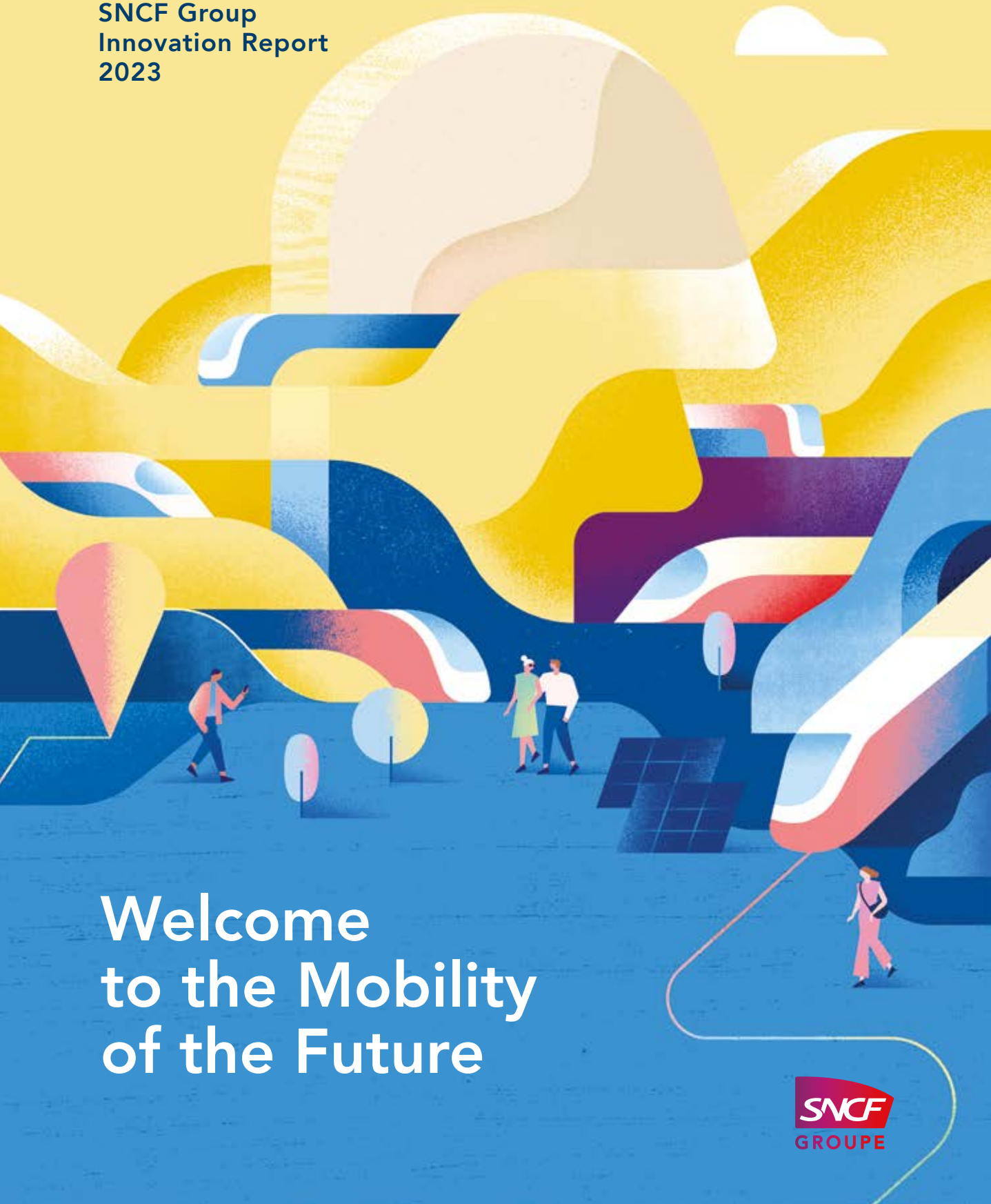
SNCF Group
Innovation Report
2023



Welcome to the Mobility of the Future

SNCF GROUPE

Contents

Make rail the backbone of inclusive, decarbonized mobility

Acting to promote an ever-advancing, inclusive, and sustainable society is the raison d'être of the SNCF Group. We are working to develop public transport solutions to offer everyone, everywhere, real alternatives to private cars. Rail transport must play a larger role as the backbone of mobility while supporting the ecological transition and contributing to the achievement of society's decarbonization goals. Our objective is to double the modal share of rail transport and offer an increasingly competitive service that meets the needs of the French population. Innovation and new technologies will play an important role in this effort to improve the performance of the rail system.

Recent initiatives of the Group illustrate our capacity for innovation:

- Creation of SNCF Renouvelables to increase our reliance on renewable energies, with the aim of complete electrical autonomy for the rail sector by 2050.
- Continued development of decarbonized trains, with the commercial operation of the first hybrid regional train (TER) by the end of 2023.
- Innovations to make metropolitan regional express services more attractive through multimodal solutions.
- Improved mobility in rural areas through new light trains with adapted capacities and hybrid rail-road shuttles, which of course are autonomous.

This Innovation Report 2023 also highlights the key role that collaboration with academic and industrial partners plays in the development of innovations. These technological advancements benefit from the support of the French government and the European Union provided through France 2030 and the European research program Europe's Rail. These projects demonstrate the industrial excellence of the rail sector and the sector's commitment to enhancing the efficiency and performance of the rail system, a commitment fully shared by the SNCF Group and everyone working with it.

Jean-Pierre Farandou,

SNCF Chairman and CEO

> As a result of energetic mobilization, particularly within CORIFER, the Research and Innovation Steering Council of the rail sector, a shared vision for the future has been formulated.

Strengthening synergies among the various stakeholders in the rail sector – industrial groups, SMEs, research institutes, and academics – to accelerate innovation within our industry was our priority in 2023. As a result of this energetic mobilization, particularly within CORIFER, the Research and Innovation Steering Council of the rail sector, a shared vision for the future has been formulated. For the period 2023-2030, a roadmap of priority innovation projects has been drawn up to guide the France 2030 investment programme. Structured around four major themes (industry and infrastructure of the future, inclusive mobility, zero-carbon trains, and smart trains), this roadmap reinforces our strategy, whose aim is to make rail transport the backbone of inclusive, decarbonized, resilient, and efficient mobility.

The Call for Expressions of Interest (CEI) launched by the French government in June 2023 will contribute to the ongoing modernization of the rail sector through the implementation of innovative projects. The number and diversity of projects submitted demonstrate the vitality of our industrial ecosystem. Whether their aim is to envision the services of tomorrow, to save and consume energy more efficiently, or to boost network performance, they all share the same goal: to accelerate the modernization of the rail system and, more than ever, to innovate for the benefit of our customers.

All of this is made possible with the support of public agencies implementing the France 2030 plan on behalf of the General Secretariat for Investment: the Agency for the Environment and Energy Management (ADEME), the National Research Agency, Bpifrance, and the Caisse des Dépôts. Innovation is also advancing at the European level in the framework of the Europe's Rail programme, in which we are participating. By involving stakeholders from across the European Union, we promote the creation of a unified, efficient, and high-capacity railway space capable of providing the decarbonized mobility desired by the French and all Europeans.

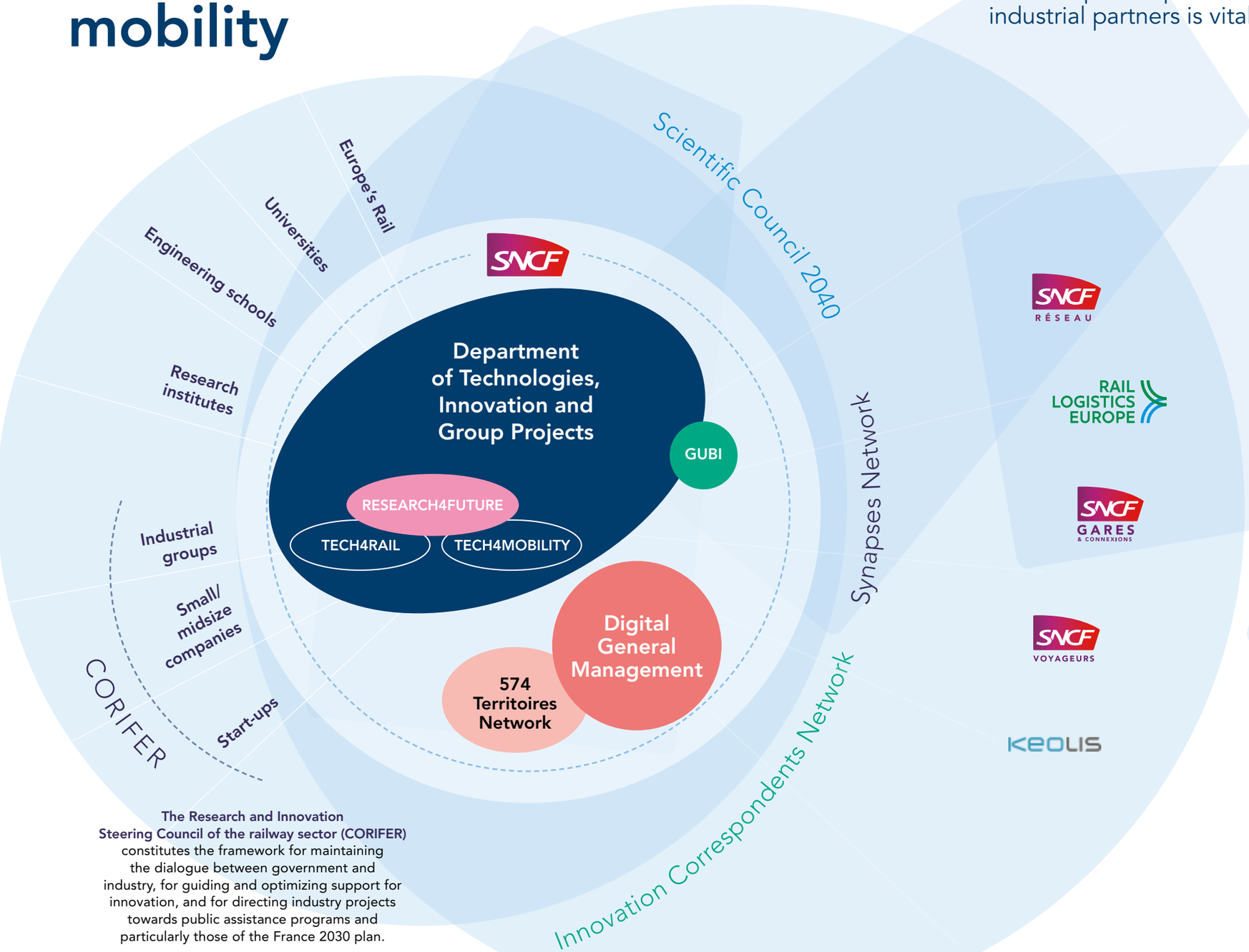
All the projects and all the progress presented in this annual Innovation Report are the result of the collaborative spirit that drives the teams at the SNCF Group and their partners. I hope you enjoy reading it!

Carole Desnost,

Chief Technical Officer
Technologies, Innovation
and Group Projets SNCF

Our ecosystem for rail transport and decarbonized mobility

To double the modal share of rail transport and develop decarbonized mobility, the companies of the SNCF Group and their subsidiaries carry out research and innovation projects in diverse areas such as digitalization, decarbonization, energy efficiency, and mobility in rural areas. Expertise provided by internal networks and by academic and industrial partners is vital to these projects.



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.

Synapses Network

This network overseen by the DTIPG is made up of 582 scientific and technical experts who are named by a selection committee for a renewable three-year term. These experts contribute to research and innovation in six clusters: Energy, Sustainability, System Security, Maintenance, Resource and Operations Optimization, and Mobility Services & Experiences. Coming from different entities, they work together in each cluster to ensure a systemic approach is taken. The Synapses Network transmits competencies and develops expertise in key areas (artificial intelligence, cybersecurity, etc.) for the future of the Group. Synapses experts lead many of the projects presented in this report.

Innovation Correspondents Network

Representatives of the companies and subsidiaries of the SNCF Group make up this network, which orients scientific research according to the needs of its activities.

Scientific Council 2040

In 2022, the Group set up this advisory body under the DTIPG to identify the key issues of the next two decades.

"574 Territoires" Network

The SNCF Group has seven regional digital innovation centres in France. They provide assistance locally to SNCF teams involved in the Group's digital transformation and ensure close contact with the local external ecosystem to support digital innovation at SNCF. This network's activities are focused on the dissemination of a digital culture within the Group, on supporting digital projects and their scalability, and establishing external partnerships in the regions that will help achieve the SNCF Group's goals.

Single Patents & Innovation Platform

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

Research and innovation: teams dedicated to rail transport and decarbonized mobility

Department of Technologies, Innovation and Group Projects

The DTIPG's mission is to coordinate and accelerate the technological transformation of the SNCF Group. To do this, it relies on three entities:

- **Research4Future** It studies and assesses the potential of new technologies in collaboration with the academic world and research institutes (telecommunications, robotics, cybersecurity, materials, AI, modelling, cognitive sciences, and decision-making) and prepares future innovations upstream from the two "innovation accelerators," which are:

  Tech4rail It develops innovations for the rail system through collaborative industrial projects (e.g., the Innovative Light Train TELLi, hydrogen-powered trains, hybrid trains, battery-powered trains, train localization).

  Tech4mobility It addresses all issues related to emerging mobility solutions (e.g., the very light train DRAISY, the FLEXY shuttle system, the autonomous public transport service pilot MASIPRO) to define new mobility services operated by SNCF businesses.

Digital General Management

Digital is one of the Group's four core strengths. Digital General Management (DGA) lays out the roadmap for the Group with the aim of making SNCF the European leader in digital mobility. DGA comprises two competency hubs: Group Digital Management, which defines the strategy and oversees the digital function for all SNCF activities, and e.SNCF Solutions, a unit responsible for digital production serving the IT departments and business units in the Group.

Rolling Stock Engineering

It plays a role throughout the lifecycle of trains and their safety equipment: from acquisition and operational specifications to dismantling, including testing, maintenance engineering, renovation, and extending lifespan. It innovates in every area: operational and maintenance performance, energy efficiency and traction decarbonization, passenger comfort, and safety systems.

Traction Department

All aspects of train driving and related competencies are united in this department. In cooperation with Rolling Stock Engineering, it defines the specifications of the driver's cabs of new and refurbished trains, develops innovative driver assistance systems, and operates test and measurement trains.

Mass Transit Academy

This is the SNCF Group's Centre of Excellence for high-density areas. With a focus on innovation, it provides training, benchmarking, and "learning expeditions." It also runs a Lab' for systems innovations and exploitation of data.

TER Innovation Department

It helps the teams that respond to calls for tenders from the Regions to offer tailored and differentiated solutions. Working with staff of the TER division and its community of industry experts and partners in the regions (start-ups, industrial suppliers, and academics), it conducts trials with new products and services in the field and prepares their deployment in partnership with other departments of the SNCF Group.

SNCF CONNECT & TECH

A subsidiary of SNCF Voyageurs, SNCF Connect & Tech innovates in two key areas. The first is e-commerce with SNCF Connect, the all-in-one service for sustainable mobility; the second is the design and development of digital products and services for the SNCF Group, the regions, and local authorities.

RAIL LOGISTICS EUROPE

Strategy and Development Department

It contributes to the deployment of large-scale digitalization and automation projects in rail freight. It does this by structuring needs and testing disruptive innovations before their implementation in partnership with manufacturers and equipment suppliers.

General Management Projects, Maintenance, and Operations

The operations, services, and digital activities of SNCF Réseau are grouped together in the DGPME, which develops new methods and innovative technologies to design, monitor, maintain, and operate the 28,000 km of lines in the national rail network and its infrastructures in ever-better ways.

Rail Open Lab

SNCF Réseau (president in 2023), FIF, RATP, and SERCE have participated in the Open Lab since 2018. This is one pathway for development in the rail sector, where progress is traditionally made over long cycles. The agility and pragmatic approach of the Rail Open Lab allow rapid testing in short, 4-month periods and in real conditions of new technologies for the maintenance and operation of rail infrastructure.

ALTAMETRIS

A subsidiary of SNCF Réseau, Altametris develops the use of digital twins for the maintenance of industrial infrastructure. Its R&D program includes data collection by drones and inspection robots as well as 3D LiDAR data processing and utilization by artificial intelligence systems.

SFERIS
ALLIÉ DE VOS DÉFIS FERROVIAIRES

The Innovation & Development department of SFERIS, a subsidiary of SNCF Réseau, is an incubator for emerging projects related to infrastructure management and the execution and security of rail projects.

Strategy, Operational Excellence and Innovation Department

It centralizes the management of the transformation of SNCF Gares & Connexions with the objectives of instilling a culture of innovation and facilitating project prioritization.

Customers, Marketing & Technology Department

It coordinates technological innovation initiatives in the areas of customer experience, services, and rail operations in stations. At Paris Nord and Libourne, it has developed a "station laboratory" approach, turning these two stations into real-life demonstrators of innovations. It is also seeking ways to use AI in station operations and in office automation tools.

