RAIL 2050 VISION

RAIL - THE BACKBONE OF EUROPE'S MOBILITY

ERRAC
The European Rail Research Advisory Council

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Foreword

Rail transport is an essential contributor to the economies of the Member States of the European Union. It provides effective and essential travel into the great cities of Europe, high speed sustainable travel between cities and regions and forms an essential long-distance freight transport backbone for Europe.

The latest advances in technology, through digitalisation, automation and material science, provide a great opportunity to change our lives and a better Europe to live in. But to capitalise on these advances, railways must invest in research and development alongside partner transport modes. Indeed, rail and all the transport modes must work together to create a seamless transport journey for their customers – passengers and freight companies. By the same token, this technology is also a threat to those who do not transform their transport capability.

The railway industry of Europe continues to be world leading in its performance. It is a leader in the design and manufacture of railway systems and products, providing employment to 2.3 million and making a significant contribution of 143b GVA (1.1% of GDP of the Member States).

This Rail Vision 2050 sets out the future capabilities needed from railways to meet the future needs of Europe and provides a route to utilising the new technologies to achieve these capabilities. To deliver these capabilities and to maintain their essential contribution to Europe, the railways need continued support and investment to embrace the technological opportunities and simplified regulation to improve cost competitiveness of the European Railway Industry. ERRAC fully supports the continued work of Shift2Rail (S2R JU) and future extensions of that Joint Undertaking. But it also strong advises that the S2R Master Plan and scope should focus on the major and essential functions of a railway system. It does not, due to funding constraints, yet cover the entire railway system. In particular, the development of genuinely multi modal transport system design and integration, the wider social and economic issues of human factors, noise and vibration in society, sustainability and environmental challenge, are wider transport factors that need a combined focus across all modes of transport and need separate funding and planning in future European research framework programmes.

Andy Doherty

ERRAC Chairman,
Network Rail

Glossary

ATO : Automated Train Operation

CBTC : Communication Based Train Control

CO_2 : Carbon dioxide

EC : European Commission

EEA : European Environment Agency

ERTMS : European Railway Traffic Management System

EU : European Union

GDP : Gross Domestic Product

GVA : Gross Value Added

ICT : Information and Communications Technology

JU : Joint Undertaking

kWh : Kilowatt Hour

LRT : Light Rail Transit

NOx : Nitrogen Oxides

PM : Particulate Matter

PM10 : Describes inhalable particles, with diameters that are generally 10 micrometers and smaller.

RDI : Research, Development and Innovation

S2R : Shift2Rail

SERA : Single European Rail Area

SMEs : Small and Medium-sized Enterprises

Our Vision – An Introduction

Rail transport already plays a vital role in supporting Europe's society, developing its economy, and protecting its environment. It has the potential to contribute much more. This is recognised in the European Commission's policy for transport[1], which identifies rail as a major driver in developing the strategic objective of smart green and sustainable growth. A combination of public and private stakeholder participation provides excellent services (both publicly promoted services and commercially based travel and logistics) for Europe, and strong leadership in the world's railway supply chain, from the manufacturers to the operators.

Rail is in a privileged position to become the backbone of an intermodal "Mobility as a Service" for passengers and "Delivery as a Service" for goods.

Our vision is:

In 2050, rail transport in Europe is the backbone of an intermodal **"Mobility as a Service"** within cities and beyond, for both passengers and goods, meeting the needs of customers, EU citizens and society. The suppliers and service organisations of the **European rail industry are recognised as the world's thought leaders** for railway products and services.

This document describes today's rail sector in terms of its economic, societal and environmental contribution, the challenges and opportunities it faces arising from societal changes and other trends, and presents a view of what Europe's railway might look like in 2050, having taken advantage of opportunities to innovate, and the bigger contribution it could make. It identifies the key enablers and a range of mechanisms which are central to the delivery of the vision, including the critical need for continued and enhanced support for research and development.

[1] COM (2011) 144 final: White Paper, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system.

