

FOSTER RAIL

Future of Surface Transport Research Rail

Coordination and Support Action

Grant Agreement No 605734

Date of Annex I against which the assessment will be made: 23-05-2013

Deliverable D3.2

Strategic Rail Research and Innovation Agenda

WP	3	Strategic Rail research and Innovation Agenda
Task	3.2	SRRA update into a SRRIA

Dissemination level¹	PU
Nature²	

Due delivery date	M9
Actual delivery date	M13

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Other contributors to the deliverable	UIC, UITP, CER, NETWORK RAIL, IST LISBON, ANSALDO STS, ALSTOM, SNCF, DB, EURNEX, TRAFIKVERKET, RATP, TMB,
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¹ Dissemination level: **PU** = Public, **PP** = Restricted to other programme participants (including the JU), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the JU)

² Nature of the deliverable: **R** = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other

Document name:	Strategic Rail Research and Innovation Agenda		
Reference:	FOSTER RAIL_WP3_3.2_UNI_SRRIA	Dissemination level:	PU
		Version:	Final

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1. Foreword

A strong rail sector is key to sustainable mobility in a low-carbon Europe. It is also essential for the growth of the European economy and for social cohesion. Rail must be a fundamental part of an integrated transport system, with each transport mode playing to its real economic strengths, to enable a more competitive European economy.

In support of European Union (EU) action to provide sustainable solutions to the current economic problems, the European Rail Research Advisory Council (ERRAC) believes that research and innovation will enable the European rail sector to retain its leadership and increase its competitiveness.

Rail is now a knowledge-intensive and internationally competitive sector, striving to create an optimal eco-system for innovation. It pulls together (from across the continent) excellent research institutions and a well-performing manufacturing industry, with a strong and increasing dedication to research, development and innovation (R&D&I).

This new **Strategic Rail Research and Innovation Agenda** (SRRIA) is well placed to guide and inspire future research and innovation over the coming decades.

The European Commission's framework programme for research and innovation "HORIZON 2020", launched in December 2013, includes a flagship initiative for rail research, the SHIFT²RAIL³ Joint Undertaking. It is the first Public Private Partnership (PPP) in rail research to seek focused research, innovation and market driven solutions by accelerating the integration of new and advanced technologies into innovative rail product and services, thus responding to the current mobility challenges.

Through this SRRIA, ERRAC reaffirms Europe's need to offer a well-balanced, business-led and strong programme of research and innovation for the railway system over the next decades.

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³ For detailed information, please visit www.shift2rail.org

2. Executive summary

The European Rail Research Advisory Council was established in 2001 with the ambitious goal of creating a single European platform with the competence and capability to help revitalise the European rail sector and make it more competitive, by fostering increased innovation and guiding and monitoring research efforts at European level.

This SRRIA specifically addresses the European efforts required for research and innovation to achieve the ambitious goal set out by the European Commission in the Transport White Paper published in 2011⁴ where it is recognised that European transport is at a crossroads, and that old challenges remain but new ones have arisen.

Although transport accounts for about a quarter of all greenhouse gas (GHG) emissions, rail is responsible for significantly less than 1% of transport's total share. Almost all the emissions arise from car use, aviation and shipping, which are almost completely dependent on fossil fuels.

Transport is recognised as being of key importance for both employment and economic growth. The White Paper underlines the need to implement “new technologies” to ensure sustainable mobility.

The European Commission is committed to a “Europe 2020” strategy based on smart, sustainable and inclusive growth but also concerned about the environmental, security, social and economic implications of current patterns of energy use. It wants to find ways of decoupling economic growth from resource and energy use. It also wants to see a shift to a resource-efficient, low carbon, growth economy, avoiding transport pollution and congestion. This calls for a massive technological improvement and a radical systemic change. Rail is seen as being an important part of the solution.

Among the ten high level goals for a competitive and resource-efficient transport system (Section 2.5 of the White Paper), nine imply significant development of rail infrastructure, services and technologies, as follows:

Developing and deploying new and sustainable fuels and propulsion systems

- (1) Halve the use of ‘conventionally-fuelled’ cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO₂-free city logistics in major urban centres by 2030⁵.
- (2) [...]

Optimising the performance of multimodal logistic chains, including by making greater use of more energy-efficient modes

⁴ Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:EN:PDF>

⁵This would also substantially reduce other harmful emissions.

- (3) 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors. To meet this goal will also require appropriate infrastructure to be developed.
- (4) By 2050, complete a European high-speed rail network. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050 the majority of medium-distance passenger transport should go by rail.
- (5) A fully functional and EU-wide multimodal TEN-T ‘core network’ by 2030, with a high quality and capacity network by 2050 and a corresponding set of information services.
- (6) By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system.

Increasing the efficiency of transport and of infrastructure use with information systems and market-based incentives

- (7) [...] Deployment of [air traffic] equivalent land and waterborne transport management systems (ERTMS⁶, ITS⁷ [...]). Deployment of the European Global Navigation Satellite System (Galileo).
- (8) By 2020, establish the framework for a European multimodal transport information, management and payment system.
- (9) By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport.
- (10) Move towards full application of “user pays” and “polluter pays” principles and private sector engagement to eliminate distortions, including harmful subsidies, generate revenues and ensure financing for future transport investments.

Overall transport activity is expected to grow substantially by 2050, with freight volumes increasing by more than 80% and passenger volumes by more than 50%.

Research and innovation can bring ground-breaking solutions to most of these objectives and challenges. ERRAC is involved in defining the research and innovation strategy of the rail sector in Europe, supporting and enhancing co-operation among European stakeholders as well as creating links with other sector stakeholders and decision-makers (at European, national and regional levels).

