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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

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1. Executive Summary

The FOSTER RAIL project is addressing the challenge to strengthen and support research and innovation cooperation strategies in the European rail sector. The project's work plan foresees to enhance coordination among main stakeholders and actors in the European rail sector and rail industries and integrate the work done so far by ERRAC and its working groups. Starting with the already published ERRAC-ROADMAP, the FOSTER RAIL project will continue to coordinate the research and innovation agenda and priority setting process among the wide range of relevant stakeholders in the rail sector. The outcome of FOSTER RAIL will be a Rail Business Scenario as basis for new Strategic Rail Research and Innovation Agenda (SRRIA) and specific Rail Technology & Innovation Roadmaps aimed at 2050. The output will among others be used to advise the European Commission, Shift2Rail and other research programmes on their content.

Task 4.1 "Technology and Innovation Roadmaps" of the Work Package 4 will deliver updated and upgraded technology and innovation roadmaps in line with the SRRIA's strategic alignment and fill the gaps in the existing ERRAC Roadmaps. The new set of roadmaps (fully taking into account the work performed under the ERRAC Roadmap project) will be a plan that matches short-term and long-term goals with specific solutions to help meet those goals. The roadmaps will apply to a new product or process, or to emerging technologies. One of the aspects of this task is to summarise, cluster, prioritise and publish the sector's R&D needs. On the basis of this work, ERRAC advises the European Commission annually on the sector's R&D needs & priorities. This deliverable D4.1 provides the unitary template for each of the part-roadmaps in order to arrive to 10 compatible part-roadmaps.

2. Description of the Deliverable

The previous EC funded project “ERRAC ROADMAP” has developed 9 research & technology roadmaps in support of ERRAC. Not all of these roadmaps were built up along the same structure, which made it sometimes difficult to combine or integrate related priorities or to compare issues. In order to avoid this, the WP4 team has identified in an early stage the main elements for the new Technology & Innovation Roadmaps. During the course of the work inWP 4 this template has been updated several times.

This Deliverable D4.1 defines the unitary template as it has to be used by each of the Roadmap leaders for the drafting of their part-Roadmap.

The final FOSTER-RAIL Research & Innovation Roadmap will consist of 10 new part-roadmaps and this template has been developed and agreed in order to have a common structure and description for each of the part-roadmaps, facilitating the integration and interoperability.

3. Costumer Experience

3.1 Introduction

Customer Experience, covers a very vast topic, since parts of almost all other themes and roadmap topics could be subsumed to it – the railways sector is meant to provide services to different customers, therefore all improvements or changes either target or influence the customer in one way or another. However, a split along certain criteria has been introduced in order to make sure that there will be as little overlap as possible.

The identified roadmap topics that have a more technical and/or operational have been assigned to their respective subjects/areas. Consequently, the present roadmap does not go too much into the technical aspects of the research, but tries to have (partly) a "helicopter view". The roadmap tries to focus more on the 'softer' aspects, even though the technical aspects continue to be mentioned the topics that have a significant direct influence on the rail customer and their perception via-à-vis the railways sectors have also been included in the "Customer Experience" roadmap. Other topics are intrinsically vast and significantly influencing other roadmap topics – therefore they appear in their relevant roadmap, but also in the "Customer Experience" one. Many of the topics identified under the "Strategy and Economics" Roadmap are also linked with the "Customer experience", since the two roadmaps are twinned, and customers are naturally one of the key aspect in a company strategy and economics planning. And, of course, there are the direct topics that pertain to customer experience – either individuals or companies that benefit from the services of the rail transport sector.

This roadmap the notion of 'customer experience' covers both personal mobility and business customers (e.g. freight).

Starting from the vision outlined by the SRRIA, the 'Customer Experience' Roadmap proposes the as vision the following:

- 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.
- The actual and the perceived experience and environment of the customers are very positive, as both aspects are intertwined. The so-called 'look and feel' is in many cases the main selection criterion for the (potential) customers. Consequently the functionality, comfort, price but also aesthetics of the rail sector attract the customers. Stations and rolling stock (both the exteriors and the interiors) are the most important, since these two elements not only provide the main visual of the rail domain, but are also the places where customers spend most of the time when using rail services.

All these enhancements are at an affordable cost:

- Real or perceived nuisance factors such as noise and vibration are minimal. Rail research 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).

- Fares, adapted to respond to the growing and more various demands of the customers, while maintaining them on the rail system during (most of) their travel, while at the same time attracting more customers and increasing the fare revenues.

- Business analytics facilitate more customer driven services. Data collection and improved and harmonised statistics feed convincing economic and demographic 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 and safety 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. - Integration of the databases across transport modes offers door-to-door freight transport including a rail link with fast and accurate service pricing.

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

3.2 Key issues and objectives

Taking into account the current political socio-economic and technical developments, the rail sector is faced, like many other sectors, with a number of *key challenges*. It must be noted that these challenges need to be answered as a 'business as usual' activity in the coming years, not just as part of the desire to enhance the role of the rail sector in the general transport landscape. Although the main challenges can vary from country to country (and even region to region), two of them stand out as being overarching challenges at the European level: *decarbonisation and digitalization*.

Digitalization is inherently addressed by the railways through their very nature while the latter is becoming an increasingly present topic in the rail environment, but mostly due to the progress registered in other domains, which make these technologies both desirable and necessary to address customer demands. However, relying on the present status quo or being reactive to developments in other sectors will not be sufficient for the railways to remain a key player in the transport sector.

Consequently the railway stakeholders have designed the SRRIA and its implementing roadmaps in order to present the *sector's vision in response to the general or particular challenges that the railways face*. This vision, can be broken down into 4 main topics:

- *lower costs* (both for customers and the rail actors that serve these customers);

- *reliability of services*;

- *comfort and/or better vehicle utilization* (with an accent on the availability of space);

- *adaptability to the different challenges* – mostly in physical terms (rolling stock & infrastructure).

In order to implement this vision, the key issues and objectives identified by the SRRIA are:

- Ensure attractive prices for customers while increasing the 'value for money' of the services;

- Simplify mobility from door to door through seamless multimodal journeys that are easy to plan, select and book, thus allowing easier changes in case of unexpected problems with interconnections or degraded conditions. With each avoided activity the mobility concept will be more attractive. Less activities mean also less possibilities for system failures;

- Ensure the safety and security of passengers;

- Ensure up-to-date information about journeys in advance and with alternatives;

- Analyse, define and scale user acceptance of innovative mobility measures and services

- Improve operational reliability, and the affordability of the travel cost, delivered in close coordination with other transport modes, thus enabling seamless and sustainable mobility in all parts of Europe;

- Ensure that the rail system is accessible and attractive to all passengers, whatever their social category, age and life characteristics and their possible physical impairment. Special attention will be given to senior citizens, families with small children and the passengers with reduced mobility;

- Improve public transport interchanges between transport modes with adequate solutions for year-round necessities: weather shelter, waiting conditions & time, comfort, information, ways to walk, etc.;

- Offer door-to-door freight transport including a rail link, with fast and accurate service pricing;

- Extended digitalization e.g. simplify/ standardize information, ticketing for inter-/intramodal trips;

- Analyse, define and scale passenger needs and obstacles for (railway based and general) mobility. Understand and respond to public needs following in-depth socio-economic studies on: pricing policies, integrated charging and payment systems, passengers' modal choice(s) and travel consumption, pricing and taxation of transport infrastructure and transport means, general user behaviour, the impact of ownership or use of transport modes, etc.;

- Explore and implement 3rd party benefits, so that such combinations will integrate the rail sector in other activities/domains, thus promoting it as a source of improved benefits;

- Customers should benefit from as many direct connections as possible – which would also mean adding more lines and stations (especially in the urban environment).

The overall vision aimed by the rail sector representative is to offer the entire range of customers a set of services that can reply to each of their needs, with the highest standard. This set of services is to be understood not only as the proficient and modern rail transport service that everyone wishes, but a set of services that puts rail at the core of the land transport sector while at the same time creating the necessary links with other transport sectors in order to create a truly seamless door-to-door trip.

3.3 State of the Art and on going research and innovation within and outside rail

a. Shift²Rail

The Shift2Rail is a Joint Undertaking between the EC and major European rail stakeholders, with the aim of achieving a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system.

The S2R is divided into Innovation Programmes (IPs), each addressing a major rail area, as follows:

IP1 – Rolling stock

IP2 – Traffic management and control systems

IP3 – Infrastructure

IP4 – IT solutions

IP5 – Freight-related technologies

S2R is also addressing cross-cutting activities in order to ensure a better response to the various customer needs, as well as a higher integration of the JU activities.

At the moment the IP research activities have not yet started, but preparatory activities have already begun for a number of IPs.

Shift2Rail will address the following challenges:

- The overall challenge: strengthening the role of rail in the European transport system;
- A quality of service and cost challenge;
- A European challenge – overcoming the fragmentation of rail markets;
- An infrastructure challenge;
- A competitiveness challenge;
- A know-how challenge;
- Innovation – a tool for the long-term.

Although S2R is divided according to the technical needs, all aspects pertain to customer experience in a direct way. All research is designed to make the railways a more attractive,

cost-efficient, reliable, (inter-)connected, comfortable and adaptable transport system, in order to meet the present and future demands of its customers.

b. H2020

- Planning sustainable urban areas by integrating rail freight: based on a catalogue of requirements for the optimal use of rail freight services in urban areas;
- Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility) and using transport as an enabler of urban design and renewal;
- Managing the impact of demographic trends and, in particular, the ageing population;
- Effectively harnessing new transport -related ICT technology and data management opportunities;
- Land-use and spatial planning around sustainable efficiencies of public transport; operate trains for 60 - 80% with energy from renewable sources; develop common appraisal methods for cost benefits analysis of cross border business;
- Impact of new integrated transport and land-use policies and measures;
- Accessibility as a tool and as an objective;
- Integration of ticketing and charging services - (New) charging and pricing policies strategies;
- Interchanges for passenger travel and transport - Integrating interchanges, nodes of the smart city;
- Integrated Urban mobility Systems and Governance -Mobility management and social networks.

c. National research

Austria:

- Accessibility and attractivity of rail-based mobility services (barrier-free access, seamless infrastructure knots, accompanying services e.g. for luggage transport);
- Multimodal mobility lifestyles and integrated mobility services;
- New means of transport;
- Tools to shape sustainable mobility patterns;
- Sensors & Measurement, Traffic Management & Information, Cooperation & Integration;
- Development of concepts and solutions for rail freight traffic for first and last mile;
- Development and optimising of services on modal hubs;
- Innovative wagons;

d. Relevant Research & Technologies outside rail that can support, directly or indirectly, the improvement of customer services and perceptions on the rail sector.

