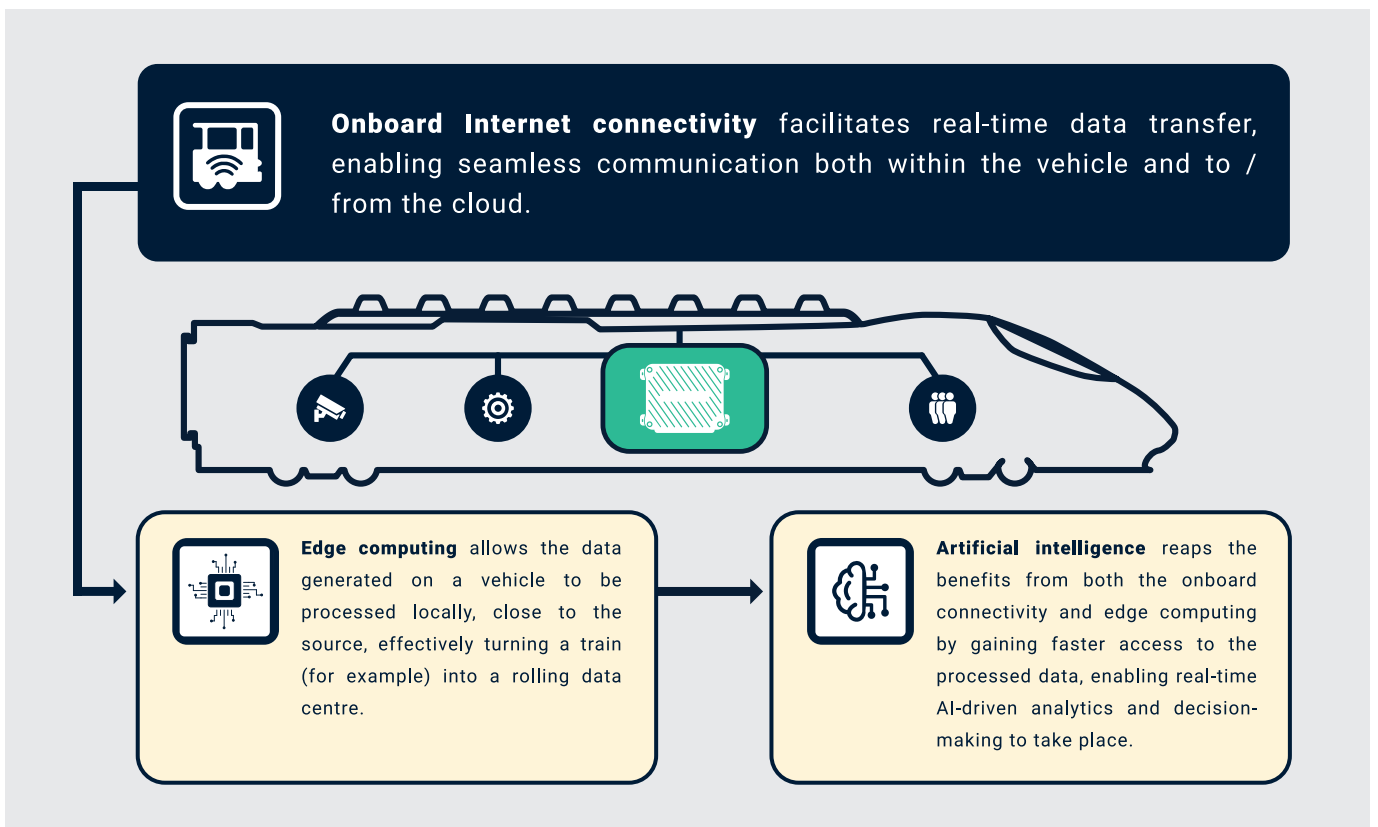
With the ability to process and act on data in real-time, Edge computing is ideally suited for public transport and contributes to making operations safer, more efficient, and passenger friendly.



WHY PROCESSING DATA AT A NETWORK'S EDGE MAKES SENSE



CONNECTIVITY AS THE BACKBONE FOR ARTIFICIAL INTELLIGENCE

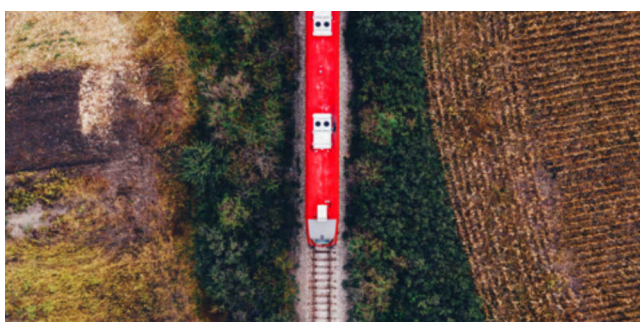


THE POWER OF ARTIFICIAL INTELLIGENCE

Confusingly, “Artificial intelligence”, “Machine learning” and “Deep learning” are sometimes used interchangeably, but they are in fact three different but interrelated concepts.

Artificial Intelligence is the broad overarching field, with **Machine Learning** being a subset that includes algorithms trained to make predictions or decisions based on data. **Deep Learning** is a further subset of Machine Learning, employing deep neural networks inspired by the human brain.

Within public transport, various types of artificial intelligence-based systems are used. Where previously it might have been necessary to rely solely upon retrospective data analysis to optimize a solution, machine learning systems are capable of processing vast datasets in real-time to predict possible outcomes, spot irregularities, and arrive at the most effective solution to solve problems. Deep learning incorporates neural networks with multiple layers to solve yet more complex tasks; for example, object recognition in images and video footage.



There is an interplay at work between leveraging Internet connectivity on public transport vehicles, harnessing computer power to process the data being generated at a network's edge, and incorporating AI technology – Namely:

- **Onboard Internet connectivity** facilitates real-time data transfer, enabling seamless communication both within the vehicle and to/from the cloud.

- **Edge computing** allows the data being generated on a vehicle to be processed locally, close to the source, enhancing security and data privacy, and reducing the need for all data to be sent off-board to be processed.
- **Artificial intelligence** reaps the benefits from both the onboard connectivity and edge computing by gaining faster access to the processed data, enabling real-time analytics and decision-making to take place.

