# Shaping the future

2024 Innovation Report
of the SNCF Group

# Jean-Pierre Farandou,

Chairman and CEO, SNCF Group

Progress is useful if it is shared and accessible to everyone. To innovate is to step outside the box and go beyond proven solutions to overcome obstacles and tackle the greatest challenges. We have made strategic technological choices that will profoundly transform rail transport.

Digitalization is now central to all our operations, from traffic management to maintenance, while artificial intelligence is offering new prospects for optimizing our operations and strengthening our industrial performance. Thanks to advances in battery technology and, in the longer term, hydrogen technology, we will assist regional authorities in deploying decarbonized mobility solutions.

Another big challenge is energy self-sufficiency. SNCF consumes 9 TWh annually, making it the largest electricity consumer in France. The creation of SNCF Renouvelables in 2023 marked a decisive step in meeting this challenge. By 2030, we aim to cover 15 to 20 percent of our electricity needs through the installation of 1,000 hectares of solar panels. Photovoltaics applied to long linear infrastructures, energy storage, and smart energy management will be crucial technologies for achieving this goal. Innovation must also address the economic challenges the Group is facing in an increasingly competitive environment. That is why we have adopted an approach where technology must help make rail transport more affordable, with, for example, trains that are more energy-efficient, like the next-generation TGV; and by designing mobility systems suited to all regions in projects like TELLi and DRAISY; and by developing unique expertise in predictive maintenance to reduce breakdowns and improve the reliability of our infrastructure.

Through its commitment to innovation, SNCF plays a major role in regional development by working closely with local industrial partners such as Texelis, at Limoges, in the TELLi project and Lohr in the DRAISY project.

This collaboration with local stakeholders is a key means of addressing mobility needs and contributing to the economic and technological vitality of the regions.

To innovate is to step outside the box and go beyond proven solutions to overcome obstacles and tackle the greatest challenges. We have made strategic technological choices that will profoundly transform rail transport.

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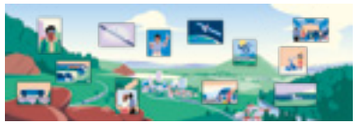

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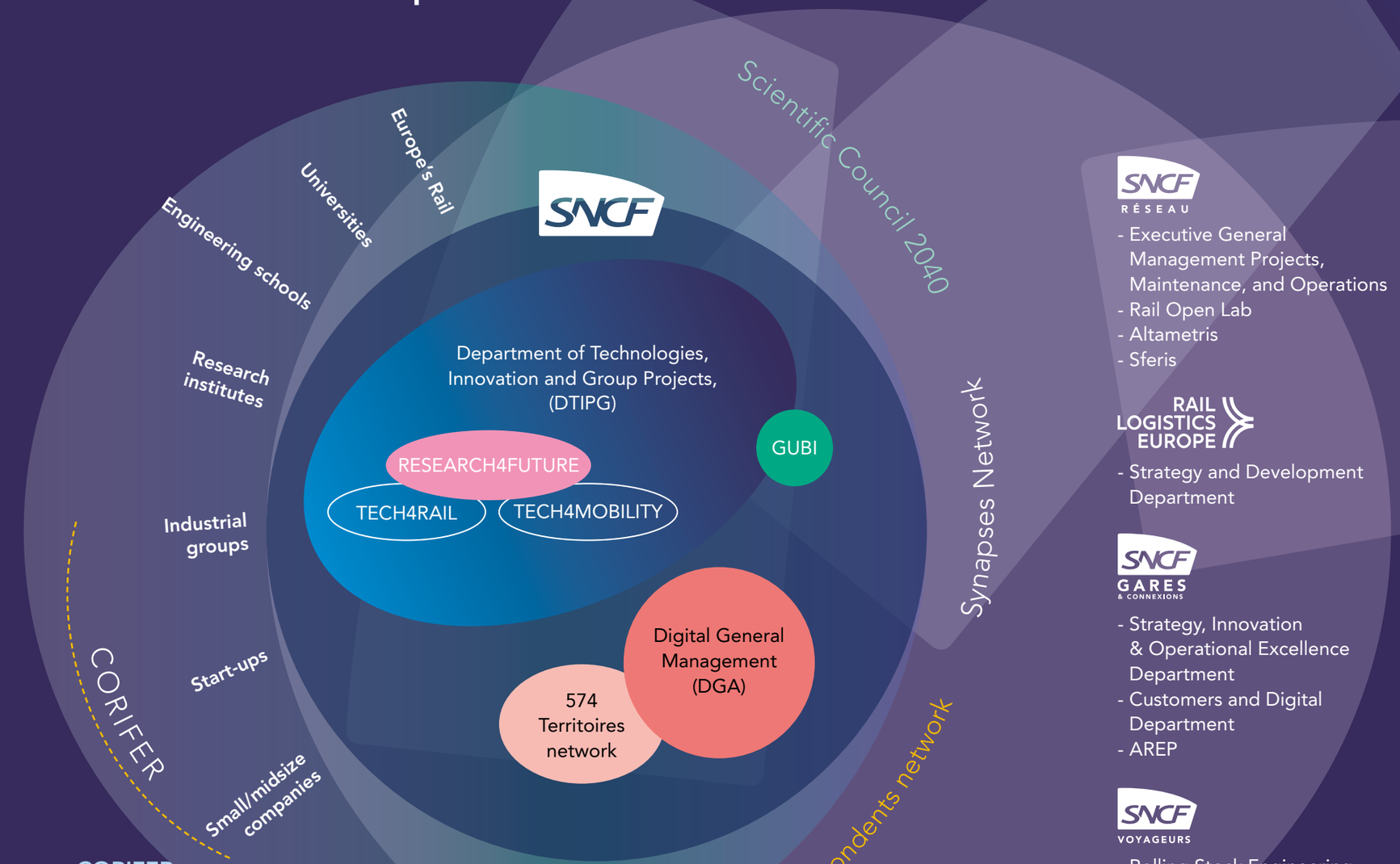
# The research and innovation ecosystem serving the growth of rail transport

The companies in the SNCF Group and their subsidiaries lead research and innovation projects in fields as wide ranging as digitalization, decarbonization, energy efficiency, and improvement of mobility in the regions. These projects are also enriched by expertise coming from internal networks as well as from partnerships with the academic and industrial worlds.




## CORIFER

The Research and Innovation Steering Council of the railway sector (CORIFER) constitutes the framework for maintaining the dialogue between government and industry, for guiding and optimizing support for innovation, and for directing industry projects towards public assistance programs and particularly those of the France 2030 plan.

SNCF RÉSEAU
- Executive General Management Projects, Maintenance, and Operations
- Rail Open Lab
- Altametris
- Sferis

RAIL LOGISTICS EUROPE
- Strategy and Development Department

SNCF GARES & CONNEXIONS
- Strategy, Innovation & Operational Excellence Department
- Customers and Digital Department
- AREP

SNCF VOYAGEURS
- Rolling Stock Engineering
- Traction Department
- Mass Transit Academy
- TER Innovation Department
- SNCF Connect & Tech

## Synapses network

This network overseen by the DTIPG includes 604 scientific and technical experts from all SNCF Group entities. Certified by a selection committee for renewable three-year terms, they foster research and innovation in six clusters: Energy, Sustainable Development, System Safety, Maintenance, Resource Optimization and Operations, and Mobility Services & Experiences. Regardless of their home entity, they collaborate within each cluster to ensure a systems-based approach. The Synapses Network supports knowledge transfer and develops expertise in critical fields such as artificial intelligence, cybersecurity, civil engineering, complex systems, acoustics, and more. Synapses experts lead many of the projects presented in this report.

## Scientific Council 2040

This body is made up of strategic and technical leaders from SNCF Group companies and subsidiaries. Its purpose is to inform SNCF's governance on future challenges and technologies, guide the Group's innovation and research strategy, and identify opportunities for differentiation and diversification in a competitive environment.

CLICK HERE

Meet the teams driving research and innovation at SNCF Group companies

## Innovation correspondents network

Bringing together representatives from the SNCF Group's companies and subsidiaries, this network guides research and innovation efforts, relying on two new groups created in 2024 within the DTIPG:
- The Innovation Business Partners, who help translate the needs of the companies and subsidiaries into projects and also oversee their development
- The Innovation Technology Leaders, who contribute their expertise in emerging technologies (AI, robotics, etc.) to help steer research projects.

## "574 Territoires" network

The SNCF Group has seven digital innovation centers across France. These sites allow SNCF teams to receive close support in the Group's digital transformation while also engaging with the local external ecosystem to help promote SNCF's digital innovation. This network has several key roles: to promote a digital culture within the Group, to support and scale digital projects, and to forge external partnerships in the regions that will help meet the SNCF Group's objectives.

## Single Patents & Innovation platform (GUBI)

The GUBI is tasked with protecting SNCF employees' inventions by guiding them through the patent filing process. The GUBI manages SNCF's patent portfolio and promotes the licensing of its patents in industry.

# Offer customers environmentally friendly mobility

OBJECTIVE

5

The train is currently the high-capacity mobility solution that delivers the best environmental performance. A journey by train results in 70% to 90% less greenhouse gas (GHG) emissions than one by car or plane. However, trains account for only 11% of passenger and freight transport. The greater the share of rail, the more the overall $CO_2$ emissions curve declines. To expand rail usage, our aim is to strengthen our inherent advantages. For example, around half of the TER regional train fleet is still diesel-powered and runs on non-electrified lines. The SNCF Group is lending its support to Mobility Organizing Authorities to find alternative solutions with projects for battery-powered, hybrid, or hydrogen trains, that is, ones that are designed as decarbonized trains. Research efforts are also being directed toward converting the engines of construction and freight shunting equipment. We are also innovating in the realm of energy efficiency to reduce our consumption as much as possible, whether by improving driving practices or using biofuels.
Offering customers environmentally friendly mobility also involves better integration of infrastructure and land use into their surroundings. Minimalist design, air quality, vegetation management, and the preservation of wildlife are other key areas of research and innovation for the SNCF Group.

Muriel Signouret
Director, CSR, SNCF Group

**"To reduce our environmental footprint, the SNCF Group has three main priorities: decarbonizing its activities, developing a circular economy, and preserving biodiversity. Our goal is to reduce $CO_2$ emissions by 30% for our transport activities and by 50% for our buildings by 2030, compared with 2015, the year the Paris Agreement was signed."**





THEME

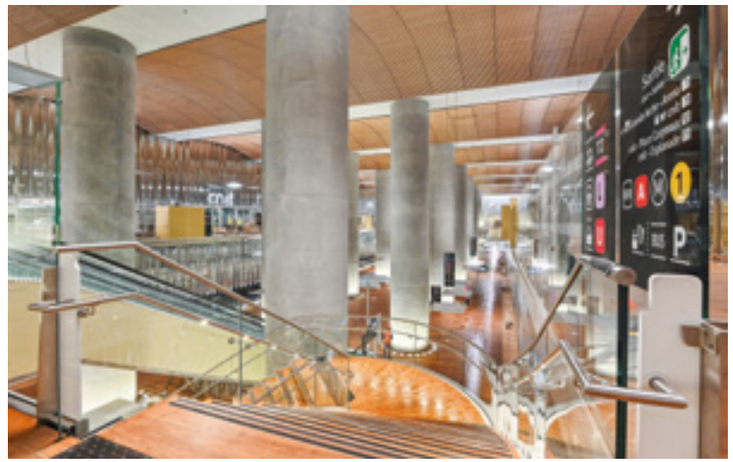
# Decarbonization and preservation of biodiversity

Climate change is one of the main causes of the decline in biodiversity, and the greenhouse effect is the primary driver of climate change. The innovation programs we are pursuing to decarbonize our activities thus help reduce the pressure on biodiversity. With 28,000 km of rail lines, 3,000 stations, 12 million sq. meters of buildings, and over 100,000 hectares of railway property involved in our daily operations, we host and pass through a multitude of ecosystems. Therefore, we must develop innovative solutions to protect our natural heritage while ensuring the safety of our staff and rail operations as well as, of course, the regularity of train services. These innovations include more targeted and environmentally friendly vegetation management, animal deterrent systems to prevent collisions, and infrastructure to restore ecological continuity of land and water.

## PrediQA
to predict air quality in underground rail facilities

The Rolling Stock Engineering department of SNCF Voyageurs has developed a tool called PrediQA that uses AI (machine learning and neural networks) to predict fine particulate concentrations 24 to 48 hours in advance in underground stations. The objectives? To measure emissions based on diverse factors (traffic frequency, weather, etc.) to anticipate pollution peaks and then to inform passengers about air quality on their journey and to manage energy consumption by optimizing station ventilation.

The system was successfully tested in a Swedish metro station as part of the Rail4Earth project of Europe's Rail. In the Paris region, PrediQA uses real-time data from the Railway Testing Agency and AirParif. This initiative is part of SNCF Group's Air Quality policy and its efforts to control particulate pollution in underground rail environments. Currently, fine particulate concentrations are continuously monitored in five underground stations at the request of Île-de-France Mobilités: Sevran, on the RER B line; Magenta, on the RER E line; and Avenue Foch, Neuilly–Porte Maillot, and Porte de Clichy on the RER C line. As part of a project also funded by Île-de-France Mobilités, the Péreire–Levallois, Saint-Ouen, and Les Grésillons stations on the same RER C line will be equipped with experimental micro-sensors with the aim of adapting the model to predict particulate movement between these six consecutive stations.



The concentrations of fine particles are continually measured in stations on the RER E line.

The first of a series of new models of standardized footbridges has been installed at Saint-Jean-de-Losne, in east-central France.

# More economical and more ecological footbridges

SNCF Gares & Connexions has around 2,800 small and medium-sized stations in France, which is why it is interested in developing models of standardized footbridges that are more economical, environmentally friendly, functional, and aesthetically pleasing, all while fully complying with rail safety and maintenance standards.

Each standardized footbridge model significantly reduces the quantities of materials used (40% less steel and 80% less concrete). They also have 10% lower crossing heights, thus reducing stair lengths, a benefit for users. Thanks to their factory-made, fully modular components, which are lightweight for transport, the footbridge has a high repairability index and can be installed by welding in less than six hours.
A catalogue of these footbridge models in 3D is available to engineering firms. The first of one series (17 meters) was installed at Saint-Jean-de-Losne in 2023, and a second (80 meters) is currently under construction in Nevers. These easily replicable footbridge models meet multiple needs, including accessibility upgrades, safety, station renewal, and Metropolitan and Regional Express Services (SERM) development.

**Partners**
French state; Bourgogne-Franche-Comté region.

**35%**
**lower cost**

**45%**
**reduction (approx.) in carbon footprint**

**Within 5 years**
**in more than 30 stations**

## Julie Reiner
**Secretary General, SNCF Gares & Connexions**

"In response to the climate challenge, the project owners and designers at SNCF Gares & Connexions are committed to developing new construction models that use fewer resources, emit less carbon, and are less costly overall. Aligning economic and environmental performance requires the development of innovative solutions, as demonstrated by the footbridge in Saint-Jean-de-Losne."





# Selective seeding
## Controlling vegetation on service tracks

SNCF Réseau is conducting experiments to reduce the use of phytosanitary products for track maintenance. Since alternatives tend to be more expensive, the focus is on identifying ones that do not require frequent use. Selective seeding is one such solution suitable for service tracks and marshalling yards. It has been tested at Dole, in eastern France, since 2018 and implemented at 32 marshalling sites with a total area of 42 hectares as well as at some electrical substations.

Seeds and plant-based/organic materials are mixed with water and sprayed on the tracks, a technique called hydromulching. This creates a permanent vegetative cover that requires mowing only once a year. The mixture is chosen for its adaptability to mineral environments and ability to meet maintenance and operational requirements on service tracks. After several years of research and development in partnership with the company Natura'lis, this solution was launched as a branded product called Végérail in March 2025.

# Acoustic deterrence
## Protecting wildlife and reducing animal collisions

Acoustic deterrence systems protect wildlife and lower the risk of collisions.

Train delays and cancellations, rolling stock repairs, customer compensation… the consequences of collisions with wild animals are significant. Over 2,600 hours are lost each year. Collisions with large mammals can require repairs costing thousands of euros. To protect wildlife and avoid the consequences of collisions for maintenance and train punctuality, the SNCF group is developing and testing acoustic deterrent systems.

