TECH4RAIL

A VISION OF THE RAILWAY SYSTEM OF THE FUTURE

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TECH4RAIL

EDITORIAL

In the 21st century, mobility is being transformed, is being redefined. Customer expectations are increasing; travellers and shippers are demanding greater quality, individualized service at lower costs, and all in complete safety.

With the proliferation of mobility offers, the train must reinvent itself to become more frequent, more flexible, more reliable, cleaner and more competitive, as well as fully integrated into the mobility landscape of the future.

New technologies are beginning to invest the railway sector: digitalisation, automation, big data, internet of things, robotics. Artificial intelligence, autonomy, new computer powers and energy technologies will certainly also be part of the system of tomorrow.

Building on these basic observations, SNCF wanted to assess how these new and disruptive technologies might bring about progress in the rail system as a whole. This is the origin of its TECH4RAIL program, which aims to boost the rail system through innovation.

Rail system is here understood to mean all the elements that contribute to providing services using this mode of transport, from their design to their implementation, in response to what customers, passengers and shippers want. The emphasis here is on the industrial aspects of this system which, while essential to the nature, the quality and the reliability of the services on offer, are relatively unknown to the general public

All these aspects inform our vision of the rail system of the future. Its success will depend on the mobilisation of new skills and all of our talents, as well as on open and innovative partnerships. This vision is first and foremost about meeting customer needs. And it is to be combined and enriched with the opportunities that the other actors in the sector are exploring, in France and, of course, across Europe, which will be the natural arena for the deployment of a thoroughly revamped system.

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SNCF

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IN THE FACE OF THE PROFOUND UPHEAVALS WITHIN MOBILITY, THE RAIL SYSTEM MUST REINVENT ITSELF

RAIL TRANSPORT IN FRANCE AND EUROPE MUST FACE A PROFOUND REVOLUTION IN MOBILITY

+ Today, customer demands are greater and are pushing railways to reinvent their offer in order to make door-to-door travel simple and personalised (from trip preparation to ticketing and real-time information), offering a fluid and comfortable connection between modes of mobility. And this for both passengers and freight shippers.

+ The migration of value from hardware to software is bringing new mobility players who display greater agility to the forefront and is threatening railways through business models based on powerful and direct customer relationships. In addition to this competition from new entrants, there is the opening up of the rail transport market (2019-2023) and an increasing questioning of its relevance.

+ The acceleration of urbanisation creating a capacity challenge for traditional transport networks.

+ The French rail system, despite its leading position in Europe (second largest with 1.2 billion passengers per year and first in High Speed rail) and the profound transformations it has undergone in recent years, is facing deep-rooted structural difficulties: ageing infrastructure (average age over 30 years), unbalanced use of the network (80% of passenger trains run on 27% of the network), as well as a complex and under pressure system, particularly in the area of mass transit.

+ Its model is also being called into question because of the public debt crisis which limits financing prospects in a context where the system needs substantial investments to modernise.

NEW TECHNOLOGIES: AN OPPORTUNITY TO TRANSFORM THE RAIL SYSTEM

Major technological breakthroughs are impacting transport business models, but are also providing new opportunities to modernise and transform the rail system. The emergence of robotics and autonomy will allow on-demand trips, more door-to-door journeys and greater flexibility, as well as increased performance through better repeatability of service performance.

The revolutions in computing (High Performance Computing, edge computing, quantum computers, blockchain) coupled with those in telecommunications (5G, C/V2X, LTE-M) are going to open up new perspectives for dematerialising the rail system and accelerating data exchanges and processing, particularly between the trackside and the trains themselves.

Artificial Intelligence (AI), combined with big data and the Internet of Things (IoT) are going to impact the nature of services, production processes and customer relations:

+ Big data creates a new ability to capitalise on internal and external knowledge to improve operations and the customer experience.
+ The Internet of Things connects all elements inside and outside the system to a shared communications and data network. It has many relevant applications, from predictive maintenance to safety.
+ Artificial intelligence is a powerful lever for dealing with the increasing complexity of the system by developing algorithms for real-time management of assets and traffic, as well as tools to help revamped decision-making that is more cognitively based.

The development of these new technologies also calls for a mastery of new challenges, especially those related to passengers security and cybersecurity.

New threats as well as opportunities are emerging in all areas of the rail system. In densely-inhabited areas, rail suffers from an ageing infrastructure and a congested network which threatens to harm its competitiveness in the face of new forms of mobility: it must improve its reliability, its resilience and increase its ability to offer quality broadband.