- Advanced IT - including big data processing and analytics, passenger information systems, wearable technology;

- The industry internet - using the 'internet of things' including sensor networks;

- Novel use of satellite-based services for traffic and transport solutions, made possible through technology development and the implementation of Galileo. The link with parallel developments, like smartphones, 5G and logistic solution is a key issue;

- Smart grids - economic, legal and institutional framework for the development of smart grids for energy capture (e.g. from kinetic processes) storage and adaptive feeding to rail, road and other applications;

- Strategies and objectives for the use of active and passive systems to provide constant vigilance against both daily crimes specific to the transport systems and terrorism and cyber-attacks;

- Multi-senses vehicles – innovative solutions for people with mobility impairment.

3.4 The Roadmap

The present priority topics ensure both coherence between past and future work, and to create a comprehensive approach of the sector toward the R&D&I needs for the years to come.

Below is an outline of the main topics for the "Customer Experience Roadmap", structured according to a number of sub-themes. It can be noted that many of these sub-themes are cross-sector, and there is a natural overlap between some of them. Addressing several inter-related topics within the same research effort is an added-value. The indicative timeline of these research proposals is also indicated between brackets.

T0 = topics that should be addressed as soon as possible, even in the same year that the Roadmaps are issued. ERRAC members had already proposed some topics to the EC before the mid-term of H2020.

T1= 2020

T2 = 2030

T3= 2040

T4= 2050

T5= +2050

General Main Objectives of this roadmap for the entire period are:

- Development of tools used for planning and monitoring mobility;

- Better understanding of the user behaviour a and better knowledge of user expectations and possible reactions to new measures and mobility services;

- Harmonised data and statistics for economic studies and traffic forecasts;

- Studies to understand the response of users to pricing policies;
- Long term investment models and planning including new urban rail systems.

Noise & Vibration

- decrease noise and vibration levels (T0-T4);
- Improvement of interior acoustic comfort for passengers (T0 -T2);

Logistic services - rapid reaction to queries - response time to enquiries in terms of service availability, routes, schedules, pre and end haulage satisfying customer demands (T0-T3).

Seamless passenger journey

- Integrated information systems handling the whole journey across modes and different mobility providers (T0-T3);
- Adaptive interiors configuration for different flows of passengers and different types of users e.g. family activities, mobile office and group travel (T0-T3);
- Logical station layouts, good signage, location and maps and information on onward local ground transportation options (T0 – T4);
- Comfortable waiting areas, research, understand and where feasible accommodate passengers' varying priorities at different hubs (T0-T3);

PRM - Mobility for all (T0-T4).

Land use - Improving the spatial appeal to passengers of the urban environments in which transport hubs are located (T0-T3).

Customer needs and behaviour

- Customer needs and expectations including protection of privacy, and translation into functional service requirements (T0-T4);
- Tools for customers (travellers, companies, authorities) to calculate the impact on decarbonisation and other socioeconomic aspects when using the different rail systems (T1-T3);
- Mobility and location behaviour of individuals and firms (T0-T4);
- Social determinance of mobility behaviour (T0-T2);
- Measuring customer satisfaction and involving customers in service design and operation (T0-T2);
- Impact of new integrated transport and land-use policies and measures (T0-T2);
- Accessibility as a tool and as an objective (T1-T3);

- New services which can be provided to customers in trains or stations, e.g. tablets, audio books, movies, night trains with single cells instead of compartments (T0 – T3);
- Improve communications with customers: before, during and after service (T0-T5).

Personal Security - Design, technological and organisational measures to improve customer and staff security (T0 – T3).

Safety and homologation - Management of degraded mode and minimising disruptions to passengers (T0 – T3).

Competitiveness and enabling technologies

- Improved accessibility for specific categories (T0 – T3);
- Enhanced digitalization throughout the sector (T0-T5).

Security

- Key asset protection - Train security perception (T0- T3);
- Key asset protection - Station security perception (T0- T3);
- Human factors - Passengers and other users security perception (T0- T3);
- Detection Systems - No intrusive sensors (T0- T3);
- Detection Systems - No time spent in security check (T0- T3);
- Procedures, Regulations and standards - Privacy and personal freedom protection (T0-T3).

Based on these aspects, a first general conclusion can be drawn: the rail sector needs to dedicate more attention and efforts to breakthrough innovations and technologies. On the one hand it would ensure that it is keeping up to date with the general progress in other domains, as well as with the growing demands of the young generations of tech-savvy customers. On the other hand such dedicated and sustained research would ensure that rail does not just keep up the pace, but can also take the lead in some cases and establish itself as a reference in the transport sector.

Such developments will also require as key prerequisites a high level of environmental friendliness and a systemic approach of the performance of the system from design, to operation, including maintenance.

3.5 Implementation Plan

a. SHIFT²RAIL

The JU has started work in 2015 and its work will span throughout the lifetime of H2020, with some activities scheduled to be finished a bit after the end of the framework programme. Even though (most of) the final outputs of S2R will not be available for market roll-out, the programme foresees bold progress for many railway segments that will be easily adopted and implemented by the rail stakeholders in a rather short period of time.

Moreover, S2R tries to address all rail customers and proposes answers the two main challenges at the EU level: decarbonisation and digitalization.

S2R will cover much of the research for the periods T0-T2 and the beginnings for T3.

b. H2020

In the case of H2020 ERRAC members consider that a 2-stage approach should be implemented.

The first stage corresponds to the first half of H2020. The topics for this first part have already been outlined in chapter 5:

- Planning sustainable urban areas by integrating rail freight: based on a catalogue of requirements for the optimal use of rail freight services in urban areas;
- Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility) and using transport as an enabler of urban renewal;
- Managing the impact of demographic trends and, in particular, the ageing population;
- Effectively harnessing new transport -related ICT technology and data management opportunities;
- Land-use and spatial planning around sustainable efficiencies of public transport; operate trains for 60 - 80% with energy from renewable sources; develop common appraisal methods for cost benefits analysis of cross border business;
- Impact of new integrated transport and land-use policies and measures;
- Accessibility as a tool and as an objective;
- Integration of ticketing and charging services - (New) charging and pricing policies strategies;
- Interchanges for passenger travel and transport - Integrating interchanges, nodes of the smart city;
- Integrated Urban mobility Systems and Governance -Mobility management and social networks.

The second stage, corresponding to the second half of H2020, should address the remaining research topics that have been pinpointed for the T0 – T2 period.

c. Other public funding programs

The following categories of funding have been considered as public funding programmes:

1. The different EU sources of funding.

2. The state (national/regional) sources of funding.

EU funding – here not taking into account either S2R or H2020 – comes through a wide array of channels and methodologies, which can be accessed directly or indirectly.

The main sources are the European Structural and Investment Funds[3]:

- The European Regional Development Fund (ERDF)[4] which aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions. The ERDF focuses its investments on several key priority areas: innovation and research; the digital agenda; support for small and medium-sized enterprises (SMEs); the low-carbon economy.

- The European Social Fund (ESF)[5] invests in people, with a focus on improving employment and education opportunities across the European Union. For 2014-2020 the ESF will focus on four of the cohesion policy's thematic objectives: promoting employment and supporting labour mobility; promoting social inclusion and combating poverty; investing in education, skills and lifelong learning; enhancing institutional capacity and an efficient public administration. The ESF consequently represents a source of funding that can address the need for training and qualifications that will meet the demand of the rail sector, both today and in the years to come, thus responding to some of the topics identified under the customer experience roadmap.

- The Cohesion Fund[6], aimed at Member States with a Gross National Income (GNI) per inhabitant is less than 90 % of the EU average. It aims to reduce economic and social disparities and to promote sustainable development. A significant part can be allocated to general environmental activities: energy efficiency, developing rail transport, supporting intermodality, strengthening public transport, etc. In theory some rail stakeholders can use part of these funds for transport-related research. But this also depends both on the national legal framework and the future EU-related developments in the field of research funding.

- Alongside these funds, the EU also has the possibility to offer grants in support of projects or organisations which further the interests of the EU, or contribute to the implementation of an EU programme or policy[7]. Numerous topics covered by these grants can be subsumed to the R&D&I aims of the rail sector: competitiveness, education and training, energy, environment, sustainable development, shifting freight from road, etc.

The state funding comes in two major channels:

- The various national and/or regional schemes that support R&D&I development.

[3] http://ec.europa.eu/regional_policy/thefunds/index_en.cfm

[4] http://ec.europa.eu/regional_policy/thefunds/regional/index_en.cfm

[5] http://ec.europa.eu/regional_policy/thefunds/social/index_en.cfm

[6] http://ec.europa.eu/regional_policy/thefunds/cohesion/index_en.cfm

[7] http://ec.europa.eu/contracts_grants/grants_en.htm

- The involvement of foreign states (or state-owned organizations) in major research activities through: loans, grants, capital market investments, etc.

d. Private funding possibilities

The main methods to obtain private funding for rail R&D&I (in addition to those pledged by the already-involved stakeholders) are the following:

- Other private companies that wish to enter the market.
- Public-private partnerships (PPPs) for major and expensive research topics.
- Loans from banks.
- Drawing funds from the capital markets (either from private companies or PPPs) for major projects.
- Private equity investors in major companies or major research projects.
- Major universities, especially those with large endowment funds like those in the US.

However, the rail environment is one which generally does not offer high returns of investment in a short period of time, therefore it is important that the sector – with efforts from the states, the EU and the other stakeholders – will try to become more attractive for these sources of private funding, otherwise major possible investors will continue to avoid it.

In the case of customer experience the major advantage is that in some cases the rail sector, instead of doing all the research by itself, can (and should) envisage partnerships with other stakeholders and customer representatives in order to find out how to best respond to their demands.

Moreover, in some cases the rail sector research should strive to be able to accommodate the solutions that the other parties are developing for the customer-experience side. In this case the railways sector needs to meet 2 key criteria: openness and continuous dialogue with the other stakeholders, and to develop/use as many open-source, adaptable technical solutions as possible, in order to enable a real “plug-and-play” solution for the widest array of developments.

Many of the current developments have been done with the help of other parties, and it is recommendable that rail stakeholders, while not completely handing over these developments, can (and sometimes should) let other actors take the lead in doing necessary research.

