RAILWAY TECHNICAL STRATEGY EUROPE

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This Railway Technical Strategy Europe has been developed and published by the UIC on behalf of members that are constituents of the Railway Operating Community (ROC) in Europe, and also represented in UIC European Regional Assembly.

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1. INTRODUCTION

Railways can be the backbone of an integrated, multi-modal mobility system in Europe. Its realisation depends on vision, investment, innovation and enterprise. It requires a forward-looking technical strategy that commands the support of stakeholders across Europe. The European railway sector set out its vision for the railway system of the future six years ago in *Challenge 2050*[i]. The following year we published the *Rail Technical Strategy Europe (RTSE)*[ii]. Last year European rail freight CEOs published their vision, *30 by 2030*[iii].

The mobility market is changing rapidly. The Railway Operating Community (ROC)[iv] is integral to this.

This second *RTSE* progresses this work. It aims to capture some of the trends that have emerged in the mobility market and in transport-related technology since our earlier publications. It describes how railways fit into the mobility framework and the ways in which we will move forward.

2. THE RAILWAYS' CONTRIBUTION TO MOBILITY

Railways have strengths that are particularly relevant to the future of mobility.

- They can handle large volumes at high speed and very safely.
- And railways are one of the most sustainable modes of transport.
- Railways are energy efficient, using mainly electric haulage; and they are active in testing-out new carbon-neutral power sources such as hydrogen and other alternative propulsion concepts.
- Railways already provide an almost seamless web of connectivity. Their potential to complement, and thus reduce over-dependence on, other modes is vital to the delivery of sustainable mobility and relieving congestion. There is growing demand for improved connectivity, whether between states, regions or major settlements, or between modes.

Connected mobility is at the heart of the services that we operate and is essential to the management of the trains.

By contrast, autonomous and connected vehicle technology, e-mobility and electrification in the road sector will demand a step-change in behaviour and organisation if the potential benefits of these developments are to be realised and opportunities for connectivity maximised.

The ROC has the experience, skills and systems that can facilitate the new mobility era. Realisation of this innovative step-change in societal mobility depends on each mode collaborating with the others and delivering the elements for which it is most suited and at which it is most efficient.

3. THE CONTEXT

The sector's technology horizon has evolved significantly since publication of the first Rail Technology Strategy Europe in 2014. The last five years have been characterised by some significant drivers of change.

a. **Demand for transport** has continued to grow, not just when measured in terms of share of GDP[v] but also when judged in terms of the quality of service sought, while efficient transport continues to be seen as a cornerstone of European integration[vi].

b. **Globalisation** continues to act as a driver in gaining efficiencies and driving down costs through economies of scale, particularly when supported by common standards and thus sharpening competitiveness and innovation as preconditions for business evolution.

c. **Urbanisation** is another driver of change: around three out of every four people in the EU live in urban areas (compared to around 50% in 1950). This is projected to rise to over 80% by 2050.
Urban areas account for 85% of Europe's GDP with real estate at a premium. Space devoted to road traffic, including space for parking road vehicles, accounts for more than half the total area of many cities while urban transport accounts for almost one quarter of CO^2 emissions. The European Commission's most recent Transport White Paper set the goal of achieving CO^2-free city logistics by 2030.

d. **Road congestion** has a major negative impact on competitiveness and on the environment of urban areas in particular. The European Commission estimates that congestion costs around €130 billion annually.

Railways, when capacity is maximised, are a very strong congestion-busting solution

e. **Environmental concerns** have risen in prominence:
   1. **Decarbonisation** has grown in significance as a policy priority, drawing additional impetus from the commitments agreed in Paris at COP21 in 2015.
   2. **Public health** considerations are driving increasing concern about the impact of road vehicle emission of particulates, both exhaust and non-exhaust. The noxious effect of the latter – caused by brake and tyre wear, road surface erosion and road dust particles – will still threaten public health even in the era of e-vehicles.
   The European Environment Agency calculates that almost 487,600 premature deaths in 2014 in the EU were attributable to $PM_{2.5}$, NO_2 or O_3 exposure[vii] (not all being road-vehicle related). To put this in context, road traffic accidents resulted in 25,700 fatalities[viii] that year.
   By comparison, in 2016, there were only 31 rail-related fatalities resulting from collisions with obstacles (other than incidents involving level crossings), collisions between trains, derailments, fires in rolling stock, electrocutions, shunting operations and accidents involving dangerous goods[ix].