In less populated rural areas, rail has a fragile economic model and reduced relevance when it comes to the door-to-door journey compared to the current car and the autonomous car of tomorrow: it will thus have to open up to new solutions such as light shuttles on demand or low-cost rail models.

High Speed, although a particularly attractive offer for rail, is unevenly profitable: it must enrich its value offer, work on its cost model, and offer more capacity on key routes.

Freight transport, in a context of a decline in heavy industry (which was its major area of relevance) will have to find its growth drivers in services to major ports and multimodal transport. Rail freight plays out on a continental European scale. Its competitiveness is based on cost reduction and the search for new alliances, but also on the performance of the system: capacity, nodes management, long-distance train slots, etc.

TACKLING CHANGES IN MOBILITY, EMERGING THREATS, AND USING NEW TECHNOLOGIES TO TURN THEM INTO OPPORTUNITIES,
THE RAILWAY SYSTEM MUST UNDERGO PROFOUND CHANGES IN THE COMING DECADES.

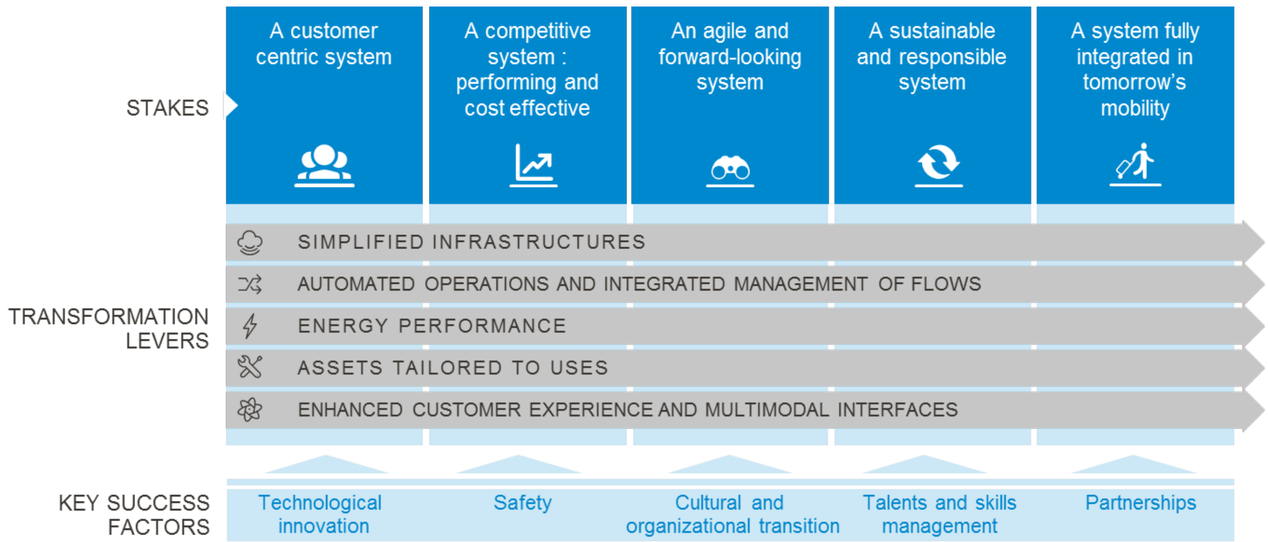
Consequently, SNCF, as a Public Rail Group, wishes to set out its vision of the rail system of the future, which is structured around:

Five issues that are crucial to the target to be reached by 2030-2040

Five levers of transformation, which will prepare the way forward, with particular emphasis on technological breakthroughs

Key factors on which a successful transformation will depend

VISION OF THE RAIL SYSTEM OF THE FUTURE



› 02

FIVE CHALLENGES FOR THE RAILWAY SYSTEM BETWEEN NOW AND 2030-2040

OUR AMBITION

TO BUILD FOR OUR CUSTOMERS A COMPETITIVE, AGILE, SUSTAINABLE RAIL SYSTEM, FULLY INTEGRATED INTO TOMORROW'S MOBILITIES.

A CUSTOMER-CENTRIC SYSTEM

The rail system of the future places the customer at the heart of its priorities – passengers and shipping customers. It must guarantee the reliability of the service provided – safety, reliability, availability and resilience – at a competitive cost. For travellers, it must offer greater frequency, especially in densely-populated areas. The system must also bring fluidity and simplicity: the result should be a door-to-door journey for customers, thanks to digital tools that facilitate transitions between modes of mobility and offer optimised routes. The customer experience will be enriched by personalised, digital customer relations and improved on-board comfort. The railway system will transmit clear, real-time information to the customer, positioning itself as a "partner in people's lives" and a facilitator of their mobility. The rail system must be capable of improving continuously thanks to feedback from its users, thus giving them the ability to be actors in the system.