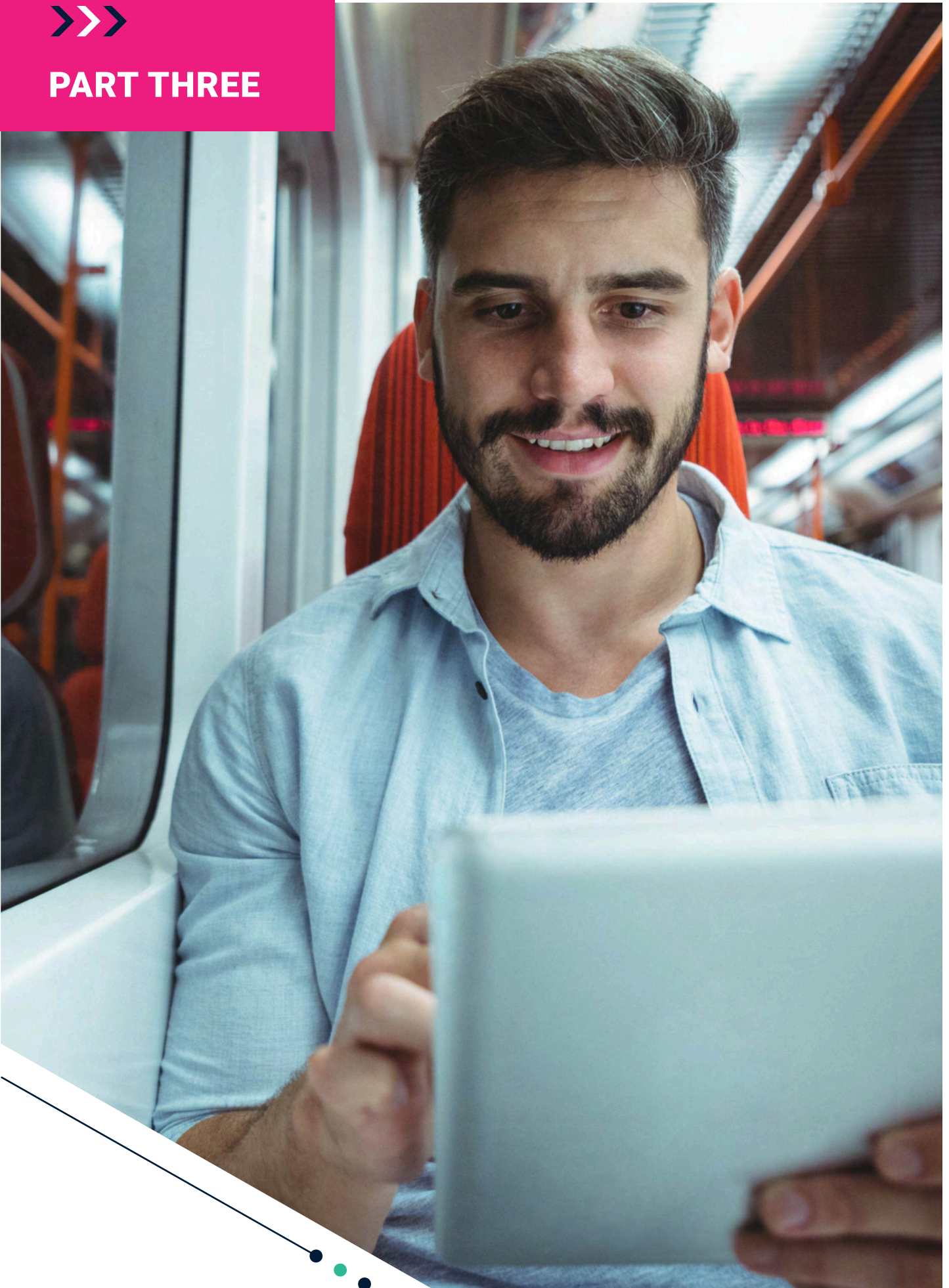


In summary, innovations such as satellite, Wi-Fi 7, edge computing and artificial intelligence are not only improving Internet connectivity but also contributing to a broader evolution in the transportation sector, fostering a more connected and convenient travel experience.

As these technological trends continue to develop over the short, medium and long-term, public transport operators will be able to deliver enhanced connected services which meet the ever-growing data demands of both their passengers and onboard systems. This evolution will support a more dynamic and responsive transport network, capable of adapting to real-time conditions and providing passengers with uninterrupted Internet access on the move.



PART THREE





**TAKING PASSENGER SATISFACTION
TO THE NEXT LEVEL**

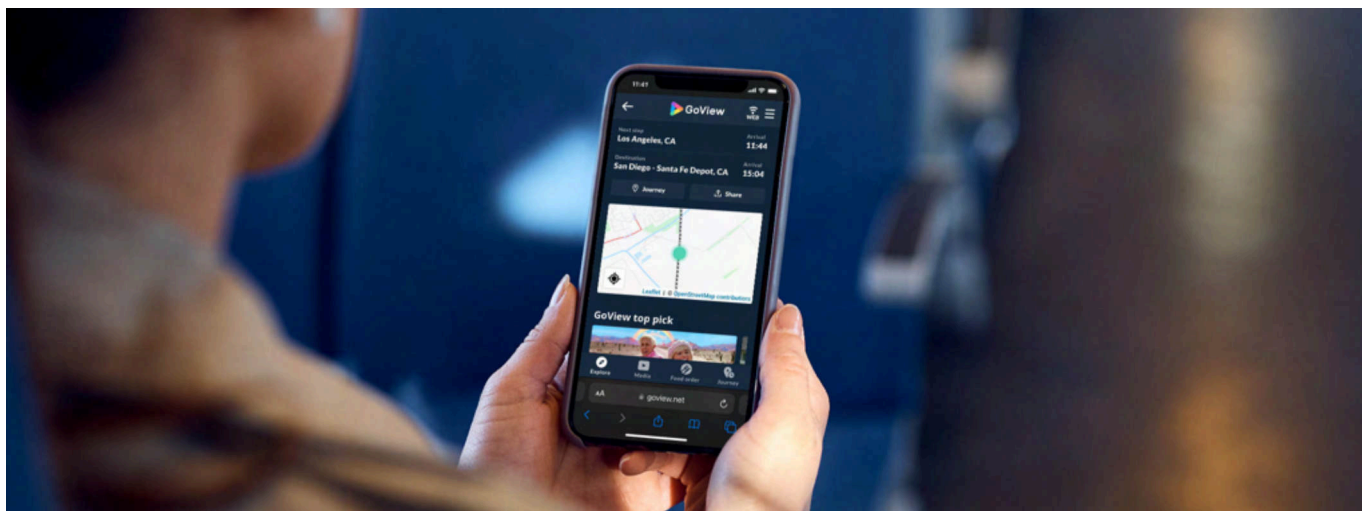


TAKING PASSENGER SATISFACTION TO THE NEXT LEVEL



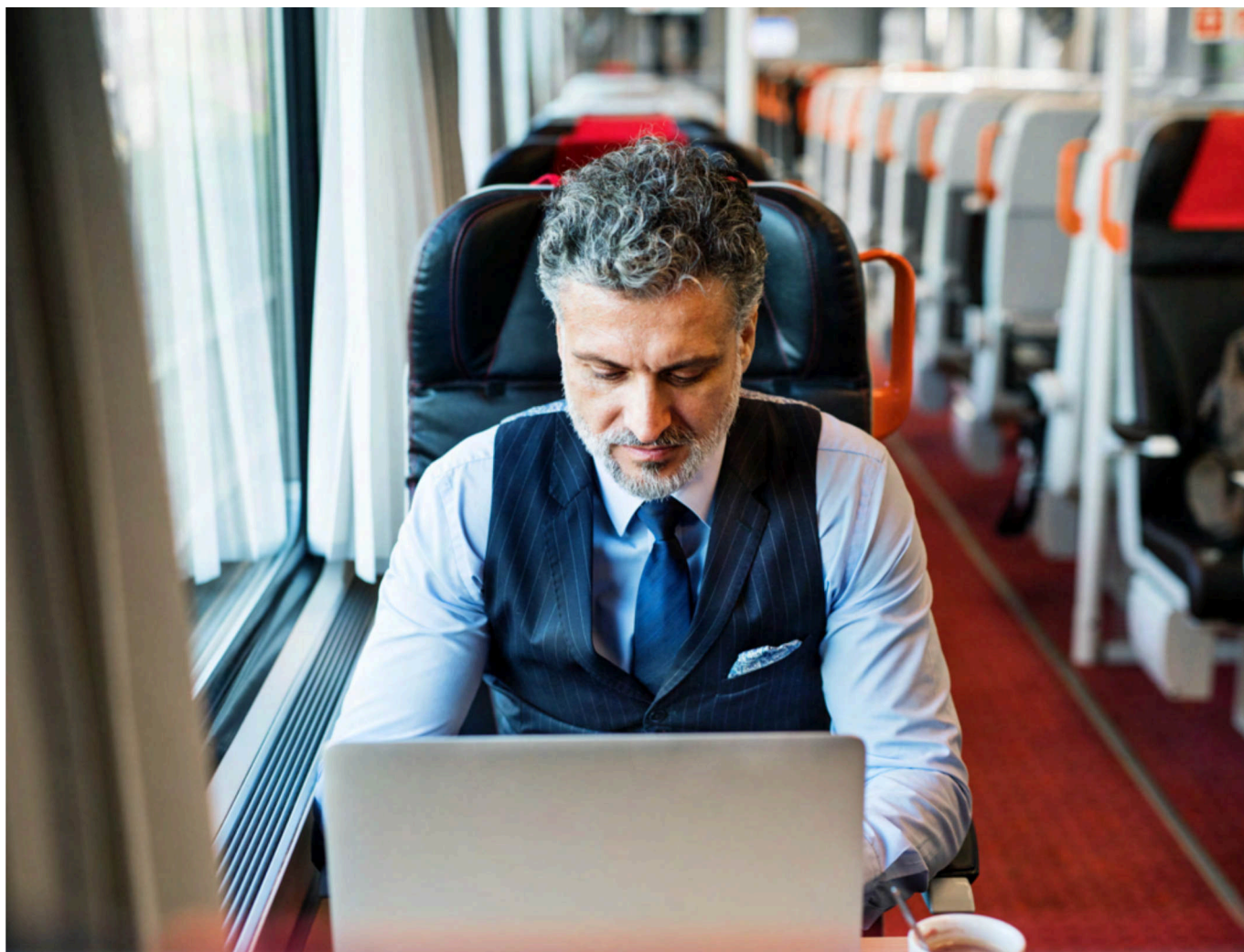
A rail journey transcends mere transportation from point A to point B - it's a transformative experience that redefines how passengers work, relax, and forge connections.