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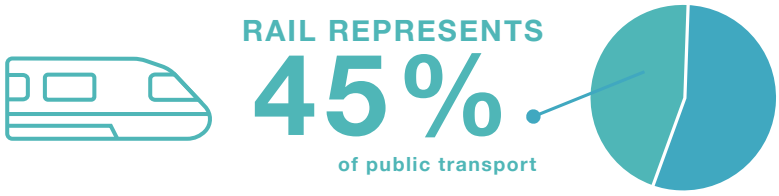
1. Rail – A massively valuable asset for Europe

1.1 Starting Point

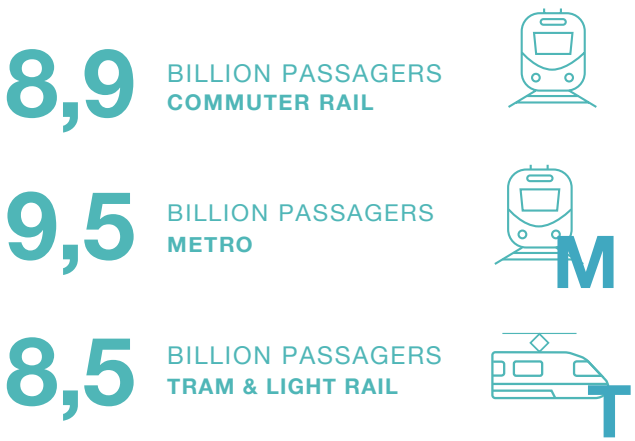
Europe's railway network is the heart of its mobility, serving the travel needs of its citizens and playing a key role in the distribution of the goods which they buy and use. By linking towns, cities, regions and states-whether through commuter travel in the growing urban centres or through regional, long-distance and international travel-rail delivers a seamless web of connectivity which accounts for 9 billion individual trips annually (2012) within the EU. Rail's share of inland freight transport is 18.3% (2015)[2], providing a major contribution to the livelihood of the continent.

Innovative technologies have contributed to rail's growing share of the passenger market, which increased by 17% from 2001 to 2012[3]. For instance, the highly successful expansion of the high-speed rail network and the implementation of other technical and customer-serving innovations, such as the TGV, ICE, AVE and Frecciarossa programmes, have become the flagships of European transport and as such have been widely copied around the world. But mostly, this has allowed a complete change of the economy in some of the newly high-speed connected regions, facilitating the transfer of skills and competencies from one region to another without the need for a permanent move.

In European metropolitan areas, 400 billion trips are made each year: 15% by public transport, 30% by non-motorised means and 55% by private car. Rail represents 45% of public transport. In absolute terms, commuter rail carries 8.9 billion people each year, metro 9.5 billion and tram/light rail 8.5 billion. In some cities growth has been spectacular, such as in Brussels, where the local operator STIB has carried 37% more passengers over the last decade.[4]



RAIL REPRESENTS
45%
of public transport



2 Freight transport in the EU-28 modal split of inland transport modes (% of total tonne-kilometres)

3 UIC/CER

4 STIB source quoted by UITP, 2017

Rail transport is especially valuable in metropolitan areas since it combines high capacity with high safety, energy efficiency, travel reliability and, critically in dense areas, uses less urban space. High-speed rail systems connect cities and regions in minimised journey time and maximised passenger comfort.

In addition, local railway systems provide feeder or connecting services for travellers who use rail or air for long-distance travel. They address the whole transport system by providing connection, creating a collaborative multi-modal transport approach in Europe.

The safest form of land transport

Rail is the safest form of land transport, having the lowest risk of death and serious injury: rail is 1.5 times safer than travel by long-distance coach and 24 times safer than travelling by car[5]. Similarly, tramways are 6 times safer than cars in terms of accidents[6]. A shift from other transport modes to rail thus improves the overall safety of the European transport system.

An economic catalyst

Rail utilizes and promotes the development of skilled labour, serving as a catalyst for economic growth whose value is often underestimated. Indeed, the contribution made by rail is larger than that of either the air or maritime sector. The sources of this contribution range from large engineering and parts manufacturing companies to a panoply of SMEs. This thriving research and knowledge economy helps keep Europe at the cutting and competitive edge of technical development. About 2.3 million people are employed in the railway sector, relating to the operation of trains, management of infrastructure, manufacture and supply of locomotives and rolling stock, and the provision of other goods and services. This produces EUR 143bn GVA for Europe's economy, 1.1% of its GDP. When wider economic effects are included, the total contribution to the economy has been estimated as supporting up to 4 million jobs in total, producing EUR 250bn. GVA, representing 1.8% of GDP[7].