3.6 Visual Roadmap, milestones and deliverables overview

	T-0 Today	T-1 2020	T-2 2030	T-3 2040	T-4 2050	T-5 +2050
Noise & Vibration	Decrease noise & Vibration levels					
	Improvement of interior acoustic comfort for passenger					
Logistics Services	Rapid reaction to queries - response time to enquiries in terms of service availability, routes, schedules, pre and end haulage satisfying customer demands					
Seamless passenger journey	Integrated information systems handling the whole journey across modes and different mobility providers					
	Adaptive interiors configuration for different types of users e.g. family activities, mobile office and group travel					
	Logical station layouts, good signage, location and maps and information on onward local ground transportation options					
	Comfortable waiting areas, research, understand and where feasible accommodate passengers' varying priorities at different hubs					
PRM	Mobility for all					
Land use	Improving the spatial appeal to passengers of the urban environments in which transport hubs are located					
Customer needs and behaviour	Customer needs and expectations including protection of privacy, and translation into functional service requirements					
		Tools for customers (travellers, companies, authorities) to calculate the impact on decarbonisation and other				
	Mobility and location behaviour of individuals and firms					
	Social determinance of mobility behaviour					
	Measuring customer satisfaction and involving customers in service design and operation					
	Impact of new integrated transport and land-use policies and measures					
		Accessibility as a tool and as an objective				
	new services which can be provided to customers in trains or stations, e.g. tablets, audio books, movies, night trains with single cells instead of compartments					
	improve communications with customers: before, during and after service					
Personal Security	Design, technological and organisational measures to improve customer and staff security					
Safety and Homologation	Management of degraded mode and minimising disruptions to passengers					
Competitiveness & enabling technologies	Improved accessibility for specific categories					
	Enhanced digitalization throughout the sector					
Security	Key asset protection - Train security perception					
	Key asset protection - Station security perception					
	Human factors - Passengers and other users security perception					
	Detection Systems - No intrusive sensors					
	Detection Systems - No time spent in security check					
	Procedures, Regulations and standards - Privacy and personal freedom protection					

Fig. 1 - Visual Roadmap, milestone and deliverables overview

3.7 Conclusions

The railway sector is faced with a number of *challenges* today and in the future. These are challenges both in terms of the natural competition between transport modes, but also on a systemic scale: *decarbonisation and digitalization*. In order to reply to these challenges, the rail stakeholders have undergone a number of studies concerning the R&I aspects that need to be done in order to ensure the improvement of the rail systems on a sustainable, competitive and long-term basis. The final output is the SRRIA and its implementing roadmaps, *the sector's vision in response to the general or particular challenges that the railways face*. This vision can be broken down to 4 main topics that need to be addressed: *lower costs* (both for customers and the rail actors that serve these customers); *reliability of services*; *comfort and/or better vehicle utilization* (with an accent on the availability of space); *adaptability to the different challenges*, mostly in physical terms (rolling stock & infrastructure). And in order to respond to these aspects, the SRRIA has been divided into a number of broader topics and subsequently into roadmaps.

The "Customer Experience" roadmap presents the necessary steps to undertake in order to address the customers' needs. Many of the technical aspects are better covered by the technical roadmaps, which is why this roadmap only mentions them more through a "helicopter view", and focuses instead on the 'softer' aspects. It is also twinned with the "Strategy and Economics" Roadmap.

After presenting the current state of the art and on-going research and innovation activities (e.g. S2R and H2020), the roadmap outlines the main R&I topics (and their subtopics) that need to be addressed: noise and vibrations, customer services (e.g. seamless passengers journeys, PRM, logistics), safety and security, digitalization, etc. All these topics are covered in a timeline up to 2050, divided into several steps. Subsequently, the implementation (financial) possibilities of these R&I targets are outlined. The last clause is dedicated to the conclusions of the roadmap.

The data from this roadmap shows that "customer experience" encompasses numerous aspects of research, including some in which rail is not the main developer, but can become one of the main beneficiaries.

In the case of the EU-funded research, the main target of this road-mapping exercise, in the short term are S2R and H2020. For the long term solutions there are a number of solutions which can be envisaged. Two of them are, quite naturally, the subsequent EU Framework Programmes and the possible "Shift2Rail" v2.0 and 3.0, following the model of the aviation sector. S2R deals with research that will improve the performance of railways. In this case it is the rail sector that is at the helm of research and innovation, and the plan will certainly bring numerous benefits the customers.

In the case of H2020, there are numerous research topics that can address “customer service” in the case of rail. In most of these cases the rail sector is an important partner, but does not necessarily lead the way. In other cases it is just one stakeholder among the others. However, this can be strength, not a weakness. Railway stakeholders can thus tap into the knowledge of the other stakeholders and partner with them in order to obtain results that are applicable for not only railways, but as many sectors as possible – thus strengthening the link between rail transport and other economic sectors. It is also a way to ensure that many of the rail research effort are “future-proof” – they will not quickly become obsolete in case of other technological developments from other markets. Another aspect in the H2020 research is that solutions found for one particular economic sector can be transferred to the rail sector. Therefore the rail stakeholders (and maybe the EC as well) should try and monitor the results, so as to be informed of the existing potential solutions.

Standards are an important part of the R&I landscape and the railway sector in general, since they enable reduction of costs and technical/operational interconnectivity, thus helping both the rail system and its customers. Standardisation can be pursued in numerous segments of the railway sector, and especially in the mainline rail market(s).

With this work the rail sector is proposing a vision of the future railways and the implementing steps that can materialize this vision, while taking into account the various challenges to be met, both today and in the future, in order to be closer to the existing and potential customers. It is certainly not finalized, as the roadmaps will need to be refined in the future, in order to meet new demands and face new challenges. However, the sector is driven by the customers, as it exists because of them, hence the existence of this roadmap and its multiple links with all the other roadmaps.

4. Strategy and economics

4.1 Introduction

Strategy and Economics is a very vast topic, to which, in theory, almost all other themes and roadmap topics could be subsumed. However, the FOSTER RAIL partners had made a split along certain criteria in order to make sure that there will be as little overlap as possible.

All identified roadmap topics that have a more technical and/or operational aspect have been assigned to their respective subjects. The present roadmap tries to have a more "helicopter view" approach, and deal with the more general directions of research, or with the forecasted/possible major changes.

Nevertheless, there are certain subjects within these roadmaps that would require a vast amount of effort and resources to be implemented, or a significant part of a paradigm/plan to be changed, consequently they feature in this roadmap. Another case refers to those topics that cannot be implemented within a short period of time, being the fruit of many years of research and implementation. These topics can therefore be found both in the Strategy and Economics Roadmap and in their subject-matter roadmap as well. Other topics are intrinsically vast and significantly influencing other roadmap topics – therefore they appear in their relevant roadmap(s), but also in Strategy and Economics. In some cases topics are transversal, and so it was decided that placing them solely in this roadmap is the best approach. Last but not least, this roadmap tries to include topics that are not directly attributable to the other roadmaps, despite the fact that they have a high significance for the rail sector.

The visions either directly outlined by the SRRIA or stemming from its core messages are:

- 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 should problems arise with modal connections or degraded operating conditions. Families and passengers with reduced mobility benefit from adequate facilities. Perceived nuisance factors such as noise and vibration are minimal. 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 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. Families benefit from adequate facilities, thus strengthening their choice for rail transport.

- 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 attractive, competitive and reliable services.

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

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

- Socio-economic studies address user responses to various pricing policies, to facilitate their travel by rail and public transport through integrated charging and payment systems and to influence their modal choice.

- Today the railways are the most eco-friendly and safe land transport mode. However, all other transport industries are investing significantly in these areas, consequently rail cannot afford not to further invest in both safety and environmental friendliness. These two topics need to be the highest on agenda of all top managers and decision makers in the rail system.

- embracing new technologies such as digitalization and automation will ensure a good positioning of the rail sector, while at the same time improving the business models.

4.2 Key issues and objectives

The railway sector is faced with a number of *challenges* today and in the future. These are challenges both in terms of the natural competition between transport modes, but also on a systemic scale, the most important being *decarbonisation and digitalization*. Tackling them needs to be at the core of the railways strategic and economic agenda. Part of it is already done, but all concerned actors acknowledged that these are only the first steps.

Consequently, the rail stakeholders have prepared over the last years a number of studies concerning the R&I topics that need to be addressed in order to ensure the improvement of the rail systems on a sustainable, competitive and long-term basis. The final output is the SRRIA and its implementing roadmaps, *the sector's vision in response to the general or particular challenges that the railways face*. This vision can be broken down into 4 main topics:

- *lower costs* (both for customers and the rail actors that serve these customers);

- *reliability of services*;
- *comfort and/or better vehicle utilization* (with an accent on the availability of space);
- *adaptability to the different challenges*, mostly in physical terms (rolling stock & infrastructure).

To address these aspects, the SRRIA has been divided into a number of broader topics and subsequently into roadmaps. And because of the way in which the SRRIA had been designed, this roadmap is twinned with the roadmap dealing with the "Customer Experience", therefore there is a great overlap between the vision and priorities of the two.

This roadmap addresses the needs of all stakeholders involved: operators, authorities, industries, but also the "end-customers" – both personal mobility and business/transport of goods. The ultimate goal is to improve market share and increase revenue and profit without any prejudice to the quality of service, products, etc.

The key issues and objectives based on the SRRIA outline are:

- Seamless multimodal journeys that are easy to plan, select and book.
- Real-time traffic and whole-journey information about journey options at any time, and especially in degraded operations conditions.
- Better integrate information/expectations from users in order to achieve better services. 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.
- Improve traffic mobility management and travel information tools.
- Improve business analytics facilitating more customer-driven services. Integration of the databases across transport modes. Data collection and improved and harmonised statistics.
- Ensure the reliability, accessibility, affordability, safety, security and attractiveness of rail services.
- Invest in new technologies for trains, infrastructures in order to enable much faster, reliable and consistent services.
- Reducing costs throughout the sector: supply chain, operations, etc.
- Digitalisation and ICT, e.g. Future Internet, internet of things, advanced computing, content technologies and information management (Bid Data), Cybersecurity,etc.
- Consequences of disruptive technologies for the Railway Sector, e.g. 3D printing
- Innovative solutions for future logistics operations.
- Automation of Rail Operation (Robotics, Nanotechnology, etc.), Autonomous Train Operation, Train Convoying, virtual coupling of trains.
- New propulsion systems (e.g. Gas, Hybrid).

- understand how long term trends in society and technology will influence mobility patterns and to the need for consistent ways of appraising the costs and benefits of alternative innovations.

The overall vision of the rail stakeholders in this sector is to find new solutions or improve the existing ones, in order to achieve a resilient, performant, environmentally friendly and cost-efficient rail system. This enhanced rail system must not only able to compete on equal terms with other transport modes, but should also try and become the backbone for land transport – for both passengers and freight.

4.3 State of the Art and on going research and innovation within and outside rail

a. Shift²Rail

The Shift2Rail is a Joint Undertaking between the EC and major European rail stakeholders, with the aim of achieving a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system.

The S2R is divided into Innovation Programmes (IPs), each addressing a major rail area, as follows:

IP1 – Rolling stock

IP2 – Traffic management and control systems

IP3 – Infrastructure

IP4 – IT solutions

IP5 – Freight-related technologies

At the moment the IP research activities have not yet started, but preparatory activities have already begun for a number of IPs.

The overall challenges that S2R tries to address are: strengthening the role of rail in the European transport system; a quality and cost challenge; a European challenge – overcoming the fragmentation of rail markets; a competitiveness challenge.

b. FP7

Due to the vastness of the “Strategy and Economic” subject and the different interests of various actors, it can be claimed that (almost) any research project is strategic to at least one railway stakeholder. Consequently this document does not provide a list of FP7 topics here, but only outlines a some of the most important projects in certain rail domains as examples: SECUR-ED & PROTECTRAIL (largest land transport security projects, the former for urban, the latter for mainline), MODSafe (safety), NGTC (signalling), NODES (interchanges), CleanER-D, OSIRIS or MERLIN (energy), etc.

c. H2020

Since the H2020 is only at its very beginning, and many of the rail-related topics are now covered by the Shift2Rail Joint Undertaking, the other options for rail research projects are lower than in the previous EC-funded framework programme. However, ERRAC has informed the EC of a number of research topics that the rail stakeholders would like to address in the next few years with the help of H2020.