Since September 2024, speakers installed at the front of three TER railcars in the Auvergne-Rhône-Alpes region have been emittinng warning signals recognizable by large mammals to cause them to flee. These signals are automatically triggered via geolocation in high-risk areas. Onboard cameras record the effects on wildlife. The signals were developed as part of a CIFRE (Education through Industrial Research Agreement*) doctoral thesis, then tested at the Haute-Touche zoological reserve (a facility of the National Museum of Natural History). Another approach in trials on the Oudon–Ancenis and Écouflant–Tiercé sections of the Nantes–Sablé-sur-Sarthe line consists of beacons with speakers installed every 50 meters along the track that emit signals just before a train passes. These signals include warning sounds, predator noises, hunting horns, or gunshots. A third solution, wildlife level crossings, is scheduled for implementation in the Paris region in 2025.

*This research is co-funded by SNCF, SNCF Voyageurs, SNCF Réseau, and Université de Saint-Étienne.

## Renaturation of ICF Habitat land

In 2024, AREP developed a data analysis tool for ICF Habitat (SNCF's real estate subsidiary) to assess land cover and vegetation on its land holdings. The objectives are to identify the development and renaturation potential of non-built property, to adapt biodiversity to site-specific conditions, and to reduce green space maintenance costs. The tool assesses the potential of each site by measuring and comparing opportunities for ecological improvement, risks of degradation through urbanization, and levels of ecological continuity.

Commercial trials of the hybrid TER Régiolis were conducted for one year.

## Hybrid trains

Trials of the hybrid TER Régiolis in SNCF's first project to decarbonize by modifying existing rolling stock ran for one year. After entering commercial service first in the Occitanie region and then in Nouvelle-Aquitaine, Grand Est, and Centre-Val de Loire, the hybrid train lived up to all expectations in terms of safety, reliability, on-time performance, fuel savings (about 20%), and range (over 1,000 km).

The hybrid TER Régiolis combines electric, diesel, and battery power. Two of its four diesel engines were replaced with lithium-ion batteries. Its multiple power modes –catenary/batteries or diesel/batteries – provide operating autonomy. The batteries store braking energy for reuse during acceleration. The next step is to enhance the energy management system to predict upcoming charging opportunities along the route to obtain a 30% reduction in fuel consumption (battery instead of diesel, recharging from the catenary or by recovering braking energy rather than with the diesel engine, etc.). Artificial intelligence could also be employed. Development is underway.

**Partners**
Occitanie, Nouvelle-Aquitaine, Grand Est, and Centre-Val de Loire regions; Alstom, CAF

**Fuel savings of up to**
**30%**

### The role of biofuels in hybridization

The hybrid TER Régiolis also offered an opportunity to test biofuels and confirm their operational performance: HVO (Hydrotreated Vegetable Oil) was tested in Occitanie, partnering with Dyneff; B100, an esterified oil made from French-grown rapeseed, was used in Nouvelle-Aquitaine with SAIPOL, and in Grand Est with Bolloré Energy. Temporary refueling solutions were set up for these operations. Running the hybrid TER with biofuels brought an additional reduction in greenhouse gas emissions and pointed to another alternative to fossil fuels. No negative impact on the operation or performance of the hybrid train was observed.





## Battery trains

Battery-powered trains combined with partial electrification of rail lines (see sidebar) offer a robust and economical alternative to full electrification, which is costly and takes a long time to implement. They reduce $CO_2$ emissions by 85% and eliminate nitrogen oxide (NOx) emissions. Batteries can be charged from the catenary or at stations equipped with charging terminals. They can also recover and store braking energy, then reuse it when starting up, delivering energy savings of about 20%. On non-electrified tracks, they have a minimum range of 80 km.

Two bi-mode railcars have already been converted to fully electric by replacing their diesel engines with lithium-ion batteries. After tests in Crespin and at Alstom's railway testing center in Bar-le-Duc as well as on the French rail network to assess noise, electromagnetic compatibility, traction, and energy performance, more tests must be done to ensure the batteries create no safety hazards. Two more trains will be converted in 2025, and one in 2026 before entering commercial service in the partner regions.

**Partners**
Auvergne-Rhône-Alpes, Hauts-de-France, Nouvelle-Aquitaine, Occitanie, and Sud regions; Alstom

**Yann Harcouet**
**Head of the TER rolling stock decarbonization program – SNCF Voyageurs**

The first battery train, the B82775, was tested at Crespin and at Alstom's railway test center at Bar-Le-Duc as well as on the French rail network.

### TWO WAYS TO SUPPORT BATTERY TRAIN OPERATIONS

#### Partial rail line electrification

This approach consists in electrifying only portions of a rail line and skipping complex infrastructures (bridges, tunnels) that entail high installation and maintenance costs. On unelectrified sections, trains run on battery power, thus enabling the switch to 100% electric traction on current diesel-operated routes.

#### Static fast charging

To ensure reliable and frequent service with battery trains, SNCF's Department of Technologies, Innovation and Group Projects is continuing research into the obstacles to high-power static charging below 1500V DC. The objectives are to reduce battery-powered train charging times, improve commercial availability, increase operating range, and avoid costly rail line electrification.

"Decarbonizing our 1,000 regional TER trains that run daily on diesel is a priority. To achieve this, we are exploring all available technological options in the short, medium, and long term. The hybrid train is a first successful step, and we aim to go even further with battery and hydrogen trains."

**H2 TECHNOLOGIES**

# H2 ICE

## An internal combustion engine fueled with hydrogen

The hydrogen internal combustion engine (H2 ICE) operates on the same principle as a conventional diesel engine. Industries are looking with growing interest at this technology, which has reached a sufficient level of maturity to be tested in the rail sector. Its key advantages: no $CO_2$ emissions; a lower purchase price than fuel cells; and lifespan identical to a diesel engine's and extendable through maintenance. Made primarily of steel, it uses very few rare metals and is resistant to harsh environments (impurities, dust, etc.). Because this engine is suitable for applications requiring a lot of power—and thus large quantities of energy—the aim of the H2 ICE project is first to decarbonize locomotives running on non-electrified lines for freight, maintenance, and construction operations.

The quantities of energy required by these engines mean that hydrogen must be carried in liquid form, which is more compact but must be maintained at a temperature of –253°C. The feasibility of the H2 ICE project is being assessed first through simulations before deciding whether to move forward with testing and prototyping. A partnership with IRT Railenium is being set up now.

The hydrogen traction system consists of fuel cells, which generate energy from hydrogen stored in special tanks.

# Régiolis H2 fuel cell train

This project offers a fully decarbonized alternative to diesel traction using hydrogen ($H_2$). It also contributes to the development of a low-carbon hydrogen ecosystem by assisting partner regions in their requests for proposals to find hydrogen distribution solutions appropriate for their needs.

The traction system of hydrogen trains consists of fuel cells that generate the electrical energy for the motors that drive the trainsets, using hydrogen stored in tanks. These fuel cells work in conjunction with batteries, which provide additional power during acceleration and allow the recovery of braking energy. Hydrogen trains have a range of 600 km. In 2024, the assembly of the pre-series hydrogen trainset was completed in Reichshoffen. Validation and certification tests will follow in 2025 in parallel with the launch of the series production with 12 Régiolis H2 trainsets.

**Partners**

Auvergne-Rhône-Alpes, Bourgogne-Franche-Comté, Grand Est, and Occitanie regions; Alstom, CAF

This project is publicly funded in the France 2030 program managed by ADEME.





# A word from **Lucian Balea,** Deputy Director R&D, RTE

"When energy production is high locally, we must be able to absorb surplus energy at the level of France or even of Europe. This requires robust interconnections."

**What are the issues with decarbonization and the energy transition in France?**

To support the decarbonization of the French economy, the share of electricity in the country's total energy consumption must increase from 25 to 55 percent by 2050. An investment of €100 billion over 15 years will be required to do this. Major projects include strengthening the backbone of the very high-voltage network; connecting and meeting the demand of new consumers —industry, data centers, mobility, and so on; integrating the production from the growing number of renewable energy facilities; and, of course, renewing our aging infrastructure while factoring in the new realities brought by climate change.

**How can innovation contribute to this effort?**

Some €240 million will be allocated to R&D between 2025 and 2028 —a 30-percent increase compared with previous funding—at a time when challenges are multiplying and arriving at an ever-faster pace. We are developing new methods of simulation, optimization, and risk assessment to refine our investment strategies and target our asset management actions. We are designing new infrastructure solutions and inventing new tools to manage flows and balances in the electrical system. Our work also focuses on the resilience of our assets in the face of climate change: floods, heatwaves, droughts, and wildfires are major risks that must be taken into consideration. Last, our industrial strategy is influenced by questions such as public acceptance of infrastructure, landscape integration, and biodiversity protection. Anticipating the risk of shortages of materials and technology in this period of geopolitical tension is another issue.

**SNCF is going to become a solar energy producer. What challenges does the multiplication of production sources pose?**

It requires integrating these new producers while maintaining grid stability and the quality of electricity —and doing so at minimal cost. When energy production is high locally, we must be able to absorb surplus energy at the level of France or even of Europe. This requires robust interconnections. Also, solar power is connected to the grid using power electronics-based converters, whose behavior differs from conventional alternators. They do not inherently provide the same stabilizing and self-regulating effects, which requires rethinking the systems that ensure the proper functioning and security of the grid. Last, models to forecast production levels at solar farms must be developed. We are also designing automated systems to monitor the state of the grid and its transmission capacity to regulate production in real time in order to accurately determine new infrastructure needs.

THEME

# Energy efficiency

The global energy crisis has highlighted the critical importance of energy security. In response, the SNCF Group has set a goal of reducing its energy consumption by 10% between 2022 and 2024. Over 80 solutions have been identified, ranked, and investigated with support from the International Union of Railways. More than three-quarters of them have been implemented or research has been accelerated. They include both technical solutions and operational practices such as efforts to reduce non-traction energy consumption—for example, the Start & Stop system and eco-parking. One measure alone—lowering train pantographs at night outside of maintenance operations—resulted in a saving of 32 GWh in 2024, equivalent to €5 million for SNCF Voyageurs, and avoided 1,600 tons of $CO_2$ emissions!

Other contributing efforts include the rollout of eco-driving, supported by the Sirius Next driver assistance tool, and the development of projects aimed at reusing braking energy. Added to these initiatives are efforts focused on future rolling stock such as the aerodynamics of the next-generation TGV, lightweight trains like TELLi, DRAISY, and FLEXY, and improvements to SNCF's industrial and real estate assets.

## PHIL (Power Hardware in the Loop)

### Better energy management with hybrid trains

Battery and supercapacitors performance was evaluated under normal and degraded conditions.

To test the performance of batteries and supercapacitors for hybrid trains operating in the Paris region without having to modify a trainset, a test bench simulating a hybrid traction system was developed by SNCF Voyageurs' Rolling Stock Engineering department.

In 2024, the behavior of the batteries and supercapacitors was modeled based on operational data recorded in the Paris region. Their actual performance was then evaluated under normal and degraded conditions using simulations developed since 2017. Their integration led to an optimization of the energy chain in all configurations.

Several benefits were noted: in connection with Smartilien, a project aimed at onboard braking energy recovery, energy savings of 30% were achieved compared with a journey under 1,500 V DC catenary power alone, and savings of 25% under 25 kV AC catenary power. Using batteries and supercapacitors also allows 100% electric braking in stations, which helps preserve brake pads (the leading maintenance expense for rolling stock in the Paris region) and avoids the emission of fine particulate matter.

**Partners**
Île-de-France Mobilités, FEV, Alstom, Agence d'essai ferroviaire

**Using batteries and supercapacitors allows**
**100%**
**electric braking in stations**

## SCOOT

### Lightening seats on OUIGO and Transilien trains with composite materials

Trains are subject to strict axle load limits, so optimizing the weight of seats is essential. Reducing seat mass potentially means carrying more passengers, more batteries, and more comfort-enhancing features, all while lowering energy consumption and $CO_2$ emissions.

In 2022, the Rolling Stock Engineering department of SNCF Voyageurs and the SNCF Group's Technology, Innovation and Projects Department launched the SCOOT project (Optimized Composite Seat for OUIGO and Transilien). With magnesium or metal components reaching their resistance limits, SCOOT is developing new seats made from composite materials, thus reducing their weight by up to 30% while retaining their existing characteristics and designs.

**Bruno Langlois,**
**Director of Rolling Stock Engineering Development at SNCF Voyageurs**

"For the past 15 years, we have been striving to improve our energy efficiency. This policy has taken on a new dimension because of the energy crisis and our commitment to offering increasingly decarbonized transport. We incorporate these requirements into the specifications for new rolling stock and make improvements to existing equipment with technical systems or by adapting operational practices. We are also working on load-shedding solutions to relieve the power grid."

## Green Power

### Reducing energy consumption in freight train traction and parking

Energy consumption from the activities of Rail Logistics Europe (RLE) accounts for 60% of its total $CO_2$ emissions. RLE wants to assist its subsidiaries in reducing their consumption. It is projecting 5% energy savings in its European operations through the implementation of energy efficiency measures, eco-driving, and eco-parking practices.

In 2022, for its French subsidiaries, the group launched Greenpower, a program designed to reduce energy used for traction (which represents more than 90% of energy consumption) and parking. GreenPower has four main components: measuring energy consumption, promoting eco-driving, sharing best practices for eco-parking, and providing management support for the teams involved. These efforts helped RLE weather the energy crisis with minimal consequences. Performance indicators have been formalized for Fret SNCF (now Hexafret) and Captrain France. The Sirius Next driver assistance tool, already deployed by SNCF Voyageurs since late 2024, has also been used by the 1,200 drivers and supervisors at Hexafret, with adaptations for the specifics of freight transport. The goal is to reduce traction energy consumption by at least 5%. In 2025, the project will be extended to all of RLE's European subsidiaries and also promote the use of biofuels to reduce the carbon footprint of freight operations.

**RLE's energy-climate trajectory goal:**
**30%**
**reduction in $CO_2$ emissions from energy consumption by 2030, compared with 2022**

## REG'GAZ

### The turnkey system that optimizes track switch heating

To prevent snow buildup or frost formation on track switches during winter, these systems are heated either electrically or with gas burners. While de-icing with gas is more efficient, it also emits a lot of $CO_2$. The REG'GAZ project, launched in 2023 with the Rail Open Lab (see p. 30), aims to limit gas consumption to what is strictly necessary. Objectives include reducing gas and logistics costs, keeping switches in good working order (drying out of lubricants can cause switch malfunctions, impacting train punctuality), reducing the environmental footprint of the infrastructure, and reducing rail-related hazards for workers.

REG'GAZ autonomously controls and regulates the heating temperature. An information system collects real-time temperature data via track-mounted sensors. Ignition is programmed through a web app and activated via an automated system. Two prototypes are currently installed on switches, one in Chamonix and the other at Paris-Gare de Lyon, to test the regulation system. Time windows and setpoint temperatures have been defined, while in the future, the plan is to use data from operators and weather stations for the REG'GAZ system.

This prototype of REG'GAZ, which is designed to prevent snow accumulation and frost formation on track switches, is testing temperature regulation.

**Partners**
SCLE SFE, TLTI, MOÏZ

**-50%**
**reduction (approx.) in consumption and greenhouse gas emissions**

## Start & stop

### Smart energy management in fixed electric traction installations

SNCF Réseau is rolling out a catalogue of solutions designed to make energy management in fixed electric traction installations both intelligent and automatic. The goal is to eliminate idle losses from transformers at substations on low-traffic lines and reduce associated noise pollution. Depending on the transformer type and location, the benefits will vary, with average energy savings equivalent to the annual consumption of 4 or 5 households.

A Start & Stop static switch, the first solution in the future catalog, is designed for 1,500 V DC substations. It aims to better control and balance energy production and consumption times by automatically switching the circuit off and back on as needed. A first prototype has been installed at the Saverdun substation, and a second is being assembled now at Venerque, both towns in southwestern France.

**Partners**
Occitanie region; Soreel-Rehlko



# Welcome tomorrow!

The industrial revolution driven by digitalization and decarbonization has profoundly transformed the rail system and public transport, which are now closely linked to each other. There is a significant reduction in $CO_2$ emissions, increased use of public transport in urban areas and the countryside, smooth, end-to-end journeys for customers, and better connections with the rest of Europe. The modal shift to rail has become one of the main trends propelling our environmental and societal transition. One sign of the times? Taking the train has become the normal reflex.