5 Fatalities per billion passenger-kilometres: rail 0.13, bus/coach 0.2, car 3.14 – ERA 2014

6 Per m. passenger-km from a sample of 15 European cities surveyed – UITP 2016

7 The economic footprint of railway transport in Europe – CER 2014

The greenest mode of transport

Rail transport is recognised as the most environmentally friendly form of mass transport. It is perfectly integrated with other green modes of personal transport for shorter distances, such as bicycling. Its sustainability comes from its low levels of atmospheric emissions compared to automotive and air transport, widespread use of electric traction, low energy consumption due to low friction between rail and wheel, relatively small land use of its infrastructure, ability to access town and city centres, and the efficiency of comfortably and quickly moving large volumes of people and goods over long distances. With an average consumption of 0.12 kWh per passenger-km, urban rail is 7 times more energy efficient per passenger than car travel in cities[8]. Rail's carbon footprint is dramatically smaller than those of other modes of transport. Light rail produces no emissions at street level in sensitive areas and therefore contributes significantly to localised air quality improvement. In 2011, CO_2 emissions from road transport were 2.6 times those from rail in passenger-kilometres and 3.6 in tonne-kilometres. High-speed rail is also 3.4 times less polluting than air transport (2012 EEA). Rail also has much lower NOx and particulate matter (PM10) emissions and causes less external environmental cost (from accidents, noise, or other effects) than do road, maritime and air transport.

Technical innovation in railways has led to significant improvements; for example, regenerative braking is more energy efficient, which reduces both costs and environmental harm. Without railways, our cities would suffer from much more congestion, pollution, and noise. While rail is already the greenest form of mass transport, ongoing research and innovation seeks to make even more progress, targeting a zero-carbon footprint.

Major cities, such as London, are putting new rail investment at the heart of future transport strategies and plans to implement green and sustainable solutions for society (travel time will be shortened between 20 and 60% depending on travel scenarios) and foster further economic growth (creation of 55.000 jobs). Crossrail will have a major beneficial effect from 2018, and the prospective Crossrail 2 (if approved) would complement it and the other recent rail investments to facilitate the life of the city.

Many European cities benefit from modernised urban rail networks (44 metros systems and 198 Light Rail Transport networks) which also link to the long-distance rail networks to form an integrated system. In 2015-17 alone, 280 km of new tram/LRT were opened in Europe for passenger services, as well as 73 km of new metro lines. Another 371 km are currently in construction and around 500 km are at an advanced design stage. Further investment in rail networks and urban freight distribution systems can make a big contribution to the improved environmental health of our cities and their citizens.

8 **"Energy efficiency – contribution of urban rail systems". UITP Europe leaflet, 2014**

Existing Collaboration

Taking advantage of modern technology and techniques, the rail sector in Europe in recent years has-through collaboration involving both public and private bodies, government, major companies, thousands of small and medium enterprises, academia and research laboratories—successfully maintained the world leading role of its manufacturing and rail supply industry, despite strong and increasing international competition. This has required the twin forces of the 'pull' from a sector responding to more demanding customer requirements, and the 'push' of a highly innovative supply chain encouraged to invest in relevant solutions in the technical, operational and service domains. The rail sector needs strategic support through well-aligned policies at both a national and EU level and a strong commitment to its ongoing requirement to invest in research development and innovation using all necessary resources.

Considerable progress has been made in recent years to increase the level of investment from its own resources and from public support, diversify funding sources and design a more robust funding mix (following beneficiary and polluter pay principles) and produce more coherent and delivery-focused programmes. However, the rail sector's spending on RDI as a proportion of its turnover or economic value remains comparatively low. This is partly due to innovation's characteristically lengthy 'time to market'. A compelling increase in research and innovation funding will have a multiplier effect to meet increasing societal expectations.

Skilled workforce

European rail mobility is sustained by a skilled workforce, that daily delivers maintenance, operations, planning and services, to the benefit of Europe's citizens and economy. Nevertheless, major changes are affecting this workforce: on the one hand, some 30% is expected to retire in the next 10 years and on the other hand, there is a need to ensure that skills and competencies are brought in to accompany the major transformation process driven by research and innovation.

1.2 A summary of rail's contribution to meeting society's needs

Rail helps to support society's needs by:

- Connecting Europe's citizens, promoting social inclusion;
- Connecting Europe's territories, generating regional spatial inclusion and efficient land use both in and around metropolitan areas;
- Offering comfortable, safe and secure travel for everyone, including the elderly and disabled (making them self-reliant).

Rail is an effective catalyst for generating economic growth in Europe by:

- Providing highly skilled jobs and innovation;
- Fostering Europe's knowledge economy through RDI investment;
- Connecting regions, markets and people.

Rail helps to protect the environment by:

- Providing sustainable mobility for passengers and freight;
- Being energy efficient for urban and long-distance travel;
- Causing much less pollution than other modes of transport.

1.3 Challenges and Opportunities

Rail faces a range of new challenges and opportunities arising from external changes and trends.