A COMPETITIVE SYSTEM : EFFICIENT AND COST-EFFECTIVE

In order to restore its competitiveness, rail must first make strong strategic choices to target its investments in its areas of relevance, i.e. those segments where rail offers a higher value proposition than its competitors – for example by increasing capacity in dense urban areas and on the TGV segment, by increasing station capacity on these same segments, by new offers or new low-cost models on less attractive segments, etc. The system must also significantly reduce its investment, operating and maintenance costs for both passenger and freight.

Maximising the utililization of assets through better use of the network, rolling stock and facilities will also reduce costs. Finally, the system will seek alternative sources of financing in a context of reduced public subsidies and heavy rail debt, specifically via new business models like data valorization.

AN AGILE AND FORWARD - LOOKING SYSTEM

The rail system of the future must be more agile. This involves simplifying all its components with standardized equipment, simplified operations and less cumbersome operating rules. Its modernisation must also integrate the necessary migrability of technologies, to accelerate transitions and limit their expansion. In addition, the system must be managed flexibly and responsively, and also be reliable and resilient in the face of disturbances. Finally, innovation must be facilitated and the time to market of innovations accelerated.

A SUSTAINABLE AND RESPONSIBLE SYSTEM

The rail system must meet enhanced safety and security requirements, including cybersecurity. It must also continue to fulfil the public service mission assigned to it and guarantee accessibility for all its customers. The rail system must also be able to limit its resource consumption and carbon footprint, by improving its energy performance and developing eco-design methods. Reducing negative externalities (decarbonisation, polluting emissions, noise, vibrations, etc.) will make it possible to build an even more environmentally friendly rail system that is even more relevant to other modes of transport. Finally, the business transformations induced in particular by new technologies must be anticipated and supported.

AN SYSTEM FULLY INTEGRATED INTO TOMORROW'S MOBILITY

The rail system of the future must be integrated into a global mobility offer that provides customers with a door-to-door, smooth and multimodal journey. This will require the integration of information sources outside the system to enable supply to be matched to demand proactively and in real time.
Finally, stations must be redesigned to become real hubs incorporating services and all the new forms of mobility on demand.

› 03

FIVE TRANSFORMATION LEVERS PAVE THE TECHNOLOGICAL WAY TO OUR TARGET

SIMPLIFIED INFRASTRUCTURES

The rail system suffers from ageing infrastructure, is sometimes very ill-suited to current needs and is subject to high levels of technological dispersion. This makes operations costly, while capacity, resilience and flexibility issues are prevalent. At a time when investment needs are high, simplification is essential to the system's competitiveness – performance and an ability to operate at reduced costs on the one hand, and the system's agility and focus on the future (enabling it to integrate future developments and technological transitions) on the other.

This simplification has four main aspects.

01- Dematerialised signalling, the heart of the ETCS (European Train Control System), is a key performance element. While ETCS level 2 allows significant lightening of track equipment, it is at level 3 that gains will be maximised, in terms of costs, availability (through a radical lightening of track installations) and capacity – in that it makes it possible to free the system of fixed blocks.

The network will therefore aim in the short term at the ETCS level 2 standard, with systematic level 3 compatibility, as well as working toward level 3 deployment as soon as possible. The smooth migration of the current system must be ensured.

For the lines serving the less busy parts of the country, the aim will be to enable the emergence of economically sustainable traffic command-control solutions with differentiated service levels adapted to the diversity of these situations and user needs.

In addition, the development of digitalised signal boxes, based on new kinds of interlocking that are less dependent on the physical infrastructure will be another key element of the process of dematerialisation.