AREP

A subsidiary of SNCF Gares & Connexions, AREP is a multidisciplinary agency working to achieve a post-carbon future. It has developed the EMC2B approach (Energy, Materials, Carbon, Climate, and Biodiversity) to provide concrete responses to urgent ecological challenges whatever the scale of the project, from station facilities and buildings to regional undertakings.

Innovation and Industrialization Department

It provides support to the regions, from the conceptual to the implementation phases, with uniquely structured methods and the network of "Labs Open by Keolis." The Group looks to Keolis' local offices, which use a sustainability-based approach to innovation to achieve better performance and greater differentiation for all stakeholders: citizens, employees, and organizing authorities.

Club of Innovation

Its members are the innovation correspondents from Keolis subsidiaries. It is a catalyst for the Group-wide dissemination of technological and methodological innovations and for the exploration of relevant use cases for the Group's activities. In return, the analysis of local experiences provides a better understanding of the challenges and opportunities for the Group as it prepares for the future.

Highlights of 2023

Vincent Delcourt,

Director, Technological Development and Performance, DTIPG SNCF

In 2023, the teams at SNCF, SNCF Voyageurs, SNCF Réseau, and their subsidiaries demonstrated our commitment to supporting all aspects of rail research and innovation.

Everyone driving innovation in the companies and subsidiaries of the SNCF Group can attest to the wealth of work accomplished in 2023 with our academic and industrial partners to explore emerging technologies and advance innovative projects through experimentation and then industrial implementation. The diversity of projects presented in these pages is further proof of this. However, this list is far from exhaustive, and these projects provide only a glimpse of all the skills and expertise we are deploying to transform rail transport. The ecological transition, energy management, digitalization of the rail system, new types of mobility, and resilience to risks (climate, energy, cybersecurity, etc.) represent a significant part of these efforts.

To see continuing progress in the rail sector, we must also project ourselves further into the future. This is the reason for setting up our Scientific Council 2040, which got down to work in 2023. Its role is to keep the Group informed of disruptive technologies and identify the opportunities they offer to its activities. We also pursue an open innovation policy in France with other players in the rail sector as well as in Europe through the bilateral partnerships we have established with DB, CFF, NS, ProRail, and others. In these pages you will also learn more about these European initiatives.

They have given fresh impetus to the quest for progress to which we are fully committed.

> A collaborative effort, from scientific exploration to the industrialization of innovation.

Key figures

22
proposals submitted within the framework of the CORIFER 2023 program by the SNCF Group with its industrial and academic partners.

10
major academic partnerships in the research field

1,023
patents in force

46
doctoral students

25
patents pending

Research Tax Credit in 2023 **16.27** million euros, including

SNCF	SNCF Voyageurs	SNCF Réseau
5.33 M€	5.34 M€	2.89 M€

Scientific Council 2040

The members of the Scientific Council 2040 met in February and October 2023 to discuss artificial intelligence, cognitive sciences, and cybersecurity as well as the France 2030 program and the roadmap for the railway sector drawn up within the CORIFER framework.

David De Almeida,

Research Director, DTIPG SNCF

> The discussions within the Scientific Council are also an opportunity to demonstrate the value of the links between the rail industry and the academic world and the importance of strengthening them.

The experts from SNCF's Synapses Network sought to present the most realistic view possible of the fields of AI, cognitive sciences, and cybersecurity and their applications in the industrial sphere. The objective was to propose a forward-looking vision of trends to enrich the strategic thinking of the Council's members.

"These exchanges create a bridge between experts and the Group's leadership and encourage the latter to participate more actively in orienting research beyond the short term. In cybersecurity, for example, the goal is to improve on the standard approaches to preventing and dealing with attacks by using AI to address cybersecurity in industrial systems at a very early stage," explains David De Almeida, Research Director at DTIPG. "These discussions are also an opportunity to demonstrate the value of the links between the rail industry and the academic world and the importance of strengthening them. They also raise new issues, such as the sustainability of AI and the need to rapidly develop AI and cybersecurity skills, which are scarce and highly sought-after in the market."

Signpost

The Scientific Council 2040 was set up in 2022 as a forum for the strategic and technological management of SNCF's parent companies and subsidiaries. It has multiple objectives: to inform the Group's leadership about future challenges; to orient the innovation strategy and research programs; to strengthen the Group's expertise; and to identify opportunities for differentiation and diversification in a competitive environment.

Leverage effect of partnerships

"2023 was a very productive year," says Frédérick Getton, Director of Finance & Institutional Relations in the Department of Technology, Innovation and Group Projects. Work got underway in all seven projects selected by France 2030 in 2022, and funding was secured for three new projects:

Viesta 2 Conducted with Thales and XXII, the aim is to use intelligent video for security applications.

Ophelia The goal is to deploy photovoltaic installations along rail lines in cooperation with CNR (the Rhône concessionaire for hydroelectric production and France's leading producer of exclusively renewable energy), Nexans, Schneider Electric, and the SuperGrid Institute.

Raisilience This project being carried out in cooperation with Gatewatcher is aimed at enhancing rail transport's resilience to cybersecurity risks. In the framework of the CORIFER's 2023 call for expressions of interest, SNCF has also been very active, with the submission of projects that could contribute to the development of regional and metropolitan express transport in particular. Results expected in 2024.

Horizon Europe
In addition, two projects funded at the European level are included. Shield4Crowd, led by Sûreté SNCF, alongside the Interior Ministry, its European counterparts, and SMEs, is seeking synergies in the public procurement process for rail ecosystem security. Meanwhile, S5LECT, also led by SNCF, with Spain's CEIT, IRT Railenium, GTS France, and Radiolab (an Italian consortium of academics and industrial partners), is studying diverse technical solutions for a seamless transition between the 5G network, GSM-R, and satellite communications.

A word from
Jean-Paul Viricelle,
Research Director,
École des Mines,
Saint-Etienne

"Our ambition is to establish ourselves as a responsible engineering school and to be leaders in innovation that will have a societal impact. This is reflected in our education programs and in the research programs we conduct with start-ups, SMEs, and large groups like SNCF. We observe that climate and environmental impacts have become a major concern for students and researchers alike.
To reduce the environmental impact of transport, we rely extensively on digital technologies to model and simulate the entire railway value chain for both freight and passenger transport. We also take into consideration modes associated with rail such as cycling, buses, and car-sharing. We are observing that studies have become multidisciplinary, combining an interest in technological aspects with a focus on life cycle analyses, circular economy, and sustainable development. In the rail sector, CIFRE theses deal increasingly with resource optimization and planning methods to further reduce environmental impact. Our collaboration with a group like SNCF immerses our students in a very concrete reality. It confronts them directly with the challenges they will face once they enter the professional world and makes them aware of longer-term societal issues."

A word from
Adrien Thirion
Deputy Subdirector of Transport Equipment, Mechanics, and Energy at the Directorate-General for Enterprises of the Ministry of Economy, Finance, and Industrial and Digital Sovereignty.

Regional and metropolitan express services, rural mobility development, rail network renewal and modernization, and the development of rail freight, all subjects of utmost importance to the government, are also crucial to the decarbonization of mobility. Naturally, they involve the question of innovation, for which planning is a prerequisite. This implies having a precise vision of the expectations of the authorities that organize mobility. There then needs to be – and SNCF is at the forefront in this regard – a response in the form of a coherent and concise package of technological solutions that can be deployed in multiple regions.
Another domain with a great need for innovation is energy. The creation of SNCF Renouvelables, which will act as a responsible buyer, should enable the development of solutions specific to railway needs. This is an opportunity for partnerships with the French battery and photovoltaic industries, and it will be a factor in stabilizing energy prices through photovoltaic deployment.
Finally, I would like to applaud the momentum generated by SNCF at CORIFER, which has been chaired by Carole Desnost for the past year. CORIFER must serve as the key body to provide responses to long-term R&D needs, based on the planning already mentioned, by and for industrial suppliers in the railway world. It is through innovation that rail transport will maintain its competitiveness.
I strongly believe in collaborative projects as well as in supporting small, intermediate, and midsize companies to promote the development of technologies for the 21st century.

Signpost
The Directorate-General for Enterprises is a key player in the government's initiatives to transform the economy and achieve strategic autonomy for the country. A promoter of business competitiveness, it drives industrial policy, defines measures for digital regulation, and pursues policies to support local economies. It assists companies in the digital and ecological transformation of the economy and works to simplify the regulatory system and to promote an ambitious innovation policy.

> To move forward together, we must think about more than just R&D. While our mission is to detect weak signals to identify solutions, we also need to consider financial impacts and benefits after industrialization. It's a continual job of persuasion with our partners.

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

SNCF, a future producer of solar energy

To first satisfy a portion and then, in the longer term, all its electricity requirements while controlling costs that are now very volatile, SNCF is planning a large-scale deployment of photovoltaic panels on its land reserves.

SNCF is the number one industrial consumer of energy in France. To operate 15,000 trains daily (80% of SNCF's trains run on electricity) and its 3,000 stations and other facilities, it buys about 9 billion kilowatt-hours of electricity each year. It is also a major property owner, with 12 million sq. meters of buildings and 100,000 hectares of land. The idea of using its land reserves to install photovoltaic panels on a massive scale has gradually come to seem an obvious response to this need. So, in October 2023, the Group created SNCF Renouvelables was created. "By 2035, installed capacity on 1,000 hectares of land will have reached about 1,000 megawatts-peak, or about 20 percent of the electricity currently required by the rail system," says Emmanuel Mroz, CEO of SNCF Renouvelables. "About 30 priority sites for installing panels on the ground, on parking canopies, and on roofs have been identified. The installation of longitudinal and vertical solar panels is also under study. As for long linear arrays, there are still technical hurdles regarding the panels themselves and the storage of energy (see opposite, RESPIRE-R and Ophelia)."

> Our ambition is to strengthen our energy independence and meet the urgent challenges of climate change.
>
> **Emmanuel Mroz,**
> CEO, SNCF Renouvelables

OPHELIA: exploiting all possible and imaginable surfaces

How can photovoltaic energy be produced on very long and narrow surfaces, for example, along railway tracks, dikes, or bicycle paths? To find answers, SNCF is leading the rail-related research in the Ophelia project, partnering with CNR, Nexans, Schneider Electric, and SuperGrid Institute.
As part of this project, SNCF will focus over the next two years on determining the compatibility of solar panels with linear structures, taking into consideration the effects of rail operations and the need to prevent losses in the transmission of electricity due to the great lengths of the proposed linear arrays. The solar potential of the French rail network will then be studied along with the economic viability of the tested photovoltaic solutions. OPHELIA is the winner of the DEMO TASE 2022 (Advanced Technologies for Energy Systems) call for projects from ADEME and is 40% funded by France 2030.

AREP's expertise and solar energy

Mapping, data, and modelling are valuable expertise when it comes to comes to shaping a post-carbon future. AREP put these capabilities to work on behalf of the SNCF Group to identify the solar energy potential of its 100,000 hectares of land with a view to creating SNCF Renouvelables. AREP is also involved in other projects, such as the 2025 solar energy plan for stations, the evaluation of solar development potential near and over tracks in the OPHELIA consortium, and experimentation with reversible solar panels on out-of-service tracks.

RESPIRE-R: storing energy to control costs and support the network's electrical infrastructure

The RESPIRE-R project (Rethinking Energy through Innovative Storage and Management of Renewable Energy for Rail) takes on two challenges: cost control in a context of rising energy prices and the development of new solutions to support railway electrical infrastructure (RMES, line reinforcement, etc.).
Its first objective is to evaluate with a pilot site to be installed in the Occitania region the benefits of combining storage and production of renewable energy production; its second objective is to establish the economic conditions for industrialization. The storage system, which is coupled with a solar panel array, relies on batteries and a system for producing hydrogen by electrolysis. The green hydrogen will be stored and then converted into electricity using a fuel cell. The project is led by SNCF in partnership with HDF Energy, SCLE, and Teréga Solutions. RESPIRE-R is a candidate in the CEI CORIFER 2023 call for projects.

SolAREP, the solar cadastre

To calculate the potential of photovoltaic solar plants installed on SNCF properties, AREP has created SolAREP, an analytical model that combines technical, physical, operational, regulatory, and economic information derived from SNCF proprietary data and open data (geography, biodiversity, urban planning, presence of agricultural parcels, capacity of surrounding electrical networks, etc.). To develop the model, they relied on the open-source "R" calculation software. "This made it possible to conduct a detailed, iterative study of thousands of sites simultaneously. The assumptions were gradually refined with the Group to achieve a comprehensive inventory of relevant sites, ranked by priority," says Félix Pouchain, a data expert in AREP's Engineering Department.

European rail accelerates

Interoperability is key to the creation of a rail transport space. It is governed by eleven Technical Specifications for Interoperability, which provide a shared regulatory framework essential to the development of technologies through transnational collaboration and their industrial integration according to common rules.

The updating of the TSIs was completed in 2023, with nine of them approved by EU member states. The acceleration of work in the System and Innovation pillars of Europe's Rail and the strengthening of bilateral cooperation are other excellent news for rail development in Europe.

The revision of the TSIs was eagerly awaited. On 30 March 2023, nine of the eleven TSIs were voted on. "We are generally satisfied both with the content and with way discussions proceeded," says Gilles Quesnel, Director of Interoperability, Standardization, and Research Europe in SNCF's Technologies, Innovation and Group Projects Department (DTIPG). "And we are proud to have advocated, to cite just one example, a simple adjustment to the regulation regarding locomotive headlights in the TSI Operations, which will save us €90 million."

Work on the last two TSIs, Telematics Applications for Freight and Passenger Services, will continue in 2024. "The aim is to standardize data exchange models, such as for communication between two infrastructure managers about a train delay. This harmonization is crucial to simplify the journey for customers," adds Quesnel.

> The revision of Technical Specifications for Interoperability to standardize data exchange models is crucial to simplify the journey for customers.

Gilles Quesnel,
Director of Interoperability, Standardization and Research Europe, DTIPG SNCF

Supporting exploratory research

In October 2023, Europe's Rail launched a call for exploratory research projects on diverse topics: integrated mobility between aviation and rail; retrofit strategies for the European freight fleet in preparation for the deployment of Digital Automatic Coupling (DAC); the taking into account of biodiversity in transport and energy infrastructures and according value to nature; noise and vibrations; future metro systems; disruptive asset management solutions; and doctoral student networking at the European level. At the closing of the call for projects on 7 February 2024, two projects in which SNCF teams are participating had been submitted: TravelWise (air-rail intermodality) and Symbiosis (biodiversity).

Green Deal

The European Commission has initiated the Green Deal program, whose aim is to transform climate and environmental challenges into opportunities for Europe, its industries, and its citizens. The goal of the transformation targeted in this program is to make Europe the first climate-neutral continent by 2050, with, among other things, sustainable, clean, accessible, and affordable transport systems.

Technical Specifications for Interoperability

Principal Advances in 2023

Infrastructure (IF TSI)

Revision of dynamic bridge evaluation methods (avoiding the generalized use of certain tests); clarification of the upgrading criteria for "redeveloped" areas (modification of rail line performance: speed, clearance, axle load...)

Energy (TSI ENE)

Clarification of the upgrading criteria for redeveloped areas. A catenary is classified as redeveloped if the speed performance of a line is increased by more than 30 km/h

Control-command and signalling (CCS TSI)

Anticipation of GSM-R obsolescence; preparation for the deployment of a system to maintain the train's position before changing direction (safety); reduction to harmonize the versions of signalling software

Locomotives and Passenger Rolling Stock

(LOC & PAS TSI) and Freight Wagons (WAG TSI) Taking into account of the adaptation of charging facilities for battery-powered trains

Operation and Traffic Management (OPE TSI)

Improvement of rules for communication between drivers and signalling posts (ergonomics, safety); modification of the regulation for train headlights, which will make equipment adaptation much less costly

Noise (NOI TSI)

Implementation of a virtual method for evaluating the effectiveness of silent brake shoes (more economical)

Persons with reduced mobility (PRM TSI)

Taking into account of the modification of sound and light signalling systems for train access

Europe's Rail celebrates its first anniversary

This European public-private partnership supports research and innovation activities that will enable the deployment of a high-capacity, integrated European rail network. Launched in March 2022, it has two pillars: "System" and "Innovation."
Some highlights of 2023.

The System pillar

A consortium bringing together the association of European rail industry manufacturers (UNIFE), the association of infrastructure managers (EUG), the association representing rail operators (CER), and several operators has been formed to define the architecture of the future railway system. The aim is to describe the current and, more importantly, future architecture of major subsystems such as control-command, signalling, traffic management, and Digital Automatic Coupling (DAC) as well as interfaces with other transport modes such as aviation and regulatory aspects. "At the end of 2023, we proposed a plan for modifying standards and TSIs that notes the consequences of expected innovations and related regulatory changes," says Aude Chailley, System pillar coordinator in the Department of Interoperability, Standardization, and Research Europe.