Challenges

Increasing urbanisation and European competitiveness

The increasing pace of urbanisation will dramatically increase the demand for efficient and sustainable transport solutions. Only rail can respond to the scale of this challenge, being the only mode with the flexibility to serve significantly increased passenger and freight volume while minimizing detrimental impacts on the overall urban system. To enhance the competitiveness of Europe, increased freight transport demand requires greater efficiency in freight delivery. The question this poses is how to increase this capability without using more land, without increasing emissions and without increasing noise and vibrations. Rail is the answer, with its new generation of integrated products, logistic solutions and fully-automated operations.

In this context, overall changing needs and levels of demand require rail to make a step change in its attractiveness and competitiveness, leveraging its strength as a sustainable integrated platform with other modes to offer mobility solutions, including for the ‘last mile’.

Climate change

Rail faces new challenges associated with climate change, including previously rare weather events, variations in temperature, more intense storm activity and rising sea levels. Climate change is dramatically increasing the risk of disruption from damage to and failure of critical infrastructure for all forms of transport. There is a need for more resilience in transport solutions, incorporating rail’s inherent strengths.

Opportunities

SERA and Environmental regulations

A number of recent developments, such as the establishment of the Fourth Railway Package's[9] technical pillar and of the S2R Joint Undertaking, support the creation of a Single European Rail Area (SERA)[10]. These initiatives are already leading to an increase in the quality and choice of services available, more responsiveness to customer needs, and greater economies of scale. Moreover, they are boosting the competitiveness of the railway sector by significantly reducing costs and the administrative burden on railway stakeholders.

Stringent regulations on emissions are heavily influencing the planning and operation of transport systems, encouraging the development and use of greener modes of travel such as rail. Increased urbanisation, road congestion and polluting emissions will require alternative modes of transport to comply with environmental targets and reduce energy consumption, thus promoting rail use as a fundamental element of the solution.

Increasing international demand for new rail lines

Huge rail and metro investment programmes outside Europe present an opportunity to supply not only products but also skilled teams for design, operation, and maintenance. Led by Latin America and the Middle East, metro networks growth has remained constant in the rest of world and 39 new lines opened after 2000. In 2014, 388 cities worldwide had trams and light rail in operation, representing over 2,300 lines and totalling more than 15,600km of infrastructure. Nearly all regions worldwide see growth in the number of light rail and tram systems serving their cities, with a renaissance in the tram ongoing since the 1980s. Europe and North America have long been at the forefront of this global renaissance, with new systems being introduced to enhance urban public transport networks. Of particular interest, China, a country with one of the world's highest urban population growth rates, has embraced the tram and LRT[11].

Enabling technologies

The emergence of enabling technologies, such as artificial intelligence, the "internet of things", robotics, vehicle-to-vehicle and vehicle-to-infrastructure communications, autonomous driving and block-chain will provide a wide range of possibilities for innovation in the rail system and to change the way it operates, supporting improvements in rail based logistics and mobility in the short run.

9 https://ec.europa.eu/transport/modes/rail/packages/2013_en

10 It excludes urban rail from the rail technical directives .4 categories of urban railways are excluded from the EU Interoperability and Safety legislation and require a specific approach. Standardisation efforts in this field are on-going on a non-mandatory way.

11 Public Transport Trends, 2017. UITP publication.

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2. European rail transport in 2050

2.1 A transformed railway

Confronted with complex systemic challenges, European society has leveraged its substantial industrial and human capital and transformed itself into an area whose citizens enjoy unprecedented life and work opportunities, well-being and freedom, supported by a prosperous, decarbonised data economy. Issues such as climate change and ecological sustainability, economic globalisation, social cohesion, inclusion and urbanisation have been met by the citizens' creative adoption of new individual and collective habits and lifestyles, accommodated and enriched by innovative industrial processes, infrastructure, operational procedures, business models, products and services.

Now in 2050, the European rail sector is a principal agent of this social and economic transformation and an integral component of the new European industrial base: through the use of breakthrough technologies it has become a natural extension of the citizens' work and leisure environment, providing the backbone of European mobility and logistics solutions that safely and reliably interconnect communities-connecting producers to markets, and people to jobs and social activities-at a minimal cost, while making the most efficient use of scarce resources, particularly land and energy.

Cutting-edge innovations in technologies, systems and procedures in the European rail sector make Europe the leader of forward-looking rail solutions for global markets, complementing automotive, maritime and aerospace products and strengthening Europe's export economy.

2.2 A railway serving society

The innovation-powered transformation of the European rail sector gives it unprecedented technological and operational capabilities which enable it to serve society with new concepts, products and services.