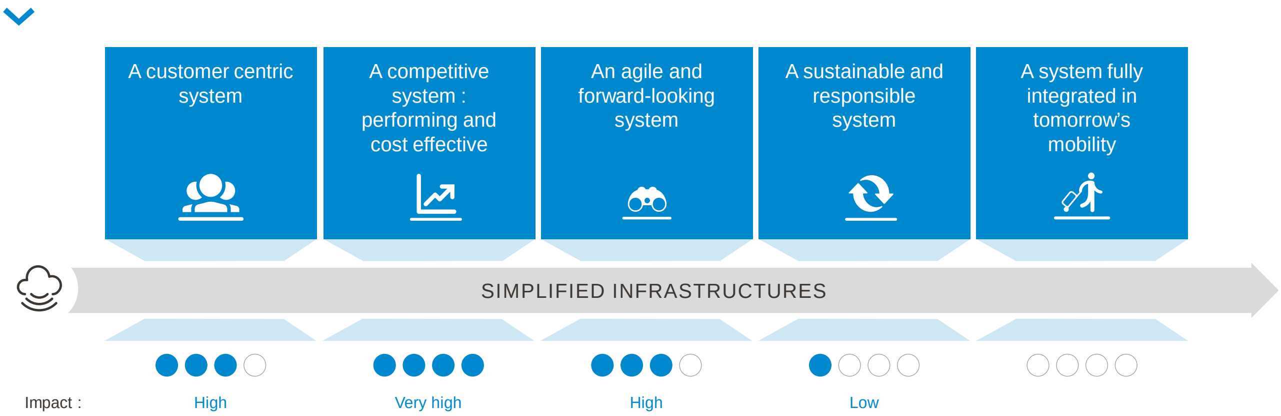
Finally, beyond ETCS Level 3, the search for additional capacity gains through virtual coupling or performance gains through more wide-scale dematerialisation will have to be investigated.

02- Fail-safe localisation of trains: localisation allows the process of signal dematerialisation to be pushed to its logical conclusion by the removal of the various means of track-based detection, which are major sources of maintenance costs and downtime. It is also an essential functional building block of the rail system of the future, making possible the end of fixed blocks in favour of more thinly-spread or mobile virtual elements, the autonomous train, a more fine-grained flows management as well as the improvement of customer information services.

03- A reliable, robust and powerful set of interconnected telecommunications networks will be necessary for all connected systems and objects to be able to communicate. The standardisation of telecommunications systems will be a major challenge, and railways will have to be able to exploit the short technological cycles of the telecommunications sector. This will involve the use of available or emerging technologies (IP protocols, 4G / 5G, V2X or C-V2X, satellite, etc.) The use of public terrestrial and satellite networks, in addition to the networks themselves, will have to be developed in order to maximise the coverage and reliability of the system and reduce the physical infrastructure.

In addition, cybersecurity will be a major challenge to ensure system integrity.

04- To go even further, the simplification of the network and its operating rules, particularly at railway junctions, must be systematised. On the one hand, the simplification of track layout and the reduction in the number of switches will make it possible to reduce maintenance costs, simplify signal boxes and improve traffic flow. On the other hand, the rationalisation of operating rules and the harmonisation of local specifities will be essential to unleash the full operating potential of this lighter infrastructure.



AUTOMATED OPERATIONS AND INTEGRATED MANAGEMENT OF FLOWS

Going beyond train traffic management, the rail system of the future will take into account, in a holistic way and in real time, all flows crossing it: trains, material resources, train slots and employees, but also passenger flows and track occupancy graphs in stations, as key links operational chain. In a "hypervision" approach to mobility, other modes of transport can also be seen as a potential resource, especially in the event of disruptions. Operational breakthroughs will be brought about by the use of automation, in trains as well as in supervision, and by the incorporation of artificial intelligence into decision-support algorithms that exploit in real time the data transmitted by the interconnected elements of the system.

Several issues will thus be addressed :

01- The reliability of the system, thanks to increased resilience. Achieving this will involve three key building blocks to be developed in parallel: ETCS, Traffic Management System (TMS) and Automatic Train Operation (ATO);

02- Customer satisfaction, since better management of traffic should enable passengers to be provided with better punctuality and comfort during their journey;

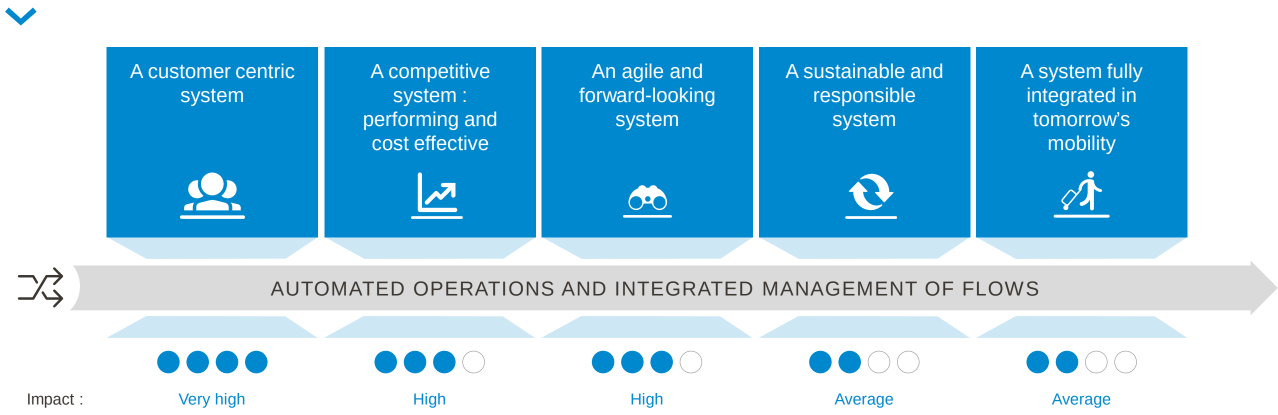
03- Economic competitiveness through increased network capacity and real-time adaptation to demand made possible by automation.