# The train, undisputed champion of tomorrow's decarbonized public transport

## Carole Desnost

Vice President, Technologies, Innovation and Group Projects

Innovation has always been in the SNCF Group's DNA. The many technological advances that have shaped the growth of the rail sector have enabled us to optimize our industrial performance and meet our customers' expectations. Today, new technologies are accelerating the transformation of rail, leading to the development of renewed, multimodal, decarbonized, and accessible services for everyone, in all regions. Tomorrow, rail will play a vital role in metropolitan areas through the future Regional and Metropolitan Express Services and in rural areas through a new range of light trains like TELLi and DRAISY. Digitalization, decarbonization, and the artificial intelligence revolution are all major transformations. They drive our innovation and research efforts in which we have set short- and medium-term goals to reconcile increased mobility with protection of the environment.
Thanks to France 2030, the French rail industry now benefits from an ambitious innovation strategy and a more substantial roadmap. The number and diversity of projects led by CORIFER are proof of the commitment and vitality of our industrial ecosystem. All these projects share the same ambition: to accelerate the modernization of the rail system and, more than ever, to put innovation at the service of our customers.

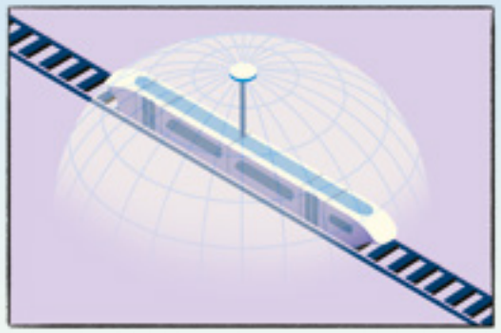
This collective effort uniting about one hundred industrial firms, academics, research institutes, and startups is already delivering significant early results and confirming, day after day, the powerful expertise of the French rail sector. All this is made possible by the support of public agencies implementing the France 2030 plan on behalf of the General Secretariat for Investment: ADEME (Environmental and Energy Management Agency), the National Research Agency, Bpifrance, and Caisse des Dépôts. Innovation is also gaining momentum at the European level through the Europe's Rail program, in which we are actively participating. By involving parties from the entire European Union, we are helping to create an efficient, high-capacity, shared rail space capable of meeting the growing demand for decarbonized mobility from the French and all Europeans.

Sizable investments are still required to complete the digitalization of the rail system and thereby substantially increase the capacity of the rail network—a goal that can be progressively achieved through the deployment of ERTMS, CCR, and ATO. All the developments shown in the future mobility mural on the following page are the result of close collaboration within SNCF Group teams and their partners aimed at meeting the needs of all our customers, in all regions, in a transport landscape that is going to become fully competitive.

All these projects share the same ambition: to accelerate the rail system's modernization and, more than ever, to put innovation at the service of our customers.

## Customer information, everywhere and at all times

Thanks to new technologies and artificial intelligence, information is shared in real-time across all physical and digital channels and is available in all languages to provide personalized service.
The harmonization of passenger and freight information systems, the complete restructuring of services with a multimodal and integrated vision, and the deployment of interactive terminals all contribute to providing reliable and accessible information under normal conditions and when there are disruptions.

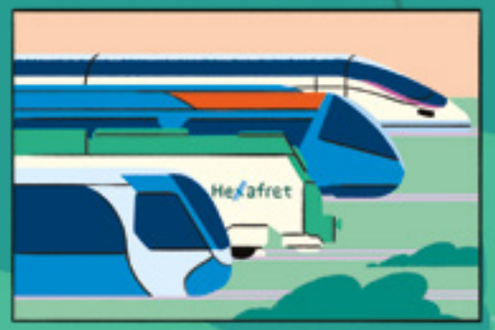


## Digital monitoring of the rail system

The key word is anticipation. Autonomous mobile systems for opening TGV high-speed rail lines and widespread deployment of sensors on fixed infrastructure and rolling stock now enable predictive, real-time asset monitoring. This array of systems helps prevent operational incidents and ensures that train services operate with perfect regularity.

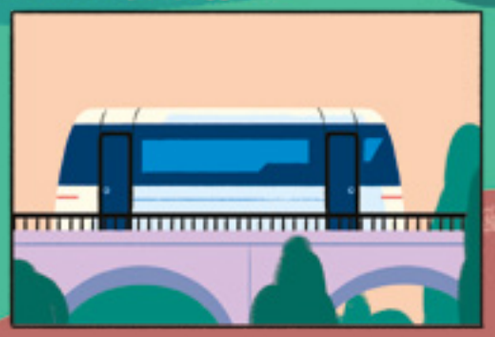
## Centralized and responsive traffic management

All train movements are now managed with digital technologies, starting with the European Rail Traffic Management System (ERTMS), which enables more trains to run safely on a single track while enhancing European network interoperability.
All traffic is controlled from centralized command centers across France, ensuring smooth flows and a quick return to normal operations in the event of disruptions.




## More trains, everywhere, for every need

Commuter services, freight transport, long-distance travel... more and more trains are operating on a highly digitalized rail network that is perfectly interconnected with the networks of neighboring countries. The heavily utilized rail system has become the backbone of mobility.

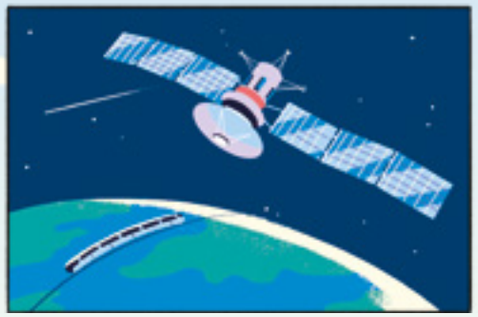


## Solutions adapted to all regions

Rail transport is present in all regions, even in the least populated areas. The new systems feature the latest technologies, with rolling stock that is fully accessible to all passengers and largely decarbonized. Their modularity allows their adaptation to the needs and passenger flows of each line. These systems allow better control of infrastructure and operational costs, which has led Organizing Authorities to increase the offering and frequency of services, thus providing a practical alternative to private car use.

## Public transport, the circulatory system for cities and their regions

Metropolitan Regional Express Services serve all the areas where people live and work around the large cities in the regions. Train, bus, tram, metro, express coach… all modes of transport converge to form a smooth network around stations and stops. Whether it is a weekday or the weekend, travelers don’t need to check their watches—they know the next train is coming soon.



## Telecom and space technologies supporting rail

Space technologies have improved the operation of the rail system. Satellite data allows ultra-precise, continuous, real-time train tracking and enhanced infrastructure monitoring. On the telecom side, these technologies provide complete network coverage with no "dead zones." The rollout of the FRMCS (Future Railway Mobile Communication System) has improved European network interoperability and enabled the deployment of new tools that facilitate operations and ensure safety.


## A climate-resilient transport mode

The effects of climate change are now part of daily life, but SNCF was prepared: infrastructure and rolling stock are better suited to extreme weather events. Resilience strategies were developed to maintain high levels of service and safety. While power outages used to be a major weakness of rail, energy storage solutions now ensure operational autonomy and onboard comfort for passengers.

## A safe and trouble-free station experience

The number of people passing through stations has increased significantly. Thanks to AI, each instrument-equipped station can predict traffic flows to better assist travelers in real time. Data analysis is being used to improve station installations and services to guarantee safety and comfort. With intuitive and easy-to-understand signage and enhanced video surveillance, travel has become smoother and safer, including for people with reduced mobility or disabilities.

## Preventive and robotized maintenance

Widespread use of fault prediction tools has drastically reduced breakdowns. By intervening before a failure occurs, technicians are not forced to work under the pressure created by operational emergencies. They are supported by multifunctional robots that perform the most repetitive and physically demanding tasks. Their working conditions, like the quality of service, have greatly improved.

## Rail at the core of multimodality

Signage, information, accessibility, ticketing, frequency, connections... everything is designed and organized to streamline end-to-end travel. Unique in terms of passenger capacity, the train has become the backbone of mobility around which a network of all other modes, from bikes and metros to buses and all forms of car-sharing, is assembled.

## Focus on renewable energy

SNCF has gradually developed its own renewable energy production to satisfy a portion of its electricity needs. Most of this energy is generated by photovoltaic panels installed along tracks, supported by energy storage and recovery technologies and smart consumption management solutions. By easing the load on the national power grid, SNCF has become a key player in achieving net-zero emissions in France.

# Develop economic and industrial performance

OBJECTIVE

2

The rail sector and the SNCF Group are now operating in a fully competitive environment. The tendering processes now being initiated in the regions, like the entry of new operators on the high-speed rail network, require continuous improvement in both industrial and economic performance to better serve the public's mobility needs. Despite a challenging economic context, the SNCF Group continues to innovate with its partners to make rail transport more attractive, flexible, and multimodal. The regions are diverse, so to take all needs into account, the solutions we implement must be diverse too. To improve transport outside cities, we innovate by imagining mobility solutions for less densely populated areas. Another challenge is preserving French and European industrial sovereignty, particularly in view of their dependence on certain raw materials and advanced technologies.

In this regard, the ability of French industries to work together in designing the rail system of the future—especially through the Europe's Rail program—is essential. This will be a matter of pooling development costs to achieve real economies of scale by leveraging expertise from other industrial sectors (aerospace, automotive, wind energy, etc.) to overcome the limitations of a small rail market while also supporting the activities of regionally based French companies across France.

Vincent Delcourt
Director, Strategy and Technological Performance, DTPIG SNCF

**"Energy autonomy and resource efficiency are now critical issues for companies and countries. In a context of geopolitical tensions, market volatility, and ecological transition, these two dimensions have become strategic factors of competitiveness for the rail sector."**





THEME

## Energy self-sufficiency and resource conservation

With an annual consumption of 10 TWh, the SNCF Group is the largest industrial consumer of electricity in France. The supply of energy essential for the operation of trains and infrastructure is a major issue in an increasingly unstable energy context. To secure our supplies and ensure competitive and sustainable energy sources, we are adopting a two-prong strategy: secure our supplies by signing long-term contracts (PPAs); become a solar energy producer with SNCF Renouvelables. By investing in green energy production, SNCF reinforces its commitment to the energy transition and energy sovereignty while gaining better control over its costs and environmental impact. To accelerate this strategy, we are also working on the development of technological components such as long linear photovoltaic panels, energy storage, braking energy recovery, reduction of losses, and supraconductivity. However, electrification also creates demands for copper and other rare metals. Promoting their recyclability has become essential.

### The RACCOR-D project

A more energy efficient multidirectional DC network for green energy too

The aim of this smart grid project is to transform the 1,500 V DC network into a smart, multidirectional system. Today, 5% of emitted energy is lost because it cannot be reinjected into the network. The goal is to recover braking energy from trains, store it in batteries installed at substations, and offset line losses with electricity generated by a solar farm.

RACCOR-D is based on two world-first innovations: a DC converter that raises voltage from 6,000 to 9,000 V and a very high voltage photovoltaic field (also between 6,000 and 9,000 V). To test the full system comprising the converter-battery, the connection of the solar field to the substation, and energy reinjection a platform is being assembled in the Aude region. Fire prevention installations for the fixed-energy storage system have been approved by a prefectural order, which will serve as the basis for a future technical decree on large-capacity stationary storage.

**Partners**
SCLE-SFE, RTE, Railenium, Institut National Polytechnique de Toulouse (Laplace), JUNIA (L2EP Lille), CEA (main subcontractor). Funding: BPI France (France 2030 program).

This project is publicly funded through the France 2030 program managed by Bpifrance.

**8 to 10%**

**energy savings per year on average. The amount depends on traffic and available space. The objective is a return on investment by site within 10 years.**

# Storage of energy as heat

## Large-scale and sustainable storage of renewable energy

A storage system patented by STOLECT will be installed at the Technicentre in Brittany.

The SNCF Group has the aim of increasing its energy autonomy so the ability to store energy from inherently non-dispatchable sources (wind and solar) is a key goal. An energy storage system patented by STOLECT connected to a photovoltaic park built earlier by by SNCF over an area of 260 sq. meters is being installed at the Technicentre in Brittany. Construction is underway, with commissioning planned in 2026.

The storage system, which is based on the Carnot battery principle, is able convert intermittent energy production (up to 5 MWh) into "dispatchable" electricity. Electricity is first transformed into heat using turbomachines (1 MW of power). This heat is stored in two tanks using refractory materials (basalt rocks and ceramics) and then reconverted into electricity during the discharge phase. Advantages of the system: It does not rely on critical raw materials, and basalt rock does not degrade over time, giving the system a longer lifespan than lithium batteries (25 years vs. 8 years).

**Partner**
STOLECT

**70%**
**efficiency is expected**

## The SNCF Group plays the energy storage card

SNCF consumed about 7 TWh of electricity in 2024, making it the largest electricity consumer in France. The need to increase its resilience to fluctuations in the energy market has made energy storage a key issue. Work began in 2024 on the development of storage solutions for all SNCF entities—SNCF Voyageurs, SNCF Réseau, SNCF Gares & Connexions, SNCF Immobilier, SNCF Renouvelables—with investments pooled to establish a sustainable economic model. In 2025, the focus will be on assessing the storage needs of each entity and identifying and evaluating existing solutions (batteries, thermal storage, etc.). This effort will begin with batteries, which appear to be the most mature option, with an efficiency of around 90%. This work will be carried out in partnership with the Energy and Climate Development Agency of the Occitanie region (AREC).

# Parallel Operation of 25 kV AC Substations

## Enhancing network power supply and energy efficiency

A significant increase in rail traffic can cause voltage drops on the rail network and imbalances on the high-voltage system. To address these issues, SNCF Réseau and its partners in the Rail4Earth project (a Europe's Rail initiative) are working on the development of an interconnected network of 25 kV substations operating in parallel. This setup is based on Flexible AC Transmission Systems (FACTS). The objectives are to improve voltage quality along catenary lines; better distribute power demand between substations; and reduce imbalances on the high-voltage grid. This would allow more traffic with no need to boost installed power.

The first step, to be completed by the end of 2026, is to validate with Siemens, in a digital environment simulating real-world conditions, the design of two converter prototypes for the parallel operation of substations. The first prototype, which is more advanced in terms of industrial maturity, is undergoing studies to determine the best control-command strategies. The second prototype will be tested through simulations to validate its architecture and control algorithms.

**Partners**
WP10 of Rail4Earth: Siemens Mobility, RFI, Trafikverket, CEIT, ProRail, ADIF, CAF

The bike hall at Paris-Gare du Nord, with 1,186 spaces, the largest secure parking facility in the Paris region and the second largest in France after Lyon Part-Dieu, opened in June 2024. Its 567 rooftop solar panels, installed over an area of 1,100 sq. meters, will produce up to 170 MWh of renewable energy per year. This project was carried out by Île-de-France Mobilités, Altinnova, SNCF Gares & Connexions, and its subsidiary AREP.

## Solarization of the Angoulême passenger hall

AREP is leveraging its expertise in mapping, data, and modeling to help the SNCF Group achieve its solarization goals. In Angoulême, installation of translucent photovoltaic panels—enough to cover 40% of the building's lighting and ventilation needs—in the 1,900-sq.-meter passenger hall.

## OPHELIA: exploit linear spaces

How can the production of photovoltaic energy be developed on long, narrow surfaces such as railway embankments, dikes, or bike paths? To answer this question, SNCF, which leads the project for its rail-related component, is partnering with CNR, Nexans, Schneider Electric, and SuperGrid Institute. AREP is contributing to the project through studies identifying the development potential for linear solar energy across all types of land.

This project is publicly funded in the France 2030 program managed by ADEME.

OPHELIA is paving the way for the development of photovoltaic panel projects along large linear spaces.

**Emmanuel Mroz,**
**CEO,**
**SNCF Renouvelables**

"SNCF Renouvelables has been in operation since early 2024. The Voltaferro pilot phase helped identify the many issues that need to be addressed. The first priority is to identify sites suitable for projects. Over 500 hectares have already been analyzed, and nearly 150 are currently undergoing environmental assessment over a 12-month period. As regards the analysis of these sites, ongoing research and development appear essential: RACCOR-D *(see p. 25)* for optimizing energy production; OPHELIA and storage technologies (see opposite) to deal with the distances involved with the infrastructure and to optimize and secure energy transmission... Relations with elected officials and local authorities are also proving crucial, and here again, the size and unified operations of the Group are playing a decisive role."

# Sevipav

## A second life for track materials

Each year, materials designed for heavily used rail lines are replaced during track renewal operations. These operations, known as "suite rapide" (fast-track renewal), are carried out by factory trains capable of renewing all components of a railway track in a single pass.