Mobility

- Every individual across Europe has access to mobility services regardless of demographics, culture, language, location, or technical proficiency;
- Efficient and barrier-free interchanges between transport modes allow for safe, reliable and smooth journeys, optimised over all available transportation infrastructure and dynamically adjusted to traffic and service conditions;
- The rail system is able to detect, understand and respond to individual and collective European citizens' mobility needs, delivering tailored, on demand, integrated end-to-end mobility solutions to which the rail system is a prime contributor, integrating seamlessly with all other available transport modes;
- Passengers are able to access real time personal communication and new services for work or leisure continuously—before, throughout and after the journey.

Logistics

- Innovative logistics services are driven by customer demand. Shipments are moved effectively, efficiently, safely and securely through the ''physical internet". The rail system is fully integrated with the automated multimodal logistic chain and forms the backbone infrastructure of the physical internet, comprising new intelligent, automated cross-modal shipment transfer nodes;
- Freight transport units are flexible, interchangeable, multipurpose and autonomous, requiring minimal handling infrastructure while maximizing utilisation;
- Freight transport units can communicate with one another as well as with infrastructure and operational facilities, minimising downtime.

Smart cities

- Rail is the backbone of urban mobility, with intelligent stations at the heart of smart cities, being places to work, live, meet and communicate. This requires a clear and solid urban development strategy with a long-term vision to build coherent transport policies;
- New energy-efficient station designs provide easy access and seamless interchange across all transport modes, enabling railways to manage growing passenger volumes and mobility demands;
- Railways are a core part of smart city planning, mobility management systems, and city fulfilment and delivery services, promoting interconnection by freeing up land which was previously needed by private road vehicles and minimizing pollution and congestion. They eliminate polarisation and disconnection between historical city centres and their peripheries; work, study and leisure environments; and young and old populations.

Improving customer satisfaction through intelligent trains using shared data

1. Taking into account data privacy management, relevant information is shared across the industry as a part of the data economy, enabling new services and applications for the benefit of the railway and its customers;
2. Rail manages a growing volume of data contributing to the data economy. Collection, analysis, interpretation and prediction are automated to provide consistent up-to-date information, supporting fast, well-informed decisions and business benefits;
3. This is achieved through a robust, resilient and secure self-diagnosing and self-healing information architecture;
4. Intelligent trains are aware of themselves, their passengers/loads and their surroundings, know where they need to be and when, and can adjust journeys automatically to meet demand. In addition, they intelligently feed information about the infrastructure to support predictive maintenance;
5. A network of fully-intelligent trains can be self-regulating in traffic, negotiating vehicle-to-vehicle and vehicle-to-X to determine movement priority and resolve potential conflicts at junctions in the network, and reacting to unexpected situations. The trains are also aware of and able to take account of the status of other transport modes.

2.3 Innovations to deliver the vision

To deliver the 2050 vision the rail industry is underpinned by technical and scientific research in Europe and around the world. The development and widespread deployment of a host of related technologies include some that represent the evolution of current developments:

- Digitalisation: the instrumentation of assets, processes and personnel with powerful Information and Communications Technology (ICT) capabilities, able to sense, detect, process, receive, transmit and analyse digital information across secure, reliable and ubiquitous networks, making them all participants of a global ''internet of things";
- Distributed cognitive computing: endowing machines with the ability to become aware of and understand their surroundings, to recognize patterns, to generate meaningful insights from large amounts of distributed data, and to learn;
- Robotics: endowing machines with the ability to perform goal-oriented tasks autonomously;
- Distributed immutable shared ledgers: e.g. "blockchain" technology, allowing the secure recording of transactions without centralized control or coordination;
- New "intelligent" materials with self-healing properties and the ability to shape themselves in response to external stimuli.

These technology trends are based on the current state of technology and the near-term developments which are possible using existing scientific and technical knowledge. Transformative future research and scientific advancement have the possibility to change technology dramatically. Long-term progress is guided by the emergence of technologies which have not yet been imagined or realised. The 2050 vision acknowledges this uncertainty and embraces yet unknown possibilities which may significantly influence all aspects of rail transport. The future of rail lies in flexibility, crucially depending on its ability to adapt to and incorporate future technological advances.

By packaging these technologies into new components, systems, processes, products, and services, the rail sector performs a comprehensive industrial transformation, introducing far-reaching innovations in the way it operates and services society. The following sections illustrate a few of the foreseeable innovations.

Autonomous train operations

Rail vehicles, infrastructure (including stations) and command and control systems are fully digitalised and networked components of the "internet of things." Each element is also endowed with local artificial intelligence which gives it the ability to perform goal-oriented tasks with a high degree of autonomy.