   Railways are significantly the safest form of land transport

   3. **Other environmental impacts** have generally assumed greater significance for policy-makers. These include the impact of traffic on noise levels, the liveability of areas afflicted by road blight and the impact of land-take for traffic schemes.

f. **Digitalisation** is in full swing. It is set to transform customer service in planning, billing for, making, tracking and connect-

ing-on from a railway journey whether for people or freight. It has the potential to offer every end-user a mobility solution that is tailored to their own need.
Innovative digitalisation will bring greater reliability, efficiency and flexibility to the production, maintenance and organisation of physical transport. It will release significant capacity, reduce delays, enable early identification and resolution of potential equipment problems, enhance safety and drive down costs. It will facilitate seamless connectivity between modes – synchro-mobility.

Digitalisation will also create new challenges, particularly in maintaining the security and integrity of cyber-systems

g. **Big Data** analytics is key to enabling key trends and patterns to be discerned from large volumes of data, often generated in real-time, and from a wide variety of sources. Together with the exploitation of cyber-physical systems, such as the Internet of Things – where the connectivity of sensors embedded into everyday objects ensures continuous flows of vital performance data, revolutionising asset management.

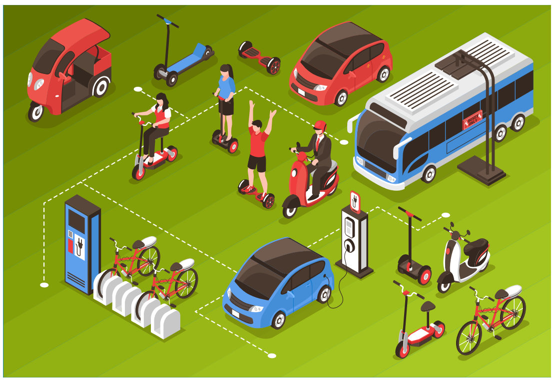
h. **Automation** makes it possible to anticipate a network of intelligent vehicles that negotiate the efficient and reliable use of transport networks in an autonomous mode, either singly or linked to other vehicles (a train), according to demand, but under remote supervision. It is already applied in the operation of some of the most intensively used parts of the railway network and widely applied in aeronautics. Intelligent infrastructure facilitates this automation.

i. **Synchro-mobility** describes the concept of all modes being integrated in one network, and in which switches between modes are achieved seamlessly, facilitated by an integrated data framework and collaborative data analytics. It underpins a system in which each mode does that for which it is the most efficient.

j. **Behavioural changes** are creating new challenges for transport providers. There are indications in some countries that commuting may be decreasing, reflecting the growth in home-working or reductions in the length of a working week. Meanwhile, as elderly people make up a growing share of the population, demand for leisure travel and for meeting the needs of people with reduced mobility is increasing.

k. **Demographic changes** are also having an impact[x]. Eurostat suggests that, due to Increased life expectancy and falling birthrates, the number of elderly people in EU-28 will have be more than 50% greater by 2080 compared to 2016. They will make up almost one third of the total population (compared to less than one fifth today). The size of the working-age population is projected to shrink considerably, further increasing the burden on those of working age to sustain the dependent population. The ratio between people at work and the remaining population is expected to fall to 2:1, compared to the present 4:1. Not only are patterns of travel likely to change, the labour market is forecast to be under considerable pressure.

l. **Road transport** is likely to become more competitive – as will other modes - with the development of autonomous vehicle technologies and vehicle connectivity. The successful development of e-vehicles, road electrification and initiatives like the introduction of platooning in the road freight sector will also have a significant impact on the economics and nature of road transport.