The topics outlined by the ERRAC members are the following:

- Planning sustainable urban areas by integrating rail freight: based on a catalogue of requirements for the optimal use of rail freight services in urban areas.
- Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility) and using transport as an enabler of urban renewal.
- Managing the impact of demographic trends and, in particular, the ageing population.
- Effectively harnessing new transport-related ICT technology and data management opportunities.
- Land-use - Land-use and spatial planning around sustainable efficiencies of public transport; operate trains for 60 - 80% with energy from renewable sources; develop common appraisal methods for cost benefits analysis of cross border business.
- Customer needs and behaviour - Accessibility as a tool and as an objective.
- Integration of ticketing and charging services - (New) charging and pricing policies strategies.
- Interchanges for passenger travel and transport - Integrating interchanges, nodes of the smart city.
- Integrated Urban mobility Systems and Governance -Mobility management and social networks.
- Improving knowledge with data collection and analysis - Consistent data collection and exchange on urban mobility and development and use of harmonised models supporting data analysis, land use and transport forecasts, cost-benefit and multi-criteria economic analysis and decision-making.

d. National research

All national research can be subsumed to the topic of ‘strategy and economics’

e. Relevant Research & Technologies outside rail

ERRAC believes that a number of strategic R&D&I topics that are being developed by other sectors will help rail stakeholders make significant progress in the years to come. The most relevant research areas that are seen as having the highest possible strategic impact for the rail sector are:

- Advanced composites & lightweight materials – mass reduction, LCC reduction, customer benefits.

- Nanotechnology.
- The industry internet - using the ‘internet of things’ including sensor networks.
- Drone technologies – e.g. to inspect and maintain transport systems.
- Development of demonstrators of robotic equipment to replace simple repetitive tasks currently undertaken by maintenance teams.
- Smart grids for energy capture (e.g. from kinetic processes) storage and adaptive feeding to rail, road and other applications.
- Inductive charging for electric vehicles, including EMUs / Hybrid trains.
- Energy storage, including future battery technologies, graphene supercapacitors; energy harvesting, including regenerative braking.
- Alternative propulsion energy sources, including hydrogen and natural gas, operation of trains from 60 - 80% energy from renewable sources.
- Next generation power semiconductor, with better efficiency, weight and volume and standards development for transport applications.
- Use of recycled materials and innovative cross-modal techniques for infrastructure construction.

Attention should also be given to the developments in the different standardization bodies at the EU or international level. In the case of the EU there are the CEN/CENELEC (the EU Committees for Standardization and Electrotehnical Standardization, respectively) and ETSI (the European Telecommunications Standards Institute). The equivalent organizations of CEN/CENELEC at the international level are the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE). The different agreements made within these organizations can have a tremendous impact on the European R&I landscape, as they can not only set some major research directions, but they can also outline new business cases for all stakeholders.

4.4 The Roadmap

The priority topics identified by the previous ERRAC roadmaps had been reallocated according to the new SRRIA Roadmap titles for two main reasons: to ensure both coherence between past and future work, and to create a comprehensive approach of the sector toward the R&D&I needs for the years to come.

The way in which these topics had been selected was already explained in this document, in chapter 3. It must also be noted that a few of the previous ERRAC roadmaps had been discarded because their approach was either too general, or was no longer reflecting the main needs of the sector. Moreover, some key topics have been added following discussions at the level of the ERRAC Steering Committee.

Below is an outline of the main topics for the “Strategy and Economics Roadmap”, structured according to a number of sub-themes. It can be noted that many of these sub-

themes are cross-sector, and there is a natural overlap between some of them. Addressing several inter-related topics within the same research effort is an added-value. The indicative timeline of these research proposals is also indicated between brackets.

T0 = today

T1= 2020

T2 = 2030

T3= 2040

T4= 2050

T5= +2050

Optimise environmental and sustainable impacts of the Life Cycle of subcomponents

- Design procurement, installation, maintenance, operations and disposal (T2 – T5).
- Political approach and economic assessment of feeding kinetic energy back to the public grid (T2-T5).
- Reduction of the vehicle LCC (including costs), while maintaining or enhancing current performances (T1-T5).

General wagon issues - New transhipment technologies and operational concepts for low cost terminals (T0-T4).

Single wagons - Integrated rail freight production concept (operational, commercial and technical) for increasing the utilisation of single wagon loads (T0 + T3).

Logistic services

- Development of transport services within single or multiple dry-ports in a TEN-T node concept (T4).
- Horizontal collaboration between shippers of the same modality (T0-T5).

TEN-T freight network

- Freight oriented and freight dedicated network (T0-T4).
- Development of TEN-T missing cross border links with efficient green co-modal nodes (T0-T4).
- Merging TEN-T core and comprehensive network via green-type of primary, secondary and tertiary nodes (T0-T4).

Freight villages

- Spatial planning for mega hubs freight villages necessary for development of co-modality and long distance transportation, new designs and layout (T0-T4).

- Urban green logistics associated to the mega hubs and freight villages (T0-T4).

Land-use

- Land-use and spatial planning around sustainable efficiencies of public transport, especially in cities (T0-T5).

- Development and implementation of appropriate performance regimes for mobility providers and infrastructure managers (T0-T4).

- Improving local integration of land-use, transport and environment (T0-T4).

- Develop cooperation between the railway and construction sectors for better land management (T1-T5) (an example here is the US case, where rail and road developments are done in tandem with real estate developers, and it is the latter that cover part of the costs for the former).

Integration of urban traffic and travel information

- Integration of traffic and travel information (T0-T4).

- Definition of data quality (T0-T3).

- Integration of information on all types of externalities (T0-T3).

- Integration of information on electromobility (T0-T3).

- Governance models enabling the integration of traffic and travel information (T0-T3).

- Interoperability for customers through common multi-application processes on a single media: create a Pilot operation in a number of Member States in preparation for wider roll-out (T0-T3).

- Create a common EU-IFM application (T3).

- Develop a commercial and technical framework for the sales and settlement of EU-IFM Products (T1-T2).

- Engage and merge with existing IFM Systems and other ITS services and transport modes (T0-T3).

- (New) charging and pricing policies strategies (T0-T3).

Interchanges for passenger travel and transport

- Design and operation of new generation resilient urban transport interchanges for greater integration of urban mobility networks (T0-T4).

- Financing and business models (T0-T4).

- Integrating interchanges with urban policies (Land use planning, economic development, smart cities, etc.) (T0-T4).

New city logistics concepts and interfaces for a more efficient freight delivery

- Framework for stakeholders' involvement in greater exchange of information on urban freight delivery (T0 – T4).

- New city logistics concepts, taking into account the impact of societal changes on commercial behaviour and goods delivery in urban areas (T0-T4).

Integrating (urban) mobility management

- Network management strategies, integrated with sustainable urban mobility plans (T0-T4).
- Research on the improvement of connections – European, national, regional and urban levels (T0-T5).
- Governance for the coordination of the network management tools (T0-T3).
- Short term forecasting models (T0-T2).
- Strategies and models to face serious network disruption, network management for climate resilience (T1-T4).
- Evaluation of models efficiency and network management tools and policies (T0-T4).
- Integration of an all modes and mobility options, and of a greater variety of network management tools, in network management systems (T0-T4).
- Study the extension of tram-train operations and services (T1-T3).

Integrated Urban Mobility Systems and Governance

- Actions influencing modal choice and travel behaviour: mobility demand management (T0-T4).
- New mobility services (transport supply), including tailored services for different modes, social groups, territories and periods of time (T0-T5).
- More sustainable land development: new activities settlement and transport services (T1-T5).
- Mobility management and social networks (T1-T4).

I**mproving knowledge with data collection and analysis**

- Consistent data collection and exchange on urban mobility and development and use of harmonised models supporting data analysis, land use and transport forecasts, cost-benefit and multi-criteria economic analysis and decision-making (T0-T4).
- Analyse and understand user behaviour throughout the different stages of mobility in order to better reply to his needs while at the same time improving the business models (T0-T5).
- A study on each transport mode to understand where and which services have to be provided by each of them. The idea is to promote and finance each transport mode in its core business environmentally sustainable (T0-T5).
- Studies to promote the introduction and charging of the different transport modes according to the environmental impact costs (T0-T5).

Cooperation between stakeholders:

- Training needs and programmes (T0-T4).
- Promote cooperation for sustainable urban mobility (understanding, awareness, incentives, etc.) (T0-T4).
- Developing the robustness and resilience of transport systems (facing and recovering from incidents and disasters) (T0-T4).
-Interregional and/or European approach of urban mobility (T0-T4).
- Improving market up-take of EU research (T0-T4).

Energy and Environment

- Use of environmental friendly materials (T2-T5).
- Develop and use of energy efficient technologies (T0-T5).
- Adaptation of the existing railway system to the new climate conditions (T0 - T5).

Infrastructure

- Tools and measures for better economic management of railways (T1-T5).
- Capacity improvements for lines and nodes to allow shorter train intervals, less crowded trains and increased punctuality (T1-T5).
- Technological and operational methods for decreasing the cost of infrastructure development while at the same time improving the infrastructure quality (T1-T5).
- Maintenance-free infrastructure (T3-T5).

Benchmarking - Benchmarking inside Rail sector and between transport sectors International cooperation for more efficient transport systems and technical harmonization (T1-T5).

Safety

- Extreme Climate events & resilience (T1 - T4).
- European level crossings risks ranking (T1 - T4).

Security

- Procedures, Regulations and standards (T0 - T4).
- Procedures, Regulations and standards - International Security Organisations (T0 - T4).

Economics

- Delivering whole life asset performance (T0-T4).

- Assess the socio-economic direct and indirect impact of rail use and rail infrastructure developments, both positive (network extensions) and negative (network closures) (T0-T3).

Regulatory framework - research into the organisational and regulatory environment necessary to encourage the adoption of innovations and the step change in cost and quality of service necessary to achieve the sector' and the Commission's ambitions (T0-T3).

- How to incentivise infrastructure managers to innovate to simultaneously improve services and reduce costs? What are the roles of train operators, regulators and governments in achieving this?

- How can passenger franchising be designed to encourage innovation? Who should procure assets, how to specify requirements and how to overcome the inevitable short time horizons and risk aversion of franchisees?

- How to ensure that the different players in the rail system work together to ensure system optimisation rather than the pursuit of sub-optimisation of their own particular part of the system, but without leading to discrimination against new entrants.

One transversal aspect for this roadmap's topics is the need for further standardization. The mainline sector is an easier field of play for such initiatives, however some transversal topics or new technologies can as well be targeted. Standardization can help improve the response to the rail sector to both digitalization and decarbonisation, while at the same time facilitating numerous aspects of innovations. It can also help reduce costs, when properly corroborated with policies and tendering practices – a very good example comes from France, where cities could obtain a significant price reduction because they placed a tender together for a more 'standardized' tram.