Combinations of autonomous, intelligent and highly responsive vehicles are able to communicate with each other and with the intelligent infrastructure, ensuring safe and reliable operations, while running closer together and contributing to reduce life-cycle costs substantially. This constitutes a successful deployment of the next generation of the traffic management systems such as European Railway Traffic Management System (ERTMS) and mass transit Communication Based Train Control (CBTC).

Distributed operation management of autonomous trains allow for adaptive and accurate adjustments to transport demand patterns, dramatically increasing the capacity and flexibility of the rail transport system for all types of operations: urban rail, high speed, freight, rural and mass transit system.

Fully automatic train operation, autonomous vehicles and intelligent remote-controlled systems guarantee an unprecedented level of safety.

Autonomous operations also enable new types of mobility on rail, such as self-operated light pods/shuttles providing seamless interconnection across infrastructures.

Intelligent assets lifecycle management: whole-life asset approach

The rail sector generates significantly more value from fewer physical assets by maximising their productive utilisation over their whole lifecycle, significantly reducing the total cost of ownership.

From design to end-of-life, the entire railway value chain is efficiently managed through a continuous flow of information, with intelligence at each level of the system to ensure flexibility and real-time responsiveness.

New materials and digitalised manufacturing processes produce assets that are inherently more reliable and have significantly reduced maintenance requirements.

Assets have robotic characteristics, such as self-diagnostic and self-healing capabilities, which eliminate service interruptions.

Assets communicate automatically with all actors across the value chain involved in safe and reliable operations (manufacturers, operators, engineering and maintenance contractors, etc) allowing optimised dispatching of robotic repair equipment, product improvement and automated traffic adaptation to asset status.

Protecting the environment and the energy supply

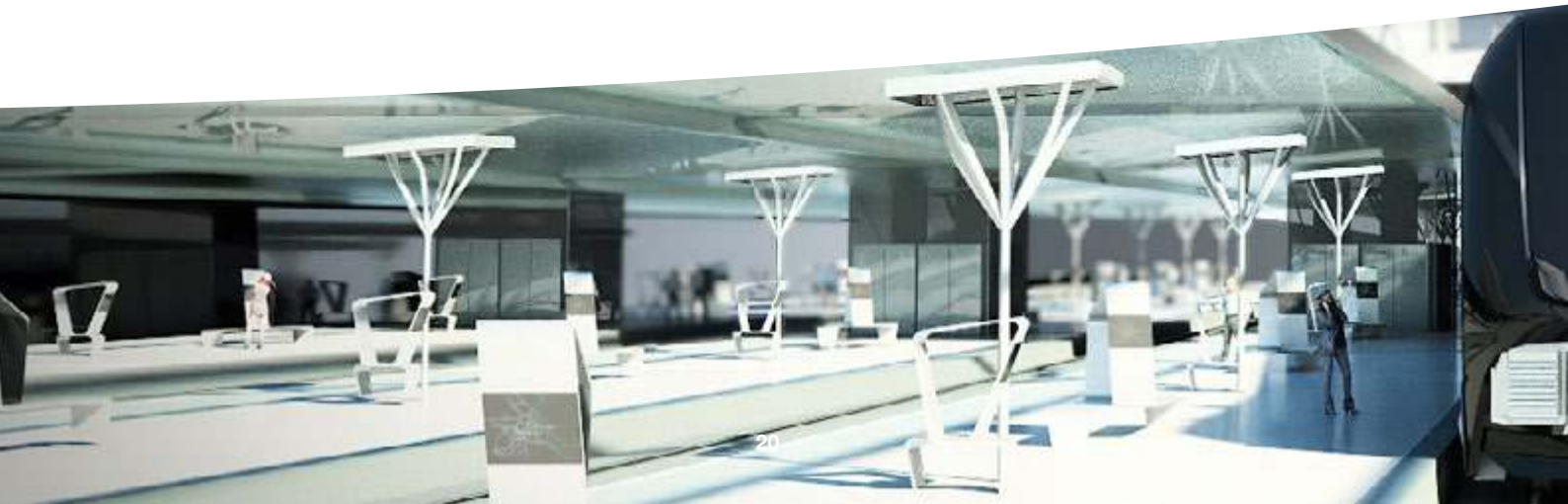
Society recognises that rail is the backbone of sustainable mobility and transportation. Rail is the standard mode of transport in urban areas, at a national level, and for distances up to 1000 km. In these areas it is the most energy-efficient mode of passenger and freight transport. Rail decouples environmental harm from transport growth by operating with a minimal environmental impact and a zero-carbon footprint. Carbon-free train operation and zero nitrogen oxides (NOx) and particulate matter (PM10) emissions are achieved. Noise and vibration caused by the railways are no longer an issue.