As we move deeper into the digital age, connectivity has become vital to travel, changing how passengers interact while on the go. By embracing this shift, operators can offer journeys that are efficient, reliable, and enjoyable, meeting the diverse needs of modern travelers.



Passengers are increasingly choosing rail for its convenience, affordability, and unique experiences. The surge in ridership is a global phenomenon and these numbers tell a compelling story: Amtrak reported a 24.6% increase in ridership in the United States during its 2023 fiscal year.³ Rail travel in the UK showed a 20% year-over-year increase during the third quarter of 2023.⁴ Deutsche Bahn, the German operator, saw an 11.5% increase year-over-year in regional rail ridership in the first half of 2023.⁵

This marks a transformative era for rail operators, signaling not just a resurgence of trains as a primary transport choice, but a revolutionary shift in what passengers expect from their journeys. The industry has the potential to recapture pandemic-era losses and draw new demographics by prioritizing the passenger experience. But to capitalize on this opportunity, transport operators must ensure that they're consistently delivering the experience their passengers expect.



THE MOVING OFFICE

The traditional view of the office as a place for individual work is giving way to a new reality: it becomes a dynamic hub for collaboration and face-to-face interaction.

The notion that productivity is confined to the walls of a cubicle is a relic of the past. In today's fast-paced world, business travelers and remote workers are breaking free from traditional workspaces and finding productivity in unexpected places. This shift is particularly evident on trains, where in-transit Wi-Fi has become essential for passenger satisfaction.

This redefinition of the office's role reinforces the value placed on the ability to perform solitary work tasks or join collaborative video calls during commutes. According to a recent report, an impressive 32% of

travelers use train Wi-Fi for work, confirming its status as a new norm. London North Eastern Railway (LNER) noted, 82% of business travelers are choosing to travel by rail to stay productive while in transit and 51% say the Wi-Fi is more reliable than other modes of transport.⁶

A recent example of this approach can be found in Porterbrook's Innovative HydroFLEX train. DG8, Icomera's industrial design team, designed the interior of the train to include an 'onboard boardroom' featuring a conference table layout and 5G connectivity, meeting the needs of passengers looking to work, study or host meetings. By better understanding passenger habits, rail operators can design future carriages with amenities that truly meet travelers' needs.

THE CONNECTED FOUNDATION

As passenger expectations climb faster than a bullet train, onboard Wi-Fi services are racing to keep up.

The ability to stay productive – and connected – during the journey is a key factor influencing the decision to choose rail travel. Yet still – in 2024 – passengers click the signal symbol in their task bar and anticipate the same level of productivity they would enjoy in a classroom, conference room, or office. Reliable wireless connectivity is a minimum standard for delivering passenger satisfaction – anything less will fall short of meeting expectations.

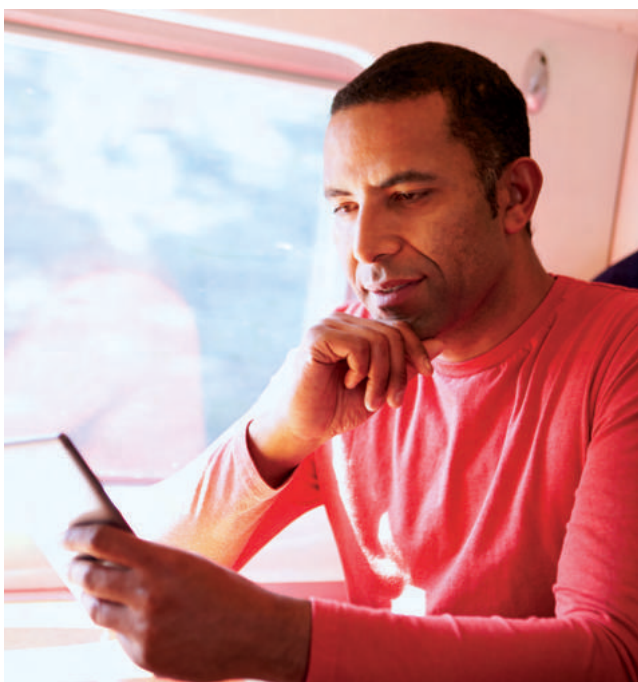
According to GSMA Intelligence, 77% of global train passengers expect to have access to Wi-Fi on board by 2025, highlighting the growing demand for seamless connectivity.⁷ A recent report from the UK rail operator LNER surveyed the next generation of rail travelers – those between the ages of 13 and 18.⁸ Younger generations of passengers may all have their own mobile phones but only 30% have unlimited data. The remaining 70% have data plans ranging between 25GB and 200GB, leaving them dependent on public Wi-Fi for connectivity to avoid exceeding their limits.



THE WI-FI CONNECTION

In the realm of Internet connectivity, the paramount challenge for rail operators is delivering a seamless connection to passengers. With the rise of remote work models, 80% of businesses globally are offering remote work options.⁹ This trend underscores the growing importance of reliable connectivity for mobile workforces, including those traveling by train. Standards will continue to increase, and rail operators need to ensure they're keeping up with expectations.

The latest onboard connectivity platforms utilize intelligent data traffic management tools. By prioritizing, throttling, and blocking different types of traffic according to pre-set priorities, such as prioritizing Microsoft Outlook applications over other services during weekday mornings and evenings, passengers exhibit a reduced risk of heavy bandwidth use.



THE WI-FI PORTAL

Onboard entertainment has long been seen as the natural complement to Wi-Fi. US coach operator, Greyhound, saw a 40-point increase in their Net Promoter Score after the first year of launching an onboard entertainment service. Media content is stored locally onboard the vehicle and does not require an Internet connection – freeing up more of the available bandwidth for passengers using the Wi-Fi for “digital chores” (emails and social media etc.).

To curate a personalized onboard experience, the use of data collection through onboard Wi-Fi usage can provide valuable insights into behavior and travel patterns.¹⁰

By analyzing usage data, operators can see what types of content passengers are looking at and use this to further optimize the travel experience. A tourist on a longer journey may well be more interested in streaming media content, while a business traveller on a short morning commute may be more likely to want quick access to up-to-the-minute news.