4.5 Implementation Plan

a. SHIFT²RAIL

The JU has started work in 2015 and its work will span throughout the lifetime of H2020, with some activities scheduled to be finished a bit after the end of the framework programme. Even though (most of) the final outputs of S2R will not be available for market roll-out, the programme foresees bold progress for many railway segments that will be easily adopted and implemented by the rail stakeholders in a rather short period of time.

Moreover, S2R tries to address all rail customers and proposes answers the two main challenges at the EU level: decarbonisation and digitalization.

S2R will cover much of the research for the periods T0-T2 and the beginnings for T3.

b. H2020

In the case of H2020 ERRAC members consider that a 2-stage approach should be implemented.

The first stage corresponds to the first half of H2020. The topics for this first part have already been outlined in chapter 5:

- Land-use and spatial planning around sustainable efficiencies of public transport; operate trains for 60 - 80% with energy from renewable sources; develop common appraisal methods for cost benefits analysis of cross border business.

- Integration of ticketing and charging services - (New) charging and pricing policies strategies.

- Interchanges for passenger travel and transport - Integrating interchanges, nodes of the smart city.

- Integrated Urban mobility Systems and Governance -Mobility management and social networks.

- Improving knowledge with data collection and analysis - Consistent data collection and exchange on urban mobility and development and use of harmonised models supporting data analysis, land use and transport forecasts, cost-benefit and multi-criteria economic analysis and decision-making.

- Planning sustainable urban areas by integrating rail freight: based on a catalogue of requirements for the optimal use of rail freight services in urban areas.

- Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility) and using transport as an enabler of urban renewal.

- Effectively harnessing new transport -related ICT technology and data management opportunities.

The second stage, corresponding to the second half of H2020, should address the remaining research topics for the T0 – T2 period.

c. Other public funding programs

The following categories of funding have been considered as public funding programmes:

1. The different EU sources of funding.
2. The state (national/regional) sources of funding.

EU funding – here not taking into account either S2R or H2020 – comes through a wide array of channels and methodologies, which can be accessed directly or indirectly.

The main sources are the European Structural and Investment Funds[8]:

[8] http://ec.europa.eu/regional_policy/thefunds/index_en.cfm

- The European Regional Development Fund (ERDF)[9] which aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions. The ERDF focuses its investments on several key priority areas: innovation and research; the digital agenda; support for small and medium-sized enterprises (SMEs); the low-carbon economy.

- The European Social Fund (ESF)[10] invests in people, with a focus on improving employment and education opportunities across the European Union. For 2014-2020 the ESF will focus on four of the cohesion policy's thematic objectives: promoting employment and supporting labour mobility; promoting social inclusion and combating poverty; investing in education, skills and lifelong learning; enhancing institutional capacity and an efficient public administration. The ESF consequently represents a source of funding that can address the need for training and qualifications that will meet the demand of the rail sector, both today and in the years to come.

- The Cohesion Fund[11], aimed at Member States with a Gross National Income (GNI) per inhabitant is less than 90 % of the EU average. It aims to reduce economic and social disparities and to promote sustainable development. A significant part can be allocated to general environmental activities: energy efficiency, developing rail transport, supporting intermodality, strengthening public transport, etc. In theory some rail stakeholders can use part of these funds for transport-related research. But this also depends both on the national legal framework and the future EU-related developments in the field of research funding.

- Alongside these funds, the EU also has the possibility to offer grants in support of projects or organisations which further the interests of the EU, or contribute to the implementation of an EU programme or policy[12]. Numerous topics covered by these grants can be subsumed to the R&D&I aims of the rail sector: competitiveness, education and training, energy, environment, sustainable development, shifting freight from road, etc.

The state funding comes in two major channels:

- The various national and/or regional schemes that support R&D&I development.

- The involvement of foreign states (or state-owned organizations) in major research activities through: loans, grants, capital market investments, etc.

d. Private funding possibilities

The main methods to obtain private funding for rail R&D&I (in addition to those pledged by the already-involved stakeholders) are the following:

- Other private companies that wish to enter the market.

[9] http://ec.europa.eu/regional_policy/thefunds/regional/index_en.cfm
[10] http://ec.europa.eu/regional_policy/thefunds/social/index_en.cfm
[11] http://ec.europa.eu/regional_policy/thefunds/cohesion/index_en.cfm
[12] http://ec.europa.eu/contracts_grants/grants_en.htm

- Public-private partnerships (PPPs) for major and expensive research topics.
- Loans from banks.
- Drawing funds from the capital markets (either from private companies or PPPs) for major projects.
- Private equity investors in major companies or major research projects.
- Major universities, especially those with large endowment funds like those in the US.

However, the rail environment is one which generally does not offer high returns of investment in a short period of time, therefore it is important that the sector – with efforts from the states, the EU and the other stakeholders – will try to become more attractive for these sources of private funding, otherwise major possible investors will continue to shun it.

It must be noted that all these R&I investments must be corroborated with investments on the existing operations and infrastructure. Moreover, rail network extensions should be made possible, especially in the urban and suburban areas, in order to better address the current challenges and ensure the roll-out of the R&I deliverables. Consequently, the roadmap authors support towards the current and foreseen investments in the rail sector, express their wish for a further increase of rail-related investments, while at the same time disagreeing with those that advocate for the 'freezing' or outright reduction of rail infrastructures and services, which ought to be replaced with other modes of transport

4.6 Visual Roadmap, milestones and deliverables overview

	T-0 Today	T-1 2020	T-2 2030	T-3 2040	T-4 2050	T-5 +2050
Optimise environmental and sustainable impacts of the Life Cycle of subcomponents			Design procurement, installation, maintenance, operations and disposal			
			Political approach and economic assessment of feeding kinetic energy back to the public grid			
		Reduction of the vehicle LCC (including costs), while maintaining or enhancing current performances.				
General wagon issues	New transhipment technologies and operational concepts for low cost terminals					
Single wagons	Integrated rail freight production concept (operational, commercial and technical) for increasing the utilisation of single wagon loads					
Logistic services					Dev, of transport services within single or multiple dry-ports in a TEN-T node concept	
	Horizontal collaboration between shippers of the same modality					
TEN-T freight network	Freight oriented and freight dedicated network					
	Development of TEN-T missing cross border links with efficient green co-modal nodes					
	Merging TEN-T core and comprehensive network via green-type of primary, secondary and tertiary nodes					
Freight villages	Spatial planning for mega hubs freight villages necessary for development of co-modality and long distance transportation, new designs and layout					
	Urban green logistics associated to the mega hubs and freight villages					
Land use	Land-use and spatial planning around sustainable efficiencies of public transport					
	Development and implementation of appropriate performance regimes for mobility providers and infrastructure managers					
	Improving local integration of land-use, transport and environment					
	Develop cooperation between the railway and construction sectors for better land management (T1-T5) (an example here is the US case, where rail and road developments are done in tandem with real estate developers, and it is the latter that cover part of the costs for the former)					
Integration of urban traffic and travel information	Integration of traffic and travel information					
	Definition of data quality					
	Integration of information on all types of externalities					
	Integration of information on electromobility					
	Governance models enabling the integration of traffic and travel information					
	Interoperability for customers through common multi-application processes on a single media: create a Pilot operation in a number of Member States in preparation for wider roll-out					
				Create a common EU-IFM application		
		Develop a commercial and technical framework for the sales and settlement of				
	Engage and merge with existing IFM Systems and other ITS services and transport modes					
	(New) charging and pricing policies strategies					
Interchanges for passenger travel and transport	Design and operation of new generation resilient urban transport interchanges for greater integration of urban mobility networks					
	Financing and business models					
	Integrating interchanges with urban policies (Land use planning, economic development, smart cities,					
New city logistics concepts and interfaces for a more efficient freight delivery	Framework for stakeholders' involvement in greater exchange of information on urban freight delivery					
	New city logistics concepts, taking into account the impact of societal changes on commercial behaviour and goods delivery in urban areas					

	T-0 Today	T-1 2020	T-2 2030	T-3 2040	T-4 2050	T-5 +2050
Integrating urban mobility management	Network management strategies, integrated with sustainable urban mobility plans					
	Research on the improvement of connections – European, national, regional and urban levels					
	Governance for the coordination of the network management tools					
	Short term forecasting models					
		Strategies and models to face serious network disruption, network management for climate resilience				
	Evaluation of models efficiency and network management tools and policies					
	Integration of an all modes and mobility options, and of a greater variety of network management tools, in network management systems					
	study the extension of tram-train operations and services					
Integrated Urban Mobility Systems and Governance	Actions influencing modal choice and travel behaviour: mobility demand management					
	New mobility services (transport supply), including tailored services for different modes, social groups, territories and periods of					
		More sustainable land development: new activities settlement and transport services				
		Mobility management and social networks				
Improving knowledge with data collection and analysis	consistent data collection and exchange on urban mobility and development and use of harmonised models supporting data analysis, land use and transport forecasts, cost-benefit and multi-criteria economic analysis and decision-making					
	analyse and understand user behaviour throughout the different stages of mobility in order to better reply to his needs while at the same time improving the business models. (date missing)					
	A study on each transport mode to understand where and which service have to be provided by each of them. The idea is to promote and finance each transport mode in its core business environmentally sustainable. (date missing)					
	studies to promote the introduction and charging of the different transport modes according to the environmental impact costs (date missing)					
Cooperation between stakeholders	Training needs and programmes					
	Promote cooperation for sustainable urban mobility (understanding, awareness, incentives, etc.)					
	Developing the robustness and resilience of transport systems (facing and recovering from incidents and disasters)					
	Interregional and/or European approach of urban mobility					
	Improving market up-take of EU research					
Energy and Environment			Use of environmental friendly materials			
	develop and use of energy efficient technologies					
	Adaptation of the existing railway system to the new climate conditions					
Infrastructure		tools and measures for better economic management of railways				
		Capacity improvements for lines and nodes to allow shorter train intervals, less crowded trains and increased punctuality				
		technological and operational methods for decreasing the cost of infrastructure development while at the same time improving the infrastructure quality				
				Maintenance-free infrastructure		
Benchmarking		Benchmarking inside Rail sector and between transport sectors International cooperation for more efficient transport systems and technical harmonization				
Safety		Extreme Climate events & resilience				
		European level crossings risks ranking				
				Maintenance-free infrastructure		
Security	Procedures, Regulations and standards - PPP					
	Procedures, Regulations and standards - International Security Organisations					
Economics	Delivering whole life asset performance					
	Assess the (socio) economic direct and indirect impact of rail use and rail infrastructure developments, both positive (network extensions) and negative (network closures)					
Regulatory framework	Research into the organisational and regulatory environment necessary to encourage the adoption of innovations and the step change in cost and quality of service necessary to achieve the sector' and the Commission's ambitions: - How to incentivise infrastructure managers to innovate to simultaneously improve services and reduce costs? What are the roles of train operators, regulators and governments in achieving this? - How can passenger franchising be designed to encourage innovation? Who should procure assets, how to specify requirements and how to overcome the inevitable short time horizons and risk aversion of franchisees? - How to ensure that the different players in the rail system work together to ensure system optimisation rather than the pursuit of sub-optimisation of their own particular part of the system, but without leading to discrimination against new entrants					

Fig. 1 - Visual Roadmap, milestone and deliverables overview

4.7 Conclusions

As outlined in the document, the railway sector is faced with a number of *challenges* today and in the future. These are challenges both in terms of the natural competition between transport modes, but also on a systemic scale, the most important being *decarbonisation and digitalization*. Tackling them needs to be at the core of the railways strategic and economic agenda. Consequently, the rail stakeholders have prepared over the last years a number of studies concerning the R&I topics, the final output being the SRRIA and its implementing roadmaps, *the sector's vision in response to the general or particular challenges that the railways face*. This vision can be broken down into 4 main topics:

- *Lower costs* (both for customers and the rail actors that serve these customers);
- *Reliability of services*;
- *Comfort and/or better vehicle utilization* (with an accent on the availability of space);
- *Adaptability to the different challenges*, mostly in physical terms (rolling stock & infrastructure).