Building on the 2007 Strategic Rail Research Agenda (SRRA)⁸ and following the publication of “RAILROUTE 2050⁹”, this updated **Strategic Rail Research and Innovation Agenda, a step**

⁶In accordance with the European Deployment plan for ERTMS: cf. Commission Decision C (2009)561.

⁷In accordance with the EasyWay 2 Implementation Plan: cf. Commission Decision C(2010) 9675.

⁸http://demo.oxalis.be/errac/errac_website/wp-content/uploads/2013/06/SRRA-2007.pdf

change in research and innovation (SRRIA-2014) aims at orienting and guiding the research efforts of the railway sector and the decisions of policy makers and other stakeholders. Increasing the attractiveness of a high capacity, environmentally friendly and cost efficient railway in Europe will underpin economic growth and societal development.

SRRIA-2014 sets out research and innovation priorities structured around three sets of themes. The first addresses the attractiveness of rail and public transport and the future demand that the rail sector aims to meet. The second set includes three critical themes within a sector-wide framework and finally the third set covers five well-established asset-related themes.

1. Attractiveness of rail and public transport

Customer experience
Strategy and economics

2. A whole system approach

Capacity, performance and competitiveness
Energy and environment
Safety (including certification) and security

3. Assets

Control, command, communication and signalling
Infrastructure
Rolling stock
IT and other enabling technologies
Training and education

⁹ <http://www.errac.org/wp-content/uploads/2013/11/D9-SRRIA-RAILROUTE2050.pdf>

3. The rail market

Passengers and freight are the two major markets of rail transport.

Within the overall passenger market the rail sector serves very different categories of customers with specifically designed services. The passenger rail market segments are mainly influenced by the distance travelled – long, medium and short distance – and by the nature and extent of the territory being served – international or national, regional, suburban and urban.

Each rail market segment (high-speed, mainline; regional; urban and suburban and freight) has specific customer needs, mainly associated with the distance and purpose of travel and customer expectations, which relate to age, education, activity, gender, income and levels of mobility.

To satisfy these requirements, the relevant market segments require specific design, construction, manufacture, operations and maintenance systems, each with their own research needs. These research needs are identified in this document.

3.1 Rail market segments

3.1.1 High speed and mainline

High speed has been a very successful and innovative rail market segment for several decades and is often the preferred choice for journeys with distances up to 700 km or a door to door duration of up to 4 hours.

Most long-distance services are operated using an efficient combination of high-speed and conventional lines, especially for accessing city centres or connecting with lines that have lower traffic demand.

Other mainline services are also essential to serve long-distance national and international travel needs. These may cater for regular and high volume flows or more specific requirements (night trains, major events, tourism).

In this segment, rail mainly competes with airlines and long-distance bus services.

3.1.2 Regional

Regional rail already serves as the backbone for local public transport but is a segment that is very sensitive to competition from the private car and bus services, so has to be made attractive to customers. However, within this market segment the existing rail infrastructure is not used to its full potential to support more sustainable land use and transport policies. The rail services are mostly operated under public service contracts and sometimes share infrastructure with mainline traffic operations. The most important issues are improved co-ordination with other public transport

services (e.g. ticketing, clock-face services, “rendez-vous”, information to passengers, etc.) and better integration in regional mobility strategies.

3.1.3 Urban and Suburban

Railway networks in urban and suburban areas play a prominent role in the transport policies of major cities, sustaining the viability of conurbations. This rail market segment serves the daily needs of urban populations and is the best alternative to the use of the private car in congested and polluted areas. It covers several different groups of systems, each of which plays its part depending on the traffic flows to be served and on the extent to which it can be separated from road traffic and shared with or separated from mainline rail traffic. The major sub-segments are: tramways - which are not segregated from general road and pedestrian traffic; light rail - which is partially protected from road traffic; metros - which are fully segregated (and are also known as underground, subway or Tube); and suburban rail/regional metros - offering services mixed or not with long distance rail traffic.

Trams have been operated for more than a hundred years throughout Northern and Central-Eastern Europe but disappeared in the 1950's from most Southern countries. Trams and Light Rail have an important role to play in future urban mobility based on the use of electricity by cars and buses (“electro-mobility”). The current generations of urban trams are low-floor and provide accessibility to all categories of customers. Many CEE cities have long established tram operations and should be supported in their modernisation efforts.

Light Rail (using low-floor modular train sets) has been a major innovation in urban rail for the last thirty years. It has usually been designed not only as an urban transport system, but as a way to reshape urban centres and to promote a new relationship between citizens and their town. Many European countries have introduced Light Rail after a period following the dismantling of former aged tram systems. Light Rail has been a huge success in countries like France (one new network every year for more than 25 years), UK, Spain, and has a bright future in all types of cities with over 100 000 inhabitants. Indeed, Light Rail brings e-mobility in modern design to all city centers. A potentially promising future for tram is the improved connection with cities' hinterlands through the implementation of the seamless “tram-train” concept, provided that prevailing interoperability requirements do not price out this option.

Metros are able to serve large volumes of traffic at very low headways (as low as 60 seconds in specific cases) and are key rail systems for cities with hundreds of thousands of inhabitants, in combination with tram/Light Rail and suburban/regional rail in the largest conurbations. Metros are very innovative, especially when operated with no on-board train staff (so-called “unattended train operation”). Such metros are spreading worldwide and the next decades will see their further development (including the upgrade of exiting lines).

Urban rail systems are operated in Europe under contracts that include public service requirements. They are implemented in close co-ordination with other rail systems (urban or not)

and bus systems, in public transport networks in which integration between modes is the key to success. Cost effectiveness, operational reliability and increased attractiveness are the biggest challenges. Addressing these challenges with innovative services (based on ITS and automation) will improve accessibility, comfort and security. Innovation and improvement in these fields will come from technical harmonisation of interfaces and the wider development and application of industrial standards by market forces, on a voluntary basis.