THE COMMUNICATION CHANNEL

Satisfied passengers expect to be proactively informed about the details of their journey without having to seek it out for themselves. Poor quality information, particularly during disruption, makes an already frustrating situation worse for passengers, and significantly more challenging for front-line staff. In contrast, if a passenger is kept informed regarding any delay, they can plan around it, and even use it to their advantage. Creating two-way communications channels between operator and passenger allows for issues to be addressed in real-time. As a result, the operator can then correct the issue and resolve the dissatisfaction before it affects other passengers.

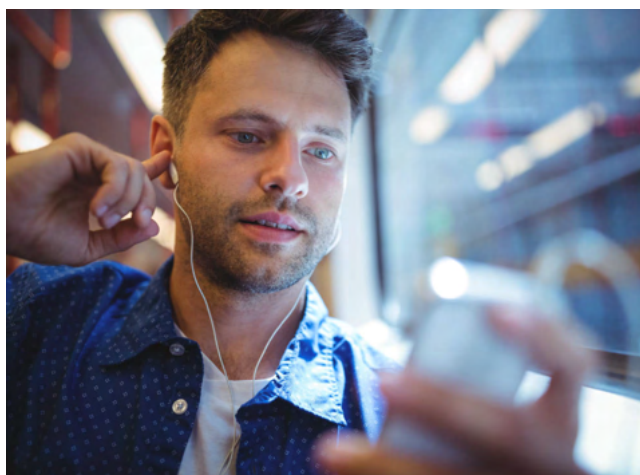
By focusing on passenger satisfaction (i.e. CSAT scores), rail operators create confidence to travel, loyalty, retention, and overall positive experiences. When passengers are offered the opportunity to communicate their journey experiences in real-time it not only empowers them but also equips the operator with actionable insights. Going one step further, immediate conversation capabilities can transform negative incidents into positive service stories, leading to increased satisfaction levels.



THE HOSPITALITY ASPECT

Convenience is the common thread that runs through every exceptional retail or hospitality experience. Regardless of whether you live in the centre of a major city, the suburbs, or in a remote community, convenience is now top of mind when considering how to get from point A to point B. **This focus on convenience is even shaping the economic picture, as many people are willing to pay more for an experience, if they consider it to be more convenient.**

Trending on longer rail routes is the offering of at-seat food and drink ordering, allowing passengers to see what's available and order refreshments via the train's online web shop directly from their Internet browser. Rail operators realize that a passenger wants to spend time in their own way – including if they want to wait. By using an at-seat ordering application, orders can be delivered directly to passengers at their seat or collected from the train's buffet car. At-seat delivery clearly provides convenience-related benefits for all passengers, allowing them to continue watching that movie or chat with their friends/family while they wait, rather than having to get up to collect their order. And lone travelers do not need to worry about leaving their luggage unattended or taking it with them around the train to collect their order – potentially losing their seat if it was not reserved.



THE ACCESSIBLE EXPERIENCE

In our technologically advanced modern world, we have an obligation to make reliable rail travel available to everyone.

Convenient and reliable rail travel should be accessible and inclusive for everyone yet 66% of people with disabilities struggle to make their journeys independently.¹¹ According to Hearing Dogs and Hearing Link, a recent survey noted only 7% of people with a hearing impairment reported being somewhat confident that they would be made aware of changes and disruptions during their journey. Of those surveyed, only 16% thought they were treated equally compared to people without hearing loss.

Digital technologies which use personal smart devices can provide at-hand support, reducing the barriers to use for customers with hearing or vision loss – and addressing some hidden needs of a broader audience as well.

These innovations provide cost-effective “quick wins” for transport operators and authorities due to the comparatively small amount of capital investment required to develop and deploy them, and the rapid speed with which this can be done.

THE REAL-TIME SENTIMENT

Rail operators are competing for passengers with private vehicles and ride sharing, and a rail service is only as good as its last journey.

Empathy emerges as the cornerstone of service quality, holding the power to profoundly influence and elevate passenger satisfaction.¹² The pandemic has brought forth a wide range of emotional responses from passengers, including fear and anxiety. Demonstrating empathy becomes crucial for rail operators. This involves understanding passengers' concerns, addressing their questions and worries, and showing compassion towards any difficulties they may face while traveling.

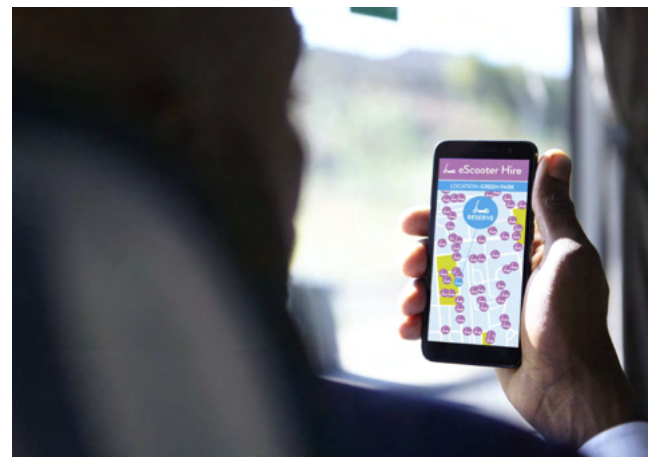
Historically, passenger feedback was most often collected retrospectively, leading to inaccuracies about which service the passenger was using. Today, rail operators are moving towards enroute feedback - collecting sentiment in real-time, tagging the date, time, route, and direction of travel.



The traditional reliance on post-journey feedback, whether in the form of complaints or compliments, has long hampered rail operators' ability to swiftly address concerns and cultivate positive passenger interactions in the moment. The ability to tap into

passenger sentiment in real-time is invaluable. Where passenger experiences are often shared online or directly with the service provider, efficiently capturing sentiments can transform service delivery.

In an era where passenger feedback can significantly influence brand reputation and operational efficiency, understanding and addressing real-time sentiment is essential. If a passenger has a disappointing experience with unkempt facilities, delayed service, or unreliable Wi-Fi, they could be more likely to consider other options for their next journey – even if their five previous journeys were problem-free.



THE NEXT STOP

The digital era of rail opens up a myriad of possibilities for operators to elevate passenger satisfaction to new heights. By focusing on the key areas outlined here – from seamless connectivity to personalized experiences – the passenger rail industry can secure a competitive advantage and prove rail travel as a mainstay for the modern passenger.

This isn't just about technology upgrades; it's about embracing a mindset shift. Operators must understand that passenger expectations are shaped by their daily digital interactions. By mirroring the convenience, personalization, and accessibility they experience elsewhere, rail travel becomes not only a viable alternative but a preferred choice for future journeys.



PART FOUR





**LEVERAGING CONNECTIVITY FOR
SAFETY & OPERATIONAL EFFICIENCY**



LEVERAGING CONNECTIVITY FOR SAFETY & OPERATIONAL EFFICIENCY



Modern trains have come a long way since their early analogue counterparts. Steam engines and brass whistles have given way to electrification and, now, to the digitalization of onboard systems and services.

As rail transport operators embark on this dramatic transformation from slow, roving coal furnaces to what could be described as ‘high-speed mobile data centers’, new opportunities for innovation are emerging as a means of meeting passengers’ expectations of reliable, and timely services in an age of ever-increasing immediacy, as well as safer and more secure traveling environments.

PROPER ANALYSIS PREVENTS SERVICE PARALYSIS

Safety has always been the priority for transport operators and infrastructure providers, however when accidents do occur, they cause major service disruptions. For example, there are on average, 500 freight rail derailments occurring in Europe each year¹³ and approximately 10% of these are due to issues relating to the wheels of the wagon not turning freely.¹⁴ This can be caused by axle or brake issues due to mechanical failure, or human error – failing to release the handbrake for instance.