In urban areas, metros and light rail are the core of public transport for large volumes of passengers, complemented by a network of bus services and shared mobility options such as taxis, car-sharing, cycle-hire, ride-hail systems and individual vehicles/shuttles to take care of the last mile. Rail stations have turned into multimodal smart hubs which also include storing and charging facilities for electric vehicles of all sizes and sorts. For trips up to 1000 km, rail journeys connecting the major urban areas in Europe have become the norm.

European authorities, treating high-speed rail as the preferred mode of transport for trips on routes up to 1000 km, have fostered the extension of the high-speed rail network through legislation which supports the efforts of the rail sector to be the environmentally-friendliest transport mode: for example, with a well-balanced tax and toll system across the transport modes. Legislation also requires that all external costs of the transport modes—e.g. wear, congestion, accidents, air pollution, carbon emissions, noise and vibration—are internalised.

In addition, new lifestyles and widespread principles, such as a sharing economy and the “fully customer-centric” approach, are driving forces. The rail sector has continued to deliver sustainable transport solutions based on its customers’ travel and transport demands.

Sustainable and ethical procurement and production have reduced the carbon footprint to zero, utilizing a whole-life approach and focusing on system inputs, recycling, transport of materials, renewable energy, operations and disposals. Suppliers and manufacturers have incorporated the principles of zero-carbon footprint and sustainable development into the whole life cycle. Zero waste cycles are implemented.



The focus on energy is twofold: a continuous effort to both reduce energy consumption and to maximise the share of renewably-sourced energy.

Alternative propulsion concepts, such as fuel cells, are introduced. Discontinuous electrification at stations and on branch lines dramatically reduces the capital costs of extending electrification. Automated Train Operation (ATO) improves energy efficiency. Optimised on-board and line-side energy storage and charging technologies (e.g. dynamic wireless power transfer) allow the railway to redistribute energy throughout the whole transport system, including at urban level, according to supply and demand. A fully-integrated system approach to an intelligent energy supply maximises renewable energy generation and the use of smart grids, including those outside the railway system, through links with the wider energy supply sector. The use of lightweight materials for rolling stock reduces maintenance costs and energy consumption. As a result of these efforts, train operations are at the forefront of energy efficiency, adopting and promoting a circular economy approach.

Ensuring safety and security

Safety: zero casualties

Rail has maintained its place as the safest transport mode and this is recognised and valued by European citizens. Manned and unmanned autonomous intelligent trains operate safely on the same railway network, controlled by artificial-intelligence based traffic management systems.

This is permitted by the real-time monitoring of asset health by a wide array of sensors, connected within an “internet of things” environment, feeding the predictive maintenance decision-making process. Further improvements come through the application of machine learning, artificial intelligence and big data analytics.

Robust modular units and infrastructure assets are easily maintained and repaired through a robotic automated system, making the operation punctual and safe.

Furthermore, global automation provides justified confidence to customers about system safety.

Security

People feel secure using rail services. Security measures are non-invasive, not interfering with the travel experience. Easy access is available for all citizens to railway facilities, products and services. Precautions against external threats, aggression and vandalism, supported by technologies are in place.

Legislation ensures a stable and reliable security framework. The leading principle is open access to stations and trains. Risks are mitigated where necessary using state of the art technology to ensure security in the best possible way with minimal impact on the daily operation. Techniques and solutions conform to the highest requirements for privacy within the relevant regulations and legislation.

Rail security is part of an integrated approach addressing the whole transport sector and beyond. It is based on the three principles of: resilience and effectiveness; a comfortable and reliable travel experience; and fast, integrated and seamless processes. Risk assessment is integrated into the security screening process for passengers and freight, based on a range of inputs such as intelligence, information and behavioural recognition, to ensure that resources are focused appropriately and effectively.

For freight, track-and-trace solutions support security issues efficiently. Points of vulnerability are places at which freight loads are transferred from one transport mode to another. Cooperation between the different modes has led to practical and efficient solutions.

The rail sector has a long-established collaboration with all other sectors to handle cyber security. New forms of cyber-attacks are therefore recognised at an early stage and are dealt with through joint cross-sectoral effort. The digital railway is fully protected by advanced cyber-security solutions.

Robust and resilient ICT infrastructure, combined with strong business continuity processes, ensure the high availability of the rail system and services.

Digital rail industry supply chain management

Rail sector engineering, logistics, manufacturing and distribution processes are fully digitalised and are an integral part of the new generation of European industry, based initially on Industry 4.0.