Suburban rail/regional metros serve trips with a typical average length between 10 and 50 km. They require high commercial speed and appropriate infrastructure, rolling stock and services to serve commuters' needs, especially in major cities.

3.1.4 Freight

Rail freight is a key element in the establishment of a sustainable transport system, as recognised by the European Commission in its 2011 Transport White Paper. The low level of external costs generated by rail freight should make it the mode of choice for freight customers looking to reduce their environmental impact. Indeed, rail is the most eco-friendly land transport mode for freight, with much lower CO₂ emissions and energy consumption per tonne-kilometre than road freight or transport by inland waterways. Rail freight is composed of the elements determining modal shift: the innovation components, the resources represented by corridors, network, management and the three traffic segments - block trains, wagonload and intermodal.

The block train is the mode of choice for bulk commodities such as solid mineral fuels (coal, coke), ores, chemicals, steel and metal waste together with petroleum products and fertilisers. The situation of the wagonload business – based on individual wagons or groups of wagons - varies throughout Europe. Wagonload is widely used in the central parts of Europe, where the industrial web is denser, and in Sweden, where infrastructure charges are the lowest.

Volumes transported by rail-road combined transport have consistently increased since 2005, with the exception of 2009, marked by the economic crisis, during which overall freight volumes decreased sharply.

In addition, due to the development of maritime containerised transport and road congestion, intermodal transport has developed dramatically in the past 30 years, becoming the fastest growing freight transport segment in Europe. Rail's role has become more important. The intermodal market segment, which is capable of extracting the maximum productivity from each transport mode according to the principle of co-modality, is expected to provide the greatest growth potential up to 2050, whereas traditional block trains serving mature markets and wagonload are unlikely to grow faster than the economy as a whole (unless innovations strongly increase their reliability and competitiveness).

Interoperable, international and intermodal transport at competitive cost is of utmost importance. Specific requirements include a one-stop-shop approach to planning services, open access to networks, cost-efficient, reliable and affordable rolling stock and simple, quick means to putting it into service on highly reliable, low cost infrastructure. Designated rail corridors will support unhampered border-crossing for international traffic, connect hubs for collecting and distributing goods and facilitate cost-efficient and high-capacity track access. Rail-served freight market segments and regional freight logistic solutions will be supported by intelligent processes and adaptive technology, allowing rail to serve an extended spectrum of logistic needs. The sector will thus be fully committed to a revitalisation of interoperable freight logistics.

4. Trends and drivers

Rail transport demand is steadily growing in Europe and the expectation is that under the policies of the 2011 Transport White Paper that growth will accelerate. The Commission's impact assessment of the White Paper suggests roughly a doubling of passenger and freight demand by 2050. Some analysts suggest that the growth will need to be much higher if rail is to reach the target of being the main mode for long distance freight and medium distance passenger transport, as total transport demand is driven upwards by economic growth, continued globalisation and European internal market integration.

Rail passenger transport demand is strongly driven by demand growth in, to and between large cities and other urban areas. Well-integrated public transport involving rail, metro, tram and bus transport (and even private modes like bike or electric car) is already capturing increased market share in urban and regional markets, not just for commuting but also for leisure trips. This trend is expected to accelerate as urbanisation increases.

The demand for long distance rail journeys is already growing in many countries and this growth is expected to increase with the development of the European high speed rail network to 2030 and beyond. The commercial speeds on this network are expected to average up to more than 300 km/hour, allowing distances of up to 1000 km to be covered in attractive travelling time, door-to-door. Express freight and parcels services will also be offered. Sector analysts expect that these infrastructures will attract substantial revenues from private investments, reducing pressure on public budgets.

Demographic evolution and lifestyle changes will affect transport demand. The elderly population (especially aged over 80) will grow significantly by 2050, with increasing public investment in health and care services. Elderly people will use trains more frequently, particular in urban areas and for long distance journeys.

The lifestyles of younger age groups, with fewer car owners, are expected to change in favour of multimodal travel patterns, particularly within cities, including walking and cycling. Public transport and rail operators are expected to provide additional solutions for first and last mile, door-to-door, long and medium distance travelling.

Diversification of labour markets and differences in prosperity between/within regions will lead to more differentiation in pricing policies, with a strong growth in yield management systems and low cost carriers on the busiest intercity routes.

From a technological perspective, innovation is expected to produce more energy and resource efficient systems for rolling stock and infrastructure. Integrated services for ticketing and traveller information and guidance, including for circumstances of service disruption, are expected to be of very high quality in Europe by 2050. Quality and safety and security management systems are

foreseen to be harmonized across Europe to keep the promise of an interoperable European wide rail system by that time.

Major innovation trends in the rail sector are based on the integration of technologies, e.g. analog components converging with digital. Rail users expect fully-functional digital communication and information transmission during their journey. Urban and heavy rail are further converging, particularly in urban areas and with regional rail, towards tram-train or metro-train (regional metro) concepts. High-speed rail may promote lifestyles in which long distance commuting on a daily, week-end or some days per week frequency becomes increasingly common.

Semi and fully autonomous and alternatively propelled car systems are expected to be a major competitor in 2050 to electrified rail mass transit. In the dense and urbanized metropolitan regions of tomorrow it is expected that rail transit will retain its major role; this will reduce congestion and the consumption of open space associated with driving and parking cars. Increased use of car sharing, walking and cycling and the provision of dedicated lanes for public transport and dedicated networks for soft modes are expected to ease mass transit operation, especially in peak hours.