The Innovation pillar

RAIL4EARTH

Undertaken by the Rolling Stock Engineering Department of SNCF Voyageurs, with Alstom as the leader, this is one of the six major projects of the Innovation pillar of Europe's Rail. It deals with sustainable development: energy, environment, circular economy, attractiveness, resilience, ecological transition, health... SNCF is involved in subjects such as standardization of on-board and ground-train battery interfaces, eco-labelling of rolling stock (similar to the familiar energy labels for household appliances), adaptation to climate change, air quality in underground spaces, modularity of interior layouts, noise and vibration prevention, and the development of new substation technologies. "We insisted on including adaptation for climate change, which the European Commission supported, as it is a subject that calls for a response after the recent heatwaves, storms, and floods. Another topic included thanks to SNCF is the attractiveness of trains, which is also key to the system's environmental performance," says Philippe Clément, head of research, innovation, and development at the Rolling Stock Engineering Centre.

IAM4RAIL

This project is coordinated by the Spanish infrastructure manager ADIF. It brings together about twenty rail operators, including SNCF, as well as representatives of industry and academia to work on Intelligent Asset Management. The goal is to model phenomena like aging, degradation, wear, incidents, and deviations, throughout the life of assets (infrastructure and rolling stock) to better understand them and to improve resilience and the responses to them. "The project aims to validate various approaches such as the use of AI and analysis of data (spatial-temporal, meteorological-historical intersection of incidents, imagery), LiDAR, infrared rays (technical inspections and tunnel monitoring), and ultrasonic probes (track resistance), 3D printing and additive manufacturing (parts repair, etc.)," explains Valéry Versailles, head of the Rail System Physics department in the RESEARCH4FUTURE program of the DTIPG. SNCF is the leader of the robotics research in IAM4Rail. The goal is to create a 'marketplace' that will allow each member of the European rail ecosystem to build modular robots for a wide range of applications using technological bricks – from hardware to software and including middleware (also called "mediator software") – that will all be compatible with each other."

2023 was the year in which major Europe's Rail projects were launched and in which tools for steering and governance among its partners were introduced.

Christophe Chéron,
Deputy Director, Interoperability, Standardization and Research Europe, DTIPG SNCF

A word from Giorgio Travaini,

Executive Director, Europe's Rail

"Reduce CO_2 emissions by 55% by 2030. Make Europe the first carbon-neutral continent by 2050... The Green Deal is not just more empty words. Faced with ongoing climate change, the entire planet must mobilize. Europe's Rail represents €600 million in European public funds and €600 million raised by operators, infrastructure managers, industrialists, and the academic world that will be available through 2031 to help achieve these goals. Because to improve the rail system, a united approach at the European level in support of research and innovation is fundamental.
To reach the Green Deal's goals, we are taking actions on two fronts – ecology and digitalization – and aiming to create technologies that will further reduce energy consumption and make energy cleaner. Rail, however, accounts for only 0.5% of emissions in the transport sector, so it is also a matter of increasing the performance and attractiveness of rail transport to keep it at the core of a multimodal system and to triple high-speed traffic and double rail freight traffic by 2050. To do these things, digital will be an accelerator, just as it is for innovation."

Bilateral cooperation grows stronger

Beyond its participation in European programs, the SNCF Group is expanding bilateral cooperation in Europe, thereby strengthening its positioning with regard to innovative projects and standardization issues.

"Besides the technological partnership that SNCF has maintained with DB since 2016, we initiated very promising discussions last year with the Dutch operator NS and its infrastructure manager ProRail, as well as with SBB in Switzerland," says Astrid Parakenings, who works on industrial partnerships within the DTIPG.

Regarding the SNCF-DB partnership, the chairmen of both companies signed a charter in Potsdam on 1 June concerning sustainable stations that addresses social and societal issues as well as questions related to climate change adaptation and energy efficiency. They also adopted a common position on railway system architecture, and they renewed their commitment to developing Open Source in the rail sector following the creation in 2022 of the OpenRail Foundation. Work on system architecture in the Franco-German partnership has enriched the System pillar of Europe's Rail. Notably, it has helped define the level of interoperability to be adopted to minimize investments, especially in telecommunications and signalling. The System pillar accordingly promotes the development of modular, scalable, and shared industrial systems among operators. To implement the transition, these new systems are associated with "migration platforms" that communalize technological targets and related steps through the 2050-2060 period.

The Marseille-Ventimiglia line, which is currently being equipped with ETCS Level 2, could serve as a model for exchanging best practices in design and operation.

Additional European funding has also been obtained for the development of the future 5G mobile communications system. This will allow synergies with public telecom networks and the launch of tests in Strasbourg of passenger connectivity in cross-border trains. It will also guarantee network resilience by ensuring that FRMCS can coexist with GSM-R until its disappearance.

The chairmen of DB and SNCF group, Richard Lutz and Jean-Pierre Farandou.

Other funding will facilitate operational research on AI aimed, for example, at optimizing traffic management. The deployment of the European database for ATO, a single storage point accessible to all European operators to develop their own algorithms and software, and the development of EGNOS 2 satellite technology, which will support train localization, are also benefiting from new funding.

The SNCF delegation and its Swiss hosts in Bern on 14 December 2023.

SBB: nearly 100% punctuality

With punctuality close to 100%, the operations of Swiss Federal Railways (SBB) are naturally of interest to SNCF, whose representatives were in Bern on 14 December to study the Swiss system. Predictive maintenance, AI, and robotization were on the agenda, as was work planning, which is done two years in advance to facilitate coordination with other modes of public transport. The regional and metropolitan express services got a look too with a case study of Zurich, whose public transport network features "last kilometre" service.

ETCS level 2 will allow an increase in traffic on the Marseille-Ventimiglia line.

Mobilising satellite app players

Under the Spanish presidency of the European Union, and with the European Commission's support, Europe's Rail, the European Rail Agency (ERA), the European Union Agency for the Space Programme (EUSPA), and players in satellite applications for rail gathered in Madrid for the Space for Innovation in Rail – Towards Satellite-Based ERTMS | #Satellite4Rail.
The principal objective was to urge actors in the satellite sector to speed up development of satellite communication applications that could provide much more precise train localization than is possible with public GPS applications. It was an opportunity for SNCF to strengthen its cooperation with others in the European rail industry as well as with the space sector to develop new means of train localization. Stay tuned...

ProRail and NS, leaders in high-density traffic

On 11 October, a delegation from SNCF met in the Netherlands with the Innovation teams of the main Dutch rail operator (NS) and the national infrastructure manager (ProRail). The Netherlands is at the forefront of predictive maintenance, AI, passenger flow management, and the development of regional and metropolitan express services owing to its dense population and its railway network, which is organized much like a country-wide metro system. All these topics will be on the agenda in Franco-Dutch discussions in 2024.

How SNCF is contributing to the ecological transition and the energy efficiency of rail transport

Decarbonization

— The SNCF Group's objective is to achieve "zero net emissions" of greenhouse gases by 2050. It has also made a commitment to reduce the emissions of its transport activities, including its buses, by 30% from their 2015 level by 2030. New engines and motors, innovative fuels, new carbon measurement tools for more energy-efficient buildings, innovation through inter-company collaboration: the SNCF Group is exploiting every means possible to speed up its decarbonization.

Hybrid trains

NEWS IN 2023 The TER Régiolis tri-mode hybrid (electric-thermal-battery) transported passengers for the first time on a non-electrified track between the Toulouse Matabiau and Mazamet stations on 16 December. This trip marked the beginning of commercial service trials, which will continue through 2024. This is a crucial step in the SNCF Group's first project to decarbonize by modifying rolling stock.

Need

Rapidly reduce the carbon footprint and energy consumption of the TER Régiolis trains already in service.

Solutions

- Modification of a Régiolis bi-mode electric-diesel trainset, on which two of the four diesel engines have been replaced by lithium-ion batteries.
- Energy from braking is stored in the batteries for reuse during restarting, resulting in an energy saving of around 20%.
- Dual power supply – catenary/batteries or diesel or biofuels/batteries – for non-electrified lines, with a range of over 1,000 km.

The combination of biofuels (see p. 26) and hybridization reduces greenhouse gas emissions by 70%.

Partners

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

Key dates

- **2019-2020** – Development and testing of the braking energy storage prototype
- **2021-2023** – Hybridization of the TER Régiolis, trials and homologation
- **2023-2024** – Commercial operation trials in the partner regions

The first hybrid TER Régiolis was rolled out on 16 December 2023 at the Toulouse Matabiau station.

Battery trains

NEWS IN 2023 Following its transformation, testing of the first battery-powered AGC (Autorail à grande capacité) got underway at the Railway Testing Centre at Bar-Le-Duc, in eastern France. The battery-powered train is the SNCF's second project to decarbonize by modifying rolling stock, following the hybrid train.

Need

To build a new battery train system coupled with partial electrification of lines to create an economically and technically robust alternative to full electrification.

Solutions

- Transformation of five bi-mode electric-diesel AGCs (high-capacity railcars) into 100% electric bi-mode trainsets: diesel engines are replaced by lithium-ion batteries, giving a range of 80 km on non-electrified tracks. Traction power and battery charging are provided by the pantograph on electrified sections of rail lines.
- Energy from braking is stored in the batteries for reuse during restarting, resulting in an expected energy saving of around 20%.

This 100% electric bi-mode modification reduces the train's CO_2 emissions by 85%, compared with diesel traction, and eliminates nitrogen oxide (NOx) emissions.

Partners

The regions of Auvergne-Rhône-Alpes, Nouvelle-Aquitaine, Occitanie, Provence-Alpes-Côte d'Azur, and Hauts-de-France; Alstom

Key dates

- **2023** – Modification of the first trainset for the Région Nouvelle-Aquitaine and testing at the Railway Testing Centre
- **2024** – Testing on the national rail network and application for authorisation from the Railway Safety Agency (EPSF)
- **2024-2025** – Transformation of four more trainsets and testing in commercial service of a trainset in each partner region

Static Fast Charging

To enable battery trains to operate seamlessly on lines with limited electrification, SNCF, in partnership with Exail, Railenium, and Galland, and with the support of the Région Nouvelle-Aquitaine, is carrying out a project for Static Fast Charging with a 1,500-volt catenary. This system will reduce the charging time for battery trains by half, thereby increasing their commercial availability. It will also extend the operating range of these new trains while avoiding costly electrification works. This project is a candidate in the CORIFER 2023 call for expressions of interest (CEI).

Partial electrification of rail lines

This approach consists in electrifying only a portion of the rail line while avoiding sections with complex infrastructure such as bridges and tunnels, which entail significant installation and maintenance costs. On these sections, the train would run on batteries. Thus, lines currently served by diesel-powered trains could transition to 100% electric traction with only partial electrification. Various projects for implementing this solution are under consideration in France.

Hydrogen trains

H2

NEWS IN 2023 Assembly of a pre-series train got underway at the Reichshoffen production site in mid-2023. Simultaneously, validation tests for various types of hydrogen equipment have begun. The work required to safely bring hydrogen trains into maintenance centres has been defined and scheduled. A hydrogen distribution station is planned for each partner region, with the first contract awarded at the end of the year for the Région Bourgogne-Franche-Comté.

A hydrogen train being assembled at the CAF plant in Reichshoffen.

Need

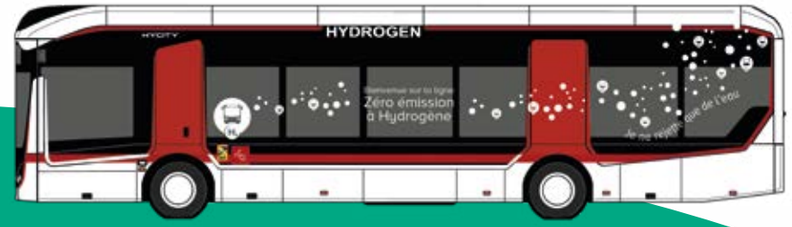
To propose a fully decarbonized alternative to diesel traction and support development of a low-carbon hydrogen ecosystem.

Solution

- Test in commercial operation 12 Régiolis trainsets equipped with a hydrogen traction system (fuel cells and hydrogen tanks combined with batteries).
- The fuel cell will generate electrical energy from stored hydrogen, while the battery will deliver additional power to the train during acceleration and recover braking energy. The train will have a range of 600 km and will be able to use its pantograph on electrified tracks.
- The regions are assisted in the tender processes to define hydrogen distribution solutions: production units and storage areas, possibly shared with other modes of transport, and hydrogen filling stations, either dedicated to railways or not.

Key dates

- **2022** – End of the hydrogen train design phase and first prototypes of hydrogen traction systems
- **2023** – First pre-series trainset, calls for proposals for the infrastructures
- **2024** – Testing
- **2025** – Production of series trainsets
- **2026** – Delivery of the trainsets and start of commercial services in the partner regions



Hydrogen buses for Keolis

In 2023, the city of Clermont-Ferrand and the public transport authority for its metropolitan area awarded Keolis a ten-year contract for the operation of fourteen hydrogen buses starting in September 2024. Keolis and its partners Hympulsion, SAFRA, GCK Mobility, and Symbio are tasked with structuring the route system, taking into account infrastructure design and vehicle operations. Ten new vehicles and four retrofitted ones, with respective ranges of 500 and 330 km (more than sufficient for the distances required for daily service of the route), will be put into circulation. Green hydrogen will be produced locally by electrolysis and distributed by a station, scheduled to be operational by summer 2024, that will provide continual operation and maintenance services.

All trains on the Paris-Granville line will now run on B100.

Excellence Industrie in Auvergne–Rhône-Alpes

Excellence Industrie, a consortium officially launched in late 2022 that includes SNCF, began taking steps in 2023 to modernize, relocate, and decarbonize industry in the regions. Bosch Rexroth, BioMérieux, EDF, HEF Groupe, Serfim, Vicat, and SNCF, through the "574 Auvergne-Rhône-Alpes" initiative (see pp. 8-9), have joined forces to enhance their innovation capabilities and use them for the benefit of regional economies.

The consortium has begun its work by focusing on four main areas:

- **Decarbonization** to combat climate change
- **Development of the circular economy** to reduce resource consumption, address raw material shortages, and relocate industry and jobs
- **Development of the future factory** to make industry more agile and facilitate relocation
- **Support for the digital transition** to effectively address all these challenges

Excellence Industrie
Auvergne-Rhône-Alpes

Biofuels

NEWS IN 2023 Experiments conducted in 2022 and 2023 have validated biofuels on existing thermal engines, with a reduction in greenhouse gas emissions of 60% with B100 and over 75% with HVO if derived from reprocessed waste.

Need
End use of fossil fuels.

Solution
Replace diesel with biofuels compatible with diesel engines:

- B100, a by-product of rape processing
- HVO, hydrotreated vegetable oil, produced from vegetable oils (excluding palm oil) and reprocessed waste (waste oil, animal fat)

Partner
Région Normandie (B100)

Key dates

- **2022** – Continued testing of B100 in commercial service and testing of HVO on an engine test bench
- **2023** – Testing of HVO in commercial service with five XGC trains in Bourgogne-Franche-Comté; B100 in continual use on 15 Régiolis trains following validation by the Région Normandie

Carbon calculator

NEWS IN 2023 AREP focused on finalizing the second version of its carbon calculator after working with users to improve it. The ergonomics have been enhanced, and new parametric models have been introduced to speed up calculation of carbon weight.

Need
To enable designers to estimate in the early phases of their work the impact of their decisions on the entire life cycle of a property development project.

Solution
A "carbon weight" calculation tool to assess a project's climate change impact according to the building typology (structure, walkway, plaza, etc.) and the construction solutions (roof, floors, facades, etc.). Design parameters can be iteratively modified in the tool to optimize the project's carbon weight.

Key dates

- **End 2020** – Start of development, user testing
- **2021** – First version of the tool
- **2022** – Connection to the INIES database (carbon weights of construction materials and equipment)
- **2023** – Second version of the tool

Download the white paper "Décarboner le transport en France : la voix du ferroviaire" (in French)

Issued by SNCF and the Federation of Railway Industries, it sets forth the commitment of all actors in the rail industry to supporting the ecological transition.

The carbon calculator was used in the work on Platform 1 in the Survilliers station.

Energy efficiency

— Optimizing energy consumption is a crucial challenge in the design and operation of rolling stock. From high-speed passenger trains to freight and regional trains, SNCF strives to consume less and consume better.

TGV M

NEWS IN 2023 A full range of tests was conducted in 2023: static and dynamic tests at Vélim, validation of air conditioning, heating, and interior ventilation at temperatures from -20°C to +45°C at Vienne, and the first trials at 320 km/h on the national rail network.

Need

A 100% French eco-TGV that will deliver a 20% reduction in energy consumption, a 30% reduction in maintenance costs, and the smallest carbon footprint in its category. It will emit up to 50% less CO_2 per seat than a classic single-level TGV running on the same route. Ninety-seven percent of its components will be recyclable (each trainset contains over 100 tons of recyclable materials, representing 25% of the train's total mass).