The UK’s Petteril Bridge Junction derailment, which saw the closure of major rail routes for seven weeks¹⁵ serves as a prime example of service disruption due to

wheel failure. The cost of the associated network disruption of such events, not to mention the cost of wagon and infrastructure repairs is substantial.



CASE STUDY

GB RAILFREIGHT IoT BRAKE MONITORING

To demonstrate the effectiveness of remote sensor-based component monitoring and alert systems, Icomera's dedicated design and engineering division, DG8, collaborated with SENSEi Networks to test a first-of-a-kind solution for wheel and brake issues for freight rail operator GB Railfreight (GBRf).

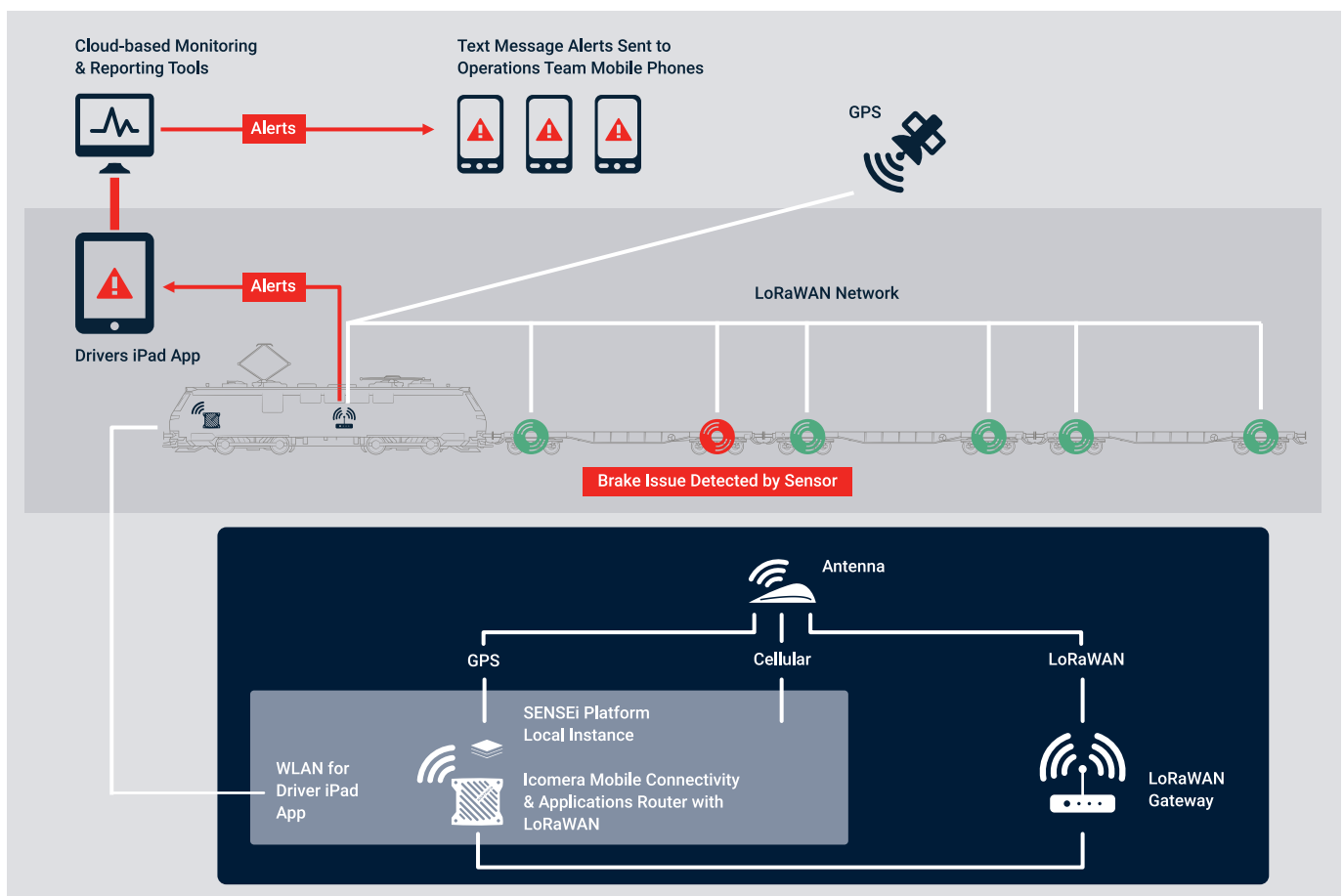
The GBRf monitoring system used a combination of new, emerging technologies, and hardware used in other industries, refactored for rail freight, to:

1. **Monitor the train's braking system** using battery-powered sensors.
2. **Identify out-of-tolerance events** using SENSEi's IoT Platform-as-a-Service, hosted as a virtual machine on Icomera's onboard router.
3. **Communicate alerts to the driver** over the

vehicle's wireless network via an app running on a smart device in the cabin, allowing the driver to take action and receive feedback on the results of that action in real-time.

4. **Send status and alert data** to a cloud-hosted server, via the Icomera router which aggregates the connectivity of the available cellular networks along the route, feeding into reports for teams back at the operational control centre.

The GBRf monitoring system, which combined a wealth of data with in-person vehicle health-checks, provided an excellent proof of concept for how interlinked digital systems can be used to connect drivers and engineering teams to real-time, train borne sensor data – a natural step towards a safer and more efficient rail network for all users.





HEALTHY TRAINS NEED HEALTHY TRACKS

Vehicular issues are not the only cause of service disruptions and train derailments. Environmental issues such as flooding and falling vegetation are major contributors to accidents, as well as the fact that the frequent usage of track infrastructure makes it prone to extensive wear and tear.

This is especially true for switches and crossings (S&Cs), which play an integral role in the life of the railway, by guiding trains from one track to another. Their propensity for higher wear and tear (and causing several low-speed derailments per year) means that S&Cs require more frequent inspection and replacement than most other rail engineering assets.

Track infrastructure managers spend hundreds of thousands of hours and considerable financial expenditure on maintenance efforts and, when conducted during the daytime, track inspections may cause disruptions to passenger and freight services.

In addition to operational and fiscal concerns, track inspections also present significant safety issues for engineering staff as they are more often conducted manually, at night, with poor visibility, increasing the potential for serious accidents.

CASE STUDY

NETWORK RAIL VISUAL INSPECTION UNIT CONVERSION PROJECT

The UK's rail infrastructure provider, Network Rail, has over 20,000 miles of track to inspect and maintain on a weekly basis, which sees costs mount up quickly, alongside persistent logistical and safety issues, particularly where inspections of S&Cs are concerned.

Network Rail therefore sought a proof-of-concept demonstrating a safer, yet operationally viable alternative to on-foot visual inspections to relieve these pressures, which it could commence testing within a year.

Through DG8, and working collaboratively with other industry-leading solution providers, Icomera was able to answer this need and deliver a turnkey solution for Network Rail by converting two retired British Rail Class 153 "Sprinters" into cutting-edge Visual Inspection Units (VIUs) outfitted with optical sensors.

To meet Network Rail's goals, the unit conversion of the Class 153s involved integrating the following elements:

- A track condition and geometry monitoring system enabling non-contact measurement of railroad track.
- A camera system recording images of the track.
- A positioning system that accurately tags the data



from the other systems with the location on the network.