Sustainable mobility measures, based on local climate policy and planning which drives reductions in carbon emission in cities and city regions, promote modal shift towards rail transport. Park and ride and other commuting facilities constrain car travelling to inner city centres in line with parking and access restrictions expected in most urbanized areas in Europe. These development strategies also enhance long distance rail services by making car travelling in cities relatively less convenient than in previous times.

Long distance rail services must adapt to climate change. More resilient infrastructure, with improved emergency maintenance services, is expected to be in place by 2050. Also there will be comprehensive passenger information to provide advice in circumstances of service disruption, advising travel alternatives to reach destinations in time. The 'smart grid' in the future will not simply refer to the energy system, but to the transport and rail network.

Rail research and innovation policies at the European level will be strongly driven by the need to strengthen European rail industries within competitive global rail markets, successfully delivering large rail projects bids, including turn-key ones. On the other hand, rail research and innovation policies increasingly reflect a shift to rail strategy with more restrictions on road transport and the phasing out of conventionally fuelled vehicles in urban areas.

5. Challenges

Delivering an excellent customer experience is the primary driver of technical innovation. *CUSTOMERS*, a concept encompassing all the major challenges the railway sector is facing is summarised as follows:

- C Capacity.**
Improve the performance of railway infrastructure to absorb a bigger share of traffic. Information management systems and intelligent mobility concepts involving customer information for freight and passenger services for enhanced accessibility and availability. Increase the attractiveness of integrated public transport systems for existing and future passengers.
- U User**
Develop products and services that attract passengers to choose the rail transport mode. Promote complementarity between different types of rail service and between those services and other modes. Meet market needs with seamless door-to-door transport for both passengers and goods with improved technologies, systems and services to ensure an effective and efficient co-modality.
- S Safe and Secure**
Even though rail is a very safe and secure mode of transport, the perception of personal security is a challenge, as it is for any form of public transport. The challenge has greater significance in an ageing society, where perceptions of personal security are often identified as one of the top concerns of the elderly. It is perhaps even more difficult to reassure rail passengers because of its mass transport nature and its complex networks.
- T Technological breakthrough & competitiveness of the rail sector**
Develop advanced innovative solutions for rolling stock, signalling and infrastructure that are cost competitive, including retrofitting solutions. Research and innovation will have to improve the performance and adaptability of products and production processes. Even more promising than rail sector internal innovation may be identifying and adopting technological innovation driven by other sectors and not yet exploited by rail.
- O Optimised design and operations/connectivity/interoperability**
Ensure the full interoperability of the European railway system for long and medium distance travel as an essential requirement for the development of new rail services and the removal of barriers to trade. Coordinate and integrate long, medium and short distance transport services to provide attractive transport conditions to European citizens. Target new interoperability requirements for improvements in competitiveness, efficiency, reliability, maintainability and sustainability. Harmonise and rationalise safety and security for increased interoperability.
- M Maximised value for money leading to modal shift**
Foster the competitiveness of the (European) rail industry facing worldwide competition. Reducing the cost and time required for product certification and maintenance, passed on to the customer, will promote modal shift towards rail.

E Efficient & environmentally sustainable

Enhance the environmental advantages/performances of the rail mode by further optimising energy consumption and reducing noise emissions. Noise and vibrations are major environmental challenges for rail transport. Further enhance the use of power regeneration and energy supply throughout the railway system. Increase the recycling of materials used in the construction and refurbishment of rail vehicles and infrastructure.

R Reliable & resilient

Advance reliability, punctuality, availability, comfort and customer information systems thus meeting passengers' expectations and enhancing the trust of freight transport decision makers contributing to the choice of rail over other transport modes. The infrastructure must be resilient to degradation from climate changes and limit weather conditions.

S Skills

Make the rail sector attractive to young engineers and provide high-quality educational opportunities in order to provide a work force able to deal with the introduction of new technologies.

6. ERRAC – Future Research and Innovation

Future research and innovation is structured around ten themes reflecting ERRAC's ambition to pursue targeted R&D&I efforts requiring extensive collaboration across the sector. The first two clusters emphasize the holistic view of the railway system, taking account of previously identified strategic business outcomes and targeted innovation processes. The third cluster addresses R&D&I requirements of long term planning for the different technological assets.

6.1 Attractiveness of rail and public transport

This cluster covers two themes which are targeting the same vision and priorities: Customer experience and Strategy & economics.

6.1.1 Customer experience

6.1.2 Strategy and economics

Vision & Priorities

→Passengers enjoy seamless multimodal journeys that are easy to plan, select and book. They experience a comfortable, safe and secure environment and are reassured by the availability of real-time traffic and whole-journey information about journey options should problems arise with modal connections or degraded operating conditions. Perceived nuisance factors such as noise and vibration are minimal. Research will improve the efficiency of transport systems, using operators' knowledge of user behaviour and citizens' expectations. The latter will take account of likely user acceptance of innovative mobility measures and services (by rail, by public transport and co-modal between public transport and individual or shared private modes). New service offers take advantage of research on new traffic mobility management and travel information tools.

→ Business analytics facilitate more customer driven services. Data collection and improved and harmonised statistics feed convincing economic studies and traffic forecasts and the development of customer oriented business models.

→Significant improvements in operational reliability, the cost of rail travel and appreciation of the security of the railway system contribute to the overall attractiveness of the system.

→The rail system is accessible and attractive to all passengers, whatever their social category, age and life characteristics and their possible physical impairment including disabled persons and persons with temporal or permanent reduced mobility.

→Reliable, affordable and attractive rail services – delivered in close coordination with other transport modes - form the core of seamless and sustainable mobility in all parts of Europe.