Starting in 2025, some of the tracks renewed with fast-track operations will be removed without separating the individual components. This results in 18-meter-long sections called "track panels," composed of rails fastened to sleepers. The aim of the Sevipav project is to preserve these track panels for reuse on lower-traffic lines, such as local service lines and service tracks. By reducing the quantities of new materials purchased, the project seeks to lower the cost of renewing these lines while decreasing the environmental impact of construction works. Sevipav is based on identifying and validating technical criteria for classifying track panels according to their potential for reuse. These criteria will ensure long-term safety and reliability.

**Partner**
Fondation FEREC

**Up to**
**254 tons of $CO_{2e}$**
**saved per kilometer of reused track (compared with a conventional process: resource extraction, production, and transport of new materials to the construction site).**

# OPTIGRAN

## Reusing Even More Ballast

In 2022, 100% of the ballast renewed on the North high-speed line was reused ballast.

Since 2022, SNCF Réseau has been reusing large amounts of the ballast removed from railway tracks, including from high-speed lines. Currently, up to 65% of the ballast removed during fast-track projects is reused on tracks.

With the OPTIGRAN project, SNCF Réseau is aiming to process and reuse up to 25% more ballast on regional low-traffic lines and service tracks. The benefits for the projects involved are multiple: an approximately 25% reduction in natural resources extracted, roughly 15% savings on the cost of new materials, and significant savings on logistics owing to the reuse of more locally sourced resources. This increase in reuse involves processing ballast within a granulometric range of 20–50 mm, compared with 31.5–50 mm at the present time. To ensure compliance with operational requirements, SNCF Réseau is developing a digital modeling tool and studying the aging of 20–50 mm ballast on test tracks.

**Partner**
Fondation FEREC

**-15%**
**in the cost of reprocessing a ton of ballast**

**-16,7t $eqCO_2$**
**in comparison with the use of new 31.5/50 ballast**

# Energy savings on rolling stock

TGV trainsets are now equipped with a system that remotely switches them over to eco mode.

## ON THE MOVE WITH THE "FIRST BOGIE" DEFLECTOR

How can the aerodynamic performance at the first bogie of a TGV trainset be improved? In 2024, a deflector integrated into the triangular plate beneath the driver's cab was tested in commercial service for two months. It redirects airflow under the bogie, leading to energy savings of between 0.6% and 1.5%. This translates into an annual cost saving of nearly €2 million. The tests validated the deflector's behavior and effects, including mechanical durability, airflow deflection toward the ground, and prevention of ballast projection. Following these successful trials, the triangular plates currently installed ahead of the first bogie on all TGV trainsets will be replaced.

## PARKING WITH ECO CLIM TGV AND ECO TGV DOORS

TGV trainsets have been equipped with an onboard computer system called Lorient. Through a processing interface and a communications module, it tracks the trainsets' location and remotely monitors their technical status. This system also controls the closing of door and manages climate control and lighting when trains are not in commercial service. The "ECO mode" can be activated either automatically or manually. It is triggered if the train remains idle in standby for more than 30 minutes without any interaction (such as a door opening, or an obstacle detected on closing).

Once activated, onboard lighting is reduced, air conditioning is adjusted based on outside temperatures (within a range of 15°C to 28°C), and doors close with visual and audible warnings.

**1%**
**energy savings with Eco Clim TGV and Eco TGV Doors**

# Major industrial partnerships in 2024

In 2024, three new projects led by the SNCF Group were selected in the 2023 Call for Expressions of Interest of CORIFER: MARS *(see p. 38)*, Mobil'Quai *(see p. 56)*, and FLEXY *(see p. 59)*. Sferis is also participating in the Simon project (intelligent monitoring and optimized maintenance of regional small lines) in a consortium led by the IRT Railenium institute. At the European level, industrial progress is being made on the ARGOS project (with the first deployments of these new digital interlocking systems planned for 2025) and the High-Performance Marseille–Ventimiglia corridor, which is supported by EU, national, and regional co-funding, in which the deployment of ERTMS now in preparation. Applications are also being developed for rolling stock in the Connecting Europe Facility program for certain TGV trainsets, for the Grand Est–Luxembourg routes, and the Sud-PACA–Italy routes. Other projects are in preparation with Railtraxx (a Rail Logistics Europe subsidiary) and Europorte for freight traffic with Belgium, Germany, and Luxembourg.

Three other exploratory research topics have been launched in the Europe's Rail call for projects *(see p. 46)*. A new cooperation agreement on innovation has also been signed between DB and SNCF, eight years after their first one. This agreement focuses on the European rail system of tomorrow —its architecture and technological modules—including digitalized trains, satellite-based train location, and future 5G communication systems. The two companies want to accelerate progress in key areas such as digital freight to improve cross-border exchanges and energy, by addressing market instability through the standardization of battery and hydrogen trains.

## Rail Open Lab, a field-based innovation accelerator

The Rail Open Lab is an open innovation initiative for the rail network with around 30 members, including industrial players, startups, and infrastructure managers. Its approach? Experiments in real operating conditions for over 4 months, with shared feedback to enhance the competencies of all members. Among the successes in 2024: A digital optical control panel to assist SNCF Réseau work trains with maneuvering at yards and depots (for checking track occupancy and routing); a high-power horn handling prototype to facilitate the transport of these 14 kg warning systems and their use on worksites; Reg'Gaz, a system that optimizes the heating of track switches *(see p.16)*. The challenges in 2025: Successfully industrializing these high-potential solutions and onboarding new infrastructure managers, including Infrabel, the Belgian rail infrastructure operator.

**Funding from the French government via France 2030, through the CORIFER CEIs (2021 and 2023), amounted to €250 million, representing about**
**€700 million**
**in R&D activity for the rail sector.**

### Frédérick Getton,
Director Finance & Institutional Relations, DTIPG SNCF

"The Rail Open Lab is a different way of innovating that is very complementary to R&D. It proposes, tests, and deploys innovations over very short timeframes. Its expertise is now attracting other infrastructure managers, which is a very good sign."





THEME

# Resilience to climate change

Europe and France are particularly exposed to climate change, with projections indicating an average temperature increase of 4°C by the end of the century, accompanied by increasingly frequent and extreme weather events. The most critical risks involve water-related disruptions – flooding, flash floods, and alternating drought and heavy rainfall – which especially affect engineering structures and earthworks. Rising temperatures also impact electrical systems, affecting both infrastructure and rolling stock. In the SNCF Group, SNCF Réseau and SNCF Voyageurs are working to model, assess, and map vulnerabilities in the rail network and rolling stock over time. They are also developing decision-support tools to help identify and prioritize investment needs for strengthening the resilience of the rail system.

### Thomas Joindot,
Chief Technical Officer, SNCF Réseau

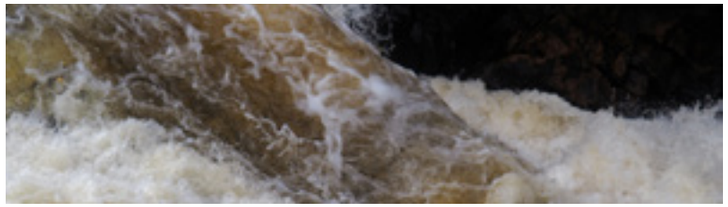
"How do we develop network management strategies? We already know how to assess the resistance of a specific structure to local climate changes—for example, how to reinforce it against flooding. But with climate change, the challenge is to predict the effects of global climate shifts on all our infrastructure. This is where we are focusing most of our R&D efforts."

## Platipus
### Projects for the analysis of vulnerable structures at subaquatic and aquatic sites

The aim of the Platipus project is to anticipate the impact of extreme climate events on the 10,000 engineering structures at aquatic sites in the rail network. These phenomena can lead to scour at the foundations, causing structural damage, imbalance, or even collapse in extreme cases.

Platipus is based on the development of a decision-support tool powered by AI, which analyzes supplied data to identify vulnerable structures at risk of scour and optimize preventive and early-stage maintenance operations. The platform now incorporates climate change parameters, including scenarios from the IPCC, such as a 4°C rise by 2100. The relevance of predictions and their value to maintenance and asset managers (real-time water level warnings from field data, prioritization of work, etc.) have been proven. Thanks to partnerships with other infrastructure managers, a machine learning model applicable internationally has been developed. Industrial rollout is planned for 2026, and work to automate the algorithms will continue through 2032.

**Partners**
Université Gustave-Eiffel, CentraleSupélec, setec, MOMI, Network-rail (GB), Japan Railways, RTRI (Japon)



# Adaptation of rolling stock to climate change

In line with the European research project Rail4EARTH (Europe's Rail), which focuses on adapting the entire rail system to climate change, the engineers in the Rolling Stock Engineering Department of SNCF Voyageurs are looking specifically at the adaptation of rolling stock.

Objectives: identify key vulnerabilities, estimate the costs of solutions to ensure the availability and reliability of rolling stock in the climate conditions of the next few decades, and assess the consequences for maintenance and operations if no action is taken. The research extends to all types of rolling stock—mass transit, regional trains, and all generations of TGVs, including new models whose technical specifications now incorporate enhanced climate parameters. Priority is being given to trains expected to operate beyond 2050.

To structure this initiative, an extensive four-phase plan has been laid out:

**1. Understand and equip**
- Improve knowledge of the vulnerabilities of existing rolling stock
- Develop simulation tools for temperature behavior, air conditioning, and electronic cabinets
- Identify solutions to increase resilience to harsher climate environments
- Test solutions

**2. Analyze the fleet**
- Assess the gains in resilience achieved with adaptations to priority series of rolling stock.

**3. Calculate the cost of adaptation**
- Determine the costs and timelines for implementing modifications.

**4. Deploy adaptations**
- Industrialize the modifications on rolling stock selected by the owner (SNCF Voyageurs for TGVs, Organizing Authorities for Transilien, TER, and Intercités).

At the core of phase one is the development of simulation tools to accelerate understanding of vulnerabilities and identify potential solutions before moving on to testing and implementation.

In the meantime, several trials of passive solutions have already been conducted on trains currently in service, some of which were designed decades ago for maximum temperatures of 40°C. Examples of such solutions include painting roofs white, installing thermal insulation on rooftop electrical equipment, and applying heat-reducing (athermic) film to windows. For example, by the end of 2025, the roofs of Corail coaches operating on the Transversale Sud line will be repainted white.

An international benchmarking survey is also underway to identify solutions already used in geographic regions currently experiencing climate conditions like those expected in Europe.

Following an assessment done in 2024, a similar initiative is being taken for the technicentres to adapt the workshops and working conditions of their personnel.

The climate change adaptation plan for rolling stock calls for the implementation of modifications to trains selected by their respective owners.

# SNCF Réseau and climate change

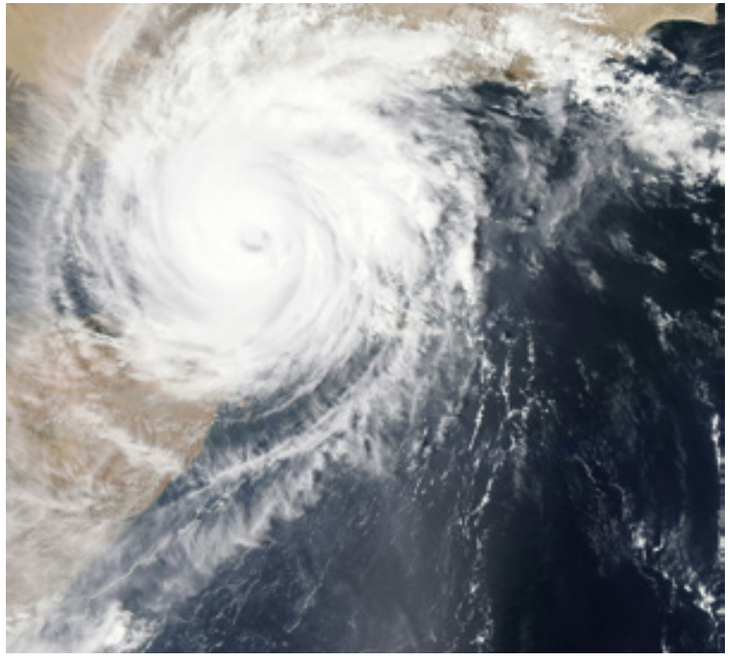
**Today, 4.6% of delays and 5.6% of train cancellations are due to climate instability. The direct costs stemming from such climate-related events (damage, repairs, lost track access fees due to train cancellations, etc.) are estimated at between €20 million and €40 million per year. As for the expenditures to deal with these problems—for example, intensified vegetation management—they have increased by €50 million over the past 10 years. SNCF Réseau is taking this new reality fully into account with a three-pronged strategy:**

**1. Adaptation of maintenance and monitoring,** targeting the most vulnerable areas with special attention to catenaries during heatwaves and earthworks during heavy rains; careful upkeep of hydraulic structures and vegetation management.

**2. Adaption of operations and network functions:** Preventive cancellations in the event of storm warnings; slower train speeds during heatwaves to minimize the risk of damaging catenaries slackened by the heat, etc.

**3. Adaptation of assets,** ranging from minor adjustments to large-scale projects, taking maximum advantage of scheduled regeneration cycles.

To better observe and understand the physical degradation of and attacks on infrastructure (heat, heavy rain, etc.), SNCF Réseau is expanding its modeling capabilities and developing decision-support tools. The objective is to translate general climate forecasts into predictions of local impacts on the network, to aggregate all local problems in each region, and to prioritize actions based on cost-benefit analyses regarding resilience. The last would include:
- "no-regret" actions that have substantial benefits such as renovation/modernization, long service life, and available funding;
- case-by-case actions: depending on risk exposure, commercial potential, cost, and time to regeneration;
- high-cost actions: major retrofits with limited commercial return.



This adaptation strategy is based on close collaboration with the rail and utility network industries, which face similar climate-related challenges, with support from meteorological operators.
Further cooperative efforts are being pursued to modify practices around rail rights-of-way, including initiatives with farmers and landowners (enhanced maintenance, hedge planting, change of crops, soil decompaction to improve water permeability, etc.).

**€20m to €40m/year**
**The direct costs incurred due to climate-related disruptions (damage, repairs, lost revenue due to cancelled trains, etc.)**

# MINERVE

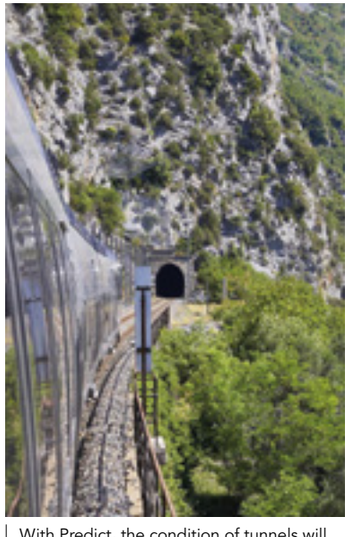
## Prediction of the impact of climate events on infrastructure

MINERVE contributes to the transition of the rail network toward design, construction, operation, and maintenance that is more efficient, reliable, and environmentally friendly, thus helping to increase resilience to climate change while also boosting competitiveness.
The project involves the design and development of digital methods and tools for modeling rail infrastructure (BIM and digital twins combined with AI) using reliable, comprehensive, and up-to-date data.

The modeling of climate events and related risks is the main objective of the MINERVE project.

Among the projects in the MINERVE framework is a tool for predicting climate risks and their impact on rail assets. It models climate events and infrastructure vulnerabilities, quantifies risks by asset and by region over specific time periods, and identifies priorities, risks, and the benefits of investments. Currently tested with a demonstrator in the PACA (Provence-Alpes-Côte d'Azur) region, this predictive analysis method is intended for implementation across the entire rail network.

**Partners**
MINERVE: RATP, Kayrros, CentraleSupélec, Colas Rail, IREX
Climate Risk Prediction Tool: Kayrros, CentraleSupélec, setec, Systra



With Predict, the condition of tunnels will be assessed and managed over time.

## Predict

Predict is a decision-support tool powered by AI specifically developed for the management of underground rail structures.
It is designed to better prioritize the maintenance and regeneration of these structures to ensure their safety and durability and to optimize the planning of operations. Predict enables medium- and long-term forecasting of the cost trajectories of the maintenance and regeneration of these structures.

Predict has led to the development of a predictive model for the aging of underground structures, with the projections visualized through two key indicators: the potential rate of degradation and the forecasted condition rating of structures at future dates. This tool is built on a new digital platform called ADN OST (Digital Data Analysis for Underground Structures), which went into production in July 2024. It takes into account the intrinsic characteristics of structures, the condition indicated by the ratings calculated automatically in the successive updates of the RADIS (Detailed and Computerized Record of Damage to Underground Structures) since 2006, along with all the factors of aging such as the type of surface coating, geology, rainfall levels, and topography.