Development of micro-mobility vehicles (sometimes defined as road vehicles weighing less than 500 kg and including e-bikes and e-scooters) could lead to major changes in vehicle use as well as in reducing the demand for road space, particularly in urban environments. They typically lend themselves to organised sharing, especially if their flexibility is unconstrained by the need for docking-stations. Micro-mobility, possibly combined with vehicle-sharing, may replace many of the short trips currently made by car. Besides making cities more liveable, this could lead to more investment in public transport, including rail. The uptake of new micro-mobility solutions is likely to develop quickly and could impact on the transportation sector long before there are significant numbers of electric or autonomous vehicles. The railways are preparing for this eventuality.

m. **New transport technologies** such as delivery drones or pods (like Autonomous Nano Transport Systems, known as 'ANTS'), or the adaptation of older technologies, as is the case with Hyperloop, Maglev and freight airships and blimps, have the potential to bring fundamental change to mobility provision.
The railways have experience and skills that will be of value to other guided systems, as well as to those dependent on the management of interfaces between systems, as with autonomous and connected vehicles.

4. THE FUTURE EUROPEAN RAILWAY SYSTEM

4.1. CUSTOMER FOCUS

In moving towards the system of tomorrow, understanding the needs of the customer is essential for business success.

Users want a mobility system that is affordable, reliable, safe and available with capacity that is sufficient to meet demand comfortably.

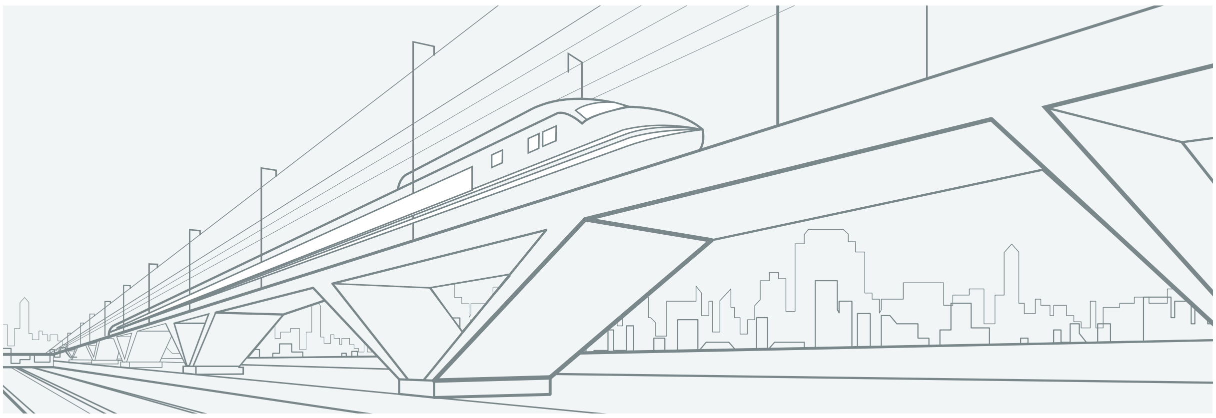
This requires the delivery of high-quality service that is focussed on consistent operational excellence, capable of adapting to changing customer expectations, to external influences and to new business challenges and opportunities.

4.2. A SHARED VISION

The ROC has a shared vision for the future European railway. Each of the main topics below is a key element of the vision. It has been written as if we were standing somewhere in Europe around the middle of the century.

The ‘**Outcomes**’ describe what this means in practice.

The ‘**Enablers**’ are the technical tools that have allowed or will allow this to be brought about)



4.2.1. The railway is the backbone of an end-user focussed, integrated mobility system that provides seamless transit, irrespective of mode, each mode collaborating with others to deliver the elements at which it is the most efficient

Outcomes:

1. The ROC has seized the opportunities created by 'Synchro-mobility' - the integration of mobility and related IT systems - to create a flexible, synchronised, intermodal network, encouraging more productive public investment.
2. The railway system is fully integrated with the multimodal logistics chain.
3. The network that the system serves provides seamless transit for people and freight, irrespective of mode, with interconnected and interoperable services.
4. Freight and passenger services are responsive to customer needs, resilient to changing external conditions and efficient.
5. End-user needs are met by making mode and routeing decisions on a case-by-case basis, as late in the transport planning process as possible.
6. Legacy barriers to cross-modality, including infrastructure limitations, have been mitigated.
7. Synchro-mobility will drive new concepts in infrastructure planning enabling more effective, integrated investment.