→The European rail manufacturing industry has technological and industrial leadership worldwide. New technologies for trains, infrastructures and ICT enable much faster, reliable and consistent services.

→ Integration of the databases across transport modes offers door-to-door freight transport including a rail link with fast and accurate service pricing - essential for the attractiveness of a service which must be competitive and reliable.

→ Rail freight customers benefit from regularly updated Estimated Time of Arrival (ETA) using information provided via enhanced train connectivity systems.

→ Improved braking systems enable freight trains to access more efficient and reliable paths.

→ Rail freight competitiveness is enhanced by high train utilisation from the use of IT based space booking systems.

→ Longer trains optimise the use of network capacity.

Socio-economic studies address user responses to pricing policies, to facilitate their travel by rail and public transport through integrated charging and payment systems and to influence their modal choice and travel consumption through pricing and taxation of transport infrastructure and transport means. The studies need to assess the effect on user behaviour of various regulations favouring or restricting the ownership or use of transport modes.

6.2 Whole system approach

Rail is a service business oriented system which must be designed, constructed, operated and maintained holistically, taking into account the important interfaces between its constituent parts, some of which are safety-critical and upon which the integrity of the system depends. No part of the rail system should therefore be developed without considering the effect on other parts of the system.

Rail systems developed for a given rail market segment, will only be successful if each is understood and managed taking account of the whole system, with particular attention to the interfaces between its sub-systems. This holistic approach is also needed to address environmental issues (e.g. noise and vibration, energy); achieve resource-efficient technologies; share the benefits of innovation; and reduce whole life cycle costs. The sector's costs can also be reduced by faster, transparent and efficient authorisation and certification processes for the interoperable European railway. They should be undertaken in an economic manner and harmonised across the EU member states.

Research should target the adoption of a sector-wide framework supporting the implementation of change and subsequent improvement to reliability, availability, maintainability and safety (RAMS). This will be a significant step towards a consistent and robust rail system.

6.2.1 Capacity, performance and competitiveness

Vision and priorities

→ Seizing on the opportunity for a huge modal shift to rail, the rail sector adapts continuously to new market demands by focusing on the customer experience, new operating plans, co-operative alliances and its technology deriving requirements. To remain competitive and meet the challenge projected by the European Commission of rail being the backbone of transport in Europe, the whole European rail sector combines its efforts towards the goal of being closer to end customers' expectations of rail services.

→ To attract new customers, rail capitalises on its strengths: for example its absolute commitment to safety, its green credentials, its global leadership in high speed land services, its traffic management systems technology and telematics. As a main facilitator of mobility and a fundamental part of the transport system, rail also offers reliable and efficient services for the benefit of multi-modal and seamless door-to-door journeys.

Aiming to develop organisational arrangements maximising capacity on busy corridors and improved system utilisation, the priorities are:

- More reliable system components, leading to a highly reliable system which is a prerequisite for the development of track capacity; improved system utilisation, yield

management and organisational arrangements, which maximise capacity on busy corridors; business continuity, optimised by real-time traffic management, maximising capacity, conserving energy and minimising inconvenience to the passenger and the freight user; reduction of in-service failure.

- Reduced overall life cycle exploitation costs for all rail sub-systems, the minimisation of the effects of obsolescence and the effective migration of emerging technological innovation. Innovation shall allow for highly automated rail both technically and operationally and for monitoring vehicle and infrastructure condition and maintenance, hereby enhancing system resilience, reliability and cost efficiency, improved customer service.
- Continued improvement of every aspect of the passenger's trip (obtaining information, purchasing tickets, enjoying station services and travelling in local, regional, intercity and high speed trains, etc.), and of the freight shipper's experience along the supply chain.

All these major developments must lead to win-win solutions for rail freight, which faces fierce competition from other modes.

6.2.2 Energy and environment

Vision & priorities

→Rail continues to play a key role in reducing the environmental impact of transport. By offering increasingly efficient transport which lowers environmental impacts, rail helps create a more sustainable approach to transport. Modal shift to rail, away from more polluting modes, in particular aviation and road freight, is able to reduce further the transport environmental footprint, benefitting society.

→To meet the challenges of climate change, energy supply and transport network congestion, rail has attracted a multi-fold increase in its share of passenger and freight markets, particularly for longer-distance trips.

→The European railway sector seeks to supply its customers and society with attractive, carbon-free and resource-efficient solutions for sustainable mobility and transport.

To maintain and enhance its leading sustainability performance, based on responsible business leadership, the European rail sector will engage in research in the following priority areas:

- Energy supply - this is a critical function in the rail system both for traction power and for heating, comfort, lighting and other operational needs. Rail will become a system that relies much less on the consumption of fossil-sourced energies. This may come about through more and sustainably-sourced electrification of the system or by the use of alternative sources of renewable energy.
- Energy efficiency - even though rail is a very energy-efficient and green transport mode, research is needed on energy efficiency and eco-design to improve further the performance of rail. Rail has developed the "Moving Towards Sustainable Mobility, 2010" strategy which sets very high environmental performance targets.
- System management - minimum energy use and better traffic management based on the development of new technologies will enable energy savings and better overall railway system efficiency.

- Reduced energy consumption - rail will develop systems which consume less energy but also regenerate energy. Stations, terminals and other railway installations and trains will use their own renewable and environmentally-friendly energy sources wherever this is feasible.
- Energy distribution - the development and deployment of resilient and efficient energy distribution schemes will involve smart grid solutions, energy harvesting devices and improved energy self-sufficiency.
- Climate change adaptation - railways will develop into the most resilient transport mode dealing with climate change threats, with research into the effects and management of weather, water, heat impacts on rail infrastructure.