The deployment of an intelligent Traffic Management System aims to move from assisted traffic regulation to flow management, made possible by knowledge of the overall state of the system, and by real-time data collection from infrastructure managers and mobility operators alike. Data analytics and AI provide opportunities to predict and simulate future situations and facilitate decision making in complex situations where the parameters are numerous and the optimal solution for the system is not necessarily a return to the originally-intended situation. The transformations brought about by these technologies must take into account the cognitive capacities of employees and a human-machine relationship that must be reimagined.

The autonomous train (ATO) is the second major game changer to be addressed (in parallel to the intelligent TMS) in order to transform operations. Depending on the segment of business, the ATO can be deployed in GoA2 mode, automatic driving with driver, up to GoA4 mode, i.e. completely autonomous driving. Automation is a response to line saturation and makes it possible to run more trains with a constant level of infrastructure. In addition, the optimisation of traffic speed and better compliance with the schedule contribute to a better service for the customer. In GoA4 mode, the simplification of resource management is a source of agility and flexibility, leading to greater competitiveness in markets such as Freight or Regional train services. Several challenges remain to be met, in particular concerning obstacle detection, environmental monitoring, precise geolocation and the establishing the safety of the automatic train.

While intelligent TMS and ATO can achieve significant gains in system performance and agility, it is through the integration of ATO, highly automated TMS, and ETCS that maximum leverage effects will be achieved. The major challenge will be the interaction between subsystems. Thus, on-board automation means train behaviour can be predicted by the infrastructure, which is also capable of integrating real-time mobile performance data and traffic status information. The overall optimisation of operations will result in instructions being issued to mobile systems. This alchemy, which will divide in a new distribution of intelligence both on board and on the ground, is the fundamental factor in the optimisation of the system.

The collaboration, already ongoing, between the European railway actors will be crucial to ensure the success of this TMS+ATO+ETCS integration process.



ENERGY PERFORMANCE

The energy bill for train haulage approaches 800 million euros annually. The global energy market is subject to multiple pressures: strong instability in traditional energy financial markets, policies that strengthen regulations and a civil society increasingly engaged on sustainable development issues. These expectations also constitute a dynamic conducive to innovation: new energies, technological proliferation, new services and businesses offered both by the energy majors and by new players.

This area of transformation aims to make energy a driver of the rail system's performance and to engage the SNCF Group in an energy transition approach. It will also make it possible to support the development of new forms of mobility.

3 core technological issues must be addressed

1) electricity storage – this is becoming a reality –
2) smart grids with active grid management, and finally
3) research into new energy sources, in particular hydrogen.

Electrical storage on the network is a solution that makes it possible to strengthen substations to ensure train regularity at peak hours.

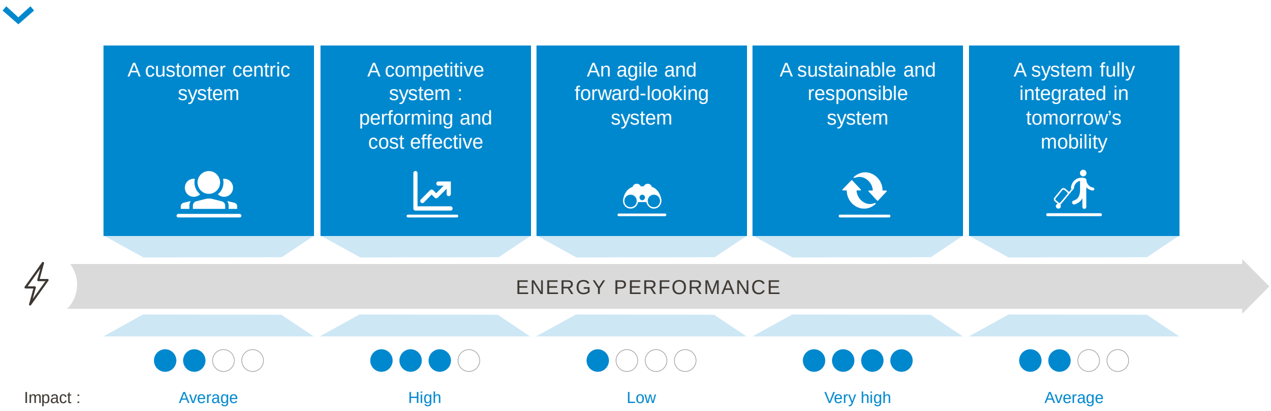
It meets cost and implementation time requirements in addition to other solutions such as parallel stations, feeders, or the creation of a new substation. Several technologies can be implemented according to the circumstances of use (super capacitors, batteries, flywheels).