Enablers:

1. A European level organisational and communication infrastructure, inclusive of all relevant stakeholders, facilitates the introduction of new technologies.
2. There is a robust, resilient and secure governance structure for the timely collection, analysis and interpretation of data, with open architecture and protocols permitting full interoperability.
3. There is a network of core TEN-T corridors designed to shift large volumes of traffic reliably and at high speed, with resilience assured by 24/7 availability and flexible cross-modal capacity.
4. Cross-modal arrangements are in place for the infrastructure management of the core corridors.
5. Common standards and standardised interfaces facilitate interoperability, eliminating operational delays between operators, systems and modes, and creating economies of scale.
6. Information and data systems have been developed based on Blockchain to assure communication within the super-network whilst protecting commercial confidentiality.
7. Cross-modal hubs, connected by interoperable railway corridors, have been established at major traffic handling points throughout Europe, facilitating physical connectivity between modes.
8. Multi-modal shipments are transferred seamlessly and efficiently.
9. Formations (for instance, train consists or road platoons) and schedules are designed to reconstitute themselves in real time providing a truly flexible response to fluctuating patterns of demand.
10. Freight customers are supported by reliable track, trace and alert systems. Passengers benefit from telematics that enables each one to plan the most cost-effective, time-efficient and convenient co-modal journey.
11. Real-time and reliable maintenance data facilitates improved decision-making for long-term asset planning.
12. Funding has been targeted at eliminating system barriers to capacity constraints, interoperability, including gauge variances, incompatibility between train management and control systems, energisation systems, etc.
13. EU-level intervention has secured a level playing-field between transport modes.

4.2.2. Railways provide best value in terms of service quality and cost, handling large volumes efficiently and very safely

Outcomes:

1. The ROC has addressed its cost base making railways a strong player in all the markets in which it chooses to compete.
2. Significant improvements have been achieved in network capacity, reliability and resilience.
3. Automation, together with ‘smart’ operations and maintenance regimes, have boosted safety and reliability.
4. Users can plan multi-modal journeys, make bookings, monitor progress, vary their itineraries, benefit from predictive information about perturbations and identify the best work-around solutions.
5. Principal population centres throughout Europe are linked by a coherent network of services on lines built for speeds in excess of 250km/h operating at average speeds of more than 200 km/h. These are supplemented by attractive conventional services using lines that have been upgraded to permit speeds of at least 200km/h.
6. Freight train performance is compatible with the use of passenger-quality train paths. Infrastructure limitations to heavy and long trains have been tackled on all the TEN-T ‘Core’ Network Corridors and their extensions, including their links to Asia and the Middle East.
7. The pursuit of high-quality never ends, reflecting the challenge of an ever-changing competitive environment. A training culture, network-wide, nurtures customer-focus while user satisfaction drives professional reward.

Enablers:

1. Design specifications are based on common sector standards developed by the railways; these maximise quality assurance and smooth safety authorisation, facilitating integration into the operational railway whilst delivering economies of scale.
2. Low-cost solutions - often pioneered by other modes including light rapid transit - have been adopted where appropriate, enabling services to be maintained, and often improved, on more lightly used parts of the ‘heavy-rail’ network, drawing inspiration from other sectors such as light rail, automotive and aviation.
3. The ROC has ensured installation of ERTMS and completion of the TEN-T ‘Core’ Network Corridors by 2030.
4. Innovative techniques have been adopted to reduce the cost and disruption of infrastructure upgrades and maintenance.
5. Technologies have been developed to facilitate the operation of services between systems with differing legacy standards, e.g. track and loading gauges, power supply and train control systems.
6. Trains are able to operate themselves and run close together, safely, based on an automated train operation system, boosting capacity significantly.
7. Improvements in coupling technology, power distribution and braking facilitate longer (over 1500m) and heavier freight trains between hubs on the core network.
8. Staff training ensures that both end-user facing front-line staff and those other staff and contractors whose work may impact on end-users, are alerted to the importance of end-user satisfaction.
9. Digitalisation has been used cost-effectively to increase capacity, reduce delays, enable adaptation in real-time to changing operating conditions, thereby ensuring resilience to perturbations, ensure that comprehensive real-time information is available to inform the ‘smart’ maintenance and operation of the railway, enhance safety and to meet the needs of its users.
10. Use is made of satellite and drone data (e.g. drawing on data captured by Laser Image Detection and Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (InSAR)).