Subsequently, the roadmap outlines the current and foreseeable state of research at both national and international levels, with an emphasis on the EU cooperation– FP7, S2R, H2020. The next chapter presents the main topics of research identified and agreed by the ERRAC partners: environmental and sustainable impacts of the Life Cycle of subcomponents, general wagon issues, TEN-T freight network, city logistics concepts and interfaces for a more efficient freight delivery, land use & urban mobility management, interchanges for passenger travel and transport integrated urban mobility, improve data collection and analysis, stakeholders' cooperation, energy & environment, infrastructure issues, safety & security or the regulatory framework. The implementation opportunities of these R&I topics at national, European or wider international levels are then outlined by the roadmap, together with the support for further investments and disagreement with advocates of rail services and/or infrastructure reduction.

In conclusion, the roadmap outline and analysis show that the upcoming challenges as well as the potential and opportunities for research are tremendous. There is a vast number of rail research topics to be addressed for both the short and long term, and a number of them overlap. Furthermore, there are a large number of potential channels through which they can be addressed.

The main channel is still the traditional one, namely the EU-funded research projects. In this category we find both the S2R JU and the regular EC research framework programmes (today H2020). The EU-related research continues to be the main manner in which rail research will be conducted at the EU level, since it is the only way in which all stakeholders can come together around the same table and try to reach a common understanding. And while it is true that S2R will significantly change this landscape, the new situation does have certain advantages:

- The S2R JU will ensure that a significant amount of funding (approx €1 billion) will go into rail-related research, benefitting a large number of stakeholders. It will pave the way not just for increased cooperation, a more coordinated research and better rail solutions, but also to a wider standardisation process within the rail sector, which should increase the overall benefits.
- The H2020 programme (as well as the future framework programmes) have indeed lost many of the specific rail research topics in favour to S2R. However, this leaves a clear way to other rail-related research topics. Unlike in the S2R case, when rail will be almost the sole topic of research, the H2020 programme will enable stakeholders to link the railways sector with other social-economic activities. This aspect is crucial, since a harmonious and organic development of a European competitive economy cannot be done in separated clusters, with no cross-sector influence and synergies. Such efforts under H2020 can also lead to standardisation activities, also ensuring that the products can be used by multiple stakeholders not just in the field of railways, but also in other economic arenas. Consequently, S2R and H2020 offer complementary approaches to rail research and innovation.

And while the target for this road-mapping exercise is to match the sector's research needs with the main upcoming challenges and the available EU research funds, it is clear that more resources need to be allocated for certain topics. Therefore the roadmaps have outlined a number of other sources of funding – national allocations, private alternatives – in order to fill in any gaps. These alternatives can be considered both for the EU-level cooperation and for the national rail research done by the stakeholders.

5. Safety (including certification) and security

5.1 Introduction

The scope of this document is to describe in the area of railway safety and security.

- Present situation
- Vision
- Area of action
- Road map development

This roadmap safety and security is a horizontal roadmap. Further more specific safety and/or security aspects may be necessarily addressed in specific fields for example in the fields for rolling stock, Control Command Signalling (CCS) or Urban Railway Systems. As a consequence all other roadmaps shall refer to the roadmap “Safety and Security” as far as safety and/or security issues are concerned.

Safety for passengers and freight shall be provided by a combination of technical safety (technical reliability), process safety (including human factors) and security.

Starting from the vision for a future railway system the identified requirements given in this roadmap should result into clear areas of actions as well as areas of research.

Considering that the EC WHITE PAPER (‘*Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system’*, 28 March 2011) [1] asks for confirming EU as world leader in safety and security of transport in all modes of transport.

> „Infrastructure managers and railway undertakings shall establish their safety management systems to ensure that the rail system
>
> 1) can achieve at least the Common Safety Targets (CSTs),
> 2) is in conformity with safety requirements laid down in the Technical Specifications for Interoperability (TSIs), and
> 3) to make sure that the relevant parts of the Common Safety Methods (CSMs) and notified rules are applied.”
>
> See [12, Article 9]

This document aims on supporting the conformity assessment of TSI safety requirements by harmonized safety assessment methods where the TSI is calling for. It further aims to complete the CSM-RA on risk acceptance principle 3 for risk estimation. This document does not aim at all any standardisation of the Safety Management System (SMS) itself. As consequence of the formerly intended part 3 of the EN 50126 series has been waived in full agreement of the entire railway sector.

For the illustration of the regulation principles for the interoperable railway system see Figure 0.

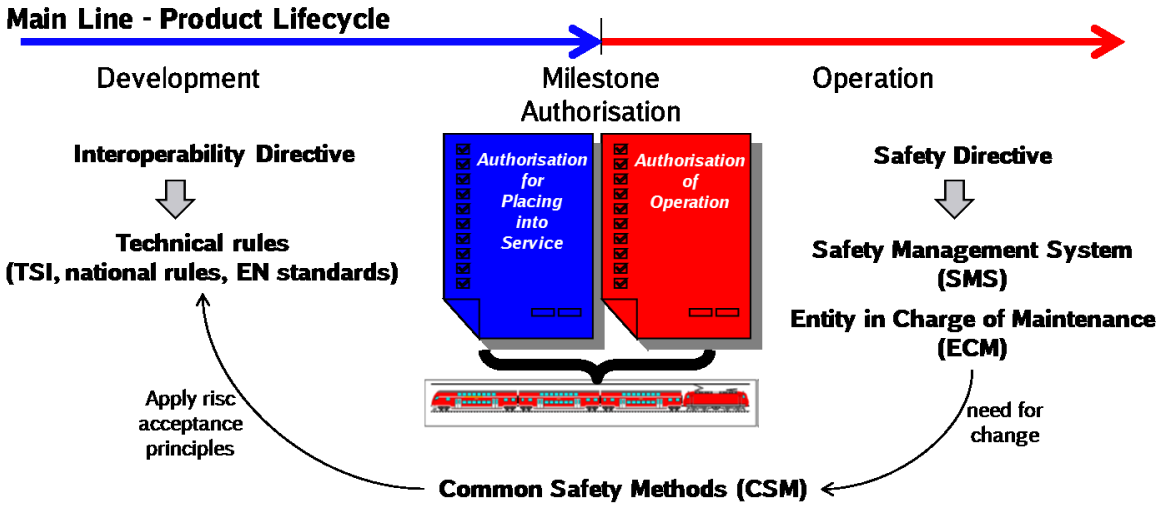

Figure 0 Main line product lifecycle

Therefore this document is mainly focusing on technical safety and security (see Figure 1, left side (blue).

The scope of this document encompasses the railway system as defined by the Interoperability Directive but is not limited to it.

Digitalization as the mega trend of today will foster the joint implementation of requirements for safety and security across all modes of transport and services.

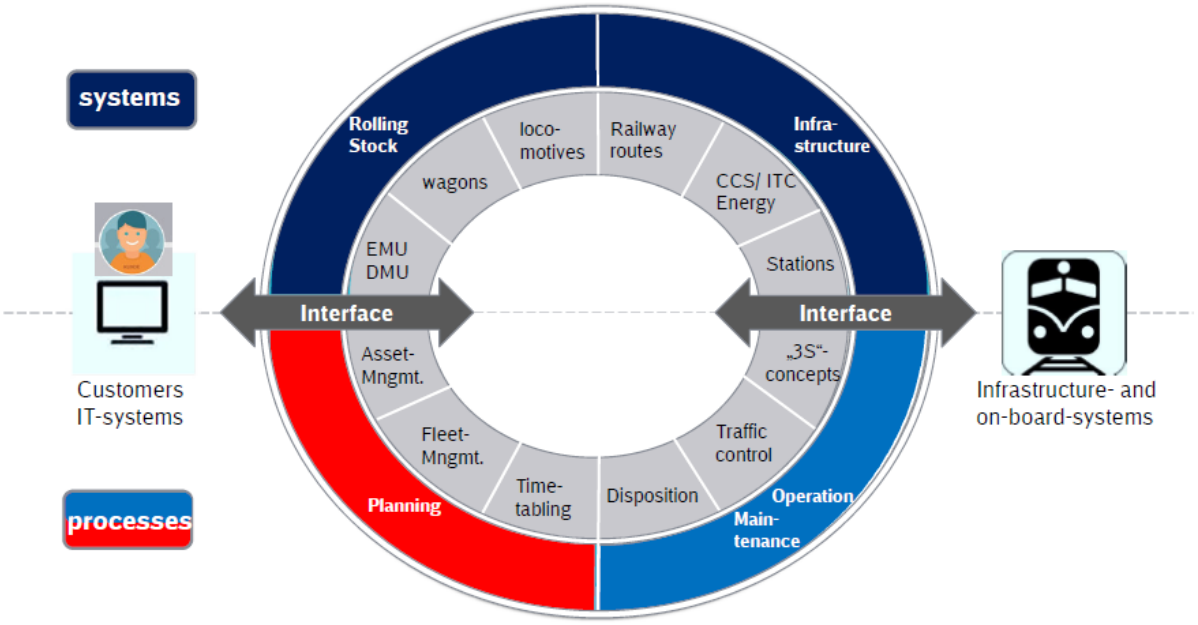

Figure 1 Digitalisation includes all technical systems and processes

The railway system is composed of four structural sub-systems (Urban Railway differ to this, see separate chapter regarding urban rail in the roadmap):

- rolling stock
- infrastructure
- control command and signaling
- energy

and three functional sub-systems:

- operation
- maintenance
- telematics applications

The human factor has to be taken into account in all technical and functional sub-systems.

As the railway system is supposed to migrate to an integrated part of an intelligent (land) transport system, the requirements for safety and security should be enlarged to other modes of transport and those requirements should be mutually recognized between all modes of transport.