**Partners**
OSE Engineering, La Martinière.

MINERVE is publicly funded through the France 2030 program managed by Bpifrance.





THEME

# Digitalization, a driver of industrial and economic performance

Digitalization has a role to play in all areas, whether strictly rail-related or not, and while the time needed to see a return on investment varies from one project to another, it unquestionably delivers productivity gains and improved service quality. It also accelerates development of software applications and systems, which are created with a modular mindset.

Operations are the primary beneficiary, as digitalization allows the number of trains running on the network to be increased without modifying the infrastructure, and with safety standards at least as strict as previously. ERTMS, traffic supervision systems that can detect circulation conflicts, train geolocation, infrastructure monitoring via connected devices on installations or trains, and driver-assistance tools are the best examples. The customer journey is the second major beneficiary of digitalization as it enables centralized, real-time information across all platforms, connectivity onboard and in station, and efficient reservation systems, thereby delivering an unprecedented level of service.

## ERTMS on Paris–Lyon: a major milestone

In November 2024, after five years of work with no impact on travelers, the LGV+ project reached a major milestone with the commissioning of 58 new signal boxes and a command center in Lyon on the Paris-Lyon line, which accounts for one-third of the high-speed traffic on the French rail network. These installations pave the way for the deployment on the line of ERTMS, the European signaling system that affords a high level of safety and performance. Thanks to ERTMS, by 2030 it will be possible to increase peak traffic from 13 to 16 trains per hour in each direction, a 25% boost in capacity.

### Luc Laroche,

**Director, Rail System Innovation Program, DTIPG SNCF**

"Digitalization is one of the keys to meeting the growing demand for mobility. It will allow us to increase frequencies on existing tracks, thus avoiding the need to build new lines, while maintaining or even lowering the cost per passenger or ton transported.
On the new Paris–Lyon line, ERTMS will enable us to go from 13 to 16 trains per hour per direction.
If line exit capacity permits, this could rise to 18 trains with further digitalization of train driving.
Our projects concern both the 'ground', such as cost-effective signaling solutions for small lines, and the 'onboard', for example, more modular onboard equipment architecture to simplify maintenance and thus reduce costs."

# Smart Station

## How train stations are becoming smarter and greener

Thanks to the tools described opposite, Smart Station aims to ensure maximum availability of key equipment (automatic doors, elevators, escalators, etc.) and technical systems in train stations. It promises faster response times in the event of breakdowns and contributes more broadly to the achievement of the ecological goals of SNCF Gares & Connexions. These include lowering energy consumption, the two main sources being, first, lighting, heating, ventilation, and air conditioning (HVAC), with a targeted emissions reduction of 22,000 tons of $CO_2$, and second, water, with a saving of 21,000 m³. These figures represent the expected benefits over the first eight years after the second phase rollout of Smart Station, which will begin between 2025 and 2028.

In preparation, about 11,000 sensors have been installed in 700 stations. An application intended for supervisors, station staff, and maintenance teams provides 3D visualizations of stations and real-time alerts of any malfunctions. Starting this year, new systems will be rolled out for real-time monitoring of water consumption and remote control of energy-related equipment such as lighting and HVAC. The implementation of remote opening systems at 200 stations will be added to the program starting in 2025.

**Partners**
Ssinergie, Décima, Bouygues Energie Services, HTTP, GraphicStream

### From digital twins to asset management

Smart Station relies on digital twins, i.e., accurate 3D virtual reproductions of stations, and the creation of IT tools for industrial asset management. These tools enable the sharing and analysis of descriptive data and support decision-making related to investments. This combination of instruments provides a precise understanding of the station infrastructure and its components (vacancy, obsolescence, financial data, etc.) and helps prioritize investments to optimize efficiency.

# LIVE

## a passenger information tool

A natural outcome of the opening of the passenger rail market to competition is that SNCF Gares & Connexions has become the information integrator in stations, with station operations now clearly separated from those of the transport operators. The LIVE program will deliver harmonized and responsive passenger information, with the aim of ensuring fair treatment of historical operators and new entrants. The system will integrate data from transport operators, transmit safety alerts, ad track information supplied by the network manager, and provide visual and audio communication of information and coordination during both normal operations and service disruptions.

This unified passenger information system will replace existing systems (ADAM, CATI, IENA/Dauphine). Built on a "serverless" cloud architecture, it dynamically allocates resources based on demand. LIVE will be deployed progressively as stations meet connectivity and equipment criteria. Small stations with few functions were equipped in 2023. Medium and large stations will see installation of LIVE by the end of 2025, followed by very large stations in 2026 and stations in the Paris region by 2027.

**Partners**
Transport operators, Mobility Organizing Authorities

**1,252**
**stations were equipped with the LIVE system at end-2024.**

# FRMCS

## Future Railway Mobile Communication System

GSM-R, the 2G platform used for communication between train drivers and controllers as well as for signaling, will become obsolete by 2035. FRMCS, based on 5G and MCx technologies (call prioritization, group calls, etc.), will begin replacing it in Europe as of 2030. Expected benefits include increased reliability, development of value-added services (e.g., video-assisted shunting, remote operation), and enhanced data transmission. FRMCS will also be modular and scalable. Thanks to the decoupling of radiocommunications and rail applications, operational tools will not need to be reworked as telecom technologies evolve.

To develop its standards, test its components, and transform prototypes into industrial products deployable at the European level, the program is divided into four projects:
- EU-Rail FP2-R2DATO WP25 (5G prototypes)
- 5G RACOM
- 5G REMORA (radio links and coverage)
- 5G SNCF Cores (private 5G interconnection)

SNCF Réseau is using the technical specifications to create a full product catalogue for development with industry partners by 2027. The new FRMCS prototypes will be deployed at the end of 2026 on the trial routes Paris–Brussels and Metz–Luxembourg.

**Main partners**
SNCF Réseau, ÖBB, SBB, DB InfraGO, ADIF, ProRail, DB, IRT Railenium, Université Gustave Eiffel, Alstom, Hitachi Rail, Siemens, Kontron, Airbus, Obvios, CEA, IMT Atlantique, SIRADEL, MERCE/ Mitsubishi, Nokia

Funding: Bpifrance (5GRACOM and SNCF 5G Core), ANR (5G REMORA), Europe's Rail (FP2-R2DATO)

FRMCS-5G is the European rail communications system that will replace GSM-R (2G) by 2035.


**200,000 km**
**of tracks to migrate to FRMCS in Europe**

# 5GMED

## Enhanced train-to-ground connectivity

In 2024, the European project 5GMED demonstrated the possibility of seamless service across borders as well as the economic relevance of sharing 5G infrastructure among several rail/road partners. The project also included the use of edge computing technology for applications requiring low latency and, for the rail sector, the combined testing of 5G with a 70 GHz mmWave network (millimeter waves). Objectives: To improve train-to-ground connectivity for operations (excluding GSM-R/FRMCS critical services) and enhance passenger experience (onboard connectivity). The tests were conducted on the Perpignan–Figueras high-speed line.

By optimizing 5G network configurations on both sides of the border and combining them with other technologies such as the 70 GHz (deployed on the Spanish side), seamless service was maintained. The 70 GHz network provides significantly higher speeds than the 5G bandwidth allocated for rail use. Installing data centers near the tracks enables low-latency services (obstacle detection).

**Main partners for the rail part:**
Comsa, Axbryd, LFP, Cellnex, i2Cat

**< 100 ms:**
**the time needed to switch from 5G to another network after optimization**

## Network monitoring by commercial trains

SNCF is working to automate the monitoring and supervision of the rail network to improve maintenance. In addition to dedicated equipment (such as the IRIS 320, track inspection vehicle/ESV, and the multifunctional vehicle/EMI in the Paris region) equipped with sensors like cameras and LiDAR, commercial trains are also being used for this purpose. This is the objective of the STC (Surveillance by Commercial Trains) program.

In the Auvergne-Rhône-Alpes and Paris regions, systems for analyzing track geometry have been installed on 15 trainsets, including on the RER Line C. In the Paris region, several solutions, chosen according to the generation of onboard safety equipment, have been implemented to identify faults in ground beacons. A catenary monitoring system has been installed on one trainset to provide data for industrialization studies.

To monitor track geometry, a variety of signals are collected by accelerometers, gyrometers, GNSS receivers, and other devices. These raw data are processed and integrated into the Surveillance & Supervision Information System, included on maintenance workers' devices, to indicate positions on the rail network, measure various parameters (level, alignment, cant deviation), correlate excess values with known defects, assess their potential to evolve, and prioritize maintenance operations. A trial project was conducted throughout 2024 with the Paris Est infrastructure division in a limited area. Its geographic scope will be extended in 2025.

## The MARS LGV System

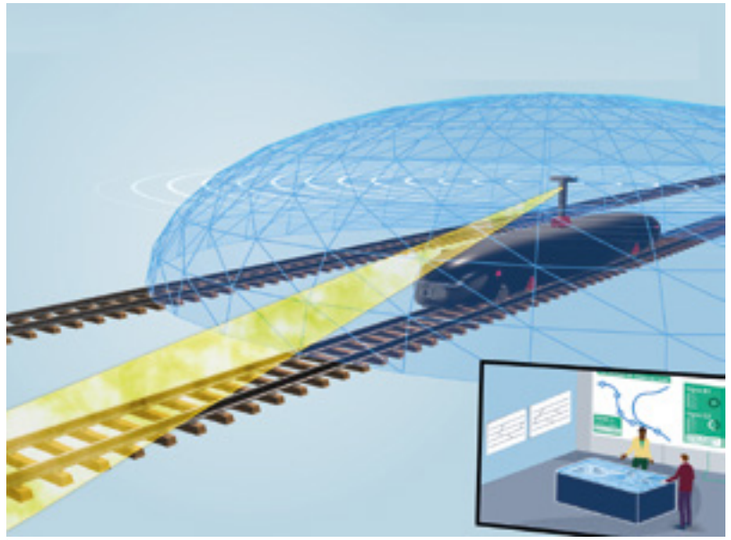
### Autonomous mobile units for high-speed line safety inspections

Every morning before the first TGV high-speed trains begin running, the high-speed lines are inspected using empty trains that have been taken out of commercial service. A new system, called MARS, has now been developed that offers a more flexible, cost-effective, eco-friendly, and efficient alternative. These autonomous mobile units (standard GoA4) powered by batteries and traveling at 230 km/h are continuously controlled by an operational center.
These autonomous mobile units are stationed at strategic points on the high-speed network and programmed to perform inspection runs. Each unit perceives its surroundings in 360° using sensors (cameras, LiDAR, radar, etc.), and the collected data are analyzed in real time to verify there are no anomalies to ensure commercial trains can operate at full speed and with complete safety.

The demonstrator project, launched in 2024, is based on several technological components (sensors and algorithms for perception and recognition, LFP battery-powered electric traction systems, autonomy, data, and telecoms, etc.), with the development of a modular and scalable system as its objective.
Goal: To arrive at an industrial-grade product by 2030.

**Partners**
Forsee Power, Compagnie des Signaux, IRT Railenium, Socofer France, Spirops

This project is publicly funded through the France 2030 program managed by Bpifrance.



MARS LGV is an autonomous, economical, and environmentally friendly line inspection system.

## Chairs: a bridge between the academic and industrial worlds

The SNCF Group is involved in around twenty academic chairs, either bilaterally with academic partners or multilaterally with other industrial entities. These chairs, which are established for periods of three to five years, cover a wide range of fields such as modeling, risk and resilience of complex systems, artificial intelligence, robotics, telecommunications, innovation management and design theory, cybersecurity, digital twins, design, spatial planning, and sustainable mobility. They are designed to pool expertise and resources to reach the critical mass needed for productive research, to share risks, and to develop a systemic vision that goes beyond the rail sector. A chair also offers the opportunity to deepen understanding of rail-related issues and to enhance the Group's appeal to students and future graduates. The most recent one is the "Artificial Intelligence and Optimization for Mobility" chair, created in 2024 with École Polytechnique, which has ambitious research objectives in the field of technology hybridization such as AI and operations research, decision sciences, and others.

**David De Almeida,**
Research Director,
DTIPG SNCF

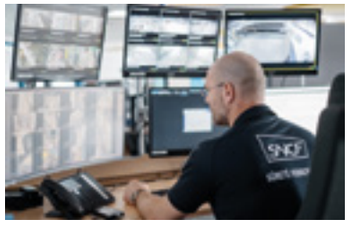
"Setting up a new chair is a serious commitment that demands human and financial investments over several years. It requires knowing our academic partners well – being aware of their research capabilities and their knowledge of the issues we are dealing with – and knowing our industrial partners so that we can all safeguard our respective interests regarding competition and image. Trust is established in advance through the hosting of CIFRE doctoral students and collaboration in national or European projects."

Inauguration of the Artificial Intelligence chair created jointly by the SNCF Group and École Polytechnique: Jean-Paul Cottet, Director of the Fondation de l'École Polytechnique, Laura Chaubard, Director General of the École Polytechnique, and Jean-Pierre Farandou, Chairman and CEO of the SNCF Group.

## Augmented video surveillance for rail security

The law of 19 May 2023 authorized for the first time the Rail Security department to experiment with the use of algorithmic processing to analyze video surveillance footage.
Objectives: improve security at high-risk events (sports, cultural, etc.). Four use cases were tested: presence of abandoned objects, presence of an individual in a restricted or sensitive area, excessive crowd density, and crowd movement. The trials began in 2024 during the Paris Olympics and continued until 31 March 2025, as provided for by the law.

Eight video operators at SNCF were trained in the processing of alerts generated by the Cityvision software program, which had been selected by the Ministry of the Interior. Their attention was drawn in particular to data protection and ethical issues in data processing.
By using this application, they were able to analyze footage supplied simultaneously by up to 300 cameras in eleven train stations in the Paris region. Results in terms of intrusion detection and abnormal crowd density were particularly good.



After verification by an operator, the generated alerts led to concrete action being taken, demonstrating the operational value of these technologies.

# The transformative power of AI

Artificial intelligence, a pervasive and transformative technology, has for years been shaping all activities in the SNCF Group—from railway operations and customer relations to digital and support functions. A true catalyst for innovation, AI can relieve employees of repetitive tasks, allowing them to focus on higher-value activities. It is a means of improving quality, economic efficiency, and industrial performance, particularly in the area of energy optimization. In maintenance, predicting potential breakdowns helps avoid costly immobilizations, possible financial penalties (delays or train cancellations), while increasing the overall reliability of the rail system. Each project is rolled out with close attention paid to technical and cybersecurity aspects, as seen with the SNCF GPT platform launched in 2023. Now available to 100,000 employees during its trial phase, it offers secure access to the capabilities of generative AI.

## Multilingualism on Transilien SNCF Voyageurs channels

In April 2024, a translation engine for real-time passenger information was integrated into the digital channels of the traveler information system in stations and on trains. This was followed by an instant translation tool for audio announcements in station. Both tools, which are powered by generative AI, proved their efficiency during the 2024 Paris Olympics by providing information and guiding visitors in English and Spanish.

## Detecting telecom defects

Altametris, a subsidiary of SNCF Réseau, creates, operates, and develops digital systems for all infrastructure to improve safety and performance. For telecom infrastructure, Altametris develops and trains AI algorithms capable of automatically detecting defects on components such as shelters, telephones, and cable ducts. These algorithms use 2D and 3D data collected from network monitoring, particularly using LiDAR, a technology that generates point clouds. To optimize algorithm performance and significantly increase computation speeds, Altametris first turns the data into ortho-LiDAR images by projecting 3D point cloud data onto a 2D plane. This method allows rapid and highly accurate object classification within the point clouds. Training results in 2024 have been promising, with scores of 94% for reliability and 99% for detection accuracy.

## Artificial vision onboard trains

Using images and videos, SNCF Voyageurs' Rolling Stock Engineering is developing artificial vision systems that analyze the environment onboard trains. A processor connected to the train's IT network processes feeds from security cameras in real time. Trigger events are selected for each use case, e.g., doors opening/closing or train departures. Among the most advanced use cases in 2024 were passenger density measurement and detection of people still onboard at the end of service. A trial of video-based passenger counting is underway on a TER in the Auvergne-Rhône-Alpes region. Other applications include security (detecting misconduct, abandoned baggage), predictive maintenance (identifying equipment failures or track wear), safety (monitoring tracks, level crossings, door access, and trackside signals).