Solution

A 100% French eco-TGV that will deliver a 20% reduction in energy consumption, a 30% reduction in maintenance costs, and the smallest carbon footprint in its category. It will emit up to 50% less CO_2 per seat than a classic single-level TGV running on the same route. Ninety-seven percent of its components will be recyclable (each trainset contains over 100 tons of recycled materials, representing 25% of the train's total mass). With:

- Improved aerodynamics
- An energy storage system that will maintain passenger comfort for several hours or enable the TGV M to be moved a few dozen kilometers in the event of incidents such as an interruption of catenary power
- Thermal insulation of cars, automatic closing of access doors, eco-parking, and a more robust heating/air conditioning system that ensures optimum comfort in temperatures up to 50°C even with crowded conditions on board
- Modified braking architecture to prioritize the return of energy to the catenary
- Optimized ventilation of technical equipment (motors, transformers...)
- New guidelines (eco-driving, eco-parking, management of trainsets and locomotives at standstill) that will result in additional energy savings beyond the already estimated 20%

The third TGV M test trainset on the national rail network.

A modular TGV, with higher capacity, better accessibility, and more connectivity:

- 740 passengers (634 currently)
- The number of cars (7, 8, or 9) adapted to passenger flow
- Transformable spaces (1st or 2nd class, more or fewer seats)
- Capacity to carry 8 bicycles
- Fully autonomous accessibility, designed with input from organizations representing people with reduced mobility
- Integrated sensor network for improved reliability and predictive maintenance

Partners

ADEME, Alstom, Nendo

Key dates

- **2018** – 100 trainsets ordered for France, 15 for European routes
- **2022** – First trainset presented at Alstom (La Rochelle)
- **2023** – Static, dynamic, climatic, and pre-validation tests
- **2024-2025** – Admission and pre-operation tests
- **2025-2035** – Initial deployment on the Paris-Lyon-Marseille route

Eco-parking: another avenue to optimize energy consumption

To evaluate and then reduce the energy consumption of parked trains, systems of alert and dashboards to measure idling times and heighten the personnel's awareness to improve equipment management have been developed: VigiLoc Eco-parking for freight and LiveMAT Energy for regional transport. At Fret SNCF, results were significantly better in 2023 than in 2022, with an 11% improvement in thermal locomotive performance. During the same period, the decrease for TERs reached 24.5% for the series of trains monitored. This was mainly the electric mode, with closer monitoring.

SIM3-PO, an energy twin for rolling stock

NEWS IN 2023 Validation of AGC models with the SIM3-PO tool was followed by the launch of an initial study in the Région Nouvelle-Aquitaine, with the aim of rolling out the very first French battery-powered train by the end of 2024. The simulations confirmed the system's robustness in operation, even when there were unforeseen incidents. Additionally, work began during the year on defining driving strategies that would save even more energy.

Need

To precisely estimate the energy consumption of rolling stock to make future trains more efficient and environmentally friendly.

Solution

- Develop a simulation platform to assess rolling stock performance in several configurations and validate the conditions for robust operation.
- Develop an energy twin by modelling the traction system of each type of train (electric bi-mode, hydrogen, hybrid, rechargeable battery/BEMU, tramway...) to simulate energy flows and the effects of replacing the thermal engine/alternator/rectifier with battery packs.
- Model driver interactions to incorporate driving effects.

Partner

Masteris

Key dates

- **2021** – Development of SIM3-PO
- **2022** – Modelling of AGC BEMU, bi-mode electric (catenaries/rechargeable batteries), hybrid Régiolis (électric/thermal/battery), tramway
- **2023** – Industrial use, study in Nouvelle-Aquitaine, start of driver modelling
- **2024** – Hydrogen modelling
  Alignment of the tools for measuring climate control consumption with SIM3-PO

Energy autonomy

— With SNCF Renouvelables (see pp.14-15), the SNCF Group is set to become one of the leading producers of green electricity in France. It is also aiming to develop storage solutions and systems to inject renewable energies into the network.

Energy storage

NEWS IN 2023 At the Technical Centre in Brittany, construction of the energy storage enclosure has been completed, and design work on the installation advanced. Tests are planned for 2025.

Need
To develop large-scale, sustainable storage solutions for renewable energies to encourage their use in the rail sector.

Solution
A storage system based on the principle of thermal conversion called the "Carnot battery" converts intermittent production (up to 5 MWh) into "manageable" electricity:
- Electricity is converted into heat with turbomachinery (1 MW of power)
- The heat is stored in two cylinders using refractory materials (basalts, ceramics)
- The heat is converted back into electricity during the discharge phase. The projected efficiency is 70%.

A global first (patented by STOLECT).

Partner
STOLECT

Key dates
- **2023** – Construction of the demonstrator begins
- **2024** – Installation of two tanks containing rock and the turbomachinery
- **2025** – Completion and start of testing

The project's partners at the ground-breaking ceremony in April 2023.

RACCOR-D
(Smart Direct Current Rail Network for greener electricity)

NEWS IN 2023 This smart grid project now has its own site for the testing and validation of its technological technological building blocks. This was done for the first industrial chain of batteries in 2023. Connection to the catenary is scheduled for late 2024 or early 2025. The connection of the photovoltaic field, installation, and connection will be completed by late 2025.

Need
To transform the 1,500-volt direct current network into a smart, more energy efficient multidirectional network that can both recover braking energy in batteries installed in electrical substations and integrate new components such as solar panels and electric vehicle charging stations. Energy recovery could deliver energy savings of 10% to 15%. Currently, about 5% of the SNCF Group's consumption is lost because it cannot be reinjected into the network upstream.

Solution
- A direct current converter (a very compact and lightweight high-frequency electronic transformer) that can increase voltage by between 6,000 and 9,000 V (a global first).
- A photovoltaic field with very high voltage up to 9,000 V (a global first).
- A site to test and validate the technological building blocks and allow renewable energy sources to be supplied to railway facilities.

The advantage: environmental activities are possible around solar panels (agricultural photovoltaics, plantings, beehives).

Partners
SCLE-SFE, RTE, RAILENIUM, Institut National Polytechnique de Toulouse (LAPLACE academic laboratories), JUNIA (L2EP Lille), CEA. funding from Bpifrance (France 2030)

Key dates
- **2021** – Project launch
- **2022-2023** – Prototype, industrialization studies
- **2024-2026** – Platform tests

Minimizing consumption

— Minimizing consumption is not only about energy. It concerns all materials, from water to rare metals to textiles. It also involves choosing materials that are more environmentally neutral and combatting planned obsolescence to escape from a system of "produce-consume-dispose."

Lengthening the life span of rolling stock

NEWS IN 2023 An assessment of around thirty TGV Duplex trains was undertaken with the aim of extending their life span by 10 years. While SNCF Engineering can already draw on its experience with single-level trains made of steel as well as on the operations at mid-life of Duplex trains and on manufacturer simulations and crash tests, studying the resistance of the aluminium structure of TGV Duplex trains provides a new look at the problem.

Need
To extend the service life of double-decker TGV trains beyond their usual life span (manufacturer's specification: 30 years) to meet the growing transport needs of the French population. To continue to use rolling stock that is still in good condition and whose life span has already been extended by two to four years through rigorous maintenance by adding another 10 years or up to 20 million kilometres (compared with the current 15 million kilometres) to its service life.

Solution
A program called "Deprogrammed Obsolescence Operations" for TGV-Intercités, based on assessments of all organic and functional elements of the TGV Duplex (bogies, motor blocks, wiring, body structure, etc.). These findings should be applied during future operation of these trains starting in 2026. This includes:
- Identification of key vulnerable areas using multiple tools and techniques: visual inspection of the trains, endoscopy of the internal structure, drone inspection of roofs, non-destructive testing (magnetic particle, dye penetrant, ultrasonic, and eddy current testing), etc.
- Identification of root causes, determination of solutions (specific coatings developed with the Railway Testing Agency to combat corrosion from toilet chemicals, modification of seals, and increased attention to welding quality to combat aluminium cracking from sustained high-speed operation)
- Development of a precise mapping of defective areas, a list of work to be carried out on each train, and dimensioning of repairs by numerical simulation
- Proposal of opportunistic modifications: reduce energy consumption, improve interior comfort, etc.

Key dates
- **2022-2023** – Programme launch and assessment of aluminium bodies
- **2024-2025** – Continuation of studies on the organs, intermediate floors, inventory of maintenance work, optimization of reinforcement methods and repairs
- **2026** – Launch of the operation in industrial technical centres to extend the life span of TGV Duplex trains

Second Life

NEWS IN 2023 The needs of companies that recover railway materials were analysed to create a tool to facilitate sorting signalling equipment to improve reuse or recycling.

Need
Give a second life to signalling equipment or components of signalling equipment (disposed of or left over from construction sites).
Extend the lifespan of mechanical signalling systems.

Solution
A mobile app to identify the equipment in the field and provide the necessary information for its second life:
- 3D modelling of equipment
- Identification of the item with image recognition using a smartphone/tablet
- Integration of instructions in descriptive equipment databases: reuse or resale or recycling

Key dates
→ **2022-2023** – Project launch
→ **2024** – Prototype for about 20 items, Proof of Concept
→ **2025-2026** – Industrialization

CAT FIC

NEWS IN 2023 The project was launched in September with the aim of setting up circular economy circuits for copper used in electric traction. Preliminary studies estimate that this recycling would reduce carbon emissions by about 25%.

Need
Develop more reasonable copper consumption in a market under strong pressure and where extraction is increasingly expensive and water- and energy-intensive.

Solution
- Identify potential recycling channels for copper from the railway sector (ISO quality); implement industrial sorting, supply chain, and materials recycling processes.
- Experiment with the reuse of contact wires from the main network on lines with less traffic (local lines, service tracks, static charging...) and modify design standards to allow previously prohibited reuse.
- Develop related logistics chains: preparation/sorting of materials, quality control and testing, deployment of contact wires from recycling or for reuse.

Partners
MTB Recycling, CIMES, LamCube Centrale Lille.
Certified by the TEAM 2 competitiveness centre

Key dates
→ **2024** – Mapping, methodologies, and studies
→ **2025** – Trials

Mobil'Quai: a second life for composite materials

A patented technology that interests the SNCF Group: tiles made from crushed and compressed composite materials, which have the advantage of not impermeabilizing the ground they cover. Plus, in the event of deterioration, they can be crushed to produce new tiles.
The aims of this project launched in February 2023 by SNCF and submitted in the CEI CORIFER in November are: to adapt these tiles to the railway environment in terms of resistance and safety standards; and to study materials produced by SNCF that could be recycled to make them. The goal is to develop prototypes to launch test campaigns in 2025 and to make a first production model in 2026-2027 (subject to funding in the framework of France 2030).
The project also aims to consider "service design," for example, to integrate guidance strips for the visually impaired and connected objects for magnetic loops to guide the deaf. Besides improving passenger reception, this agile solution could be used for new stopping points for events or in frugal infrastructure (RMES, light trains, loading and handling docks, new sidings, etc.).

Reducing the environmental footprint

— Through its infrastructures, stations, service points, and industrial facilities, the SNCF Group interacts directly with a multitude of ecosystems. Vegetation management and biodiversity protection are thus part of its activities.

Natural vegetation management

NEWS IN 2023 SFERIS conducted the first experiments on biomineralization at its operational laboratory in the Morvan.

Need
To develop natural alternatives to glyphosate and reduce the need for vegetation management along tracks.

Solution
SFERIS is studying a new liquid product composed of non-pathogenic bacteria capable of producing calcium carbonate to solidify sand grains. It recreates the biomineralization process of living organisms (production of hard materials such as bones and shells) and prevents vegetation regrowth. Effectiveness for five years is under study.

Partner
GreenPRAXIS

Key dates
→ **2022** – SFERIS launches an operational laboratory for sustainable vegetation management
→ **2023-2024** – Trials and improvement
→ **2025** – Marketing of the product

The Japanese knotweed plague

Japanese knotweed is an invasive exotic plant that is spreading in railway rights-of-way and causing numerous technical problems (track deformation, dislocation, risks of work accidents, etc.). A ten-year experimental program has been launched to test covering methods to contain its spread. Tests are currently being conducted in Saône-et-Loire and monitored by the National Institute for Agricultural and Environmental Research (INRAE). The encouraging initial results were presented at railway technical gatherings in June 2023.

Reduce collisions with animals

Collisions between trains and large mammals have serious consequences such as delays, cancellations, and the need to repair damaged equipment. Various solutions are being studied to reduce the number of collisions. One method being tested is sound-emitting systems along the tracks or on board trains. Thesis research conducted under an Industrial Training and Research Agreement (CIFRE) in partnership with the Université de Saint-Etienne and the National Museum of Natural History is aimed at creating a sound that would trigger a flight response in large mammals. After creating different sounds in the laboratory, trials were conducted with animals at the Haute Touche Zoological Reserve. More trials will be conducted soon in a railway environment.

Adapting to climate change

— Climate change is already a reality, with extreme heat, floods, landslides, and erosion now impacting the railway system. New technologies, including the digitalization of the network and AI, make it possible to measure its long-term effects on rolling stock and infrastructure and to develop adaptation strategies.

Platipus

(Projects for the analysis of vulnerable structures at subaquatic and aquatic sites)

NEWS IN 2023 Efforts were focused in 2023 on enhancing the reliability of the Platipus platform's assessment with machine learning algorithms of the risk of infrastructure undermining by incorporating climate change parameters. Several studies were also completed, including one commissioned by SNCF Réseau and conducted by the Université de Gustave Eiffel, a partner in the project, to analyse the feasibility of applying the technique developed by RTRI (the Japan Railways research institute) for assessing the condition of the piers (impact vibration tests) of railway bridges in the French network.

Platipus is designed to make infrastructures with foundations in rivers more secure.

Need

To anticipate the impact of exceptional weather phenomena on the 10,000 structures at aquatic sites in the rail network due to potential erosion of foundations and deterioration and/or unbalancing of the structures they support, which can even cause them to collapse in extreme cases.

Solution

Create an AI-based decision support tool to:
- Identify vulnerable structures subject to undermining
- Improve monitoring and pre-corrective or preventive maintenance

Partners

Université Gustave-Eiffel, Setec, MOMI, Resallience, Deltares (Netherlands), Network Rail (GB), Japan Railways and RTRI (Japan)

Key dates

- **2019-2021** – Project launch, diagnostic and stability studies of infrastructures
- **2022** – Launch of the Platipus digital platforms (programmers/users)
- **2023-2024** – Review and delivery of the studies
- **2025-2026** – Validation and industrial deployment of the machine learning solution

Solar radiation protection and energy consumption

In 2023, the Rolling Stock Department used its Climax software to test how the installation of protection against solar radiation (e.g., film on windows and heat-reflective paint on roofs) would impact energy consumption during winter weather. Monitoring of OUIGO Espana trains, TGV 2N trains on the Southeast network, and Corail cars showed no increase in energy consumption at these times and confirmed improvement in comfort during warmer weather.

Adaptation of rolling stock

NEWS IN 2023 The year saw the launch of the Rolling Stock Adaptation to Climate Change project, an initiative along the lines of RAIL4EARTH (see p. 18) and the Datathon, organized by the SNCF Group last year too. The Datathon approach, which consists in detecting weak signals in rolling stock data, proved promising.

Need

To identify vulnerabilities of rolling stock and foresee how their energy consumption will change due to global warming by anticipating future developments from signals considered weak today but potentially strong in the future.

Solution

- Create an AI-based vulnerability modelling tool (machine learning), integrating climate data from Météo France, onboard train networks (MyTrainData), CMMS equipment (Osmose), and train punctuality tracking software (Bréhat).
- Use this data to describe the expected evolution of climate change impacts and the consequences of inaction.
- Define investment priorities to make rolling stock resilient to climate change.

Key dates

- **2023** – Launch of RAIL4EARTH; Datathon SNCF; launch of the Adaptation of Rolling Stock project
- **2024** – Creation of the tool, validation of the modelling

A tool to predict climate risks

NEWS IN 2023 Making better investments to adapt to climate change is becoming crucial. This is the aim of the climate risk prediction tool developed in 2023 as part of the Minerve project (creation of a digital twin of the railway system).
The tool is deployed nationwide in France, with a pilot phase in PACA to further develop the modelling and validate the tool's robustness. Initially focused solely on the rail network, the goal is to extend it to the entire system to have a unified approach to risk analysis.

Need

To assess the resilience to climate change of infrastructures in the rail system and to have a decision support tool for making investments, among other things.

Solution

Create a decision support tool combining the Geographic Information System (GIS) and AI to:
- Identify and model climate hazards using French and European databases
- Model vulnerabilities to these hazards based on incident histories and the failure principles derived from them (nature, frequency, intensity)
- Objectify risks by asset, hazard, and region for a given time frame to identify priorities, risks, and gains from investments

Partners

Kayrros, Centrale Supélec, Setec, Systra

Key dates

- **2023** – Project launch, validation of modelling
- **2024** – Deployment in the pilot region (PACA)
- **2025** – General deployment and further work to develop a system approach

How SNCF is strengthening its industrial performance

Connected trains

— Automation, the processing of enormous amounts of data... smart technologies are revolutionizing passenger and freight services. And presenting a cybersecurity challenge.