Advanced engineering systems and risk analysis methodologies for the design and operation of the structural railway sub-systems are considered to be of specific importance.

There will also be integrated approaches linking human elements, structural integrity, active safety including monitoring systems, rescue and crisis management and, if needed, completed by passive safety measures.

Safety has to be considered as an essential requirement to structural and functional sub-systems of the railway system (this differs for urban railway system) according to the IOP Directive. It is an internal aspect for the railway system and also for its interfaces to the external environment.

Security will be addressed wherever external impact is considered to be potentially hazardous for the railway system. A point of attention will therefore be the protection of “critical infrastructure” according to the NIS Directive [10].

The present document sums up the ERRAC Roadmap on Railway Safety & Security aspects; this living streamlined piece of work was born in 2010, and the following is the current edition.

As far as the Safety Roadmap is concerned, the most relevant framework is the

- European Railway Agency (ERA) being empowered to more legitimately cover the role, as a unique, Europe wide, authorization and safety certification delivery body

as far as the European community rail is concerned. It should be noted that ERA intensively cooperates with other agencies in terms of safety (e.g. aviation / EASA).
- safety regulation represented by the safety directive [12] with its derived regulation like CSMs.
- safety standardization represented by IEC 61508 and its rail sector specific standards like EN 50126 and related standards.

As far as the Security Roadmap is concerned, the future research needs are still based on the following complementary priority areas: Human Factors, Technologies, Common procedure & regulations and cooperation with authorities.

As for safety, this document concentrates on the European community rail system whilst enlarging the scope towards full integration of the railway into an intelligent intermodal transport system. For security this document considers from the beginning general measures for any critical infrastructure rather than limiting on railway specific measures.

The safety and security methods proposed by this road map are purely generic and do not impose any specific technical design. The road map has the aim to define the requirements for further development. The results of the further development may be different for interoperable and urban rail.

For the interoperable railway system the application of safety methods may be requested by RSD [12] and TSIs. For urban rail systems the application of safety methods is up to the applicant and its relevant regulatory framework. VDV 161 series [25] may serve as an example of such voluntary guidance.

The current situation and proposals regarding safety acceptance, approval and certification of urban rail systems are presented in several deliverables of the European project MODSAFE (www.modsafe.eu) [15].

The current situation regarding security of rail systems as well as an integration framework are presented in several deliverables of the recent European FP7 PROTECTRAIL project [26].

The current situation regarding security of urban rail systems – as well as proposals agreed by urban rail public transport operators affiliated to UITP, supported by industrial companies - are presented in one deliverable of the recent European FP7 SECUR-ED project (www.secure-ed.eu) [16].

5.2 Key issues and objectives

The roadmaps are based on the prorities of SRRIA.

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.

Safety

- Rail continues to be the safest mode of surface transport and has added additional secondary safety resilience.
- With a growing reliance on automated processes and interventions, requirements associated with ‘human factors’ need to evolve and require for innovative staff training methods and tools. HRO (High Reliability Organisations) is a preferred way to get failures down in systems with increasing complexity.
- Improved management of critical interfaces with third parties (e.g. at level crossings) are a further subject to improvement
- A harmonised process at European level to drive the verification and certification/authorisation of Safety Management Systems, vehicles etc. will be a strong contributor to increase safety by reducing variety to the degree technically and economically justified.
- Intelligent and consistently applied fall-back systems to assure safety during degraded mode designed into every critical sub-system and component are an important contributor to assist staff and reduce human errors.

Security

- 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.
- Increasing mobility requires more multimodal transport.
- Multimodal transport therefore is based on an integrated security organisation, with active and passive security management systems in multimodal transport nodes.
- Resilient architectures and additional layers of security, including sophisticated firewalls between operational systems, counter cyber threats.
- The technical equipment and the cross-modal organisational arrangements have to support the implementation of this vision.

It has to be underlined that no rail specific management of security shall be developed. Security methods proven in other industries and especially common IT securitiy measures are deemed to be applicable for the railway sector. Main goal is to provide maximum access and service to the customer without decreasing security levels.

3.2.1 Core Massages of Roadmap “Safety and Security”

Safety

"Safety methods should be aligned with other industries and getting harmonized with them"

- This document does not aim at any standardisation of the Safety Management System (SMS) itself.
- Go towards common industry standards rather than sticking to rail specific methods and processes for safety analysis and demonstration, as far as reasonable applicable.
- Safety regulation is fully covered by “Common Methods on Design Targets” (EU-Regulation: CSM-RA, CSM-DT, CSM Monitoring and Supervision) and has the potential to further harmonise with approaches applied in other industries than rail
- Safety standardisation for railway technology seems to be widely superfluous if the rail sector adapts the processes set out in other industries
- Risk based safety approach need to be much more facilitated by fast and easy-to-apply standard methods in order to reduce time-to-market for innovation
- Each risk based safety demonstration establishes technical rules that can further be exploited by the rule based safety approach when doing safety demonstrations.

Security

"Security requires a differentiated approach for technical threats and physical threats"

- Security has to be treated differentiated for physical and technical threats.
- To deal with physical threats the open access to the railway system requires railway specific research activities. Following the current situation the European Commission will launch a study focusing on training for personnel, contingency planning and technical improvements. The outcome of this study should be ready in 2016 and shall guide the further evolution of this roadmap.
- Do not establish rail specific security methods for technical and cyber threats. Learn from outside. Apply best security practices from leading industries (e. g. road, aviation) and join them in research.
- Focus on protection and resilience. Be most alerted on cyber-crime for business continuity rather than national safety that turns out to be just a sub-set of the prior one.
- Learn from safety methods to systematically identify security hazards and use this as benefit for managing security.

5.3 State of the Art and on going research and innovation within and outside rail

5.3.1 Present Situation « Safety »

Some industries and EU member states have preferred and established the risk based safety approach whilst the railway sector and a significant number of member states still impose technical rules dedicated to safety rather than setting risk acceptance criteria on design targets.

The risk based approach is applied in all other safety critical industries (petrochemical, aviation, nuclear plants etc.), even in railway systems outside Europe. A quantitative risk approach is well established since long time.

Rule based approach is well established and applicable for mechanical and electrical engineering. Risk based approach is more appropriate for programmable functions, electronic components and software.

Imperative for the rule based approach is a clear specification of the area of use for the rule in order to prevent extension or confusion of a rule towards applications for which no experience or even a hidden hazard exist.

Essential precondition for the risk based approach is either providing a method that is such detailed and unambiguous that misuse or failing in applying the method can be discovered without doubt. Or the framework of demonstrating the acceptable risk is mutually recognized and cannot be challenged. In any case an unambiguous safety target is needed per analyzed function. Therefore the risk based safety approach is in a number of cases difficult to apply once a target is missing or imprecise. This is exactly why we need professional research on risk based approach in order to facilitate its fast and cost efficient application.

Two main categories of railway accident causes are to be considered coherently with safety projects and researches clustering and implication analysis:

- Railway Internal Causes (currently causing less than 20 % of significant accidents):
    - Infrastructure
    - Rolling stock
    - Human Factors
    - Railway users

- Railway External Causes (currently causing more than 80 % of significant accidents):

- Third parties (Trespassing (currently causing about 50% of significant accidents), vehicle at level crossings, pedestrian at level crossing, pedestrian on public railway area)
- Weather and Environment

As regards the European community rail system, European Legislation requires Member states to report to ERA on precursors, significant accidents and serious accidents occurring in their territory.

The NSAs must report all significant and serious accidents. The NIBs must investigate all serious accidents, notify the ERA of these investigations and, when closed, send the investigation report to the ERA.

The term significant accident covers a wider range of events than serious accidents according to directives 2004/49/EC, 2009/149/EC and regulation 2003/91/EC.

Significant Accident	Serious Accident
Any Accident involving at least one railway vehicle in motion, resulting in at least one killed or seriously injured person, or in significant damage (more than EUR 150.000) to rolling stock, track, other installations or environment, or extensive disruptions to traffic	Any train collision or derailment of trains resulting in the death of at least one person or serious injuries to five or more persons, or extensive damage (more than 2 Million EUR) to rolling stock, infrastructure or environment, and any other similar accident with an obvious impact on railway safety regulations or the management of safety.

Acciden types are:

- Derailments of trains
- Train collision with another train
- Train collision with an obstacle
- Level Crossing accident
- Individual hit by a train
- Individual falling from a train
- Fire in rolling stock
- Electrocution
- Accident involving dangerous goods

The Ratio between Significant and serious accidents is stable in the reported years and is about 75:1.

The ratio between hazards and significant accidents is not stable but strongly growing probably due to methodological differences between countries in reporting precursors. Regarding precursors, the RUs and IMs should investigate them in line with their SMSs, without forgetting those related with human errors, as failing to manage degraded situations, and organizational failures that are reflected in the operation.

The ratio between hazards and significant accidents is about 10:1.

Hazards are: (according to [12] – Annex I – Common Safety Indicators)

- Broken Rail
- Track Buckles and other track misalignment
- Wrong side signaling Failure
- signal passed at danger when passing a danger point
- signal passed at danger without passing a danger point,
- Broken wheel on rolling stock in service
- Broken axle on rolling stock in service

The economic impact of significant accidents has five components:

- Costs of fatalities,
- Cost of injuries,
- Costs of material damage,
- Costs of damage to the environment
- Cost of delays.

Socio-economic consequences of accidents should be taken into consideration, especially as far as the competitive advantage of the railway system is concerned. However, quantification is still challenging.

Major present Policy driver is the EC Transport White Paper (1).

In respect of Safety issues, the EC White Paper published on March 2011, presents many articles with special interest in improving safety and security in Railway Transportation.

Especially in chapter 3 “The strategy – What needs to be done” we find the Articles:

34. Enforcement of social, safety, security and environmental rules
36. Single European Railway Area
37. Quality jobs and working conditions
38. Transport security
39. Safe transport

The European legislative framework is mostly based on the following Directives and Regulations so far:

- Railway Safety Directive
- Interoperability Directive
- ERA Regulations

In EC 2011 Transport White Paper (1) ten goals for a competitive and resource efficient transport system are clearly expressed and the ninth of ten addresses an improving transportation system safety:

- 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.

In annex 1 of the same paper the EU asks for an improvement in transport system safety suggesting some initiatives in the European community rail system. The paper outlines:

1. *Progressively achieve a sector-wide approach to safety certification in the rail transport sector, building on existing approaches for infrastructure managers and railways undertakings and evaluating the possibility to rely on a European standard.*

2. *Enhance the role of ERA in the field of rail safety, in particular its supervision on national safety measures taken by National Safety Authorities and their progressive harmonisation.*

3. *Enhance the certification and maintenance process for safety critical components used to build rolling stock and railway infrastructures. Enhance the role of ERA in these certification and maintenance processes*

Most of these targets have been achieved by

- The implementation of the 3rd railway package and the involvement of the railway actors (ERA, NSAs, NIBs, stakeholders of the sector) and the corresponding necessary investments (equipment, methods, certification and supervision, …). Establishing ERA as future provider of the single safety certificate for any EU RU with international operation
- Joint Network Secretariat Urgent Procedure is going to be established in due time
- Establishing EU wide principles and system of entities in charge of maintenance for freight wagons (see EU regulation on ECM). It is expected that EU will extend the ECM-regulation on other type of rolling stock

Standards are supposed to support and complement the related regulation. For most technical products placing on the market is based on safety requirements and assessment criteria provided by product standards. Process standards provide methods to ensure the generation of safe products or to perform safe processes and may serve as basis for certification or acceptance.