Storage will also be developed on board the trains. This is a first step towards the gradual replacement of diesel through the hybridisation of trains. These hybrid trains will reduce energy consumption by 20% while also reducing CO_2 emissions. Storage will also recover braking energy and will therefore contribute to the energy efficiency of the rail system. It will also guarantee the operation of auxiliary equipment in the event of overhead line breakage to ensure the comfort of customers in disturbed situations (lighting, air conditioning, etc.).

The operation of fully or partially energy autonomous trains is a solution to reduce electrification costs by avoiding the need to equip costly single points like bridges, tunnels.

Energy management will increasingly rely on dynamic supply and demand management. This active management is imposed by three strong constraints: energy price volatility, differences between forecasts and actual consumption, and the intermittency of production associated with renewable energies. These temporal and spatial variabilities require active management based on the use of powerful digital tools and the implementation of systems capable of performing a balancing function, through storage, energy exchange with other actors or through consumption modulation. For example, the replacement of generators by batteries, in addition to ensuring the backup of railway installations, will allow, through active energy management, the implementation of new services (peak shaving, load leveling).

In the longer term, new sources of energy supply will have to be considered, favouring renewable energies. The hydrogen market is taking off worldwide and represents a serious alternative to diesel by 2040. Its production is imaginable in electrical substations during their off-peak period; this network would constitute, by virtue of being located throughout the country, the backbone of a local supply of green hydrogen in the service of, for example, other mobility systems. It would thus open up new economic models that could be evaluated with partners from the energy sector.



ASSETS TAILORED TO USES

The life cycles of rolling stock and infrastructure are long, both in terms of time to market and service life. Maintaining them in good condition for the entire duration of their ownership remains restrictive and costly. As a result, assets must improve their flexibility due to very fast pace of technological developments expected by customers and adopted more rapidly by competing modes of transport.

Reinvented maintenance and monitoring will meet the agility and competitiveness challenges: self-monitoring equipment and infrastructure will continuously monitor their "well-being" through a network of sensors and associated data analysis;

+ Human interventions, assisted by automation and robotisation, will then be reduced, thanks to the development of predictive maintenance;

+ The system will anticipate and facilitate repair work, in particular via intelligent diagnostic tools. Developements of Internet of Things is furthermore an opportunity to reinforce safety systems.

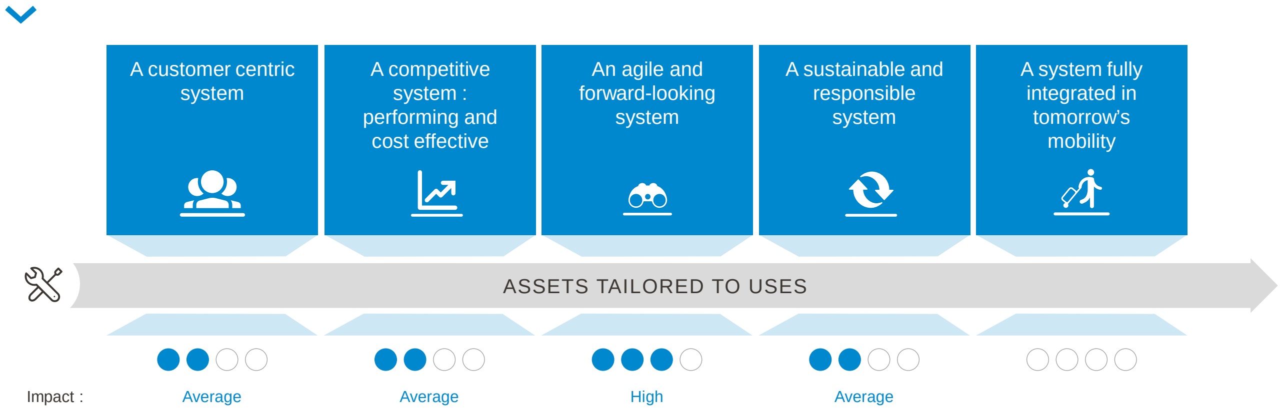
+ Modular design modes and component standardisation will contribute to system agility and competitiveness: designed as a set of interchangeable plug and play elements, modular components will allow more flexibility, simpler integration of new technologies and shorter development cycles.