Optimizing train localisation

NEWS IN 2023 The Loc4Rail project has demonstrated the effectiveness of a system for reliable and precise train localisation using various types of sensors. Development continues in the CLUG* project under the name CLUG 2.0 within Europe's Rail R2DATO project for the future TSI ERTMS.

**Certifiable Localisation Unit with GNSS in the Railway Environment, funded by Europe*

Need

To safely increase train traffic while controlling costs by significantly reducing ground equipment.
By bringing together railway companies, industrial partners (railway signalling, navigation), laboratories, and research institutes, this initiative is promoting train digitalization and automation through the development of a localisation system for use in speed control, train tracking, and track monitoring.

Solution

The future localisation system will be based on GPS and Galileo satellite systems, combining GNSS (Global Navigation Satellite Systems) and cartographic and inertial navigation data. The project is pursuing two geolocation solutions:

- The French Loc4Rail project, based on Exail's inertial navigation technology as well as precise GNSS technology (GeoFlex and CNES)
- The European CLUG and CLUG 2.0 projects, using the European GNSS augmentation service EGNOS (in partnership with Airbus)

For these two solutions, certain applications have already been identified:

- The inertial technology of Loc4Rail could be used for static fast charging (see p. 24)
- Satellite solutions (based on the European GNSS augmentation service EGNOS) will be an essential component of ETCS level 3 to support moving block systems

Partners

CLUG 2.0: DB, SBB, Airbus DS, ENAC, CAF, Siemens, UNIFE, EUSPA
Loc4Rail: Exail, Geoflex, CNES

Key dates

- **2019** – Launch of CLUG (/2022) and Loc4Rail (/2023)
- **2023** – Launch of CLUG 2.0 and R2DATO
- **2026-2027** – Performance demonstrations for ERTMS and operational ground-to-train performance (geolocation for fast charging)
- **2031** – Safe (SIL4) and interoperable geolocation solutions ready for ERTMS

Sirius Next

In 2024, train drivers will have a new driving assistance tool: Sirius Next. Developed in a project launched in 2021, it will offer more features than its predecessor, Sirius NG, thanks to an algorithm integrating punctuality, energy efficiency, and rolling stock preservation. The characteristics of the infrastructure and rolling stock will be integrated to provide dynamic reference speeds and to optimize acceleration/braking. Energy savings will average 10%. A profile view will show what is ahead on the track (notable points, next stop, scheduled time/real-time), the track profile (up and down gradients), with maximum speeds, and construction zones.

Development of platforms for interoperability and modularity simulation and testing

NEWS IN 2023 The test bench at the ERTMS France Laboratory (LEF) of SNCF Group's Rolling Stock Engineering (CIM Le Mans) has been enhanced with new simulation capabilities in the R2DATO project of Europe's Rail. A partnership with the Spanish laboratory CEDEX is also under review for the design and interoperability testing of ground and onboard systems.

Need
To develop testing solutions for the new technological building blocks of railway digitalization and to implement a collaborative network of laboratories for the development, validation, and certification of new systems.

Solution
With the LEF's totally modular test bench, which features generic and adaptable technologies, new systems for geolocation, lateral signalling perception, and 5G-based radio (FRMCS) will be tested in collaboration with several European partners working in an expertise network independent of industry and industrial partners. The test bench will provide a comprehensive testing solution for digital driving assistance systems, marking a minor revolution in certification and interoperability testing. The train geolocation system is expected to be the first prototype available.

Partners
Université Gustave Eiffel, Railenium, ADIF, CEDEX, RENFE, DB, KB, DLR, CAF, NS, GTSD, Hitachi, SMO, Mermec, FSI, RFI, ATSA, TRV, KTH, Chalmers

Key dates
→ **2023** – Deployment of R2DATO and integration of GNSS into the test bench
→ **2024** – Testing of a geolocation system prototype

ITxPT laboratory

Leveraging the expertise of the LEF (the ERTMS equipment certification laboratory), the SNCF Group has set up a new laboratory in partnership with the ITxPT association to conduct labelling tests for bus and tramway equipment and software. The objective of ITxPT is to establish interoperability and interchangeability standards to promote modularity and maintainability throughout the lifecycle of rolling stock and to offer less costly public mobility systems. Accredited in June 2023, the laboratory is already working with around twenty international clients. Specifications for the railway sector will also be published in 2024, pointing to potential new markets.

DAC
Digital Automatic Coupling of Freight Wagons

NEWS IN 2023 The DAC operational processes were defined during the year and will now be used to develop its functional specifications. The analysis of its operational constraints has been completed. The prototype of the e-coupler, the electrical component of DAC data transmission, is currently being selected from proposals of industrial suppliers.

Need
To automate the coupling/uncoupling of wagons to significantly improve rail freight efficiency and harmonize the European railway system. Digital automatic coupling is the priority innovation project for rail freight in Europe.

Solution
European rail freight relies on a universal screw coupling that is time-consuming and burdensome to operate.
Its digitalization involves:
- An onboard digital connection
- Monitoring sensors: brakes, wheels, overall driving, loading, train integrity (the "Monitor" project, launched in February 2023)
- Sharing of operational data and wagon localisation at the European level
- Testing of automated brakes

When ultimately combined with technologies like ERTMS, DAC will allow longer and heavier trains to be operated while supplying essential information regarding train integrity.

Partners
DAC4EU consortium in the TRANS4M-R project of Europe's Rail: DB Cargo, Rail Cargo Austria, RLE, Mercitalia, Renfe, Siemens, Alstom, Knorr-Bremse, Faiveley-Wabtec, Voith, Dellner

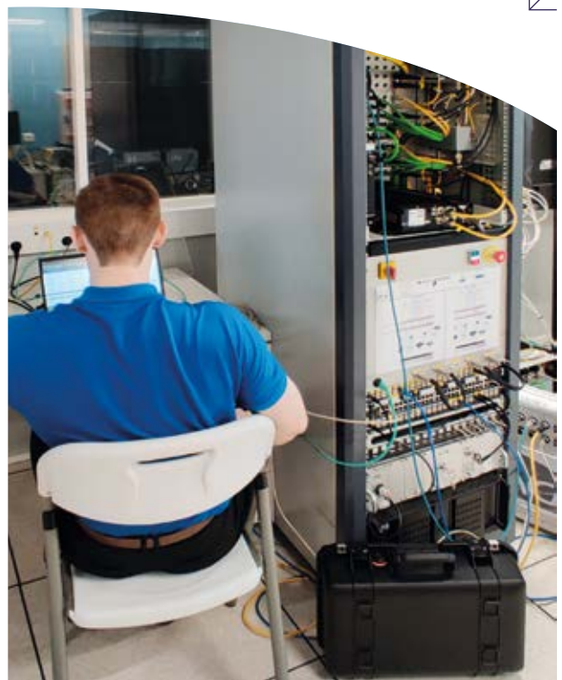
Key dates
→ **2022** – Fret SNCF testing of the German demonstrator
→ **2025-2026** – Industrial version (DAC5), testing of automated brakes, migration, and funding studies
→ **2028-2033** – Project for possible two-step migration: a system compatible with the screw coupling, then replacement with DAC

EXPLORATORY RESEARCH

Cybersecurity

All connected systems are vulnerable to cyberattacks. Ensuring reliable access to mobility services and guaranteeing the protection of personal data make cybersecurity, coupled with extreme vigilance by employees, essential. Cybersecurity must be considered from the outset of a project and throughout a system's lifecycle. Among its tools is AI, which can detect an attack, then isolate and destroy the virus before it infects the system. Research is also focusing on the analysis of techniques used by attackers so that protection can be automated and technological barriers erected to ensure the resistance and resilience of systems designed to handle ever-increasing amounts of data.

POC Cybersecurity Probe
A cyberattack detection probe is a virtual or physical device that analyses the flow on a network and provides information and alerts regarding the network's operation. A Proof of Concept (POC) was launched in 2023 by experts in the System Security cluster of Synapses (see p.7) to assess the reliability of probes available on the market. Its findings will guide the purchasing strategy or the internal development of probes adapted to the railway sector's needs.



Connected network

— 5G, artificial intelligence, IoT, lasers, 3D... digital technologies are revolutionizing the monitoring, maintenance, and operation of infrastructures to create the rail network of the future.

FRMCS

A programme that will truly revolutionize rail system communication at the European level.

GSM-R, an interoperable and secure railway mobile communications system supporting voice communication between train drivers and controllers as well as signalling, is based on 2G and is set to become obsolete in 2035. The Future Railway Mobile Communication System (FRMCS), based on 5G and MCx (call prioritization, group calls, etc.), will gradually replace it and offer many more applications such as train autonomy and video surveillance. To develop standards for the FRMCS and test its technological building blocks, five collaborative projects were set up:

5GRail A European project completed in 2023, conducting laboratory and field tests of the initial 5G FRMCS prototypes constituting the network and ground-to-air system (a global first)

R2DATO A follow-up in 2023 to 5GRail in Europe's Rail aimed at transforming 5G FRMCS prototypes into industrial products

5GRACOM A Franco-German project initiated in 2023 to explore radio links and coverage to ensure communication quality while reducing costs by avoiding the need for new radio sites

5GREMORA Allows the French telecom sector to benefit from test campaigns conducted within 5GRACOM; this project is funded by the National Research Agency (ANR)

Cœur 5G SNCF A Bpifrance project launched in 2022 by SNCF to study interconnection possibilities with other private 5G networks to meet non-security needs of infrastructure managers or railway companies, especially at maintenance centres

These five projects deal with different building blocks of the Future Railway Mobile Communication System (FRMCS) that will replace GSM-R. To ensure the overall coherence of this system, which could be the main catalyst for the digitalization of railway transport, a programme is supposed to be launched at the European level under Europe's Rail in 2024, preceding a massive deployment of FRMCS starting in 2030.

Autonomous Safety Reconnaissance Vehicle (MARS)

Candidate in the CEI CORIFER 2023

NEWS IN 2023 Building on research on the digitalization of train operations, the MARS project represents a global first and has been endorsed by the i-TRANS competitiveness cluster. It will lead to the production of an autonomous vehicle operating at level "GoA4" and travelling at 230 km/h to confirm tracks are clear for TGV traffic.

Need

To propose a reconnaissance system for TGV lines that is more flexible, cost-effective, environmentally friendly, and efficient than taking a TGV train out of commercial service every morning.

Solution

- A fleet of "autonomous security reconnaissance vehicles," positioned at strategic points in the network and programmed to conduct reconnaissance runs under the supervision of a controller overseeing their operation.
- These vehicles, equipped with 360-degree vision, sensors, cameras, and LiDAR and travelling at high speeds, analyse and transmit real-time information essential to ensuring the safety of upcoming train operations.
- The collected data is useful for rail network maintenance operations.
- The MARS system will serve as an innovation springboard for French railway manufacturers as its technological building blocks may be applicable to everyday train operations.

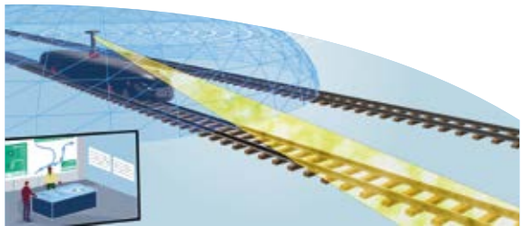
Partners

Forsee Power, Hitachi Rail STS, Railenium, Socofer France, Spirops

Key dates

(subject to funding from France 2030)

- → **2022-2023** – Concept development
- → **2024** – Project launch
- → **2026-2029** – Construction of a demonstrator
- → **2030** – Calls for proposals for the manufacture of the vehicles



SURFO

NEWS IN 2023 To validate SURFO (SURveillance par Fibre Optique), the system was included in several projects in 2023: rail defect detection (Marseille-Ventimiglia), underground monitoring (Les Aubrais-Vierzon), train tracking, and other applications (LGV Est, following EOLE in 2021).

Need

To monitor the railway platform and its environment in real time using the 28,000 km of optical fibre on the SNCF rail network. The objective with SURFO is to confirm the possibility of transforming optical fibre into vibration sensors and to identify use cases with added value for the company.

Solution

- Develop signal processing algorithms to translate vibrations into data for identifying anomalies.
- Categorize anomalies using machine learning (AI) that learns and then detects significant events.

This frugal technology – it would reduce operating costs and optimize maintenance – could be adapted for all lines equipped with optical fibre, including small rural lines. This solution is based on a physical phenomenon of interaction between light and matter. Vibrations affecting the optical fibre alter the light passing through it. Characteristics of the vibrations are carried by the light and can be extracted from it.

Partners

Télécom Paris, Université Gustave Eiffel, Institut de Physique du Globe de Paris, Université de Grenoble, Université Côte d'Azur, Bureau de Recherches Géologiques et Minières (BRGM), Société des Grands Projets (SGP)

Key dates

- → **2018-2019** – Project launch
- → **2020-2021** – POC for several use cases such as defective rails or rockfalls to demonstrate the system's potential
- → **2021-2024** – Industrialization

Connected stations

— Digitalization is accelerating the transformation of stations, from the management of assets and their maintenance to the services offered and control of energy consumption.

Digital twinning of stations and asset management

NEWS IN 2023 Definition of the strategy, roadmap for ISO 55000 certification (asset management), IS developments, recruitment of data managers... all were in the news in 2023 around this project stemming from the digitalization of assets and developments preceding the digital twinning of stations.

Need
To improve our understanding of our assets – property, technological, and financial – to prioritize our actions, with an emphasis on economic efficiency and service quality.

Solution
- Definition/implementation of asset management methods and practices for stations.
- Improvement of the descriptive quality of data on assets.
- Deployment of roles, skills, and associated processes: creation of eight data manager positions in our operations.
- Developments in IS, creation of a decision support portal (needs, risks/opportunities).

Partner
TB Maestro

Key dates
- → **2023** – Project launch
- → **2024** – Industrialization

Smart Station

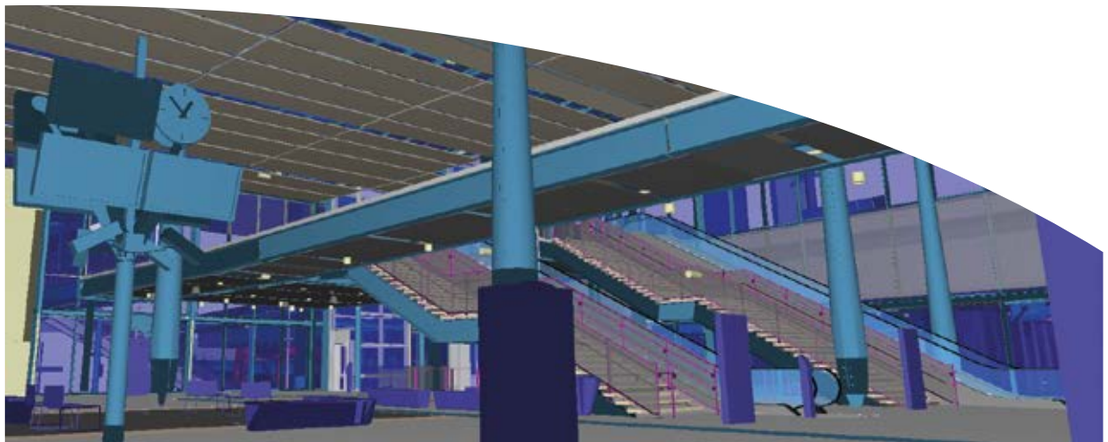
NEWS IN 2023 Smart Station, a station equipment supervision system, has achieved its first objective. At the end of 2023, 831 users, including 326 supervisors and 128 viewers from building energy agencies, had been trained in the system's use, and high satisfaction with it was expressed.

Need
To ensure optimal operation of priority equipment (automatic doors, elevators, escalators, etc.) by creating short information circuits for station agents and providing very rapid response in the event of malfunctions.

Solution
- Sensors on equipment: automatic doors, elevators, escalators, gas/electricity meters (phase 1), water meters, heating/ventilation/air conditioning, building lighting (phase 2).
- An application displaying 3D plans of station spaces and informing of any malfunction in real time, available for supervisory and mobile use.
- Training on the tool for supervisors, station agents, and building energy agency staff.

Partners
Engie Solutions, Cabinet Wavestone, Graphic Stream

Key dates
- → **2019** – Project launch
- → **2020** – Initial implementation
- → **2021** – Industrialization
- → **2022** – 360 stations
- → **2023** – 700 stations, 8,900 connected things
- → **2024** – Demonstrator for an extension to 200 stations scheduled to open, 2nd phase



LIVE
Passenger information system for stations

NEWS IN 2023 The new passenger information system for stations, named LIVE, was deployed during the year at 1,200 small stations.

Need
With the opening up of the passenger market, SNCF Gares & Connexions plays a role as an integrator of passenger information in stations. In these circumstances, the LIVE program is intended to ensure that established carriers and new entrants receive equal treatment in terms of passenger information (acquisition of transport plans, visual and audible dissemination of information to everyone, coordination during normal times and disruptions).