## IAMADOC
### Querying maintenance documents

A RAG (Retrieval Augmented Generation) model, which combines semantic database searches with generative AI, enables querying of maintenance documents. The aim is to quickly obtain reliable, summarized answers constructed from multiple and very large reference texts. Early trials show a potentially significant time savings (a 90% reduction in search time) when navigating through more than 10,000 documents. The accuracy of the answers remains variable and requires validation against the sources before use.

## VIESTA
### Intelligent video for safety

Launched in 2024 with Thales/Hitachi and XXII, this project involves experiments with intelligent onboard video for security purposes (real-time event detection for quicker responses and an increased sense of security) and operations (passenger counting). The objectives: ethical, anonymized data processing and development of frugal algorithms that consume less energy and are compatible with the limited computing power available onboard a train.

## An interactive kiosk to welcome and guide travelers at stations

Since July 2024, an interactive kiosk has been tested at Gare du Nord in Paris. Based on generative AI, a 3D virtual avatar speaking six languages interacts vocally with travelers in real time (routes, train schedules, directions, etc.). An interactive screen displays additional information. This proof-of-concept solution meets a growing demand for personalized and augmented services, access to information, and traveler assistance.

It was developed in partnership with a consortium of start-ups led by the development agency Alp Valley. It is powered by Llama 3.3, Meta's open-source language model. This new interaction method is also available on mobile devices through a WhatsApp channel, accessible by scanning the QR code displayed on the kiosk or through the Gare du Nord's WhatsApp number.

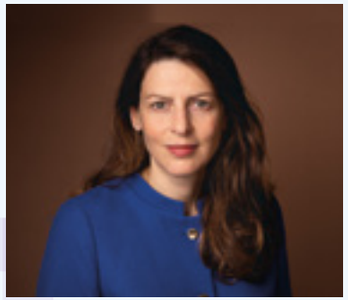
**Julien Nicolas,**
Chief Digital Officer, AI Group and e.SNCF Solutions, SNCF Group

"The SNCF Group has a major objective: to double the modal share of trains. Innovation, and therefore AI, are means to achieving this goal. AI is not new to SNCF, but since the advent of generative AI and the easier accessibility it offers, we are of course stepping up our efforts to ensure it benefits everyone and increases the performance and productivity of the Group's activities."

Onboard intelligent video should enable faster responses.

# The transformative power of AI

## A word from **Laura Chaubard**, Director General, École Polytechnique



**In 2024, the SNCF Group and École Polytechnique partnered in the creation of a teaching and research chair that would focus on artificial intelligence and the optimization of mobility. Beyond the initial projects already underway that combine AI and operational research, how are the engineering students at École Polytechnique engaging with the challenges of sustainable mobility?**

"We are living in a time of intense scientific and technological ferment. There is, of course, artificial intelligence, but scientific breakthroughs are also multiplying in fields like healthcare, physics, and energy. Many of these advances have disruptive potential as significant as, or even more rapid than, AI. I am thinking in particular of quantum technologies and nuclear fusion. In the years to come, France and Europe's positioning and sovereignty will depend on mastering these technologies.

Our engineering students are especially concerned with the challenges of the environmental transition, and our primary mission is to provide them with a systemic understanding of it. When we talk about transport, we are also talking about infrastructure, manufacturing, and energy as well as political, geopolitical, and demographic issues. Embracing this complexity can be dizzying, but understanding it is a key skill our students must acquire. They are eager to know where they can truly have an impact, and they fully grasp how critical modal shift to rail is for the environmental transition.
Thanks to the creation of our joint chair, teams are working closely together to invent the artificial intelligences of tomorrow that will be tailored for the industrial and critical applications that SNCF needs to improve performance and productivity. Learning-based technologies cover a much broader spectrum than the widely discussed tools like ChatGPT. When it comes to technologies that will bring the most value to the economy, the race has not really begun yet. We have both the talent and the partners to lead it, in France and in Europe.
By relying on SNCF's expertise, use cases, and data, we can develop AI technologies and models that are far more sustainable, both ecologically and economically, as well as being much more secure. Artificial intelligence will bring technological breakthroughs to optimize the complex systems inherent in rail transport. For example, it will be possible to increase traffic by creating 'safety bubbles' around each train in operation through reliable predictions. Breakdowns will be anticipated to ensure the availability of rolling stock and facilities. AI will also enable better information sharing to predict delays and trigger the right responses to minimize their impact on traffic. Our researchers are very enthusiastic about developing these AIs that will truly serve the rail sector."

"When it comes to technologies that will bring the most value to the economy, the race has not really begun yet. We have both the talent and the partners to lead it, in France and in Europe."





## Birth of TechLab Composites

Mastering the design, manufacturing, and maintenance of parts made from lightweight, high-strength materials is essential to developing new ranges of rolling stock that are lighter and therefore more energy efficient. The goal is to reduce train mass and improve the mass-to-mechanical-strength of components. A further ambition is to continue offering greater onboard comfort, whether through additional equipment or features, and to increase passenger capacity and train autonomy, particularly by equipping them with batteries.

A maintenance operation in the Polyester Workshop at the Rouen Technicentre.

The purpose of TechLab Composites, a unit established in 2024 at the Railway Testing Agency in collaboration with the DTIPG, is to promote the use of composite materials in research and development projects. In terms of manufacturing, one of the lab's goals is to assist the Rouen Quatre-Mares Technicentre in producing components in a single operation using a process called "infusion." This process involves impregnating composite materials with thermosetting resin under vacuum, which allows mass production of large parts.
An initial step in the use of the process has has been achieved with the successful manufacturing of side hatches for the double-decker TGV along with the transfer of skills to the Technicentre. The TechLab will also explore new technologies such as bio-based composites and pre-impregnated materials used in the aerospace industry. Greater expertise in the manufacture of composite structural parts is expected.

Analysis of data from trains in commercial service helps confirm that maintenance tasks have been properly performed.

## Rapid progress in predictive maintenance for rolling stock

Predictive maintenance algorithms have been developed by the Rolling Stock Engineering department of SNCF Voyageurs. These are regularly used to improve the reliability of rolling stock and drastically reduce breakdowns, all while lowering maintenance costs. Analysis of data transmitted by trains in commercial service confirms that maintenance operations have been properly performed. Teams are also alerted as soon as a system shows signs of potential failure.

The algorithms are based on an unsupervised machine learning model. This model performs statistical analyses by clustering systems according to types of behavior, observed maintenance non-conformities, and failures of systems across the same fleet to assess their operational viability. The technology has already been deployed for multiple types of equipment (NAT and Regio2N), and it is currently being implemented for the new RER NG trains. It proved its reliability during the 2024 Paris Olympics by warning of failures in key systems such as passenger access and air conditioning.

# Surfo

## SURveillance by Fiber Optics

Surfo is a cost-effective technology that uses the 28,000 km of optical fibers in the rail network to monitor the rail platform and its surroundings in real time. The system can support multiple use cases simultaneously: broken rail detection, subsoil monitoring, train tracking, rockfalls, and track obstructions, among others. Housed in an existing telecom room and connected to already installed optical fiber, its costs are very low, including for maintenance.

Surfo has two components: the transformation of optical fiber into a vibration sensor using a physical phenomenon by which interactions between light and matter cause changes in the light traveling through the fiber due to vibrations; and the development of intelligent algorithms using signal processing and AI to translate vibration characteristics into information useful to maintenance teams and the rail operator.

Thanks to fiber optics, Surfo can detect surrounding vibrations, track the location of trains in real time, detect possible intrusions, and monitor the condition of rails and tracks.

In 2024, four pre-industrial Surfo units were deployed on the French rail network to provide real data for automatic detection models for rail events. At the same time, Surfo is being operationally implemented for broken rail detection on the pilot Cannes–Nice section of the High Performance Marseille–Vintimille (HPMV) project.

**Partners**
Télécom Paris, Université Gustave Eiffel, Institut de Physique du Globe de Paris, Université de Grenoble, Université Côte d'Azur, BRGM, Société des Grands Projets (SGP)


The robot PRIME equipped with its new vegetation control accessory.

## Prime puts robotics on the tracks

The multifunctional Prime inspection robot uses laser sensors to measure track profiles in open areas and tunnels and the wear on catenary contact wires. Powered by batteries and equipped with LiDAR and GNSS systems, Prime carries out pre-programmed tasks with an autonomy of up to about 12km. Successful initial tests were conducted in late 2024.
Prime is fully scalable, allowing more functions such as vegetation control to be added in the future. Developed with NRD and Trafikverket, Prime is one of a line of modular robots developed in the IAM4RAIL project of Europe's Rail.

# 3D Usine

## With its 3D factory, SNCF Group is aiming to lead the world in LiDAR data processing in the rail sector

The 3D Usine encompasses the entire value chain, from data acquisition with track-surveillance (EMI, ESV, WIMSV) or aerial vehicles (helicopters, drones) to the analysis, processing, and use of the data to supply precise infrastructure mapping to rail infrastructure managers.
The goal is to explore and develop innovative applications for maintenance and asset management.

Usine 3D relies on the development of algorithms for the detection of objects and defects in LiDAR-generated point clouds. Since 2023, several use cases have been industrialized, including clearance gauge analysis, catenary geometry, and ballast profiles and volumes. SNCF Réseau's 3D team is continuing to produce new applications to enhance network safety. Algorithms for automated detection of fences and retaining walls as well as vegetation clearance analysis based on catenary data are currently in development.

**Partners**
Usine 3D
Altametris, Eurailscout France, SNCF Réseau

# DAC

## Digital automatic coupling for freight wagons

The digitalization of coupling and decoupling operations for freight trains requires the development of a Digital Automatic Coupling (DAC) system to replace the current universal screw coupling system used across Europe. This digitalization involved designing a digital e-coupler, a task completed in 2024, to enable the digital connection of all the vehicles (power car and wagons) that make up a train. The DAC integrates onboard monitoring sensors that enable automated brake tests, automatic train composition detection, train integrity monitoring, and the sharing of operational and location data at the European level. Operational benefits of the DAC include less time needed to sort, prepare, and reconfigure trains; greater safety and less physical effort for workers; and more reliable exchanges of information. Technologies like ERTMS and DAC are catalysts for change that will ultimately allow longer and heavier trains to run in Europe while supplying real-time data on train composition and integrity.

**30 to 70%**

**more trains can be sorted in the same length of time with DAC at gravity-based sorting yards**

**Jérôme Ebrardt**
**Projects and Innovation Manager, Rail Logistics Europe**

"DAC is the major innovation project for rail freight. Led at the European level, its objective is to improve the efficiency and competitiveness of the sector through digitalization and automation of many production operations. A cost-benefit analysis is underway as part of the European DAC Delivery Program. Subject to CEF funding, the next step for the PIODAC consortium will be to initially launch about ten freight routes by 2027, including one in France with Rail Logistics Europe and Ermewa."

## Expanded collaboration between CNES and the SNCF Group

In November 2024, the SNCF Group and CNES (National Centre for Space Studies) signed a new framework agreement expanding cooperation initiated in 2016. The goal is to leverage space technologies to optimize rail transport, with a focus on three areas: observation of the Earth, connectivity, and localization. Satellite data will enable ultra-precise, continuous, real-time train localization and better infrastructure monitoring, thus helping to anticipate climate-related events such as landslides and wildfires near tracks. On the telecom side, space technology will complement terrestrial systems, providing optimized coverage even in so-called white zones. Working together, the two organizations are aiming to make space a key driver of rail performance and resilience, particularly with regard to climate change. This partnership is a new example of how space technologies can contribute to rail transport, a sector vital to the French economy.

# Rail in Europe

Europe's Rail (EU-Rail) projects are progressing steadily from phase to phase, and work on ERTMS is becoming more defined. These are key steps in building the European rail system of the future.

## EU-Rail Projects

### FP1-MOTIONAL *(MObility managemenT multImodal envirOnment aNd digitAl enabLers)*

The FP1-MOTIONAL project, in which the SNCF Group is participating, brings together operators, manufacturers, and academics to address issues of train traffic planning and operations as well as digital continuity. The first part of the project deals with cross-border coordination, planning tools, network capacity assessment, ERTMS Level 3 performance evaluation, coordination in major incident scenarios, automated traffic management, and end-to-end multimodal integration.
"In 2024, SNCF focused on short-term planning to optimize SNCF Réseau's simulator, which is used for last-minute train path requests, and on improving coordination during traffic regulation," explains Christelle Lérin, an SNCF coordinator. "The infrastructure manager also looked at simulations and tools that take into account the unpredictability of incidents to assess the performance of new systems."
In the second area explored in the project, there are four objectives:

- The creation of a secure cloud to centralize rail asset data and an offer of related services (analytics, forecasting, feedback, etc.)
- Development of digital twins (for bridges, train air conditioning systems, etc.), with compilation of observational data to support lifecycle monitoring
- Definition of a conceptual data model for interoperable data exchange
- Integration of digital continuity into engineering processes

"In 2024, concrete results concerned digital twins. We defined our needs for bridges and are now putting together our functional requirements," says Mahmoud Hassan, project coordinator for SNCF Réseau.

### FP2-R2DATO *(Rail to Digital automated up to autonomous train operation)*

With a budget of €160 million, FP2-R2DATO is the largest EU-Rail project. Coordinated by the SNCF Group with support from Hitachi Rail GTS, it defines the steps necessary to digitalize and automate rail operations, which include autonomous driving, virtual block and digital block systems, external signal reading, remote operation, and others. "Several preliminary tasks were completed in 2024," explains Cédric Gallais, project coordinator for the SNCF Group. "These included the third of five stages for specifying virtual blocks and mobile block sections as well as specifying testing, validation, and certification processes.
Also on the agenda was the identification of operational requirements for train localization (inertial navigation and GNSS, based on previous Loc4Rail and CLUG/CLUG 2.0 projects). Geolocation systems were also tested with the Laboratoire ERTMS France. Eight demonstrators are being developed to validate the integration of these solutions into the rail system in 2025 and 2026. A data factory project is also underway covering both legal and technical aspects."

## Exploratory Research

Three research projects in which the SNCF Group is participating were proposed in the EU-Rail call for projects in October 2023. Work in them has now begun.

- **Travelwise** is aimed at improving air-rail intermodality by coordinating traffic safely through the sharing of information between operators and collaborative decision-making in both normal and disrupted conditions. POCs are planned on rail connections between Roissy and Schiphol airports.

- **Symbiosis** seeks ways to include biodiversity at all stages of rail infrastructure projects with a collaborative, holistic approach that contributes to a European reference biodiversity database.

- **Rail4Cities** focuses on transforming railway stations into vibrant urban hubs that help drive the development of sustainable cities.

Deployment of ETCS Level 2 in the High Performance Marseille–Vintimille project and Stuttgart 21 in Germany.

## ETCS Level 2, harmonizing operational rules

The deployment of ETCS (European Train Control System) Level 2 facilitates the implementation of common operational rules while remaining adaptable to local procedures. Intended for train drivers and infrastructure staff on both sides of borders, these rules are to be applied in the event of incidents occurring on the rail network. A total of 80 procedures are currently being revised as part of an SNCF-DB agreement renewed in 2024. The aim is to simplify them, enhance safety, and improve corridor performance, all while ensuring compliance with the Technical Specifications for Interoperability (TSI). To validate these new rules, SNCF Réseau and DB InfraGO are relying on ETCS Level 2 functionalities implemented in the High Performance Marseille–Vintimille project and Stuttgart 21 in Germany. Initial results will be communicated in June 2025, before testing under real conditions begins.

### Estelle Masclet,

**Deputy Managing Director, System Operations, SNCF Réseau**

"Modernizing operations means looking not only at equipment and technological systems, but also at the rules that govern their use. The work on operational harmonization is a great example of this. Doing it on a European scale ensures more productive collaboration as well as a stronger impact on our own network."

### Eric Morand,

**Deputy Managing Director, Digitalization and Signaling, SNCF Réseau**

"The phased deployment of ERTMS through 2044 is being coordinated with European networks since the selected lines connect to eleven border crossings. The plan also includes equipping one high-speed line about every two years, coinciding with the decommissioning of existing signaling systems. Another major objective is to deploy FRMCS (Future Railway Mobile Communication System) across the entire network between 2032 and 2035."

### The French ERTMS plan was presented to the European Commission in December 2024

In view of available funding, the French plan for implementing ERTMS prioritizes installing ETCS on conventional rail lines in the North Sea–Mediterranean corridor, which represents a significant share of international multimodal traffic, as well as lines in the Mediterranean and Atlantic corridors.