The promotion of environmentally adapted and efficient rail transport of passengers and goods is a key objective in Europe. Public authorities must improve societal understanding of the environmental advantages offered by the railway system in comparison with competing modes of transport.

6.2.3 Safety (including certification) and security

Safety

Vision & Priorities

→ Rail continues to be the safest mode of surface transport and has added additional secondary safety resilience. Disruptions of the service have very limited impact on customers as systems are able to restart quickly and are resilient, thanks to intelligent and consistently applied fall-back systems designed into every critical sub-system and component.

→With a growing reliance on automated interventions 'human factors' have become the critical link requiring new paradigms for innovative staff training methods and tools.

→A clear interface between safety and investment and the establishment of well-balanced cost effectiveness levels has avoided rail safety costs becoming a virtuous barrier to modal shift or to the attractiveness of rail against other transport modes.

→Innovative operational and assets management and engineering techniques, have been developed and implemented and monitor autonomously in real time intelligent infrastructure, rolling stock and other system components. Infrastructure is maintained safely with greater reliance on state-of-art automated intervention methods.

Priorities for development are:

- Progressive automation of the Control, Command and Communication systems leading to a positive impact on operational efficiency and safety.
- Improved management of critical interfaces with third parties (e.g. at level crossings),
- A harmonised process at European level to drive the verification and certification/authorisation of Safety Management Systems, vehicles etc.

- Intelligent and consistently applied fall-back systems to assure safety during degraded mode designed into every critical sub-system and component.

Security

Vision & priorities

→ Rail remains a secure mode of surface transport and has considerably reduced the sense/feeling of insecurity, which may dissuade some people to use it. →The level of security along the supply chain and between modes has been increased without hindering the free flow of people and freight, by increasing the interoperability of transport security intelligence within and between transport modes.

→Increasing mobility requires more multimodal transport venues (stations, terminals, car parks, etc.). These are potentially attractive targets for criminality due to complex layouts and organisational management structures. Multimodal transport therefore is based on an integrated security organisation, with active and passive security management systems - supplemented by trained staff - in multimodal transport nodes. This provides a continuous security system independently of the transport mode used.

→ A standardised and multi-modal approach manages disruption efficiently, minimising the impact on performance and recovery costs.

→ Technology providers are able to develop more effective security equipment to detect intrusion, aggression, vandalism, trespass, fraud, etc., as well as more privacy-friendly solutions using existing technologies such as cameras etc.

→Resilient architectures and additional layers of security, including sophisticated firewalls between operational systems, counter cyber threats.

The priorities are to develop and/or introduce the technical equipment and the cross-modal organisational arrangements to support the implementation of this vision.

6.3 Assets

6.3.1 Control, command, communication

Vision & priorities

→ The railway operates under a flexible, real-time intelligent traffic management system, maintaining the high level of safety. Trains run at very close headways, thanks to the use of moving block and convoy train operation.

→ Rail is equipped at a system level with the integration of the latest train traffic management and train control systems. Customer information and communication technology provide seamless transition between transport modes for passengers and ensure the provision of a modern multimodal freight distribution system.

→ Networks are engineered for resilience and optimised by interoperable real-time traffic management that allows for intelligent, predictive and adaptable operational control of train movements. This increases system capacity, conserves energy and reduces life cycle costs.

Priorities for development are:

- Real time traffic management capabilities for increased capacity, energy efficiency and sustainability.
- Robust and cost effective standard design, test, installation and maintenance of signalling infrastructures.
- Future generation of train control systems focusing on: autonomy, convoying, enhanced train location knowledge and its impact in capacity, environmental gains and operational costs.

6.3.2 Infrastructure

Vision & priorities

→Europe has an integrated transport infrastructure, enabling a single European rail area. This integrated transport infrastructure system for the 21st century is advanced, affordable and acceptable to Europe's citizens.

→The system is optimised in terms of performance, enabling and supporting advancements in other systems, processes and technologies involved with the seamless movement of people and freight across all transport modes¹⁰.

→Operation and maintenance of network infrastructure are reliable, supportive of customer needs, cost effective, sustainable, adaptable to future requirements, automated and resilient to hazards by bringing together innovative technologies and concepts.

→As regards mainline rail, the infrastructure is interoperable, enabling trains to operate across borders without delay or operational constraint, offering a real alternative to short and medium-distance flights and water and road-borne freight flows. As fundamental interfaces within the transport system, stations and terminals are designed to meet the needs of the future customer and are the cornerstone for the provision of quality, accessible and reliable rail services and sector competitiveness.

→Rail system infrastructure is designed to be intelligent and self-learning. It adopts relevant infrastructure technologies from other sectors.

Intelligent infrastructure is fatigue and wear resistant; system components are monitored autonomously in real time. The use of new operational and track engineering techniques across the network reduces the need for intrusive maintenance and greatly improves the train/infrastructure interaction at conventional and high speeds, such as the wheel/rail interface. A focus on intelligence provided by the system (remote condition monitoring) identifies what, when and where maintenance is needed. This minimises the impact of any system interruption and maximises service availability for the customer.

→Freight customers have easy access to terminals. Terminals manage throughput and loading and unloading swiftly. Optimised processes for train preparation reduce noise and vibration and the social nuisance from terminal operations and increase efficiency.

Priorities for development are:

- Improved design and materials to increase track resilience and cost efficiency
- Non-disruptive inspection and targeted timely maintenance interventions to reduce costs and maximise track availability.
- New infrastructure technologies. This will include new track forms, switches and crossings, and their potential for commercial development.
- Modelling tools to analyse whole-life whole-system energy and carbon impacts. The application of new materials and construction techniques, modularisation for fast change

¹⁰ "TOWARDS A PERFORMING INFRASTRUCTURE", Roadmap for Cross-modal transport infrastructure innovation

components, pre-fabricated modules can offer significant improvements in performance and reductions in investment and operational costs.