Solution
- Design, develop, and deploy a unique passenger information system to replace existing disparate systems.
- Strengthen the performance and resilience of IS with SaaS software, with end-to-end supervision and usage-based payment.
- Deployment in stages, starting with small stations, where there are the fewest functionalities from a human-machine interface perspective, to test the system's robustness under real conditions. Development of LIVE functionalities is continuing with a focus on the Paris 2024 Olympics and Paralympics. The challenge in this third stage is to separate management of the train product from the communication of passenger information.

Partners
Established transport operators and new entrants, mobility organizing authorities

Key dates
- → **2022** – Development of the system, automatic integration of transport plans
- → **2023** – Deployment in small stations
- → **2024/2025** – Deployment in midsize and large stations
- → **2025/2026** – Deployment in the Paris region

Station connectivity plan

NEWS IN 2023 The deployment of indoor antennas in major stations has begun to deliver public 5G connectivity to customers as well as a redundant WIFI infrastructure to provide a backup in the event of breakdowns. Demonstrators of private 5G networks have also been developed during the year for SNCF's own operations (asset management and office automation).

Need
To improve connectivity for the B2B and B2C customer experience, real-time equipment monitoring, maintenance, and consumption management.

Solutions
- Take advantage of the latest generation of connectivity (better coverage, stability, energy efficiency).
- Test and install these solutions: Low Power Wide Area Network (LPWAN) to extend IoT functionalities, high-speed 5G, and WIFI 6/6E/7.

Partners
Polestar, Hub One, SNEF Lab, Firecell

Key dates
- → **2022** – Inventory of assets and mapping of solution to construct the connectivity model for stations
- → **2023** – Migration of equipment connectivity from public networks to an SNCF private network, improvement of the public 5G network (indoor antennas)
- → **2024** – Experimentation with private 5G and hybrid public/private 5G

Connected monitoring and maintenance

— Beyond the gathering of information, connected surveillance and maintenance are revolutionizing network and rolling stock management. Equipment reliability is strengthened by detecting early signs of malfunctions and accurately anticipating necessary maintenance.

This metal additive manufacturing robot was installed in the Saintes workshop of the Charente-Périgord Industrial Technicentre in September 2023.

3D factory by the 3D collective

NEWS IN 2023 Analysis of clearances, catenary geometry, measurement of ballast profiles and volumes... those are a few examples of use cases developed, and in some instances industrialized in 2023, based on the analysis of 3D point clouds.

Need

Use 3D data to enhance the description of the network, projects, and maintenance operations.

Solutions

- A "3D factory" across the entire value chain: daily acquisition of LiDAR data (via track surveillance vehicles, helicopters, drones), analysis, processing, exploitation, development of business tools.
- Development of algorithms for object and shape recognition and defect detection. With these solutions, the SNCF Group aims to become the global leader in 3D data processing for infrastructure managers.

Key dates

- → **2022** – Launch of the 3D collective (SNCF, SNCF Réseau, Altametris and Eurailscout) and setting up of the processing chain
- → **2023** – Industrialization of the first applications
- → **2024** – Nationwide deployment of processing for clearances, ballast, and catenary geometry

AI for telecom fault detection

The detection of faults in telecom assets with AI relies on 2D/3D data from network surveillance. The project, launched in 2023 by Altametris for SNCF Réseau, has already validated the ability of AI models to detect faults in assets such as booths, railway phones, cable ducts, and draw chambers.

Robin, the train maintenance helper

Robin, a mobile robot developed by Altametris, inspects the undersides of train cars and transmits real-time images to maintenance workers' tablets. Robin can carry out inspections at stations or maintenance depots so that trains do not always have to return to a Technicentre. Improvements to Robin in 2023 included making it more compact and mobile and enhancing its connectivity and image quality. It also now features a stereoscopic camera and a 3D LiDAR sensor to check contact brushes.

Additive manufacturing

NEWS IN 2023 As part of the Additive4Rail consortium launched in 2022, the additive manufacturing workshop at the Charente-Périgord Industrial Technicentre in Saintes continued to ramp up its operations. It conducted more testing of metal wire deposition printing, and it is working on the production of a first part (a crossbar pivot), which will undergo commercial testing during 2024.

Need

To reduce stocks and delivery times of spare parts for maintenance, to repair damaged parts, and to develop new products.

Solutions

- Digitalization of data to create digital models and manufacture spare parts on-demand or in series.
- Introduction of new professions such as additive manufacturing engineer.

Additive manufacturing technologies, the industrial equivalent of 3D printing, combine digital design and rapid production of mechanical or structural parts through the successive addition of layers of metal or polymers.

EXPLORATORY RESEARCH

New Materials

Composite materials offer numerous advantages for the railway industry. As strong as metal yet much lighter, they allow large and complex parts to be designed while reducing the weight of trains, thus saving energy. Using polymers reinforced with fibreglass or carbon fibres, composite materials are used to make the new aerodynamic nose of the TGV, which is currently going into series production, and they are being studied to replace metal in the new seats of Transilien and OUIGO trains.

Robotics

To facilitate work for its employees in challenging conditions, SNCF is experimenting with a range of robots to perform a variety of tasks. As part of Europe's Rail, it is also leading the development of a European railway robotics ecosystem to construct robots based on common technological building blocks. The first two applications will be multifunctional infrastructure inspection and train disinfection. Employing them for other jobs such as weeding along tracks, snow clearance, platform maintenance, and cleaning of train exteriors is being considered too.

Partners

École polytechnique, École centrale de Lyon, CEA Tech, Centrale Nantes, VLM Robotics, 4D Pioneers

Key dates

- → **2016** – First application: the manufacture of parts for train interiors by SNCF Voyageurs
- → **2020** – 3D metal printing for signalling by SNCF Réseau
- → **2023** – Ramp up of the additive manufacturing workshop at the Charente-Périgord Industrial Technicentre
- → **2026** – Test of a train bogie demonstrator: on the way to a global first in R&D?

How SNCF is making rail transport more appealing

Mass Transit

— Mobility needs in dense areas, and particularly in the Paris region, require specific solutions to offer more decarbonized mobility. From rolling stock to operations and information, innovations are making rail travel smoother, more efficient, and more appealing to passengers.

Rush hour info for commuters

NEWS IN 2023 Platform displays at 210 stations now indicate the occupancy of trains before they arrive at the station. Ninety-four percent of customers find the information useful, and 42% say they change their location on the platform thanks to it*. Launched with Île-de-France Mobilités, this system received the Data Grand Prize and the gold in the Product Design category as well as the Innovation Prize in the Grands Prix de la Région Capitale 2023.

* Online survey of 1,000 respondents

Need

To provide information on the occupancy of each car to better distribute passengers on the platforms and increase on-time departures.

Solution

- Exploit real-time data from:
  - infrared sensors measuring flows at the doors of NAT, Regio2N, and soon, RER NG trains
  - for trains without these sensors, scanning done by platform cameras currently being installed, with the images converted into passenger density levels using AI
- Supply information to platform displays and digital media.

Partner

Affluences

Key dates

→ **2021** – Programme launch
→ **2022** – Testing of infrared sensors and platform cameras
→ **2023** – Deployment of the system for trains equipped with sensors
→ **2024** – Deployment of platform cameras in around 30 stations

Nudge Multimodalité

In 2023, Keolis Dijon Mobilités was a prize winner with its Nudge Multimodalité system in the Propulse* programme sponsored by the Agency for Innovation in Transport (AIT). The outcome of two years of behavioural science studies and research, this system informs and guides passengers during their travel, encouraging them to choose the most suitable mode of transport (bus, tram) for their needs and comfort. It was successfully tested in late 2022.

* Propulse

Sponsored by the Agency for Innovation in Transport (AIT), the Propulse programme is an accelerator for the most promising innovations to help achieve the objectives of the government's mobility and transport policies. All types of high-impact innovations with service, technological, social, organizational, or industrial applications are supported. In addition to the AIT's Propulsé label, the programme certifies start-ups and SMEs with its Greentech Innovation label.

Crowd monitoring in stations

(real-time counting)

NEWS IN 2023 In preparation for the 2024 Paris Olympics, flow studies were conducted during events at the Stade de France using data from sensors installed in the Saint-Denis stations in June 2023. These sensors also ensure the reliability of the data transmitted to the Paris Prefecture of Police every 30 minutes during these events.

Need

To ensure that the analyses of passenger flow data are reliable.

Solution

- Install 3D stereo sensors to measure flows in real time or with a delay (24/7 data), with the possibility of defining alert thresholds.
- Conduct comparative studies to understand passenger behaviours.
- Define use cases to adapt flow management and operations: orientation, stop and go, anti-fraud measures, planning of substitute services in case of works, adaptation of transport plans, etc.

Key dates

- **2021** – Benchmark DB (sensors)
- **2023** – Installation (La Plaine Stade de France, Stade de France – Saint-Denis)
- **2023-2024** – Comparative studies, preparations for the Paris Olympics

NExTEO

NEWS IN 2023 RER NG trains piloted by NExTEO were run for the first time on the Gagny test track in Seine-Saint-Denis. Another notable event during the year: the industrial contract for RER B and D was also awarded.

Need

To increase the frequency and regularity of trains and better manage traffic during disruptions.

Solution

Digitalize the block signalling system (train spacing) by automating traffic supervision, speed control, and the acceleration and braking phases via a ground-to-train communications system such as Communications Based Train Control, adapted to an open railway system. The blocks become mobile, virtual, deformable, and thus adaptable to real-time traffic conditions, thereby augmenting flows by safely reducing the interval between trains.

Partners

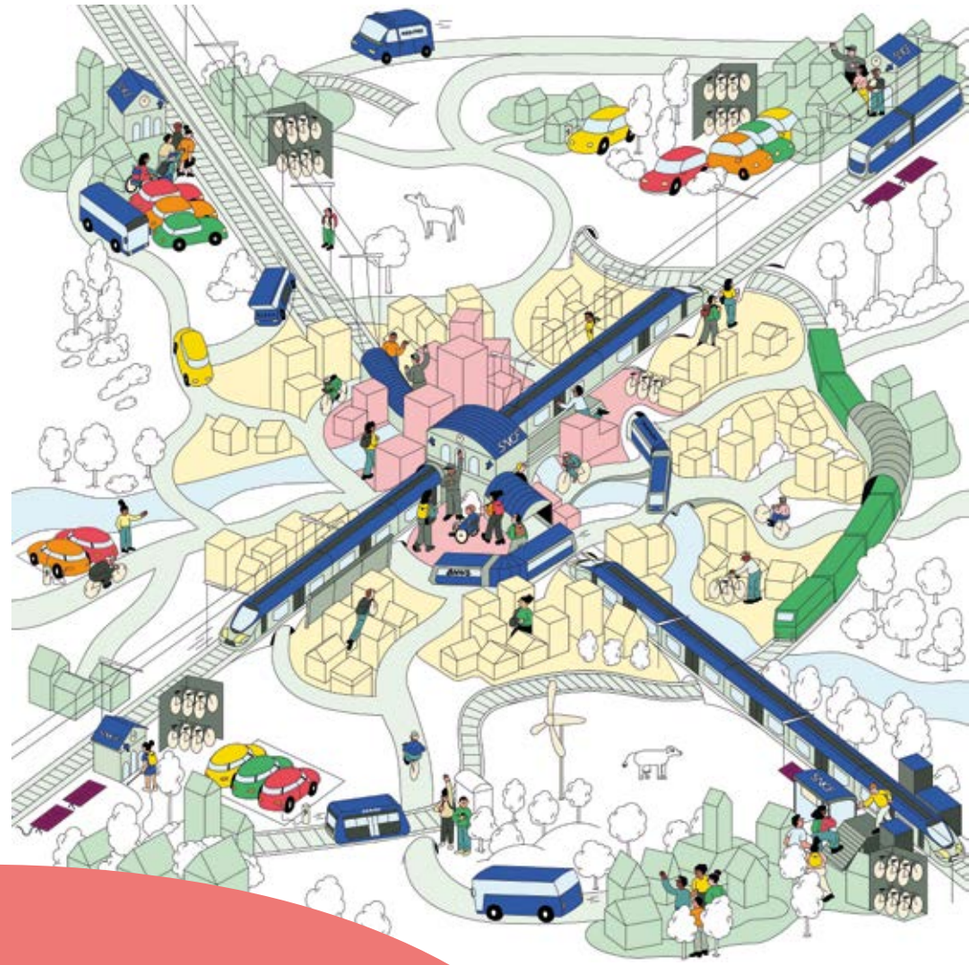
French state, Région Île-de-France (Paris region), Île-de-France Mobilités, Siemens/Eviden (RER E), RATP, and Alstom Transport (RER B and D)

Key dates

- **2016** – Contract for RER E awarded
- **2023** – Contract for RER B and D awarded
- **2025-2026** – Progressive deployment on RER E

Innovative Regional and Metropolitan Express Services

— To meet the needs and expectations of passengers and the Regions, the SNCF Group has launched the programme SERM Innovant (Innovative Regional and Metropolitan Express Services) to develop appealing and decarbonized commuter transport services in metropolitan areas through a multimodal offer to shorten travel times and simplify customer journeys.



The goal of the SERM Innovant programme is to give decarbonized public transport a bigger role in metropolitan areas and surrounding communities. The key elements are higher capacity railway infrastructure, redesigned rolling stock, stations transformed into mobility hubs, multimodal transport supervision, and easier journeys for customers.

Stéphane Chwalik

Coordinator of SERM Innovant projects for the SNCF Group

Designing Regional and Metropolitan Express Services (SERM) means developing a mobility offer with increased frequencies, longer operating hours, and better ways of combining transport modes.
"Transport networks have always been designed in a rather compartmentalized manner. As a result, it is sometimes easier to take one's car," explains Stéphane Chwalik. "Coordination between modes is therefore essential to adequately meet needs in urban, suburban, and even rural areas. This also involves development projects such as the innovative light train TELLi, the very light train DRAISY, the FLEXY rail-road shuttle, the automated, road-based public transport system MASIPRO (see pp. 54-57), and other innovative solutions. We want to explore all avenues to contribute to a surge in the supply of regional and metropolitan express services."
To move forward, the Group worked with its partners in the rail sector in 2023 to submit five projects in the CORIFER call for expressions of interest (CEI), with support from the Nouvelle-Aquitaine and Occitanie regions. These projects are the first building blocks of the SERM Innovant programme, which will focus on five key issues: the robustness and capacity of infrastructure, the transformation of rolling stock, the supervision of multimodal operations, the development of new mobility hubs, and the design of simplified and inclusive customer journeys.

A word from

Renaud Lagrave

Vice President of the Région Nouvelle-Aquitaine, President of Nouvelle-Aquitaine Mobilités

"The initial idea is indeed to talk about mobility in the plural, not just about rail, even though it is central. This is extremely important because we are talking about multimodal connection hubs, soft mobility, express buses, and so on.
We started in 2018 with through-services on TER lines between Arcachon and Libourne, and Langon, Saint-Mariens, and Saint Yzan. The half-hourly service on the first line made commuting simpler, more regular, and more dependable, with no need to change trains in Bordeaux. We are now doing the same on the second line. The next step will be to increase the frequency to every fifteen minutes and to replace inefficient modes of transport with genuine alternatives to the sacrosanct car. That's what we expect from SERM, in Bordeaux, as well as in the Basque-Landais region, and perhaps tomorrow at La Rochelle, Poitiers, and Pau.

Everywhere we have expanded the offer, ridership has increased, which means we need to innovate and rethink all mobility systems, asking questions about train equipment, multimodal connection hubs, parking, and last-kilometre solutions. We must constantly be on the lookout for innovations, whether they are technological or of other kinds, kinds, for example, new resources, financing, or economic models. In the railway sector, I expect to see innovations in signalling, electrification, rolling stock, ticketing, and integrated pricing, among other things. Our region has taken its destiny into its own hands, with concrete, multi-year commitments."

Thomas Allary,

Director of the Regional and Metropolitan Express Services (SERM) at SNCF Réseau – SNCF Gares & Connexions

"The goal of the Mobility Organizing Authorities with the SERM programme is to offer residents of metropolitan areas and their outskirts mobility services that are robust, efficient, and amply scaled. These services will be multimodal and coordinated with other modes of transport, and with rail, the mode with the largest capacity, as the cornerstone. Innovation must enable us to guarantee the robustness of its operation and strengthen intermodality, which is essential to ensure smooth, door-to-door journeys. This is the purpose of the projects submitted by the SNCF Group with its industrial and academic partners in the CORIFER 2023 call for expressions of interest."

SERM Innovant: the first five candidate projects in the CEI CORIFER 2023

MEASTIC

Controlling noise and vibrations from Regional and Metropolitan Express Services (SERM)

Need
To control noise and vibrations due to increased SERM traffic to promote acceptance of these services and improve onboard comfort so that the services are more appealing.