4.2.3. End-users consistently receive a high-quality service

Outcomes:

1. End-users have ready access to transparent and impartial information and can therefore make informed decisions when planning a journey or shipment.
2. Services are timed to the second, and the facilities advertised are always provided.
3. There is sufficient capacity to convey freight and to accommodate passengers comfortably at the time required.
4. Customers enjoy continuous access to their personalised journey information systems and all freight is traceable and trackable in real-time throughout the transit, irrespective of mode.
5. The success of the ROC companies in addressing their cost base, in persuading governments of the need for a level playing field in the transport sector as a pre-requisite of a competitive and sustainable mobility system, and recognising the importance of service quality, has resulted in end-users seeing that railways provide good value.

Enablers:

1. New design concepts accommodate digitalisation, personalised on-board passenger information and new commercial offerings. With permanent access to high speed data connectivity (e.g. 5G mobile network or WLAN) passengers are able to use their journey as an extension of their working or leisure environment.
2. Railway premises and the trains themselves are always clean and well presented. The ROC works closely with local authorities to enhance the ambiance of the environs of railway premises on a continuing basis.
3. Mobility as a Service (MaaS) allows users to access personalised, real-time information relevant to their mobility needs, irrespective of mode, ensuring seamless connectivity with simple and efficient interchanges.
4. ‘Apps’ developers work closely with the ROC to enable access operational data for the purpose of encouraging the development of apps likely to be of value to end-users. These are helpful in supplementing the information service that operators provide to passengers on journey issues and in providing options when services are subject to perturbation. This has the incidental benefit of reducing reliance on unreliable social media.

4.2.4. The railways respond flexibly to changing market demands and operational conditions

Outcomes:

1. Demand at all places and at all times is met efficiently and in a timely manner.
2. The network is engineered for maximum train autonomy and minimum service perturbation.
3. Assets are adapted to meet changing customer demands during their planned service life.

Enablers:

1. Suppliers are persuaded that the development of equipment that can be adapted economically to changing customer requirements over its life-cycle is a valuable component of the services that the railways offer to the end-user.
2. Autonomous, intelligent and highly responsive vehicles communicate with one another and with intelligent infrastructure and back-office booking processes in ways that allow provision to be adapted cost-effectively to short-term fluctuations in demand.
3. Improved track and train availability have been achieved through ‘smart’ maintenance, mitigating perturbations.
4. Intelligent trains are aware of their loadings and are able automatically to adjust the number and characteristics of the vehicles they comprise and adapt their routeing to immediate circumstances with customers advised in real time.
5. Signal timing techniques are deployed in network management systems to achieve unimpeded traffic flow (coordination of train control system to produce a progressive cascade of green lights, thereby optimising capacity, reducing braking and acceleration, energy use and emissions).
6. Real-time monitoring of the health of vehicles and infrastructure using sensors connected within an ‘internet of railway things’ to feed predictive maintenance decision-making processes.
7. Modular vehicle design, with components that can be changed on a ‘plug-and-play’ basis, is used to simplify upgrades during a vehicle’s service life: vehicles are designed to accommodate evolving customer needs, to be staff and customer-friendly.
8. Generic designs for ‘smart’ buildings and rolling stock interfaces are used instead of costly bespoke solutions to simplify expansion, upgrades and replacements.
9. All core corridors are designed to ensure that there is suitable diversionary capacity, either through the provision of alternative routes or by access to other modes.