# Make rail and public transport more appealing

OBJECTIVE

3

Demand for mobility has been rising sharply in recent years, with the French transport sector growing proportionally faster than the country's GDP. It nevertheless remains one of the most carbon-intensive sectors, making it absolutely essential to enhance the attractiveness of the cleanest public transport modes. Beyond the industrial challenges such as building a modernized, higher-capacity, and largely decarbonized rail system, there must be a real leap in how both passengers and freight customers perceive rail service. Whether it is in terms of service offerings or information, customers expect flexibility, robustness, and reliability.
To meet these expectations, the SNCF Group is reimagining mobility as a service, with an intermodal offer that drives growth and contributes to achieving regional development goals. From SERM to light transport systems and solutions tailored to rural areas, mobility in the regions is being entirely redefined thanks to numerous research and innovation programs like the full-scale experiments that contributed to the smooth operation of mass transport during the 2024 Paris Olympics.

Tanguy Cotte-Martinon
Secretary General, SNCF Voyageurs

**"Being a leader in the most decarbonized transport mode is both an opportunity and a weighty responsibility, whether it is encouraging more people to choose trains, which currently account for only one in ten trips, or reducing our carbon footprint. Offering new, large-capacity rolling stock with a high level of service and optimal environmental performance is a powerful means of expanding rail service across the country. On the other hand, where demand is more dispersed, we are designing new, lighter transport options."**





THEME

# Customer experience

The public transport modes operated by the SNCF Group are evolving to better meet the imperatives of decarbonization, increased traffic flows, and demands for safety and reliability. Their inherent qualities will be significantly amplified as rail becomes the backbone of a fully integrated multimodal transport system, offering smooth and seamless door-to-door journeys. There are many areas for innovation to integrate and develop mobility and traffic frequency as well as to optimize and make these journeys safer: for example, providing predictive information, offering more intuitive signage, adapting flow management in real time, better understanding crowd levels on board and in stations to guide infrastructure improvements, ensuring greater punctuality, safety, and accessibility. In this regard, the 2024 Paris Olympics served as a showcase for various ongoing developments. This experience will prove a lasting memory, especially for daily users. While digitalization, data science, and artificial intelligence are the foundation of these transformations, recent advances reflect a broader picture: that mobility is being reimagined as a service.

## New-generation TGVs

A more ecological high-speed train and an enhanced passenger experience

A total of 115 trainsets will go into service over the next ten years. This new generation of TGVs has been designed for greater capacity, modularity, and a reduced ecological footprint, with 20% less energy consumption, 97% recyclable components, and the lowest carbon footprint in its category. Testing is underway on the French rail network for a wide range of scenarios: double trainset operations, degraded mode, extreme weather conditions, etc.

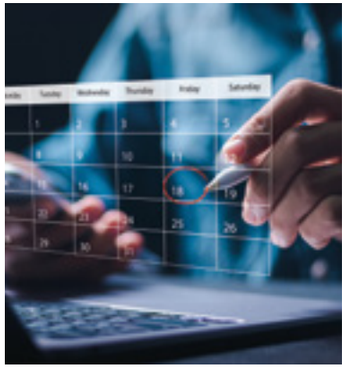
The new TGVs will carry up to 740 passengers without reducing space for each traveler. Thanks to its modular design, it can be configured with seven, eight, or nine cars to match passenger demand. Its interior spaces are fully reconfigurable: 1st or 2nd class seating only, with or without a bar car, more or less seating, etc. Accessibility has been entirely redesigned in consultation with organizations for people with reduced mobility to provide complete autonomy on board. One unique feature: energy storage units will be built into the innovative structures that will serve as interfaces between the end cars and power cars. These energy storage systems will maintain onboard comfort (air conditioning, heating, lighting, toilets, etc.) in case of catenary failure, a first for high-speed trains.

The interior of a new-generation TGV coach.

**Partners**
ADEME, Alstom, Nendo

**- 30%**
**lower maintenance costs**

# Improving reliability of freight train deliveries



Since 2024, Hexafret has been working on a system that cross-references multiple data sources to improve the reliability of delivery dates communicated to its customers no later than 24 hours in advance for all domestic and international freight traffic. This forecasted delivery date, known as the Estimated Arrival Date, is available through B2B services, including the customer portal. It enhances production and flow management and improves overall service quality.

The DPA is based on two main sources: the theoretical transport plan of Hexafret and its partners and predictive data generated by AI using machine learning methods. The AI analyzes route history by origin–destination pairs using a tool developed by e.SNCF Solutions, which is fed with wagon geolocation data. To ensure the accuracy and reliability of the system's forecasts, estimated DPAs and actual arrival times are continuously monitored.

# TVP NG

## Safer track crossings for passengers in stations

Improving the safety of public track crossings in stations that lack bridges or underpasses requires a better understanding of passenger behavior. To apply behavioral, cognitive, and biomechanical sciences (eye movements, walking patterns, reaction times, etc.), a mixed-reality test platform was developed at the Arenberg Creative Mines site near Valenciennes. This physical platform replicates part of a station at full scale, including a platform. The virtual reality system is synchronized with this physical environment to present various scenarios (weather conditions, day/night, train movements, etc.) to participants wearing VR headsets. Multiple sensors collect behavioral, eye-tracking, and physiological data and analyze the walking of participants. Supported by a benchmark of the most effective technological systems, the results of these tests, conducted since April 2024, will be used to select the best solutions. These will be prototyped in 2026, leading to a new generation of track crossings that enhance travelers' safety.

The virtual reality platform is synchronized with a physical environment, and various scenarios are proposed to test subjects equipped with headsets.

**Partners**
IRT Railenium, SCLE, LAMIH/ Université Polytechnic Hauts-de-France (UPHF)

LEARN MORE

The data collected by the LiDAR sensors is processed by a human-machine interface capable of recognizing wheelchairs or spotting abandoned baggage, for example.

# Flow management in stations using LiDAR sensors

21 LiDAR sensors have been installed on the two levels of the Paris Charles de Gaulle Terminal 2 train station. They collect passenger flow data over the 3,600-m² area jointly owned and managed by SNCF Gares & Connexions and ADP. Objectives: To understand and improve the interchange hub between the train station and the airport in order to provide smooth transitions between the two trasnport modes; to support station staff and service providers, especially those assisting passengers with reduced mobility; and to supply accurate data for future development projects.

The LiDAR sensors transmit real-time data, allowing analysis of passenger movements while preserving anonymity. These data are shared through a secure joint platform. The human-machine interface processing this data is able to count passengers, recognize wheelchairs to better anticipate assistance needs, detect congestion points and formation of queues, and spot carts left on platforms and abandoned baggage. The collected information is also valuable to understand how people use the station space, shops, and services and to analyze foot traffic, usage of ticketing machines, and so on. A POC was launched in May 2024, with about 10 employees from SNCF Gares & Connexions and the same number from ADP trained to use the tool.

**Partners**
Groupe ADP, Outsight

## Ma Gare and Ma Gare+: from experience to loyalty

A new version of the Ma Gare app was released in 2024. Following a major revamping in terms of usability, functionality, and technology, it has been refocused on passenger information, showing real-time departure/arrival boards streamed directly to passengers' smartphones. Now available in six languages, it includes a wallet system to help users easily find services, events, and commercial offerings in stations. The app also provides access to the Ma Gare+ loyalty program. Originally tested in six stations in May 2024, Ma Gare+ had been extended to over 150 stations by the end of the year, with the aim of promoting retail commerce and making waiting times more pleasant.

## A passenger flow management observatory

AREP has launched an observatory of solutions existing around the world to better manage passenger flows in train stations. The key challenge is to anticipate crowd movements, a growing risk due to increasing passenger numbers and the constraints on expanding spaces in stations. Its objective is to better understand the risks in order to propose solutions, to develop a reliable method for assessing station saturation, and to encourage contributions from rail industry stakeholders.

The observatory's first report defines six criteria for studying crowd movements over time: frequency, number of fatalities, injuries, cause, nature of the event, and location. Several solutions have been identified to optimize station capacity and travel times. These include delaying certain train arrivals to avoid flows in opposite directions, separating flows in underground passageways, and installing one-way doors on platforms. To prioritize these solutions, the observatory recommends combining performance indicators (travel time, density, flow distribution) and spatial analysis. Rail operators have also been asked to contribute data and test the proposed solutions.

**Partners**
École des Ponts ParisTech, City Mobility Transport Laboratory (LVMT)

## Optiplace
### Smart passenger placement for OUIGO

Launched in June 2024, Optiplace is a passenger seating algorithm developed for OUIGO trains. Its objectives: optimize train occupancy, smooth getting on and off at intermediate stations, and better satisfy passenger preferences (e.g., seating groups together). Optiplace represents a big leap in performance for the operator. The previous system assigned seats as soon as bookings were made, making it more difficult to fill trains. The new algorithm calculates the optimal placement for all passengers and communicates seat assignments four days before departure. This optimizes seat allocation for each journey and satisfies the maximum number of passenger preferences. Initially developed as a proof of concept, Optiplace is now integrated with the OUIGO reservation system and has been introduced into SNCF's information systems.

**Partner**
Artelys

**4,100 trains**
**optimized from July to December 2024, including 700 trains fully booked and 11,000 seats freed up and reassigned to satisfy a maximum number of passenger requests**

Thanks to Optiplace, getting on and off a OUIGO is smoother.





## A word from **Sylvie Landriève,** Director, Forum Vies Mobiles

**How have mobility patterns evolved, and what are the main expectations of the French today?**

Trains, cars, and planes have democratized rapid travel. We thought we were saving time, but in fact, we were just going farther. At the same time, our daily activities and families have become more dispersed geographically. While in the mid-20th century, the French traveled an average of 5 km per day, today they travel 10 times more than that. In response to these trends, our studies show that French people have a strong desire to live closer to their daily activities, and when they do want to travel, to do so in a simple way.

**Despite the enthusiasm for trains, the modal share for cars has changed very little. How do you explain this fact?**

Ambitious policies have been implemented for decades supporting public transit, cycling, carpooling, and sustainable mobility, but the trend remains unchanged almost everywhere.
The problem is that we still think about everything mode by mode, region by region, with no real systemic approach. Urban public transport is expanding in the centers of large metropolitan areas, but in all other regions, cars are considered adequate. As a result, they are omnipresent there."

"Urban public transport is expanding in the centers of large metropolitan areas, but in all other regions, cars are considered adequate. As a result, they are omnipresent there."

Moreover, public policies focus too much on commuting between home and work when 75% of the kilometers traveled today are for other reasons.

**What means have you identified to make public transport more attractive?**

The services already exist. We simply need to organize and coordinate them better to make multimodal travel easier. Rail is efficient, attractive, and low-carbon—it has everything needed to serve as the mobility backbone. Around it, we should build a dense network of local services matched to actual demand. Regular schedules throughout the day are essential to reassure users, as is better integration of fares and information. Portions of the road network could also be dedicated to public transport as well as to walking and cycling. At the Forum Vies Mobiles, we're convinced we are at a turning point: Will we continue with a model dominated by private cars, even if they are electric, or will we invent a truly ecological and desired alternative system? In other words, are we changing the paradigm, or simply the engine? Obviously, we believe an alternative system is the one we need to promote. It is not only possible and more inclusive, but also less costly for society as a whole.

**Forum Vies Mobiles is the French think tank specializing in mobility. Its goal is to respond to the public's aspirations while moving away from the carbon-dependent mobility system.**

THEME

# Innovative Metropolitan Regional Express Services

The SNCF Group is assisting the Mobility Organizing Authorities in the development of their Metropolitan Regional Express Services (SERM) projects. Three areas of research and innovation are involved:

1. Studies and design support tools to propose the best mobility solutions for travelers that will also benefit the regions
2. Rail and services projects that improve travelers' daily lives
3. Multimodal concepts that position rail as the backbone of mobility systems.

## 1 Studies and design support tools

The developments are aimed at better understanding travelers' needs, assessing mobility at the regional level, and evaluating the benefits in terms of modal shift and/or customer retention.

### SERM CUSTOMER STUDY

Thanks to a study launched in spring 2024, the SNCF Group now has a shared knowledge base regarding the drivers of customer retention and the modal shift toward SERM services.
The study focused on the metropolitan areas of Strasbourg and Bordeaux, which are already involved in SERM projects, as well as those of Toulouse and Lyon. Its objective was to understand all the factors – human activities, everyday constraints, social perceptions, habits, and opinions of public transport offerings – that influence the choice of transport modes. This study was conducted with 2,400 individuals who use various modes of mobility to rank and measure the effectiveness of these factors.

### POIESIS

What would be the impact of a complete multimodal offering on behavior? The Poiesis project incorporates psychological, economic, and geographic factors to analyze the mobility choices made by travelers. It has several objectives: to objectively identify the behavioral drivers of modal shift; to analyze mobility patterns in the regions; and to predict how these patterns might evolve in the future. Simulation and decision-support tools are being developed to anticipate the effects of modal shift; to validate the adequacy of transport supply to mobility needs; and to calculate cost-benefit ratios with projections over three, six, and nine years. In this joint project, IRT System-X is developing the simulation tool. Université de Montpellier is analyzing psycho-economic parameters and choice factors. Université d'Avignon and Maplab are constructing mobility scenarios, geographic projections, and a tool for understanding regional mobility needs. École des Mines de Saint-Étienne is doing multi-criteria analyses to rank solutions and identify the key parameters for designing and adapting transport offerings.

The SERM customer study focused on the metropolitan areas of Strasbourg and Bordeaux, which are already involved in SERM projects, and on those of Toulouse and Lyon.

## 2 Rail and services projects

Rail and service projects that make travelers' daily lives easier. The "classic" rail mode can be improved by increasing service frequency and enhancing modularity, two essential aspects of the SERM systems of tomorrow.

### ADAPTATIVE

The aim of ADAPTATIVE is to respond to the growing number of passengers and the need for better flows in TER trains during peak hours to maximize onboard capacity. It also seeks to propose new services during off-peak periods (space for scooters or bicycles, micro-freight, pop-up retail/food services, etc.).
ADAPTATIVE relies on scalable interior spaces with new layouts (standing/sitting options, more compact seats) and the creation of quick-attachment systems. Starting in 2025, a dynamic and immersive train layout configurator will be developed to shorten design times and assist the regions in choosing innovative layouts. A full-scale living lab will allow prototypes to be tested and validated with both passengers and rail staff. After a single transformation at an industrial technicentre, the demonstrator trainset will be reconfigurable as needed during pauses in operations. Layouts and services will be offered à la carte to meet new demands expressed by the regions for their existing trains.

**Stéphane Chwalik,**
Group Coordinator, SERM Innovant, DTIPG SNCF

"We have three priorities: put the traveler at the center of our projects; take a 3-, 6-, and 9-year forward-looking approach; and imagine more cost-effective technologies. It is also a matter of creating a denser transport network that connects all types of mobility within the regions, notably with the future TELLi, DRAISY, and FLEXY trains as well as with express buses designed for SERM to facilitate connections between rural, peri-urban, and metropolitan areas."

### OPTIMA

The aim of OPTIMA is to simplify maintenance planning and capacity management in maintenance centers in the context of high demand for train availability.
This involves the development of applications with operations research algorithms in partnership with École Polytechnique, École des Ponts et Chaussées, and École des Mines de Saint-Étienne. The objectives are to align workloads with available capacity, prioritize maintenance tasks, streamline movements and workflows, and adapt planning in the event of disruptions to maximize the capacity of existing facilities.

## 3 Concepts that promote multimodality

New mobility solutions, an appealing transport offer, and dense multimodal coverage, even in the most sparsely populated areas, are all key to encouraging the use SERM services.

To create a dense transport network in the regions, the SNCF Group is working on the development of multimodal exchange hubs tailored to local needs similar to rural mobility stations *(see p. 60)* connected to train stations that have become hubs. These future hubs will be integrated into the ecosystem of new means of transport such as TELLi, DRAISY, FLEXY, and SERM Innovant express buses. This strategic concept will be developed further in 2025 with multimodal information projects.