Solution
Explore concepts that break with current developments and industrialize innovative solutions for the sector while revitalizing the national industrial fabric:
- Develop predictive tools for vibration emissions taking into consideration particular sources (junctions and points) and a variety of soil and building characteristics.
- Develop systems to diagnose and monitor the acoustic performance of rolling stock and infrastructure; install testing devices to accelerate the deployment of innovations.
- Industrialize innovative technologies for controlling emissions: discreet screens with sonic crystals, heterogeneous barriers with wave localization, optimized acoustic metamaterials, etc.
- Look at equipment and infrastructure maintenance as a solution for emissions reduction (diagnosis, optimization, evaluation of resulting gains and costs).
- Consider perceptual aspects related to acoustics (annoyance, immersive listening, comfort).

Partners
Université Gustave-Eiffel, Vibratec, Saint-Gobain, CSTB, CNRS

Key dates
(subject to France 2030 funding)
- **2025** – Project launch
- **2027** – Experimental operational systems
- **2029** – Industrialization

EXPLORATORY RESEARCH

Mechanical and Acoustic Systems

By combining expertise in physical modelling, data analysis, and a cross-disciplinary approach, this research field seeks to optimize the design, homologation, monitoring, and maintenance of the railway system while contributing to the control of acoustic and vibration emissions.
It focuses particularly on modelling the behaviour of infrastructure and rolling stock, which is a key step in designing new transport systems such as regional and metropolitan express services (see opposite) or light trains (see pp. 54-56). The objectives are to make these systems resilient to climate change, reduce their sound and vibration emissions, and contribute to the adaptation of their monitoring, maintenance, and operation guidelines.

CORIFLUX

Measurement and optimization of passenger flows

Need
To better understand and manage passenger flows to improve safety, punctuality, and comfort and to optimize station and rolling stock design.

Solution
Design and industrialize tools to understand and manage flows in stations and on board trains that are tailored to Regional and Metropolitan Express Services (SERM).

- Develop tools for measuring the density and trajectories of passenger flows in stations and on board trains (crossing data from a variety of sensors, after anonymization).
- Analyse and understand behavioural determinants, model them, and identify ways to affect them, gain public acceptance of these methods, and increase their effectiveness.
- Implement and industrialize technical and/or organizational flow management solutions, taking into account SERM constraints.

Partners
Inria, Railenium, Université Gustave Eiffel, Spirops

Key dates (subject to France 2030 funding)
- → **2025** – Project launch: modelling and development of tools; design of a test platform; behavioural studies...
- → **2026** – First POC in a pilot station
- → **2028-2030** – Industrialization

ADAPTATIVE

Adaptation to train occupancy and bicycle installations

Need
Offer adaptable arrangements for existing rolling stock to adjust capacity to occupancy on Regional and Metropolitan Express Services (SERM) and encourage cyclists to leave their bikes at the station during peak times.

Solution
Design and test new modular train layouts and station services adapted to the evolving needs of SERM based on:

- A train and station living lab to test demonstrators, iterative validation of innovations developed with customers and agents based on ergonomic studies
- Interior arrangements that adjust to crowd levels and soft mobility demand: sit-stand configurations, fittings that can be moved quickly by agents or customers, bike racks
- A dynamic train composition configurator as a decision support tool
- A range of bike services at the station: bike and reuse centres, secure bike shelters with real-time information (available spaces)

Partners
Attax Groupe, Clarté, Railenium, Cogitobio

Key dates
(subject to France 2030 funding)
- → **2024** – Project launch
- → **2025-2027** – Launch of the Living Lab; development of interior installation models; homologation and trials on the Libourne-Arcachon line; implementation of bicycle services in stations

OPTIMA

Optimization of work planning and station capacity

Need
To increase railway system capacity at the level of the three key resources – construction projects, stations, and technical centres – at a time of strong growth in passenger (SERM) and freight demand.

Solution
Create applications integrating machine learning and operations research algorithms to simplify the planning and operational management of critical rail network resources while addressing industrialization, cybersecurity, and scalability issues –

- Works applications: to minimize the impact of construction sites and determine windows for work during commercial slots; to better synchronize those executing work orders; to ensure the reliability of the logistics chain and supply of resources
- Station applications: to optimize capacity management planning and to recalculate capacity operationally if the transport plan requires adjustment
- Equipment applications: to align workload and technical centre capacities; to prioritize maintenance tasks; to streamline movements; and to adapt planning in the event of unforeseen situations

Partners
École Polytechnique, École des Ponts ParisTech

Key dates (subject to France 2030 funding)
- → **2024-2025** – Project launch; industrial prototype for the technical centres; start of prototyping for work planning and station management
- → **2027** – Industrial prototypes available
- → **2028** – Industrialization

POIESIS

Assistance in the design of Regional and Metropolitan Express Services (SERM)

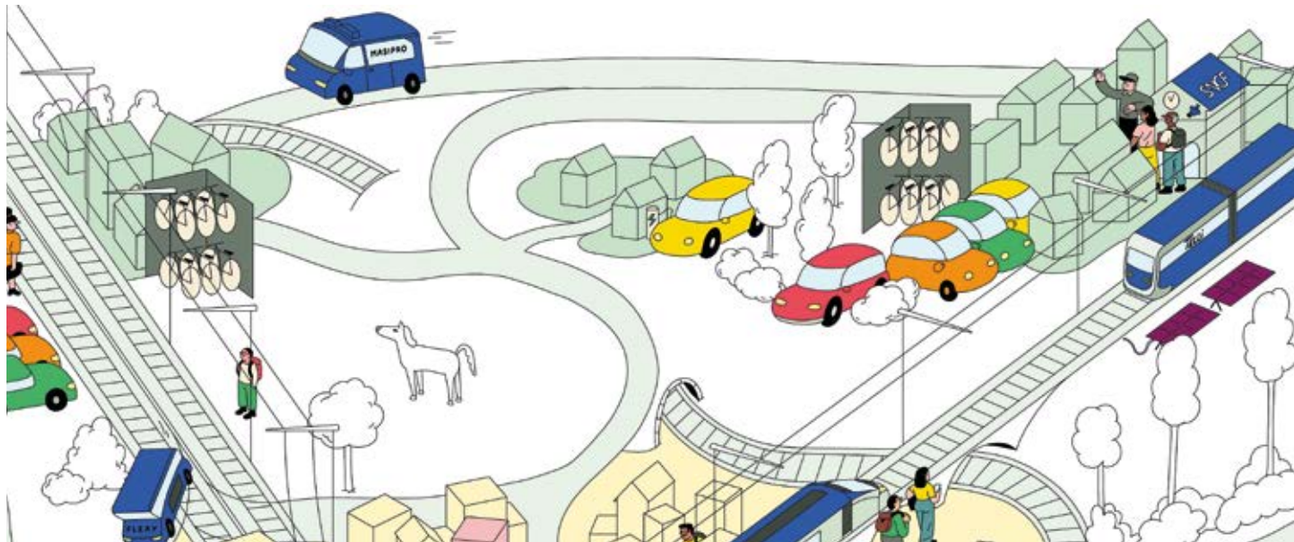
Need
To analyse the influence of psychological, economic, and geographical parameters on travellers' mobility choices to help Mobility Organizing Authorities define the optimal offer in terms of costs and socioeconomic benefits.

Solution
Create the first software that analyses the influence of psychological, economic, and geographical factors on travellers' mobility choices. It will:

- Objectify behavioural factors driving modal shift; analyse mobility and its future evolution in the regions; define the new transport economy
- Using a simulation tool, develop a digital twin of mobility to anticipate the effects of modal shift and to evaluate any externalities
- Calculate the cost-benefit ratio of various scenarios

Partners
Université Gustave-Eiffel, Université de Montpellier, Université d'Avignon, System-X, Maplab

Key dates
(subject to France 2030 funding)
- → **2024** – Project launch
- → **2024-2028** – Research and development work conducted in parallel
- → **2028** – Industrialization



Mobility in rural areas

— The SNCF's goal is to offer easily accessible and environmentally friendly public transport alternatives to private cars everywhere. That's why, to complement the TER services in rural areas, the railway is developing, in cooperation with its industrial and academic partners, a range of solutions with unique designs tailored to small lines and areas with little or no train service.

TELLi, the innovative light train

NEWS IN 2023 The project is now on stronger footing with the signing of a funding agreement with the ADEME and the eleven partners as well as with approval from the public authority regarding the design and development schedule. Thanks to support from the Nouvelle Aquitaine region, a railcar is now being transformed into a rolling laboratory to test the innovations of the Innovative Light Train, now renamed TELLi, starting in 2024.

Need

To revitalize small lines connected to the main network in rural areas through a new approach that increases service frequency while controlling system costs.

Solution

- An all-inclusive, eco-designed system integrating rolling stock, infrastructure, and operations compatible with the circulation of other types of trains.
- Digitalized systems for operation, signalling, onboard monitoring of the track and surroundings.
- High-capacity batteries providing a range of 200 km and speeds up to 120 km/h.
- Reduced weight and a new suspension system for lower track stress and reduced maintenance.
- 80 seats, accessibility for people with reduced mobility (PRM), and interior modularity allowing transport of bicycles and small freight.

Partners

Texelis, Railenium, Thales, Wabtec, CAF, Alstom, Ferrocampus-Région Nouvelle Aquitaine, Capgemini, Cerema, Ektacom

Key dates

- → **2021** – Consortium formed
- → **2022** – Winning project in the CEI Digitalization and Decarbonization of Rail Transport
- → **2022** – Funding obtained from the ADEME and project launch
- → **2023-2024** – Studies and Proof of Concept
- → **2025** – First tests of digital signalling on a pilot line in the Nouvelle Aquitaine region
- → **2029** – Nationwide deployment

DRAISY, the very light train

NEWS IN 2023 The overall system design was completed, and the technical specifications of the rolling stock (design, driver's cab, etc.) were defined. Acknowledging the quality of the project and its initial deliverables, ADEME has greenlighted further work and the development schedule. The Grand Est region has joined the project with the Sarralbe-Kalhausen line in Moselle, which will be used for technical demonstrations of the DRAISY system in 2026.

Need

To address the specific needs of small lines in rural areas with a railway system designed specifically for them. It will significantly reduce system costs through innovations in rolling stock, infrastructure, operations, and regulations. The solution must be compatible with occasional freight traffic.

Solution

- A very light train weighing around twenty tons, not TSI compliant, taking advantage of technologies and materials used in the automotive industry.
- Space for 80 passengers, including 30 seated, accessibility for people with reduced mobility (PMR), and interior modularity allowing the transport of bicycles and small freight.
- Battery providing speeds up to 100 km/h and a range of 150 km, extended by a rapid charging system at certain stations.
- Optimized operation with a frugal traffic supervision and management system.
- Simplified infrastructure due to the reduced weight of the rolling stock and on-board systems monitoring the track and surroundings.
- Specific regulations adapted to the special characteristics of the DRAISY system and dual authorization from EPSF and STRMTG.

Partners

Lohr Industrie, GCK Batteries, Stations-e, Railenium

Key dates

- → **2020-21** – Concept development, consortium formed, and application preparation
- → **2022** – Funding obtained from ADEME and project launch
- → **2023-24** – Design, manufacturing, and testing of the prototype on a test track
- → **2025** – Work on the technical demonstration line and production of the first series model
- → **2026** – Technical demonstration on the Sarralbe–Kalhausen line
- → **2027** – Start of commercial operations on the Sarralbe–Kalhausen line
- → **2028** – Nationwide deployment

FLEXY shuttle system

Candidate project with the Bretagne and Bourgogne-Franche-Comté regions in the CEI CORIFER 2023

NEWS IN 2023 Based on a specially modified commercial vehicle platform, the dual-function wheel system and its road-rail transition were tested on a section of track made available by the Région Bretagne in Rosporden.

Need

To develop an innovative and flexible public transport solution combining operation on both rail and road to better connect rural areas and give an economic second life to closed rail lines while eliminating level crossings.

Solution

- An electric shuttle, called CarFLEX, with dual-function rail-road wheels.
- A battery providing a range of 200 km and speeds up to 70 km/h on rail and 100 km/h on roads.
- 14 seated places, accessibility for people with reduced mobility (PMR), and interior modularity allowing the transport of bicycles and small freight.
- Digital driving assistance systems.
- A low-cost rail infrastructure requiring only the installation of rail-road transition platforms and the conversion of level crossings into simple road intersections with minimal rehabilitation work.
- Compliant with STRMTG regulations.

Partners

Milla Group, Michelin, Railenium

Key dates

(subject to France 2030 funding)

- → **2021-22** – Concept developed, consortium formed
- → **2023** – Organization and implementation of a test campaign on a prototype of the dual-function wheel; response to the CEI CORIFER 2023
- → **2024-2025** – System design, manufacture of the first two production vehicles, and testing
- → **2026** – Technical demonstration on a rail line in the Bourgogne-Franche-Comté region
- → **2027** – Nationwide deployment

EXPLORATORY RESEARCH

Telecoms

Research in this field is essential to ensure safe operations, to support the widespread adoption of digital technologies, and to improve railway system performance. There are numerous applications: transmission of signalling on board trains and autonomous shuttles, as in MASIPRO (see opposite), transmission of maintenance data, and on-board Wi-Fi for passengers, among others. Ongoing research projects include the FRMCS system (see p.40), augmented reality to provide personalized information to customers at stations or to agents in technical centres, and development of the telecoms service delivery model for small lines in rural areas.

Prediction and decision sciences

The SNCF Group relies on data science, applied mathematics, numerical simulation, and artificial intelligence to identify, analyse, and solve decision problems in complex railway systems. These fields offer prediction, optimization, and decision support methods to streamline decision-making in situations of uncertainty including when time is a factor. Whether it is managing rolling stock fleets for new mobility solutions (FLEXY and MASIPRO, described here), optimizing seat allocation on board, or soon, determining investments needed to adapt to climate change (see p.35), the Group increasingly relies on prediction and decision sciences. To simulate real-time operations and predict the consequences of delays as well as to propose incident resolution strategies, it has developed the Olistic simulation engine. This tool can do scenario modelling of routes, assist in optimizing transportation plans in unplanned situations, resolve traffic conflicts, and perform other tasks.

MASIPRO

Mobilité Autonome en SIte PROpre
(Autonomous mobility with dedicated infrastructure)
(funding from ADEME in France 2030)

NEWS IN 2023 During the year, a service pilot operating under real conditions was set up to allow residents of Carquefou and Nantes to use various autonomous vehicles made by several manufacturers and running in dedicated lanes to travel between residential areas, municipal facilities, and public transport.

Need

Develop a high-performance automated public road transport system to provide an alternative to private cars by using repurposed railway tracks, bus lanes, or greenways.

Solution

- Dedicated infrastructure similar to PIOMA (platform for autonomous vehicle testing) to ensure high frequencies and safety.
- Various types of road vehicles with larger or smaller capacities, shared, connected, autonomous (Level 4), and electric (low noise and reduced carbon footprint).
- Unique multi-fleet supervision.
- Stations designed for automated mobility.
- 4G/5G-supported signalling and telecommunications equipment.

Partners

Manufacturers, AD Kit provider, operators, research institutes

Key dates

(subject to France 2030 funding)

- → **2019** – Creation and equipping of a 500-m PIOMA (track, connected lights)
- → **2022** – Extension of the PIOMA to 2 km, testing, data collection, automation of crossings...
- → **2023** – Preparation of a service pilot
- → **2024-2025** – Extension of the PIOMA to 4 km
- → **2027** – Implementation of the service pilot

"Ma Course SNCF" for the 2024 Paris Olympic and Paralympic Games

"Ma Course SNCF" (My SNCF Ride) is an on-demand, shared, door-to-door transport service designed to meet the daily travel needs of residents of rural areas and enable them to reach the nearest train station without a private car. A weekly pass entitles them to four types of trips (Station, Local Shops and Services, Leisure, School), or to an Open Ride at a range of prices. The reservation system is based on a routing and pooling algorithm developed with VIA Transportation and Kisio. The service was successfully tested in five municipalities in the Sarthe from February 2021 to July 2022. "Ma Course SNCF" is being adapted to create another service, "JYVAIS" (I'M GOING THERE), which will be tested during the 2024 Olympic and Paralympic Games in partnership with the Seine-et-Marne department and organizations in the participating municipalities, with authorization from Île-de-France Mobilités. It will provide transport for daily needs and cultural and sporting events as well as facilitate residents' access to the Transilien P line serving the Olympics nautical base at Vaires-sur-Marne. This project was selected in the CEI Territories of New Sustainable Mobility launched by France Mobilités/ADEME.

Mobiliers d'Activation des Mobilités (MAM)
(Mobility Activation Installations)

To propose an economic model adapted to rural mobility, SNCF is not only focused on designing an expanded mobility offer. With SNCF Gares & Connexions and AREP, it is also revolutionizing the reception and information facilities for users of public and shared transport services in rural areas.

NEWS IN 2023 Demonstrators of innovative furniture for transport facilities in rural areas have been installed in the townships of Guimiliau and Plouzévédé (Community of Townships Landivisiau/Finistère). They will be tested for 12 months to measure their impact on residents' travel.