- Intelligent infrastructure maintenance and inspection and defect detection technologies carried out at commercial speeds.

6.3.3 Rolling stock

Vision & priorities

→Energy and mass-efficient, high capacity and optimised LCC rolling stock meet the evolving needs of rail customers. Rolling stock is critical for the provision of quality, accessible and reliable rail services as well as for the competitiveness of the sector.

→New generation trains are lighter and more energy efficient, are able to reduce previous travelling times, cause less track damage and less impact on the environment, thereby delivering a lower whole life cost. The environmental impact of noise and vibration is mitigated by innovative processes and technologies.

→At the same time, the operational reliability of trains benefits from targeted technical development, so there is less travel disruption, passengers arrive at their destinations on time and the overall better service enhancing rail's attractiveness for passengers.

→For freight traffic, faster, flexible freight trains with improved performance enable rail to deliver the reliability and cost-competitiveness that are key to exploiting market segments until now largely untapped by rail. IT systems enable buying and selling of capacity in wagons, reliable door to door track and trace services for loads and real time information on actual and forecast train position. These services add to the attractiveness of rail for the freight customer.

→ Vehicle performance has improved. Power trains consume much less energy, components have become lighter, regenerative braking has become standard and the use of regenerated kinetic energy in the grid has significantly increased.

Priorities are:

- Promoting the increase of capacity by creating more space for passengers and reducing the weight of vehicles through smaller and lighter sub-systems and components.
- Improving vehicle performance through enhanced braking and flexible coupling and by addressing technologies for better accessibility in order to reduce dwell times. Increased operational reliability, mentioned below, will also have the effect of increasing track capacity.
- Increasing vehicle operational reliability by the combination of new, more reliable components and technologies together with fundamentally more reliable architectures for key sub-systems.
- Reducing vehicle life cycle costs through the combined effect of simpler architectures, less energy consumption and cheaper and more agile certification processes.
- Extending the benefits of LCC reduction to the infrastructure through the development of track-friendly rolling stock technologies.

- Developments that reduce vehicle energy consumption by the combination of more energy efficient equipment and lighter vehicles, which is achieved both by employing incipient technologies and materials and by simplifying system architectures.
- Technical standardisation of high-level architectures and interfaces between train sub-systems for cost effective procurement and retrofitting.
- Environmentally friendly rolling stock with special emphasis in the reduction of the emission of noise and vibrations.
- New paradigms for cost efficient freight rolling stock designs with improved capacity and optimised weight and suitable functionalities for different types of freight.

6.3.4 IT and other enabling technologies

Vision & priorities

→Rail embraces all technologies that enable new forms of information and communication. It encourages the design and use of standard systems architectures and the integration of information systems throughout Europe. This helps to manage large volumes of data over the life of assets.

→The railway has a co-ordinated approach to the management of the information needed to run the operational system. The web of transportation things connects all the assets, allowing much better monitoring of the rail system, with preventive maintenance and flexible adaptation of the different components. Freight is traced and tracked in real-time through all stages of transit, whatever the mode.

→Passengers enjoy a seamless door-to-door journey, thanks to new services addressing all aspects of the travel whatever the mode of transport. Fragmentation of different services (shopping, booking, ticketing, validation, etc.) and between different modes has been removed. Moreover, the availability of real-time traffic and whole-journey information keeps the passenger abreast of the varying alternatives, including inter-connection with other modes, should journey problems arise.

Priorities for development are:

- New architectures to allow the easy adoption of new technologies with stable rules for functional requirement layers.
- IT technologies which allow interoperable services whilst limiting impacts on existing systems, without prerequisites for further standardisation.
- User-centric services, adapted to the mobility of the citizen, which put the passenger at the heart of innovative solutions: easy accessible business services on mobile applications, personalised journey information and whole journey integration and information in conjunction with other transport modes.
- Technologies to manage the transmission, capture, storage and communication from new sources such as sensors, video cameras, tablets and other hand held devices.
- High performance systems for train control.

6.3.5 Training and education

Vision & priorities

→ Training and education contributes to the implementation of the European surface transport research program and to the enhancement of the rail sector by fostering a better match between the human resources needs, making railways a more competitive and innovative sector. A range of skill development is provided by different research based education and training institutions across Europe.

→ A partnership for innovation, skills development and jobs mobilises support and helps the different players work together to spread ownership and excellence.

→ Knowledge transfer from other sectors is an important aspect of the rail transport's cross-sectoral approach: even though partnerships may be assigned to a specific sector, they often work across different business sectors.

→ Lifelong learning has become a well-accepted practice for professional career development. Staff are prepared for technology transitions and involvement in professional situations with a strong interdisciplinary nature, involving technology, economics and business, people and regulatory/policy content.

→ Learning programmes fully exploit current virtual learning environments and e-learning technologies. It is easier to network with specialists and to expose both novices and specialists to real operational situations.

Specific priorities for development are:

- Forecasts of the skills that railway will need and analysis of gaps in skills.
- Enhancement and expansion of educational access to railway courses.
- Enhancement of educational quality in the railway area (academic, stakeholders).
- Creation of mechanisms to put forward courses not offered by existing institutions.
- Development of e-learning based courses and promote the production of course materials.
- Promotion of joint PhDs using bilateral and multilateral programs.
- Promotion of joint international MSc programs in different rail related areas.
- Development and delivery of short training courses (STC).