4.2.5. Railways are the safest and most secure mode of land transport

Outcomes:

1. Passengers and staff feel and are safe wherever they are on the system.
2. All systems, applications and services are secured against attacks, including cyber-attack.
3. Consignors and consignees trust that their consignments will arrive safely, in good condition and at the time planned.
4. A culture of identifying potential risks and making provision for their management to ensure that they are as low as reasonably practical is universal amongst all ROC companies.

Enablers:

1. Passenger perceptions of personal safety are systematically reviewed and addressed. Evidence of close monitoring of the system reassures customers of their personal safety whilst in the vicinity of (including the approaches to) railway premises or when using services.
2. Wherever practical in the vicinity of isolated passengers, there is some form of visible staff or other human presence of the sort that people are likely to find reassuring.
3. Non-invasive technologies are exploited to minimise external threats, aggression and vandalism. Extensive use is made of behavioural risk-recognition technology.
4. ROC companies cooperate with one another and the relevant authorities in a timely way to exchange best practice and share information on potential safety and security hazards, including in clearing and continued monitoring of staff, contractors and others with potential access to the operational railway.
5. The ROC has invested in a pre-emptive strategy for tackling potential cyber-security risks.
6. The elimination of potential hazards, particularly in and around stations and at the interface with trains, has eliminated the risk of death and injury from trips, slips and falls.
7. Safety and security-by-design is fundamental to the conception and execution of all enhancement projects.
8. The ROC works closely with authorities and stakeholders to reduce the operational risk at critical interfaces such as level crossings.
9. There is recognition of the risk of designed-in errors with complex autonomous systems.
10. An aviation-sector style non-punitive environment to encourage fault and hazard reporting is operated.
11. The sector recognises the value of treating passengers, employees and contractors as useful ‘eyes and ears’ in monitoring safety and security.

4.2.6. The railway is as sustainable as reasonably practical and does not rely on fossil fuels for energy

Outcomes:

1. Carbon emissions from operational activities have ceased decreased through the widespread electrification of the network using environmentally-generated energy. There are sustainable, energy-efficient solutions for the remaining non-electrified routes. Train operations are carbon neutral.
2. Sustainable Development Principles[xixii] (including those enshrined in the 'Circular Economy') are embedded in the design, construction operation and maintenance of infrastructure and rolling stock assets and the procurement thereof. The railway is resilient to climate change.

Enablers:

1. Reduction of energy consumption and utilisation of renewably-sourced energy and alternative propulsion concepts such as fuel cells.
2. Advances in low-carbon construction and in the use of railway assets (land, buildings and vehicles) for energy harvesting.
3. Management tools assess whole life environmental as well as economic impact. These allow comparison of maintenance and/or replacement strategies for assets based on traffic and whole life evaluation.
4. Reduction in nitrogen oxides (NOx) and particulate matter ($PM_{2,5}$ and PM10) emissions has been achieved through sustainable and ethical procurement and production, utilising a whole-life approach and focusing on system inputs, recycling, transport of materials, renewable energy, operations and disposals.
5. Adoption of whole system management approach, including infrastructure and vehicles, to minimising noise and vibration levels.
6. Use of 'right-weight' materials for rolling stock and application of mechatronics to suspension and bogie design and to steering, thereby reducing maintenance costs and reduce energy consumption.
7. The ROC is engaged with spatial planners and developers to ensure that it is seen as an asset for better land use, combatting congestion, enabling higher-density urban development and facilitating environmental and social enhancement.

4.2.7. The railway is regarded as an attractive industry in which to work and is a magnet for talent and innovation

Outcomes:

1. A culture of continuous improvement underlies the commitment of railway people to excellence, their readiness to embrace new technologies and techniques and a desire to put customers first.
2. Working for the railway is a source of pride for every member of staff and every contractor.
3. The ROC's culture is customer-focussed and outward-looking.
4. Entrepreneurs and innovators have the right conditions to develop new products and services and the export market is expanding.
5. However guided transport systems develop, railway expertise is well-placed to embrace new technologies.