Need
To encourage residents to choose public transport and soft or shared mobility solutions over a car while promoting mutual assistance and combating the isolation of people without means of transport.

Solution
- A range of furniture and related installations to create mobility hubs to develop and make visible transport offers in rural areas.
- Low-cost and energy-autonomous facilities.
- An intermodal offer deployed around these facilities (special bikes, carpooling, hitchhiking, Citroën AMI micro-rentals, walking), and information for travellers at a single point (map of all transport solutions and methods, allocation-centred mapping, walking and cycling times between points of interest in the township).
- Actions to enhance the visibility of the offers, training, and incentives to use these new forms of mobility.
- A joint initiative with local parties (elected officials and residents).

Partners
Kisio, Université de Rennes 2, Guimilia and Plouzévédé townships, the Community of Townships of Landivisiau, Citroën, Mobicoop, KOBOO, CLEM, INGEROP

Two types of facilities:

- A "mobility station," including a shelter for waiting to be picked up and an information display (mobility offer, maps).
- A "mobility pole" for posting local carpooling and hitchhiking information, equipped with a flag, a light to signal a request to be picked up, and a mobile roller to indicate the destination.

These are rounded out with a range of bicycle services (micro-rental and self-service, secure connected racks and boxes, electric bikes, cargo bikes, velobuses, repair stations...) and Citroën AMI cars available without a driving license.

Passenger experience

— Information, ticketing, transport, comfort, safety... the passenger experience encompasses many things. The SNCF Group is relying on technology and the behavioural sciences to enhance it.

TVP NG

NEWS IN 2023 This collaborative research project was launched early in the year to design, test, and develop a new generation of "Track Crossings for the Public" (Traversées des Voies à niveau par le Public – TVP) based on the analysis and understanding of human behaviour. All concepts and technical solutions that could allow rapid implementation are under study.

Need
To make crossing tracks in stations without footbridges or underground passageways safer and reduce the risk of accidents.

Solution
A mixed reality test platform (1:1 physical model and virtual reality) is nearing completion at the Arenberg Creative Mines site near Valenciennes to assess the effectiveness of various concepts and technical solutions on behaviour and to understand the cognitive, physiological, and biomechanical impacts on people. The results will be used to select the best solutions to prototype and evaluate to achieve a new generation of track crossings. This solution will involve:
- Modelling behaviour at crossings using the behavioural, cognitive, and biomechanical sciences (looking, movements, reaction times...)
- Identifying the most effective safety systems (literature and benchmarking)

Partners
L'Institut de Recherche Technologique Railenium, L'industriel SCLE, the research laboratory LAMIH UMR CNRS 8201 of the Université Polytechnique Hauts-de-France (UPHF)

Key dates
- → **2023** – Project launch, online testing, creation of the virtual reality platform
- → **2024** – Virtual reality tests in Valenciennes, validation of principles, concept
- → **2025-2026** – Technical studies, prototyping, and trials in Vaires-sur-Marne

EXPLORATORY RESEARCH

Behavioural and Cognitive Sciences

By using the behavioural and cognitive sciences (psychology, neuroscience, anthropology, etc.), it is possible to analyse travellers and employees' behaviour and their perception of their environment during work or travel. By gaining a better understanding in this way, improvements can be made in areas such as the adaptation of received information (visual, auditory, etc.), atmosphere (staff/customer relationships, facilities, etc.), passenger flow management (redirecting to other modes of transport, positioning on platforms, etc.), and safety (station signage, safety systems around tracks, etc.).

EXPLORATORY RESEARCH

Artificial intelligence

AI represents a revolution comparable to the Internet 25 years ago. In the rail sector, it opens up tremendous prospects for providing better service to travellers and assisting agents in doing their jobs. The images, series of numbers, quotations, and statistics accumulated by SNCF are fed into powerful AI algorithms capable not only of processing these data in large quantities but also of learning to perform tasks and make predictions. The applications of AI are numerous, starting with computer vision. Supported by cameras and LiDAR, for example, it will identify abandoned luggage or count passengers while erasing biometric data (the TNI project, see opposite). Another example: AI will help monitor the rail system by analysing data transmitted by the fibre optic network running alongside tracks (the SURFO project, p. 40). In the documentary field, generative AI will facilitate the use of professional repositories through tools comparable to ChatGPT. To develop dependable uses of AI in railway activities, SNCF is participating in the Franco-Canadian research program DEEL, whose aim is to determine the conditions for certifying this technology to guarantee its safe use in the business world.

TNI

Project for the ethical and intelligent exploitation of video protection data

NEWS IN 2023 Launched in 2019, the TNI project was selected in February for inclusion in the "Data Sharing" category of the Propulse programme (see p. 47). Designed to adapt to changes in regulations, its objective is the anonymization of image and video data, meaning that after processing, no biometric or personal data remains. A Proof of Concept (POC) is scheduled on TER rolling stock to test the implemented technology and possible methods of transmitting data to the ground. In 2023, the developed models were validated, and the legal framework was established to launch field trials.

Need

To exploit videos and images from trains and stations in an ethical manner to obtain useful information for analysis and for the improvement of flows, train fittings, station services, etc.

Solution

- A tool for irreversible anonymization of personal and biometric data.
- A low-cost transmission chain for anonymized data.
- Collection and analysis of travel, consumption, and equipment usage with deep learning (AI).

Key dates

- **2019** – Project launch
- **2020-2023** – Development of anonymization technologies in line with evolving European regulations
- **2023** – Documentary, legal, and juridical validation
- **2024** – POC with TER trains in the Grand-Est region serving as a laboratory
- **2024-2025** – Industrialization

Shield4Crowd

NEWS IN 2023 Shield4Crowd is a European joint project coordinated by the SNCF Group that was launched at mid- year. It brings together European security specialists to identify the best crowd management solutions in urban environments for addressing diverse threats.

Need

To research technological solutions, currently in the early design stages (TRL 3 to 5), to better protect public spaces in the European Union against security threats related to crowd management. These threats include terrorist attacks in public places, drone threats, panic at crowded events, risks related to densely populated areas, threats from bladed weapons and firearms or unattended objects.

Solution

- Compare scenarios and risk management methods in urban environments across the entire security chain (prevention, detection, real-time analysis, resolution, post-event investigation).
- Analyse the market to identify R&D projects and future technologies capable of addressing ten identified priority use cases.
- Launch an Open Market Consultation, where companies present their solutions.
- Select a use case to launch an R&D procurement project that would then be funded by the European Commission.

Partners

French Ministry of the Interior and Overseas, Spanish and Slovakian interior ministries, Polish Platform (Poland), Muxley and Safe (France), ISEM Institute (Slovakia), DigInnov (Italy), Corvers (Netherlands)

Key dates

- **August 2023** – Project launch
- **January 2024** – Closure of the CEI Shield4Crowd
- **May 2024** – Open Market Consultation
- **July 2024** – Project closure
- **November 2024** – Calls for PCP proposals by Horizon Europe

Nudge Fragilité

In April 2023, Keolis Caen Mobilités tried out a "nudge" programme designed to encourage people with mobility issues to be more mobile. The idea was to reassure them at each step of the way and promote mutual assistance on board. How? By creating a zone at the bus shelter where they could get positioned for easy boarding, by reassuring them with stickers on board, and by making clear the location of priority seating. Cardholders were also provided to help them signal to the driver and encourage other passengers to give up their seats. The results were promising: a 6% increase in satisfaction upon boarding, 5% when seated, and 4% upon disembarking.

TER JustoGo

TER JustGo, designed and developed in collaboration with SNCF Connect & Tech, is a new pay-as-you-go payment and fare system in use in the Nouvelle-Aquitaine region since October 2023. After activating geolocation on their SNCF Connect mobile app, the customer registers his trip with a single click upon boarding and disembarking from the train. The app detects and validates each journey, and the user is only charged at the end of the month at the best rate. This solution could be introduced in other regions based on decisions of the Mobility Organizing Authorities.

How SNCF is doubling the modal share of rail

Christophe Fanichet,
CEO, SNCF Voyageurs

The finest illustration of our ability to transport more passengers in the future is obviously the arrival of the TGV M, a cluster of technical, energy, and service innovations that will enable us to provide excellent service to more customers. It will have a larger capacity – up to 740 seats instead of a maximum of 600 today; it will be modular to adapt to the number of passengers (seven, eight, or nine cars) and in terms of interior layout; and it will be accessible to all. With the lowest carbon footprint on the market, our future TGV M will be a major asset in making the train more appealing.

But innovating to transport more passengers is not exclusive to the high-speed realm; it is also at the core of our efforts to meet the challenges of mass transit. The RER NG, which operates in the Paris region and is even more spacious and open, improves the daily lives of passengers, offering better accessibility and a smoother transition between the platform and the train. Regional and metropolitan express services are being developed in all regions to better serve population basins, to strengthen links between metropolitan areas and suburbs by increasing the offer and frequencies, and to rethink multimodality as a unified whole around the rail backbone. In less populated areas, a range of new – and it is fair to say revolutionary – vehicles, infrastructures, and services adapted to rural mobility are being tested. They include innovative solutions such as the TELLi Light Train, the very light train DRAISY, the FLEXY rail-road shuttle, and MASIPRO, the autonomous public transport service pilot that will be tested near Nantes. These innovative solutions make possible new transport models adapted to the specific needs of each area. Innovation gives us choices, allowing us to tailor rail mobility for each region.

> With the lowest carbon footprint on the market, our future TGV M will be a major asset in making the train more appealing.

The other area of innovation is simplifying the customer journey. In 2023, we launched "Just Go", a pay-as-you-go solution with geolocation support that is a joint initiative of the Nouvelle Aquitaine region and SNCF Connect & Tech. TER passengers click on their mobile app when boarding and disembarking from a train, and only pay for their journeys at the end of the month. Ninety-five percent of those who tested it adopted it. All of this is very motivating. All these innovations are enabling us to offer sustainable and inclusive mobility solutions and true alternatives to private cars throughout the country.

How SNCF is doubling the modal share of rail

Developing the railway offer to meet French and European goals relies on the renovation and modernization of the existing network. We are accordingly very focused on innovation. Digitalization is key both to a more robust and higher-capacity network, as evidenced by the deployment of Centralized Network Commands, ERTMS, and NExTEO, as well as to the optimization of surveillance and maintenance methods. Artificial intelligence, data, and the Internet of Things are thus fully integrated into all our activities on a daily basis.

Digital innovation for the network is also a means of increasing its resilience and strengthening its ability to withstand climate change. With Toutatis, we monitor flood risks for earthworks and with Platipus, the risks for structures at aquatic sites. We measure snow depths in the Massif Central or rail temperatures on the Southeast high-speed line thanks to sensors. Digital and predictive technologies provide solutions, so having an excellent command of data is essential. Technical innovation is just as crucial. Welded long rails, which equip 85% of the main network, have drastically reduced track deformation. Installation of 1500-V catenaries and a modified counterweight system to make them more heat-resistant will be gradually deployed on 5,700 km of rail lines.

Innovation in the rail network helps reduce its carbon footprint. Today, we give a second life to 50% of track materials through recycling or reuse, and we will be aiming for 100% in the coming years. We are also working on signalling and power supply. As for network modernization, it naturally brings solutions that increase the energy efficiency of the rail system by reducing line losses and improving energy transmission and storage capacities.

To move quickly towards the industrialization of solutions that will revolutionize the way we operate, we rely on collaborative innovation with members of the Rail Open Lab: the Federation of French Industries (FIF), RATP Infrastructures, and the companies in the energy and digital transition network (SERCE).

Matthieu Chabanel,
CEO, SNCF Réseau

> Digital innovation for the rail network is also a means of increasing its resilience and strengthening its ability to withstand climate change.

As the exclusive manager of the 3,000 French railway stations, we play a central role in the mobility of the French. Our ambition is to be the linchpin of intermodality while addressing environmental challenges.

Marlène Dolveck,
CEO, SNCF Gares & Connexions and Deputy CEO of SNCF Group in charge of transformation

The development of Regional and Metropolitan Express Services (SERM) is turning stations into mobility hubs. We launched a "showcase" project of our expertise as an intermodal developer in Libourne. Promoting intermodality also calls for providing travellers with complete and reliable information. Our "LIVE" tool will display all departure and arrival schedules for all modes of transport connected to stations (buses, trams, subways, etc.) on a single board. This is already the case at the Toulouse-Matabiau station, which was renovated and modernized in 2023 and which now features XXL intermodal information displays. Our stations are increasingly connected owing to the arrival of 5G, real-time equipment monitoring, and other developments, and our goal for the station of the future goes much further. With the "European lab station" project at Paris-Nord, innovative services and digital solutions designed to enhance the customer experience will soon be tested. We are also working on the resilience and adaptation of stations to climate change. With our subsidiary AREP, we are revolutionizing the design and construction of railway stations. Studies for Europe's first bioclimatic station have been launched. They will be vital to the construction of the future station at the Nice airport. Its structure will be integrated into the environment, its spaces will be eco-friendly, and solar panels installed on the canopy will generate renewable energy. The energy transition is happening at train stations for everyone in France, and photovoltaics play a central role in our strategy.

We have nearly one million square meters of land to produce solar energy. Thanks to our partnership with Tenergie, over 100 station parking lots will be covered with photovoltaic canopies by the end of 2024. We are focusing our energies on the rail transport mode to make it the backbone of sustainable mobility.

> With our subsidiary AREP, we are revolutionizing the design and construction of railway stations.

How SNCF is doubling the modal share of rail

Marie-Ange Debon,
Chairwoman, Keolis Group

Keolis operates transport networks for 300 Mobility Organizing Authorities in 13 countries. Its expertise covers all modes of transport – urban, suburban, and interurban, including metros, buses, coaches, trams as well as maritime and river shuttles. We are present across the entire mobility chain: on-demand transport, long-term and self-service bike rental, parking facilities, both inside structures and on the street, and carpooling. This multimodal know-how anchored in the regions constitutes an incredibly rich resource for innovation, whose one clear goal is to develop effective alternatives to single-occupancy car use. Our approach is based on two major transitions: digital and ecological.

Thanks to digitalization and data, we will improve our services in terms of accessibility and personalization. In line with our "Think like a passenger" approach, Mobility as a Service (MaaS)* solutions, which are incorporated in the new Transport Bordeaux Métropole network app and the DiviaMobilités app in Dijon, integrate all mobility services, both public and private, in the area to deliver a better passenger experience.

We also innovate to enhance inclusion on board. In Rennes, Keolis partnered with Someware to integrate the Handimap, a pedestrian guidance solution for vulnerable travellers, into the STAR app. In 2024, additional algorithms will assess the "walkability" of stops on future Rapid Transit Bus lines in the city.

In the Netherlands, Keolis uses generative artificial intelligence to communicate in real-time with passengers when there are service disruptions. On the Yarra Trams network in Melbourne, it has applied the floor cooling product CoolSeal at the Federation Square tram station to improve passenger comfort and facilitate the work of Keolis Downer teams when there is extreme heat.

> Our approach is based on two major transitions: digital and ecological.

Last, to meet the high expectations of our Mobility Organizing Authorities, we are working on new solutions to support the energy transition such as retrofitting thermal buses and coaches with more ecological types of power, including electricity. The retrofitted electric coaches now operating in the Porte de l'Isère metropolitan area in France are a good example. Because it is committed to contributing to a sustainable future, Keolis is continually pushing the boundaries of innovation to reshape sustainable mobility.

** Mobility as a Service: The concept of planning, booking, and paying for an intermodal journey on a single digital platform.*

Frédéric Delorme,
CEO, Rail Logistics Europe and Fret SNCF

To promote modal shift, rail freight must gain agility, reliability, and capacity. In this regard, digitalization opens up vast opportunities for us. Exchanging data is fundamental to innovation projects in the rail freight sector because the more partners exchange data, the better they will be able to offer end-to-end, high-quality services to their customers by providing them with reliable information.

Rail Logistics Europe is therefore launching an internal initiative in the form of a digital ecosystem to improve data exchanges among all involved members of the group as well as with our main external partners and clients. This ecosystem will be built iteratively, with the first steps taking place in 2024.

Innovations to accelerate train formation and enhance the safety of train operations by digitalizing train preparation (brake tests, composition, etc.) are also crucial. I am thinking concretely of technical monitoring with sensors on trains and digital automatic coupling (DAC), on which we are working within Europe's Rail. The data collected will also constitute a form of "digital twin" of the train, and it will be fed into our future digital ecosystem mentioned above.

Some of the efforts can thus be redirected towards improving other services, such as enhanced train integrity monitoring.
But accelerating these operations will also, and above all, increase network availability, a key issue for the rail system. Furthermore, customers want to be advised in case of delays and informed of the new expected time of arrival (ETA). The exchange of data, including GPS data, is necessary to do this when multiple railway companies are involved in the transport service. Our ability to deploy data exchange standards at the European level will be crucial.
The other challenge will be to build adequate public-private partnerships in view of the investments that will be required.

> Data exchange is at the heart of innovation projects in the rail freight sector today.

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