- Train to ground connectivity. Since the VIUs' essential systems are permanently powered, they can constantly transmit data, including video footage, back to The Cloud; this allows Network Rail to access the systems 24/7. Should the train be operating in bad reception areas or working in tunnels, the kit is able to transmit the data after the shift has finished. Even after the driver has gone home, the train remains powered and transmits.

The VIU conversion units were each equipped with eleven cameras (eight at the front of the train, one underneath, and two at the back) which could record thousands of high-resolution images, even as the train moves at high speed. In fact, the image resolution captured by the system was high enough to allow for the inspection of individual bolts. By the end of the project's implementation, Network Rail could remotely monitor the condition of railway infrastructure through 'virtual track-walks', reducing the need for personnel to physically attend on-site and lowering the risks to their safety, all while working to prevent service disruptions due to track related accidents.

The project won 'Safety Achievement of the Year' at the National Rail Awards, demonstrating the power of leveraging connected technologies to ensure both safety and operational efficiency through preventative means.

EASING WORRIES TO GET PASSENGERS ONBOARD

Despite their potential severity, derailments themselves are comparatively rare. Public transport is



in fact the safest means of moving people across distances – ten times safer than traveling by car.¹⁶ Therefore, passengers' concerns about their safety on board the train are arguably more focused on the objects and people within their personal space, for example the conduct of the people they are surrounded by, or the security of their luggage. **After all, using public transport requires passengers to share confined spaces with total strangers, for predetermined lengths of time, with limited opportunities to remove themselves from uncomfortable situations.**

This aspect of travel is clearly front-of-mind where passengers are concerned, especially given the media's tendency to fuel fears of danger on public transport.¹⁷ Hitachi Rail's 2024 'Better Connected' report on a global consumer research study of over 12,000 people showed that "crowding remains the single biggest barrier to people using public transport"¹⁸ and that onboard safety is a major deciding factor in using public transport for 89% of passengers.¹⁹

The findings align neatly with an MTA survey of New York passengers that found 72% of respondents are "very concerned" about crime and harassment and 87% of lapsed riders consider safety the biggest factor in returning to public transport.²⁰

A study conducted with UK operator LNER also suggests that younger passengers whose formative years were overshadowed by pandemic lockdowns may experience a heightened level of anxiety and discomfort when using public transport²¹, suggesting that the best way to entice the next generation of public transport users is to focus on providing a safe, relaxing journey.

Beyond attracting passengers, safeguarding staff is another vital consideration. Recent studies have shown that 94.1% of UK front line rail staff have faced abuse at work²² and over 72% experienced workplace violence in the last year.²³

BUILDING CONFIDENCE IN SAFETY

It is clear that transport operators are listening to their customers and staff and are placing safety and security at the forefront of their decision-making.

In the UK, a multi-year research study has shown that cameras worn by staff as visible deterrents reduce the likelihood of assault by 47%.²⁴ 7,000 new cameras were installed on board Northern's fleet of trains in 2022, footage from which can be viewed by the British Transport Police in real time. The number of dangerous attacks on trains operated by Northern is

down almost 90%, with the number of recorded incidents at just 8.²⁵

The U.S. treats safety and security just as seriously. For example, Washington Metropolitan Area Transit Authority (WMATA) increased security patrols by 70% through partnerships with local policing agencies, with crime enforcement up by 300%.²⁶ By combining these patrols with 30,000 cameras on buses, trains, and stations, WMATA has seen a 14% decrease in crime and a 24% and 15% increase in rail and bus ridership, respectively.²⁷

PHYSICAL AND VIRTUAL PATROLS: A COMBINED APPROACH

The ability to view, record, and track real-time video feeds from connected cameras at the click of a button allows security and law enforcement personnel to perform 'virtual patrols'. Much like the 'virtual track-walks' mentioned earlier, this can reduce the risks to staff and passengers, as incidents can be monitored proactively and de-escalated before situations have a chance to cause anxiety, damage, or harm.

Virtual patrols by no means reduce the necessity for the physical presence of front-line and security staff. In fact, by combining physical and virtual approaches, operators provide a significant deterrent to unwanted behavior while making the jobs of transport personnel easier and safer by far.





REAL-TIME MONITORING: PREVENTION IS THE BEST MEDICINE

If a preventative approach is vital in protecting assets from damage, the same may be said for the protection of the people on the trains themselves.

Passengers and staff in danger of personal harm or theft find little comfort in knowing that video footage is recorded for later use in court, if nobody can proactively intervene to prevent the risk in the first place. This is why the 'real-time' aspect of video surveillance is so important.

To truly transform onboard surveillance systems into 'real-time' preventative measures, the train's onboard network needs to have the capability to effortlessly process all video data on the edge and offload it from trains just as quickly when footage is requested remotely.

This process is not as costly or data intensive as one might think. Remote data offload is cheaper and faster than physically removing storage media, as is the ability to perform camera device health checks directly from the surveillance VMS dashboard, as opposed to only checking them in person. Additional savings are achieved by automatically offloading data over Wi-Fi, either all at once when trains are not in service, or incrementally as they pass through station Wi-Fi networks.

It should be noted that the collection of forensic evidence is still a vital component of any video surveillance system, and the best modern digital video surveillance solutions still need to use high-definition optical sensors and secure, high-capacity onboard data storage systems to ensure that video footage is always fit for the purpose of forensic analysis.

VIDEO DATA AND AI ANALYTICS: DUAL FUNCTIONS UNITED BY PURPOSE

The technology used to monitor the devices and people on the train can also perform additional operational and safety functions, which would normally have necessitated the use of disparate systems and devices.

For example, networked digital video surveillance cameras can use advanced AI video analytics to function as Automatic Passenger Counting (APC) systems which can exceed traditional sensor-based solutions in both function and accuracy, while reducing the time and costs needed to install and maintain separate pieces of hardware.

This approach offers a huge cost-saving opportunity for transport operators, who need to understand passenger loads and travel patterns, so they can ensure compliance with safety measures and manage fleet and staff capacity planning.

Transport operators can reliably monitor total occupancy levels from consist- down to coach level, boarding/alighting numbers per station, and total vehicle ingress/egress, all in real-time.