The entire supply chain is transparent and is managed through machine-enhanced intelligent collaboration between customers and suppliers, who interact digitally. It adapts dynamically to changing demand/supply cycles, minimising lead-times, inventory, rework, waste, energy consumption, emissions and other environmental impacts.

Engineering relies on fully digital 1:1 scale, real time, co-design models, involving customers and suppliers and enabling zero on-site, formal methods testing of components, systems and their operation prior to commitment to manufacturing.

The wide application of digitalised modelling processes for the virtual safety certification of rolling stock, signalling systems and other assets, eliminating the need for full scale physical dynamic tests, has improving the overall level of system safety, allowing the rapid and low-cost introduction of innovative technology, greatly assisting rail's competitive position. More freedom in testing and fewer constraints, while preserving the safety level of the system, reduce the time to market.

Additive manufacturing processes driven by digital specifications result in minimal lead-times and cost-effective production of individual or small batches of parts and components on demand.

The digitalised rail sector supply chain optimises the authorization and certification processes of safety-critical systems, significantly reducing their lead-times and costs.

3

3. Delivering the vision

3.1 Requirements for Delivery

To deliver this vision will require:

- A seamless European research and innovation system that assures continuity through fundamental and blue-sky research, applied research, development, demonstration and innovation in products and services over many years;
- Strong cooperation between rail stakeholders;
- The integration of experts from other scientific disciplines and from academia, bringing valuable knowledge from other sectors;
- Effective cooperation with other modes of transport to provide a connected, efficient, and reliable European transport system.

It will also require significantly greater levels of financial investment in RDI than has been made available to date. The total requirement over the next 30 years could be greater than EUR 250 billion.

Market forces alone are insufficient to provide the necessary level of investment. This market failure reflects structural challenges and the diversity of technologies within the railway sector, their long life-cycles and their technical interfaces, all of which generate significant risks at different levels of the railway transport system and discourage investments from financial markets.

Therefore, public funding both at European and national levels remains vital.

Nevertheless, the co-funding of significant RDI programmes by the railway sector and its full and active participation within them will demonstrate its firm commitment to the delivery of the vision.

Delivery will also need to be underpinned by an appropriate, efficient and effective policy and regulatory framework. Public authorities should also be involved in the process, and it is necessary to create a good partnership between all stakeholders.

3.2 Mechanisms for an effective delivery framework:

The programmes established to deliver the vision should:

- Substantially increase the European funding instruments for RDI, following the European rail Public-Private-Partnership Shift2Rail JU, to harvest its benefits while looking forward to the new technologies in this vision;
- Put in place simple and effective mechanisms—accepted by all stakeholders—to coordinate shared objectives for RDI projects at private, European, national, and regional levels in the upcoming European research framework programmes and others;
- Enable and incentivise a much shorter time to market from initial research to commercialisation, assisted by an integrated research and innovation ecosystem;
- Create new dynamics in regulations to allow innovative technologies to be adopted more quickly;
- Put in place the mechanisms to bring innovation to the market, accompanied by the phasing out of obsolete technologies to accelerate the time to market to meet overall societal needs.

Supporting measures, prioritising research, testing capabilities and education, and creating wider conditions for success are also required to maintain and extend Europe's industrial leadership. Other such actions include:

- Attract, develop and retain highly-skilled staff and the best researchers, engineers and managers for the European railways, to maintain its reputation as a highly desirable, attractive, challenging and rewarding career choice;
- Maintain strong links with academic institutions and foster collaboration with specific RDI programs, enabling students to be a part of rail RDI programs at an early stage of their studies. The EU could fund courses and qualifications directly related to rail innovation;
- Promote the development of an RDI ecosystem with centres of excellence fostering a high participation in knowledge networks, opening new forms of collaboration, technology transfer from other industry sectors, and keeping railway skill sets fresh. Support a tight collaboration of rail operators, infrastructure managers, rail industry, universities and research organisations;
- Maintain leading edge design, manufacturing, and system integration capabilities to deliver projects and programmes spanning the whole innovation process, from basic research to full-scale demonstrators;
- Put in place streamlined, European-wide, systems engineering, design, manufacturing, testing / certification and upgrade processes to keep up with the pace of innovation, address complexity and minimise development costs;
- Create a leading new generation of standards;
- Introduce risk-based testing and virtual testing capabilities to reduce development cost and time to market;
- Maximise component-driven development and modularised products for the rapid deployment of innovation. Focus on disruptive technologies, using challenges to increase innovation capabilities and speed. Use agile development approaches, Hackathons, etc. and involve final customers at early developmental stages, e.g. via 'open-labs'.

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