+ Integrated modular avionics (IMA), recent trend in avionics is a technology that could enhances safety and reliability of computing systems also in railway sector.

+ Digital twins, which make it possible to recreate the entire system and its objects in a shared and modifiable virtual space, will constitute a real transformation via the digitisation of design and production processes, virtual simulation as well as testing and real-time digital operation. In addition to computerised and optimised maintenance, they will thus enable development cycles to be accelerated.

Rolling stock will be redesigned, once again with modularity as a guiding principle, to optimise carrying capacity (seasonality, weekday/weekend, etc.), while enriching the customer experience by adapting facilities over time to their needs and developing eco-design, life cycle management and circular-economy approaches. Equipment performance will be optimised with increased acceleration/braking capabilities to meet capacity requirements on saturated lines and junctions.

In order to develop new mobility systems, new mobile units will also have to be designed.



ENHANCED CUSTOMER EXPERIENCE AND MULTIMODAL INTERFACES

While constantly striving to produce an offer that is as closely suited as possible to customer needs, the rail system must be integrated into the multimodal landscape that is emerging, particularly with the arrival of new autonomous modes of mobility:

The deployment of an integrated, multimodal customer service and traffic management platform is a major challenge in a context of value migration where the ownership and exploitation of data and the ability to offer a comprehensive offer along the travel chain are key elements. The objectives of comfort and fluidity along the route will be met by personalised planning solutions, real-time multimodal information and door-to-door services.

The issue is incorporating existing platforms into the railway system per se, since in the long term the goal is to provide a real-time matching of the transport offer with the immediate or scheduled customer demand.

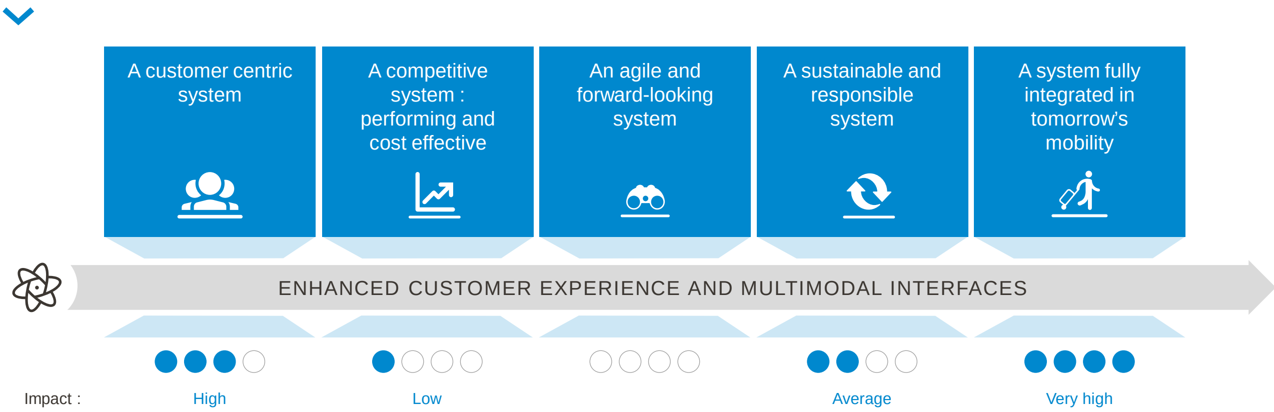
Rethinking the areas where rail is relevant to the development of new forms of mobility could lead to a revisiting of the transitions between modes, for example between dense areas where rail is extremely relevant and less concentrated neighbouring areas, where new autonomous on-demand modes of mobility could develop rapidly.

New multimodal passenger hubs, designed to ensure smooth travel for all passengers, will be created. In order to design these hubs, a detailed management of passenger flow forecasts must be carried out to take account in particular of the physical constraints of the areas concerned; for example for the management of connections between rail - high capacity- and other lower-capacity -or even personalised- modes of travel.