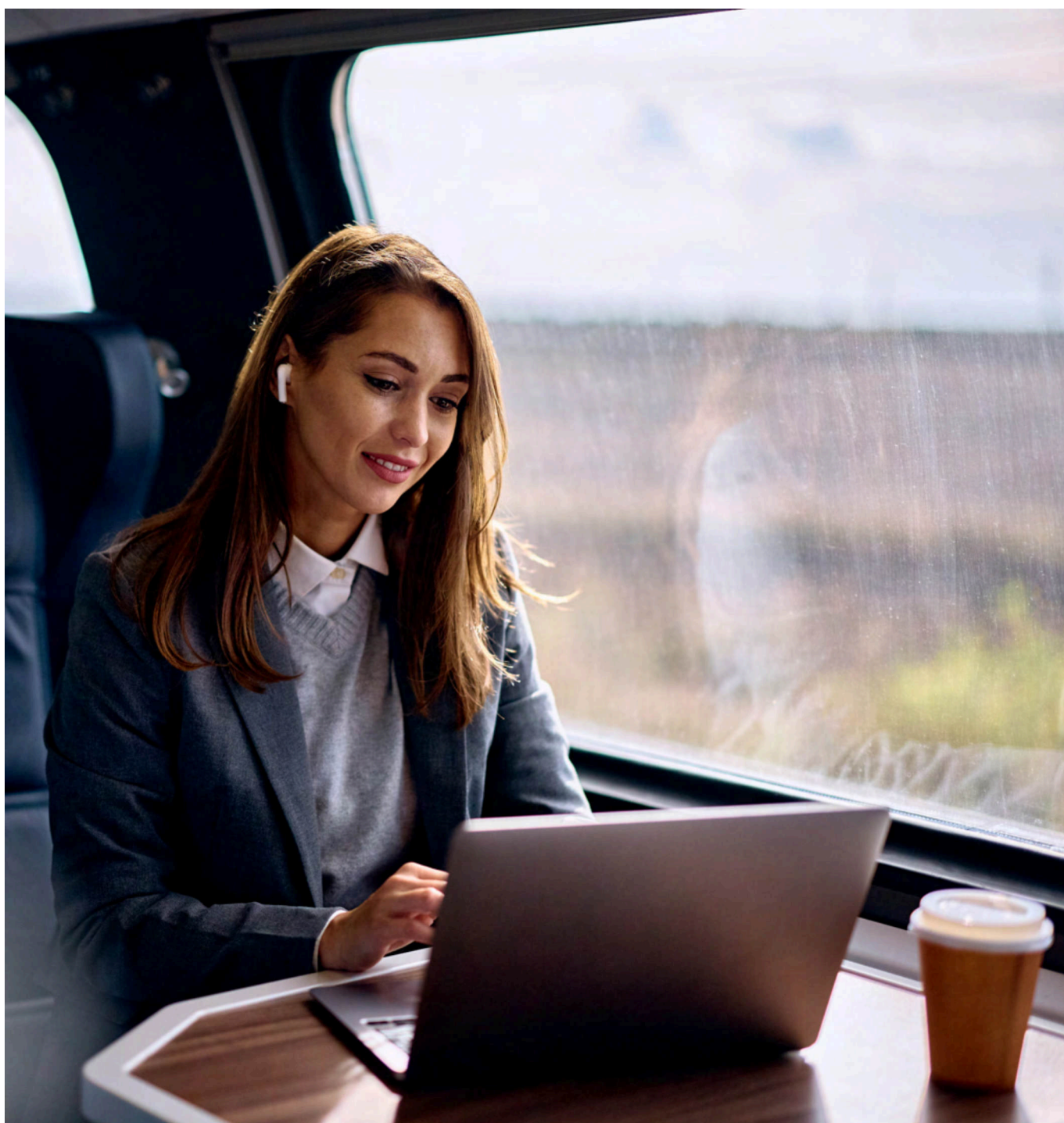
Sharing the ability to effectively gauge train occupancy levels with passengers can also make it easier for them to choose less noisy or crowded environments to travel in, ensuring that they are comfortable throughout their journey.

LOOKING TOWARDS A SAFE & SECURE FUTURE



By embracing connectivity and intelligently linking onboard devices and systems together in a digital ecosystem, the data collected can be analyzed and used for a wide range of applications such as train condition monitoring, track monitoring, onboard video surveillance and automated passenger counting.

With high-powered, reliable connectivity enabling forward-looking strategies, operators can provide a Connected Journey that is smoother, safer, and more enjoyable than ever before.





PART FIVE





**ICOMERA, EQUANS & BOUYGUES
PARTNERS ON THE CONNECTED JOURNEY**



ICOMERA, EQUANS & BOUYGUES

PARTNERS ON THE CONNECTED JOURNEY



Living through an era of unprecedented global challenges, it's imperative that we work together in pursuit of society's key goals. A collaborative approach will help leverage the collective expertise, resources, and innovation of stakeholders across multiple sectors and internationally.

As part of the Equans group and the wider Bouygues organization, Icomera has the requisite scale and reach to operate locally in all geographic regions, assisting transport operators and authorities in their pursuit of core aims. By fostering a culture of partnership and cooperation to address the complex issues that we collectively face, we can pave the way for a more sustainable, resilient tomorrow.

WHY GREEN MOBILITY MATTERS

Human-induced emissions of greenhouse gases are driving global warming; 2023 was the warmest on record by a large margin,²⁸ and the 10 warmest years in historical record have all occurred in the past decade (2014-2023).²⁹ Rising temperatures lead to more frequent and severe natural disasters, as well as disrupting agricultural systems, exacerbating food insecurity, and causing economic instability.

The transport industry is a key carbon dioxide (CO₂) contributor, accounting for around one-fifth of total global emissions.³⁰ However, by moving more people using fewer vehicles, public transport is by far the most sustainable means of transportation.

Train travel, for example, reduces carbon emissions by



two thirds compared to cars,³¹ and is recognized as being the least emissions-intensive mode of passenger transport.³²



Armed with these facts, many passengers are becoming increasingly environmentally conscious with how they choose to travel; night trains are being revived across Europe as an alternative to flying,³³ and a recent survey found that 76% of respondents want more sustainable travel options to be made available to them.³⁴

It's somewhat surprising then that a third of nations currently neglect public transport in their climate action plans.³⁵ According to a report published by the International Association of Public Transport (UITP), *"doubling the use of public transport and designing cities around it to reduce car dependency would cut urban transport emissions by more than half"*.³⁶

Offering affordable, attractive, and viable public transportation options will be vital in continuing to encourage society's shift in travel habits away from individual travel modes and towards mass public transportation systems such as trains, trams, and buses.

Having identified the uptake of public transportation as a major factor in improving global environmental sustainability, Icomera has actively promoted green mobility since our founding back in 1999. By offering Internet-enabled onboard services, we make public transport more productive and enjoyable compared to less sustainable means of travel, encouraging its growing use around the globe, and helping power the transition towards a carbon-neutral world.



EQUANS & BOUYGUES: A SHARED COMMITMENT TO SUSTAINABILITY

The magnitude of the climate challenge undoubtedly requires solutions to be implemented with the appropriate levels of scope, aspiration, and innovation. Achieving successful decarbonization globally will require a coordinated approach involving collaboration amongst nations, industries, organizations, and individuals.

It's also important to recognize that the future of transport will not develop in isolation from other sectors. Given that there is an undeniable interplay between the different areas of smart connected modern living, a holistic approach will provide the strongest possible platform for success.

This is where Icomera benefits from the foresight and scale afforded by being a wholly owned subsidiary of Equans, and part of the wider Bouygues group.

With almost 90,000 employees working to connect, power, and protect buildings, cities, and infrastructure, Equans supports customers as they transform their energy systems, digital technologies, and industries. As the world leader in multi-technical services, its organization is built around two key unique strengths:

1. Having a strong presence across dense local networks, with the global reach to deliver solutions to clients worldwide - And
2. Having a wide range of expertise across various specialised sectors to meet the scale and scope of the challenges that we face.

Through its dedicated transport division (of which Icomera is a part), Equans provides integrated and tailor-made turnkey solutions for the market. **By leveraging the collective knowledge of over 2,700 employees via a single point of contact, Equans Transport simplifies the deliverability of large and complex transit projects, providing clients with effective, innovative solutions optimized for their specific problems.**

As Pierre Hardouin, CEO of Equans France explains: *"Our agile approach, combined with our extensive expertise and passion for innovation, positions us as a*

trusted and reliable partner for a variety of clients. We specialize in delivering complex solutions in transport electrification, electro-mechanical installations, signalization, and telecoms, ensuring these systems remain in optimal operational conditions.

"Icomera's focus on mobile connectivity perfectly complements Equans' broader vision for the digital transformation of public transportation. Together, we are redefining the passenger experience, making every journey more cost-effective for transport operators, and paving the way for a more sustainable future."

Beyond Equans, the Bouygues group as a whole totals more than 200,000 employees working across six subsidiaries present in over 80 countries. Other subsidiaries within the group include the transport infrastructure and civil engineering firm Colas, and the mobile phone and Internet Service Provider (ISP) Bouygues Telecom. The diverse range of sectors that the group covers make it financially resilient to changing economic conditions and other external factors.