7. Promoting innovation – conclusions

Transport is currently at a crossroads, with an increasing trend in overall transport volumes, growing traffic congestion in urban areas and critical infrastructure bottlenecks. Reasonably priced new cars, rail rolling stock, ships and airplanes with increasing performances are being designed, manufactured and deployed and significant investments in infrastructure with visible innovation is gradually making transport more attractive, safe, eco-friendly and affordable.

Despite the success stories of High Speed Rail and of Light Rail and modern metros, and after several decades of priority given to the use of private cars and road freight modes, the railway sector as a whole is going through a slow revival period and aims at becoming more attractive, first to customers, with a moderate growth in passenger and freight traffic volumes and also to investors by delivering business-led new products and systems and new technology-based services.

Being an internationally competitive sector, it is still striving to create an eco-system for innovation involving excellent research institutions, vibrant companies devoting time and energy to R&D and demonstration activities. The innovation chain, from blue-sky research, through applied engineering to demonstration (to deployment), must be addressed at European level by bringing together critical technologies in new advanced designs, feasibility proof at concept levels and demonstrations and roll out efforts.

Well-identified cost and technology drivers as well as societal expectations (user rights, new markets, security, and environment) are clearly recognized in this SRRIA. Several key thematic areas can be identified where there is still scope for knowledge creation and subsequent progress to technological developments at higher levels of technical readiness. High capacity infrastructure, sensors, energy storage and smart grid technologies, high-capacity modular rolling stock with efficient new generation braking and bogie designs, use of lightweight materials and information systems to improve customer services and reduce life-cycle cost, are just examples with a strong potential for innovation.

Excellence in customer-oriented railway operations and services, environmental gains and worldwide competitiveness, as described in this SRRIA, call for rail sector stakeholders to set out for each rail market segment the appropriate business visions, making use of current technical experience and future knowledge and capabilities to deliver those aspirations.

ERRAC is committed to establish a long-term framework fostering the innovation process and to achieve its ambitions to contribute to the rail business success, namely:

Managing research and development:

- Support the long-term vision, strategic objectives and the innovation agenda with updated rail business scenarios.
- Update and improve the research and innovation roadmaps by defining research priorities, milestones for technology breakthroughs leading the research agenda in specific thematic areas and taking account of the whole rail system dimensions.
- Identify business prospects and promote market uptake: ensuring real/proper market uptake of the technology, operations, services, and business models developed in the different EU-funded projects by understanding the main features of final applications. Clearly identify the customer/implementer, the surrounding conditions for the business implementation and the mechanisms to close the gap between the end of project and market readiness.
- Provide information on the range of funding sources and of potential new resources for funding transport facilities.

Nurturing collaboration across the sector

- Provide access to industrial expertise and promote knowledge transfer processes from academia and research institutions through specific coordination actions and research based training and education initiatives.
- Foster collaboration and joined-up thinking by facilitating sustainable partnerships involving the sector, SMEs, academia and R&D institutions.
- Facilitate cross-fertilization from other sectors aiming to intermodal integration by cooperating with ETPs and other stakeholders from the transport sector.
- A successful future railway system needs all its assets to be of high quality and in particular the service to the customer has to be adapted to contemporary quality expectations. Dedication to the quality of these services will be ensured through the development and publishing of excellent standards by the sector. Maintaining and improving these standards in accordance with business needs, customer expectations and the provision of a positive travel experience will demonstrate the maturity of the European railway sector in collaboratively managing the rail system.
- In the rail sector, the legislative and regulatory framework and standardisation can support (when necessary) the rapid take up of research results (e.g. Technical Specifications for Interoperability and EN standards) in close collaboration with the European rail sector. Coordination is also necessary between different bodies and institutions such as - for mainline rail - the European Railway Agency.

Supporting the SHIFT²RAIL Joint Undertaking

- SHIFT²RAIL will be the first European rail Joint Undertaking to seek focused research and innovation (R&I) and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions.
- SHIFT²RAIL will promote the competitiveness of the European rail industry and will address changing EU transport needs. Through the R&I carried out within this Horizon2020 initiative, the necessary technology will be created to complete the Single European Railway Area (SERA) and fulfil the expectations of all rail markets segments.
- A system approach to the specification of the needs with the establishment of “Requirements and Implementation groups” involving the rail stakeholders.
- Step-change efforts and development of prototypes.
- Integration and demonstration at system level through “System Platform Demonstrations” around well identified market segments.
- Involvement of forward-looking market actors ready to invest in innovation and a commitment to inclusiveness ensuring a wide participation of all actors at European level.
- SHIFT²RAIL will enable the implementation of a certain number of priorities of the Strategic Rail Research and Innovation Agenda.

Exploring Synergies between Horizon 2020 and Cohesion Policy

Coordination of activities funded through Horizon 2020 with those supported by other EU funding programmes includes an appropriate articulation with Cohesion Policy funds in the context of national and regional research and innovation Strategies for Smart Specialisation.

The Transport component of Horizon 2020 strikes a balance between the holistic view - transport systems, cross-cutting issues such as intelligent transport systems and urban mobility - and the specificities of each transport mode, between competitiveness and sustainability, and between technology and socio-economic aspects.

Member States are deemed to make full use of the provisions of the Cohesion Policy allowing to combine Cohesion and Research funds, and are strongly encouraged to consider additional measures aimed at “unlocking” their potential for excellence in research and innovation.

The opportunity to combine funds from the research and cohesion policies in the next programming period marks a major progress and must be implemented in a framework of coherent programming, common prioritisation and strategic coordination of policies in each Member State and at European level. The framework should involve innovation and cohesion policy-making authorities, at European, national and regional level.

ERRAC will encourage the exploitation of synergies at policy level supporting research in identified priority fields, at program level in the design of the operational programs and at project level.