### MOBIL'QUAI
a low-cost stop solution

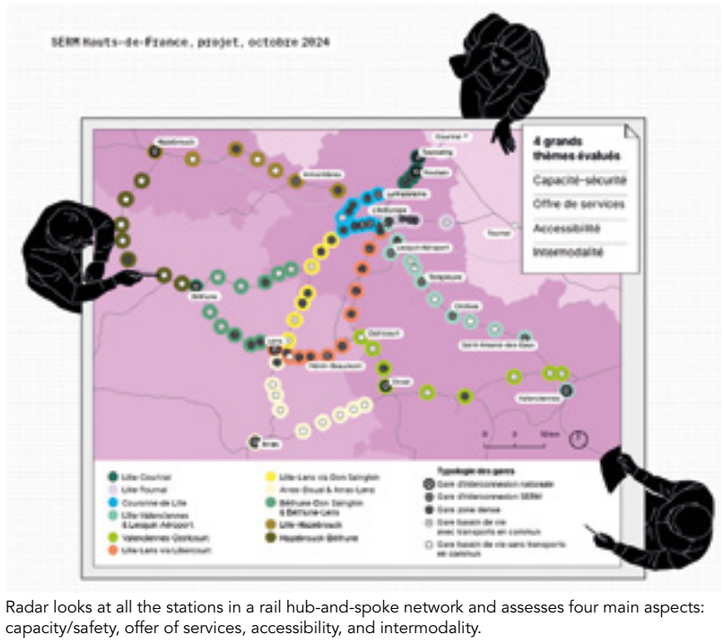
Developing denser rail service in the regions involves creating new stops near metropolitan areas, particularly on small local lines, to encourage connections to SERM services. The strong points of Mobil'Quai? A light, scalable, and reversible infrastructure with no need for excavation or concrete foundations, when the site allows it, and modular, off-site prefabrication. Potential integration of accessibility features and connected services (ticket machines, info screens), and the possibility of making them energy self-sufficient are under study. Mobil'Quai uses paving slabs made from recycled plastic and composite waste supplied by SNCF, which are recyclable multiple times. These patented slabs were developed by Purple Alternative Surface, a member of a consortium formed in 2024 by 574 Grand Est, along with SNCF Gares & Connexions, its subsidiary AREP, e.SNCF Solutions, the Department of Technologies, Innovation and Group Projects, and IRT Railenium.

This project is publicly funded in the France 2030 program managed by ADEME.

## Radar missions for SERM stations

AREP's Radar missions are intended to assist Mobility Organizing Authorities and other stakeholders in SERM projects in preparing for upgrades to train stations. Radar examines infrastructure, services, and intermodal equipment to determine their strengths and weaknesses.

Radar makes a comprehensive analysis of passenger flow capacity, service levels, and the intermodal offering. Launched in 2020, Radar has continued to evolve, with improvements made to automated data processing. It now interfaces with OpenStreetMap, the open-source mapping project that is aiming to become the world's largest freely accessible geographic database. Following implementation with SERM in Bordeaux (2020), Toulouse (2021), and Rouen (2023), Radar was used in 2024 for SERM projects in Hauts-de-France, Strasbourg, Mulhouse, and Sillon Lorrain in partnership with the Hauts-de-France and Grand Est regions.




Radar looks at all the stations in a rail hub-and-spoke network and assesses four main aspects: capacity/safety, offer of services, accessibility, and intermodality.

## Platforms of the future, an AREP initiative

In 2024, AREP carried out a study for the future Provence–Côte d'Azur high-speed line in which it assessed a representative range of platform types and layouts using the 4E framework (ecological, efficient, economical, elegant) and EMC2B principles (energy, materials, climate, carbon, biodiversity) developed by SNCF Gares & Connexions and AREP. The objectives: identify the most efficient platform models in terms of cost-effectiveness and sustainability; standardize components to simplify construction or improve existing facilities. Among these models are the lightweight, modular platforms like Mobil'Quai *(see opposite)*.

THEME

# Light public transport

The SNCF Group in collaboration with regional authorities and industrial and academic partners is developing complementary transport solutions to meet the mobility needs of rural and peri-urban areas. These innovations share a common goal: To reduce infrastructure and operational costs so that the frequency of train services can be increased, thus offering a viable and appealing alternative to private cars.

The TELLi, DRAISY, and FLEXY concepts are a response to this goal. These light and ultra-light trains are more economical and will thus enable the development of a denser transport network to extend SERM services beyond cities and greater metropolitan areas. SNCF also has the aim of supporting intermunicipal and regional communities with on-demand and itinerant transport to improve access to public services and local commerce.

**David Borot,**
**Director of Emerging Mobility Innovation Programs, SNCF DTIPG**

"After thorough diagnostics of local needs and multiple experiments with residents and local leaders, we've managed to transform some concepts into scalable, industrialized services. These new services complement traditional rail and satisfy needs unserved by public transport today."

## TELLi

The innovative light train TELLi is designed for small regional lines connected to the main rail network. This project is based on a systemic approach encompassing rolling stock, infrastructure, and operations with the objective of controlling overall costs to allow higher frequencies.

Compatible with other types of trains on the network, TELLi will have digitalized systems for signaling and track monitoring. It will be able to run on electrified lines at speeds up to 120 km/h as well as on non-electrified lines using batteries, with a range of 200 km. It will have a capacity of 150 passengers, including 74 seated, and be accessible to persons with reduced mobility. Its modular interior will allow the transport of bikes and micro-freight. To test its future innovations, a lab train went into service in June 2024 on the Limoges hub-and-spoke network with support from the Nouvelle-Aquitaine region. The commercial launch is planned for 2030.

**Partners**
Alstom, CAF, Ektacom, Ferrocampus, Cerema, Capgemini, IRT Railenium, Texelis, Hitachi, Wabtec, Nouvelle-Aquitaine and Occitanie regions

*Yellow Window / CAF*

VIDEO

*Design Lohr – Haiku Design*

## DRAISY

The DRAISY project's aim is to revitalize underused lines and facilitate the reopening of closed ones by drastically reducing infrastructure, operation, and maintenance costs, especially for small lines, using innovative, low-cost solutions for all components: rolling stock, infrastructure, operations, and regulation.

Compatible with occasional freight train traffic, the light train DAISY will have a capacity of 80 passengers, 30 seated, and be PRM/UFR accessible. Interior modularity will allow transport of bikes and micro-freight. It will have a top speed of 100 km/h, with a range under battery power of 100 km, which can be extended with a fast-recharging system at equipped stations. The new DRAISY design was unveiled in September 2024 at the Congrès des Régions de France. Commercial launch is slated for 2028.

**Partners**
Lohr Industrie, GCK Batteries, Stations-e, IRT Railenium, Grand Est and Occitanie regions

VIDEO

## FLEXY

Based on a systemic approach to reducing overall rail transport costs, FLEXY is a rail-road shuttle system designed to give a second life to rural and peri-urban lines that are no longer served.

It uses CARFLEX shuttles equipped with dual-function wheels for rail and road. FLEXY makes most of the journey by rail, but an innovative transition platform enables the shuttles to run on roads as well to connect towns to stations on the main rail network. FLEXY seats 14 passengers and is PRM/UFR accessible. These shuttles will travel at a minimum speed of 70 km/h on tracks and 90 km/h on roads, with a range of 200 km running on batteries. The FLEXY project received public funding in November 2024 in the France 2030 investment plan.
FLEXY will go into commercial service in 2028.

**Partners**
Milla Group, Michelin, IRT Railenium, Bretagne and Bourgogne-Franche-Comté regions

These 3 projects are publicly funded in the France 2030 program managed by ADEME.

## MASIPRO
### autonomous mobility in dedicated lanes

The purpose of the MASIPRO project is to lead the future deployment of an autonomous road-based public transport system with high levels of safety and service on dedicated lanes (e.g., disused railway tracks, bus lanes, greenways).

MASIPRO will use the Open Innovation Platform for Autonomous Mobility (PIOMA), which connects Carquefou to the entries to Nantes. By late 2025, the platform will be extended to 4 km. PIOMA includes a private 4G and 5G telecom network in partnership with Ericsson; a prototype of a next-generation passenger station designed with AREP; passing zones built on single-track routes; two intelligent, connected intersections. During an 11-month trial period starting in 2027, residents of Nantes and Carquefou will be able to board several types of driverless electric vehicles (Level 4 autonomy) to travel to residential areas and public facilities. These services will also connect to two public transport lines in Nantes. MASIPRO will offer a collective, inclusive, and efficient alternative to private cars in rural and peri-urban areas with limited public transport service.

**Partners**
Renault Group, EasyMile, Keolis, Beti, IRT Railenium, Vedecom

The project is publicly funded in the France 2030 plan managed by Bpifrance.

## Supporting mobility on low-density regions

The SNCF Group is developing a range of services to improve access to trains, encourage the use of alternative means of transport to private cars, promote a sense of community, and combat the social isolation of people without personal transport. Rural Mobility Stations have been tested since April 2024 in the Landivisiau region of Brittany. These stations offer multiple shared and soft mobility options at a single location (e.g., carpooling, hitchhiking, electric bicycles and minicars along with multimodal information systems). They have modern, eco-designed furniture and are energy self-sufficient.
In November 2024, the project won the regional innovation award in the "decarbonized mobility" category at the Salon des Maires et des Collectivités Locales, highlighting their role in providing access to future SERM services in rural areas. Actimob has been trialed in this same region since September 2024.
A response to the disappearance of public services and retail commerce in rural areas, Actimob brings them to remote communities in the Landivisiau area in a specially equipped vehicle. JYVAIS, a rural, door-to-door transport service, was trialed in the Seine-et-Marne, around the towns of Meaux and Ourcq, from May to October 2024. It enjoyed great success among some 8,000 users who took advantage of it to get to public services, shops, local events, and the train stations in this region, which has more than four times the area of Paris. Seventy-two percent of passengers used it to take the train.

VIDEO

*JYVAIS*, a door-to-door transport service, won the AMI "Territoires de nouvelles mobilités rurales" prize awarded by France Mobilités/ADEME.



THEME

# Mass transit, the legacy of the Paris 2024 Olympics Games

When it comes to daily transport, the Paris 2024 Olympic and Paralympic Games served as an exceptional innovation lab for the SNCF Group, particularly for the collection and use of passenger data. Given the anticipated increase in travelers, flow management was one of the most closely scrutinized aspects. How could the growing number of passengers be managed safely? And how could reliable information be provided to help everyone better manage their journeys? Tools like Crowd Monitoring, FouloJO, and CARTOJOP enabled the operational teams to anticipate passenger flows and ensure smooth movements through stations. With "Affluence à bord" (Onboard Crowding), SNCF Voyageurs is now positioned as a global pioneerd in flow management optimization, and AI has become the means of delivering passenger information in multiple languages.
Another important issue was accessibility to public transport. Through close collaboration with organizations that support travelers with disabilities, a big leap was made. Technological innovations such as Acceo, a tool for communicating with the deaf and hard of hearing, and services with the development accessible pathways specifically for persons with reduced mobility (PRMs) were tested successfully and are now part of the legacy of the Games. The Paris 2024 Olympics were also an opportunity for the Paris region to revive its long tradition as a trailblazer in mobility, as it was in the days of the first metros and RER, or more recently with the arrival of self-service bikes and cars.

## Alain Ribat,
**Director of Transilien, SNCF Voyageurs**

"The success of the Paris Games didn't happen by chance. It was the result of long and meticulous preparation and exceptional resources deployed with Île-de-France Mobilités and public authorities. Flow management, operations, supervision, passenger information, accessibility... the Games were a testing ground for many innovations —technological and other kinds as well—that now benefit both daily commuters and the many tourists visiting the region."

## NExTEO

Once deployed first on Line E of the Paris region network, then on Lines B and D, the signaling and traffic control system NExTEO will increase train frequency and punctuality as well as facilitate management of disruptions.
In September 2024, a test campaign was carried out on Line E in preparation for NExTEO's deployment. The system will be managed from a single command center in Pantin, which handles the east-west traffic. A second control center will be built in Saint-Denis for Lines B and D.

NExTEO digitalizes blocks (the intervals between trains) to assist in the supervision and driving (automated acceleration and braking). This automation is made possible by a ground-train system of the Communications-Based Train Control type adapted for an open rail system. With NExTEO, blocks become mobile, virtual, and adaptable. By adjusting in real-time to traffic conditions and reducing the interval between trains, they increase capacity without compromising safety.

**Partners**
The French state, Paris Region, Île-de-France Mobilités, Siemens/Eviden (for RER E), RATP, and Alstom Transport (for RER B and D)

## Crowding in stations

### Crowd Monitoring (real-time counting) and FouloJOP (flow visualization), two tools that assisted the operational staff during the Paris 2024 Olympics

Between June and October 2024, the Paris region stations Pont du Garigliano and Vaires-Torcy were equipped with Crowd Monitoring systems, as were the two stations at Stade de France, where testing will continue until October 2025. These four stations saw their passenger traffic surge by up to 300% during the Games. Each of their entrances was outfitted with stereoscopic sensors to count passenger flows in real time and to define alert thresholds to better manage crowding. Reliable data was provided to operational teams and shared with authorities every 30 minutes.

FouloJOP, a data analysis and sharing platform, was used to cross-reference real-time crowd counts with forecasted crowd data from CARTOJOP (see below). This made it possible to adjust flow management and operations at the four stations. Examples of these adaptations include redeployment of staff, "stop-and-go" passenger flow control, adjustment of the number of additional staff, implementation of one-way traffic patterns, ramps, or dedicated gates, and adjustments to transport plans.

**92%**
**customer satisfaction rate***

*Ipsos survey of 1,000 passengers in 2024.

## Crowding onboard

Screens on station platforms in the Paris region now display the crowding level in each train car in real time, allowing passengers to position themselves on the platform at less crowded cars, thus improving comfort and smoothing flows in mass transit operations. This innovation was a big plus during the Paris 2024 Olympics that now benefits commuters every day. It is a first in Europe on a large scale.

The system developed by Transilien SNCF Voyageurs uses infrared sensors installed at the doors of NAT, Regio2N, and RER NG trains to measure passenger flows. For trains without sensors, platform-mounted cameras scan passengers, and the images are converted instantly by AI into crowding levels. These data are exploited in real time by being fed to screens in stations and to digital media. More than 2,000 screens in 250 stations display crowding levels for each car. Since 2024, a new AI algorithm has been added that takes into account passenger behavior patterns inside train cars and compares them with historical boarding and deboarding data for each station. This ensures that the information displayed is as close to the reality as possible.

**Partner**
Affluences (AI for platform-mounted cameras)

## CARTOJOP

### Know and anticipate passenger flows during the Paris 2024 Olympics

Developed by Transilien in 2022 and enhanced up to the Paris 2024 Olympics, CARTOJOP is a data visualization tool designed to aggregate and visualize passenger flows estimated by Île-de-France Mobilités, the transport plans and calendar of Olympic events. Forecasts were regularly updated to ensure accurate estimates and an adequate match between transport capacity and demand as well as to improve transport plans and flow management in stations.

CARTOJOP provided a full overview by train line, station, and Olympic event. It had as many as 300 active users per month, including site and platform managers (for flow management in stations), the staffs of Transilien Operations Centers (to adjust transport plans), the Paris 2024 Command Center (PC JOP), and crisis rooms (for the coordination crisis management). CARTOJOP provided consistent and unified information for staff briefings, deployment of additional personnel for crowd management in stations, and the information app for staff (Infolympic).

**Partner**
Île-de-France Mobilités

CARTOJOP was also used by staff coordinating crisis management.


## Projected floor signage at Paris-Nord

A new projected floor signage system was successfully tested at the Paris-Nord train station during the Olympics. Designed to help passengers navigate during big events or complex situations that produce dense crowds (an RER service outage, for example), this system complements existing information systems. LED projectors managed from the station operations center display floor signage based on various types of visuals that can be easily adapted to real-time flow and service conditions. To improve visibility at mainline departures, a LED screen more than 7 meters wide was added to the system.

**Partners**
SITCF, Light Pub

## Key Innovation and Research figures in 2024

**35**
patents filed during the year

**11,000**
sensors installed in 700 stations

**13%**
the share of renewable energies in the energy consumption of the SNCF Group, up 14% from 2023

**1,023**
active patents

**53**
doctoral students

**604**
scientific and technical experts are the driving force of research and innovation in the six clusters of the Synapses Network: Energy, Sustainable Development, System Safety, Maintenance, Resource Optimization and Operations, and Mobility Services & Experiences

The new-generation TGV reduces energy consumption by

**20%**

and the carbon footprint by 37% compared with current trainsets

**10**
major academic partnerships

**60,000 km**
of successful commercial service performed by the hybrid Régiolis in the project's four partner regions

ERTMS on Paris-Lyon:
1st milestone.
Thanks to ERTMS, capacity on this line will increase by

**25%**
as of 2030

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