Bouygues' ownership structure is based on two long-standing core shareholders:

1. SCDM, a simplified joint stock company controlled by Martin Bouygues, Olivier Bouygues and their families - And
2. Bouygues' employees, through several dedicated mutual funds.

As a business which is still family-run more than seven decades after its founding, Bouygues works to create value over the long term for its clients and stakeholders, planning in terms of decades and centuries rather than only months and years.

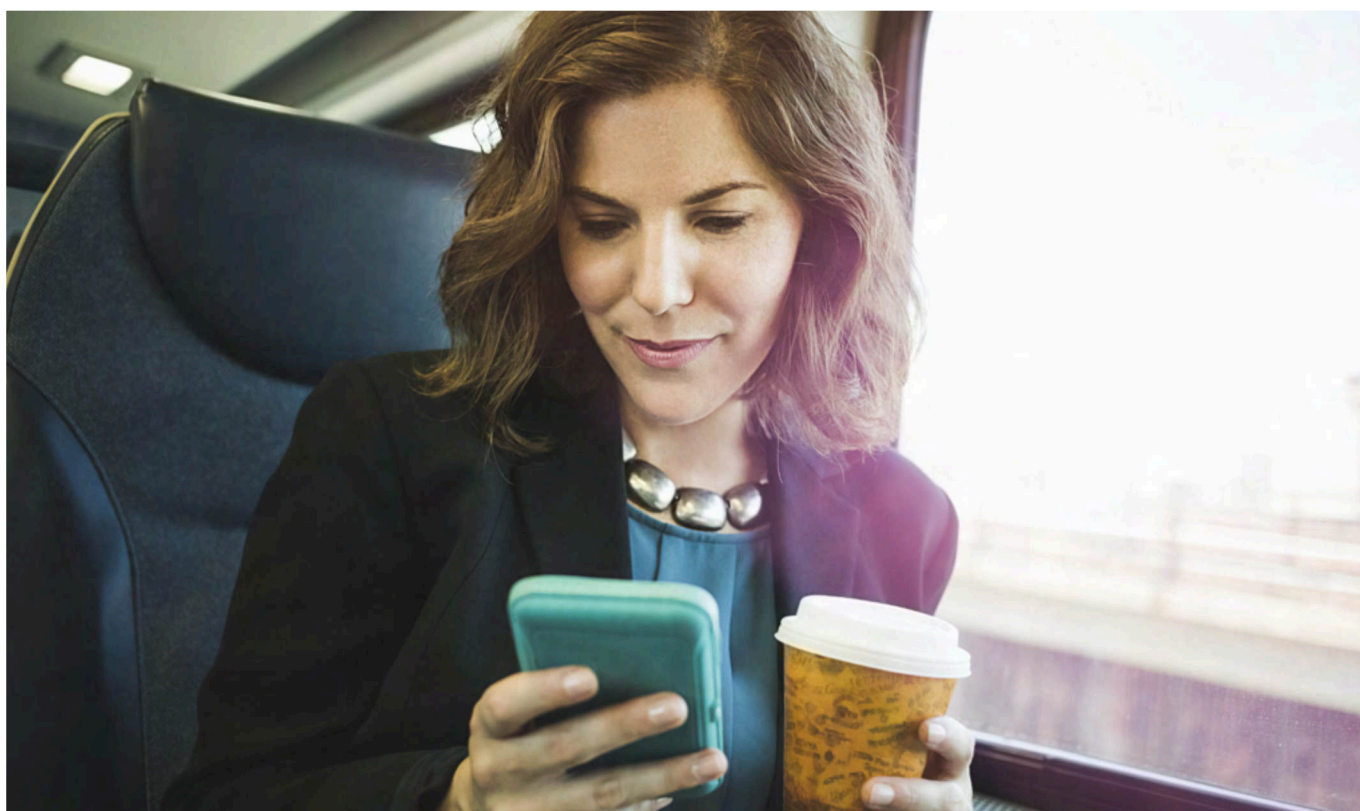
Tackling the climate emergency is also an important part of the group's overall strategy; Bouygues has committed to achieve its decarbonization targets by 2030 to mitigate the impact of its activities. As the group's Chairman Martin Bouygues states: *"Corporate social responsibility (CSR) is a key priority. We regard CSR not as a constraint, but as an opportunity to transform our business and to set us apart from our competitors."*

EQUANS TRANSPORT: TOGETHER ON THE PATH OF PROGRESS

Icomera's partner entities within the Equans Transport group augment our offering with additional digital solutions and expertise in infrastructure, a combination which allows the group to address transport systems as a whole.

For instance, Ineo Systrans' NAVINEO solution integrates Computer Aided Dispatch & Automatic Vehicle Location (CAD/AVL) systems for public transit alongside other functionalities such as real-time charge monitoring for electric buses and eco-driving assistance to support green mobility.

"Whether it be through electric buses or other environmentally conscious transport modes, NAVINEO offers turnkey intelligent transportation systems and services to help build smarter cities", comments Baudouin Huon, CEO of Ineo Systrans.





When it comes to delivering sustainable transport infrastructure, Equans subsidiaries including the Powerlines Group are leading the way. As one of Europe's main suppliers in railway electrification, Powerlines designs, installs and maintains electrification systems for railway networks and provides cutting-edge expertise in both urban modes of transport (metros, tramways, and buses) and intercity modes (conventional and high-speed lines).

Berthold Bartsch, CEO at Powerlines Group, explains: *"By installing electrical infrastructure, Powerlines makes a key contribution to ecologically sustainable economic development. As a system supplier, we're proud to cover the entire spectrum from consulting, engineering, and design, through to the installation and maintenance of infrastructure facilities."*

CREATING A SOCIALLY RESPONSIBLE FUTURE

As a company, at Icomera we're extremely conscious of our own environmental footprint and actively work to reduce it, both internally and for our clients and their

passengers. Our commitment is evidenced in the design of our products, which prioritize energy efficiency, durability, and recyclability, as well as our ISO 14001 certification which underscores our dedication to minimizing the use of environmentally harmful materials and ensuring their responsible disposal.

But working as part of the Equans and Bouygues organization allows us to push even further in our ambitions: Through the unified vision and scale of the entire group and its entities, we are working to build a zero-carbon future, where transportation is not only efficient and convenient but also environmentally friendly and socially responsible.

With public transport increasingly seen as the custodian of a more sustainable era, Icomera and our partners in Equans and Bouygues are well positioned to accelerate the industry's digital transition, delivering smarter, safer, greener mobility.

CONCLUSION

The results of Icomera's 2024 On-Train Internet Connectivity Survey highlight the crucial role of onboard connectivity in the evolution of the rail industry, with 89% of rail professionals deeming it "Important" or "Very Important."

We have seen that on-train Internet connectivity's role will be multifaceted, enabling a range of new, or at least newly digitalized, passenger services and operational systems to take advantage of real-time or on-demand access to data.

Emerging technologies will significantly enhance Internet connectivity on trains over the coming years.

LEO satellite networks will offer increased coverage and capacity in geographical areas that have not been historically well served by cellular networks, while Wi-Fi 7 will improve performance in crowded environments. Advances in edge computing will allow more data to be processed locally on board, reducing unnecessary demand on the bandwidth of the connection between the vehicles and operators' data centers. Artificial intelligence will leverage both onboard connectivity and edge computing to facilitate deeper real-time analytics and faster, more informed decision-making.



As a company celebrating its 25th anniversary, but also as a company founded in the spirit of innovation, we at Icomera will draw on our past experiences and explore new approaches to accelerate the rail industry's digital transition, making public transportation smarter, safer and more attractive.

And our vision will be supported by 90,000 experts in the Equans group, working alongside industries and local authorities to ensure that public transport will play a significant role in modern, connected, sustainable living.



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