Enablers:

1. Recruitment and training nurtures a railway-wide culture in which professional reward is related to user satisfaction. This ensures that both front-line staff and those other staff and contractors whose work may impact on end-users are alerted to the importance of meeting their needs and expectations.
2. Managers are always ready to draw upon a broader set of skills from other sectors.
3. A whole-system approach has fostered innovation and attracted the best talent across the railway.
4. The ROC champions and supports the development of technical railway schools and of collaboration with the academic research community.
5. The ROC actively supports the importance of better gender balance in technical professions and at senior management levels.
6. The sector is a global leader in collaboration. An alliance of relevant research institutions from across the world has been established, identifying the ROC as champions on innovation.
7. It has created a Virtual European Railway Academy (VERA) with a view to creating a cadre of potential sector leaders, well-versed in the practices of other operators and modes and reinforced by a programme of Erasmus-style exchanges within the sector.

4.2.8. The railway sector is outward-looking with global horizons, ready to learn from others and open to further change

Outcomes:

1. The ROC is noted for its pioneering role in promoting a collaborative approach to cross-modal working in in the Single European Transport Area[xiii].
2. The ROC is actively engaged in technology exchange and transfer, including in collaboration with other modes; it has a vision for the future, a justified pride in its past and understands how to properly mix the two to create the whole.
3. Railways are essential to the successful accommodation of environmental and land use pressures and on new social demands arising from increased urbanisation.

Enablers:

1. Collaboration is actively encouraged throughout the railway sector, including the exchange of best practice between operators, with industry and academia, and with other modal sectors, both in Europe and globally.
2. Networks of facilities for the testing and trialling of railway technical innovations have been established. These speed the development, product acceptance, market placement and operational implementation of new products and services.
3. Agile development approaches, incubators, Labs, Hackathons and early involvement of customers (including potential end-users), are recognised as important elements of customer-centric innovation.

5. DELIVERING THE TECHNICAL AGENDA

A solid technical strategy relies not only on having a vision of the future European railway system, but also on building on the legacy that went before.

The dynamic and successful role that the railways will have in the transport mix and which this RTSE supports, will be based on a ROC that works holistically and innovates to evolve. Success will be measured in the way that the 'enablers', which this RTSE describes, are developed and how they contribute to the railways bearing their share of the mobility load factor and how new customers are attracted to use the services provided by the railways.

The dynamism will come through the emerging culture of receptiveness that the railway people will have to new ways of delivering customer service, and a willingness to challenge and look beyond traditional barriers. To maximise benefits, railways will therefore examine how best to facilitate change, including the establishment of advanced organisational and operational structures and systems.

This RTSE is a beacon that lights the path towards a future railway system that can contribute better to wider social and economic goals within the communities it serves.

Delivering this will rely on the creation of a technical agenda that sets out how best to enable the outcomes that are developed in this RTSE. Far from being just another theoretical exercise, it is intended that a further piece of work will take the ideals espoused in this RTSE and convert them into practical outcomes.

It is clear that the railways will need to action delivery of these in a cohesive, efficient manner. The ROC will work closely with Shift2Rail and others internationally, both within and without the railway community, to support the development and delivery of the enablers.

Fundamental to the ROC being a strong service provider, one that fulfils its position in the mobility mix to maximum potential, is its ability and willingness to look outside its own bounds for the best and often most economic solutions. Collaborating with technology developers and other specialists in areas where the railways do not perhaps have the capability, is essential to growing a collaborative approach.

Increasing innovation within the sector requires incentives to be aligned better between stakeholders and right along the supply chain. Such benefits could flow, for instance, from closer alignment of investment cycles and the development of improved value transfer mechanisms.

Reducing actual and perceived risk associated with technical innovation is important, as this is a major barrier to interoperability. But these are not the only barriers; the success of the vision set out in this RTSE will also be greatly enabled by a greater understanding at institutional level of the potential that railway transport has to offer. Rather than see the railways as cumbersome and slow to evolve, the operational, environmental and commercial opportunities must be appreciated, and opportunities maximised - some already exist, but more should be developed.