Security is becoming a key issue particularly in mass transit that can be enhanced by new technologies while safety feeling of passengers can be worked on by improving comfort on board trains and in stations.

Safety at level crossings must be reinforced by technological innovations, while the necessary preventive measures must continue to be carried out. The first step is to equip crossings with detection systems, sensors, IoT and connectivity systems. In this area, sourcing of technologies from other sectors is a necessity in order to optimise deployment and maintenance costs.

In addition, since drivers' behaviour is a central element of safety at level crossings, one of the major levers for improving system safety is to transform level crossings into intelligent junctions capable of communicating with connected cars and, in the longer term, autonomous vehicles. In this area, the communication technologies developed for autonomous vehicles (5G, C-V2X) are particularly promising.



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› 04

FIVE KEY FACTORS WILL DETERMINE THE SUCCESS OF THE RAILWAY SYSTEM OF THE FUTURE

SNCF

THE SUCCESS OF THE RAILWAY SYSTEM OF THE FUTURE WILL BE DETERMINED BY THE IMPLEMENTATION OF FIVE KEY SUCCESS FACTORS THROUGHOUT ITS TRANSFORMATION.

TECHNOLOGIES AS CORNERSTONE OF FUTURE RAILWAY SYSTEM

The digital transformation that has already begun requires the definition and implementation of certain fundamental technological priorities. To accelerate this process of migration, railways must open up to other industrial sectors in which new technologies have been tested, or even have long been in use.

The fields of the Internet of Things (IoT) and of Data Science, in particular, are key technologies for increasing the capacity for heterogeneous data collection, analysis and exploitation, to the benefit of the efficiency of the sector. This will also require new computing power.

The development of artificial intelligence will make it possible to build predictive tools and decision-support tools for the development of automation for operations, hypervision, traffic management, maintenance, and of course customer relationship.

Diversified, solid and interconnected telecommunications networks will be required to ensure the transmission in real time of the data exchanged by all the interconnected objects in the rail system. Meanwhile, cybersecurity issues will have to be constantly addressed.

The coexistence of automatic and human systems will lead to the reinvention of new human-machine interfaces and will require cognitive issues to be taken into account in the design of technical systems.

NEW METHODS FOR SAFETY

The introduction of new technologies, which will necessarily lead to the systems being designed in a different way and will give increasing importance to software, will have to incorporate the requirement for absolute safety, which is an essential feature of rail transport.

However, the technical means to ensure and demonstrate safety will have to be rethought. Architectures based on the redundancy of simpler devices, including IoT, increased use of simulation and formal methods, for example, have to be developed.

Finally, rail will need a cybersecurity strategy in order to be resilient to cyberattacks, to ensure the integrity of the data exchanged as well as compliance with the current and future regulatory framework.

CULTURAL AND ORGANISATIONAL TRANSITION

Faced with new players and in order to cope with their agility and innovative business models, railway organisations have to make profound cultural and organisational changes. In particular, it will be necessary to bring about a culture of performance driven by an ambitious vision and an increased awareness of the imperative of competitiveness.

To accelerate innovation and the migration of railway technologies, more open and agile methods will have to be implemented. The earliest possible use of demonstrators ("try and learn") will allow the evaluation of the potential of technologies but also the conditions for their industrialisation (investments, transitions between technologies, associated business transformations). Collaborative, multidisciplinary and risk-taking approaches must also be developed.

TALENT AND SKILLS MANAGEMENT

The integration of new technologies is transforming jobs with profound changes, driven in particular by the digital revolution, which is changing the boundaries between traditional professions.

Identifying the key competencies for the future is a major issue for industrial and services companies. Attract new talents and new skills is a challenge for the railway industry.

Faced with the increase in automation, the role of humans will have to be rethought and a coherent path through the transformation process will have to be devised for employees.

SUCCESSFULL PARTNERSHIPS

The implementation of such a vision can only be achieved in an open ecosystem with a shared vision. Rail operators and industrials must therefore pursue their collaboration, while at the same time opening up to technological partnerships with other industrial sectors, sources of low-cost solutions (automotive, etc.) or high-performance solutions (military, aeronautics, nuclear, etc.).

Relevant partnerships should also be sought out in order to bring new sources of funding to the rail sector.

Finally, the alignment of technological choices between players in the rail sector will be essential to create the relevant norms and standards for the rail system of the future at European level. From this point of view, the EUAR and Shift2Rail are two indispensable partners.

« To build for our customers a competitive, agile, sustainable railway system that is integrated into tomorrow’s mobilities »