Specific practical measures to support delivery of the future European railway system, bringing together the benefits of the ideas described in this RTSE, include:

- **Priority technical areas for innovation, research and development** – ERRAC[xiv] has worked very hard on this and recently produced its vision for railways in 2050. Building on the capabilities that the ROC had identified and the areas of enable-

ment that the manufacturing community envisioned, the document sets out the research areas that should be encouraged.
Taking this RTSE as the catalyst, the dynamic ROC will consistently develop the requirements that it has for the future European railway system. These will be the pathfinder elements that will help the technological evolution and design of the hardware of the future

- **Funding the evolution** – the future European railway system will be all the more successful if it can rely on attracting sources of funding that do not only depend on government intervention. Recognising the huge impact that it can have on the mobility framework, the ROC will look to sourcing mechanisms from within and also to attracting investment from hitherto untapped sources. Perceived environment needs will take Railways

- **Access to industrial expertise** – is essential to the evolutionary process. The ROC has and will continue to say what it wants to achieve (this and previous RTSEs bear witness to that) but it will be through the design and construction capabilities of the manufacturers and suppliers focussing on the business needs of the railways that the operational delivery and maintenance of the services the ROC provides to the end-user will be most effective

- **Access to development and test facilities** – being able to prove that new designs are going to be of added business value in operation is essential. The railways will collaboratively strengthen their momentum by working with bodies that have established facilities that will help to prove the concepts for tomorrow and ensure that they are able to be effectively implemented in the operational railway

- **Standards for services and systems** – the design, construction, operation and maintenance of the services that the railways provide to the end user and the manner in which the railway system interfaces with other modes, is essential to a successful future European railway system.
  Ensuring that the evolution of the railways is cost effective, safe and attractive, is greatly supported by writing all the elements into user-friendly documents that set out a range of solutions as to how the core objective can be realised and integrated into the operational railway.

  For the shared network, where various operators use the same infrastructure, applying the same or perfectly interfacing processes is a key prerequisite for a safe and reliable operation, not only within but also beyond Europe. Having a suite of well-prepared standards incentivises the design of components - improving operational excellence, maintenance logistics, enabling scale-effects and above all, providing reliable and attractive to the customer and end-user. It will also ensure that the future European railway system is technically and operationally harmonised to the fullest extent.

  Since the railway is first and foremost a system, any part must be developed with due consideration given to the safety and cost impact (on other parts of the system) of the topic to be standardised. It is this simple perspective that will ensure that the integrity of the system is considered.

  Working closely with a range of agencies, the dynamic ROC will ensure that the right steps are taken to prepare and publish appropriate supporting documents, whether these be through ENs, that focus largely on design and construction, or through IRS[xv] that focus essentially on operation, maintenance, integrity of the railway system and customer service.

The ROC will, working with a wide range of technical experts and other ROC stakeholders, develop this technical agenda so that it best sets out how and by whom the objectives set out in this RTSE can be achieved.

6. BIBLIOGRAPHY AND REFERENCES

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[ix] UIC Safety Report, 2017

[x] http://ec.europa.eu/eurostat/statistics-explained/index.php?title=People_in_the_EU_-_population_projections#Population_projections

[xi] See Sustainable Development: Making railways greener, quieter and more energy efficient, UIC 2018

[xii] The Rail Sustainable Development Principles, RSSB (2009) https://www.rssb.co.uk/improving-industry-performance/sustainable-development/rail-sustainable-development-prinicples

[xiii] https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en

[xiv] ERRAC is the European Rail Research Advisory Council (www.errac.org)

[xv] A structured framework of standardised documents prepared and published by the UIC for use within the railway sector. They blend together a range of voluntary solutions to support the design, construction, operation and maintenance of the railway system and the services that the railways provide. See Railway Standardisation Strategy Europe, UIC 2017 https://europe.uic.org/IMG/pdf/rail_standardisation_strategy_europe_light.pdf

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