Examples for product standards for safety are EN 45545 (fire safety), EN 50553 (running capability in case of fire), EN 14363 (running capability for preventing derailment) and EN 12663 (mechanical structure).

(1) -http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm

Figure 2 shows the current situation in the domain of safety standardization, including interfaces with security standardization:

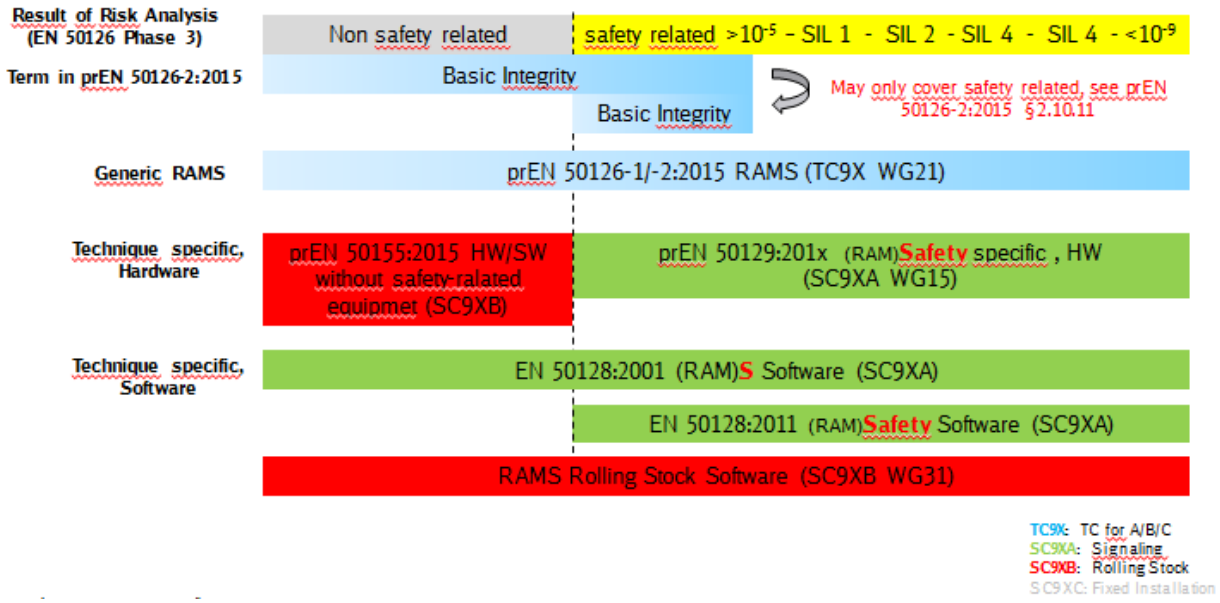

Figure 2 Present development of standards on CENELEC level for safety

Figure 3 provides the link between standardization for safety and security and the legal framework. The actual situation is explained on the situation in Germany; however the situation is similar in other states within the European Union.

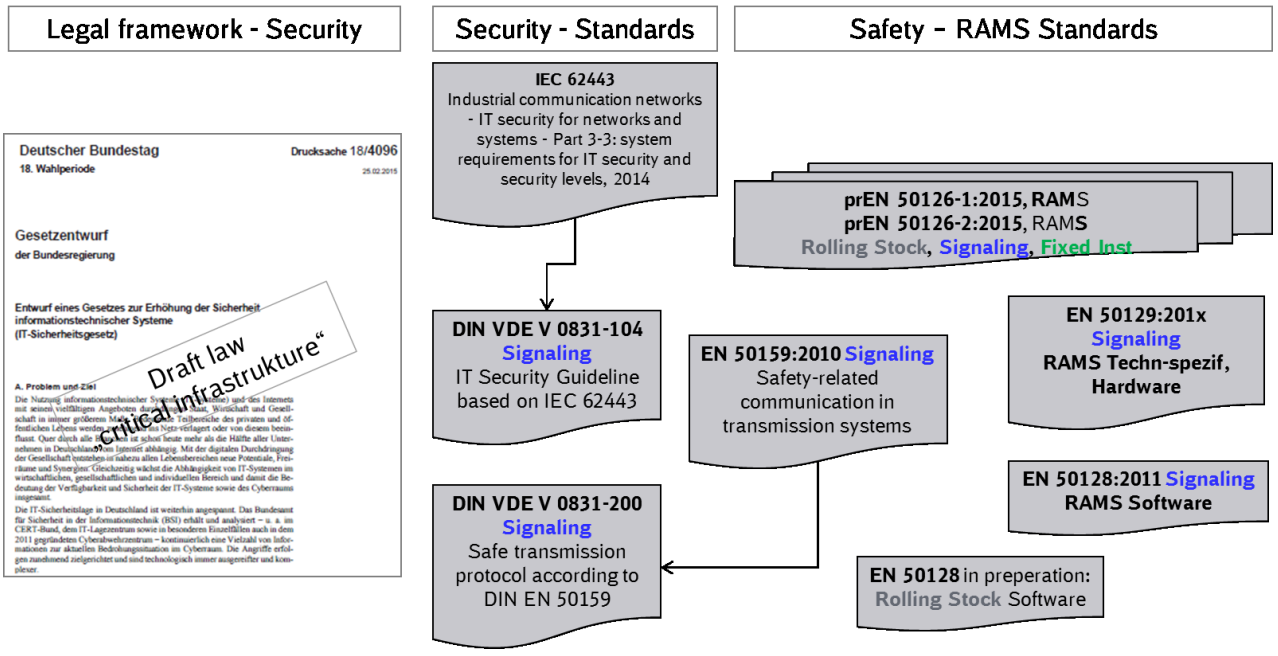

Figure 3 Link between standardisation for safety and security

As safety requirements in product standards are usually derived from engineering practices and lessons learnt from product damages or even accidents, the analytical setting of safety requirements is primarily applied for E/E/EP-systems. Therefore the CSM-RA restricts the application of quantitative Design Targets (DT) to those systems. Other technical products like mechanical or pneumatic components can also be analysed by safety methods [19] like a FMECA. Currently only qualitative measures can be derived from an analytical approach to non-E/E/EP components as the database for failures is not sufficient due to the intended extremely low rate of failures. By establishing data analytics also for non-E/E/EP-components, there may be the opportunity to apply the analytical approach for all components in the future.

5.3.2 Specific Present Situation Urban Railway Systems « Safety »

Urban railway systems are those local rail systems which are excluded from the scope of the Interoperability and Safety Directives.

These systems are not covered by any technical rail specific European legislation regarding safety and security, and relevant stakeholders are following local regulations, although they are encouraged to use some European standards.

The representative associations of operators and manufacturers of urban rail systems – UITP and UNIFE cooperating in their joint “Urban Rail Platform” have jointly convinced in 2011 the European Commission that urban rail systems should follow a specific program for standardization – currently underway as part of the Mandate M/486 [13].

According to the mandate, urban rail systems should however follow – as regard safety - some fundamental requirements which are listed in the CEN-CENELEC Guide 26 “Railway applications — Preparation of standards for urban rail systems design, construction, manufacture, operations and maintenance” [14].

The current situation and proposals regarding safety acceptance, approval and certification of urban rail systems are presented in several deliverables of the European project MODSAFE [15].

The current situation regarding security of urban rail systems – as well as proposals agreed by urban rail public transport operators affiliated to UITP, supported by industrial companies - are presented in one deliverable of the recent European FP7 SECUR-ED project[16],namely:SCR-WP11-D-UIP-041-05-D11_3_Recommendations_for_the_Improvement_of_Security_in_Public_Transport.

There will also be integrated approaches linking human elements, structural integrity, passive safety measures and active safety including monitoring systems, rescue and crisis management.

5.3.3 Present Situation « Security »

Rail security involves the protection of the railway system, goods and persons (staff, customers, society and third parties) against deliberate attacks or intent to cause damage and/or human losses. These events are not predictable because they are due to external factors.

Security covers physical and procedural security measures and is increasingly enlarged towards cyber security. Security is essential to safeguard safety requirements to be fulfilled and the continuity process of the railway system.

Security is unlike safety not a traditional and specific contributor in the design of railway products and processes. Due to increasing threats the awareness of security issues rises and are getting more management attention in the last years.

Between 2010 and 2014, the PROTECTRAIL (EU project – www.protectrail.eu) consortium and its 29 members, consisting of railway operators, railway manufacturers, security technology providers, research organisations, and major railway associations, came together to improve railway security and design an interoperability framework to integrate the growing influx of security technologies into rail operations and make them interoperable.

Security on the wide-spread railway assets has been ensured by presence of staff and social responsibility to prevent sabotage. Security is further increased by use of intelligent technology (including the support of staff to take the right decision within the national legal framework) in combination with the presence of staff. In opposite to a stable safety framework challenges in the domain of security are quickly and permanently changing. Therefore innovative technology becomes a key driver for managing security.

Rail security is an increasingly important challenge: Evolving threats, expectations of customers, connectivity between modes of transport, service chains, IT applications, telematics and data management on a global scale urgently ask for a security approach that is no longer limited to the rail system or geographical borders.

Complexity, sensitivity and connectivity of IT networks and applications are increasing the risk of internal threats by staff aiming on sabotage and/or unawareness of the risk.

As a response to this global and general challenge, it is expected that the new Network Information Security (NIS) Directive will provide the necessary requirements to get resilience in terms of security threats to come. A number of EU member states have already started to implement NIS Directive in national legislation.

Key is the common understanding of railways being robust against cyber-crime, independent whether an ICT-infrastructure is considered to be “critical” form national point of view, or not. It needs to be understood that railways security measures to protect their company critical ICT-infrastructure is deemed to comprehensively cover any aspect of a potentially critical national ICT-infrastructure. Therefore regulation addressed to critical ICT-infrastructure from national point of view does not apply to railways. Railways are sufficiently secure without identifying any part of their ICT-infrastructure as critical.

The consequences are manifold and a full set of measures and processes may be applied to manage the challenges. This includes to benchmark “railway security” with global security requirements as the railway can no longer be regarded as an isolated system. Therefore railway specific security indicators in the field of IT are not sensible. A current example for this approach is the replacement of the railway specific communication network GSM-R within the next decade by a non-railway specific industrial communication network (5G).

Beyond IT security there is a broad field of “conventional” security measures for improving objective (measurable and assessable) as well as subjective (perceived and personalised) security.

Over roughly the last twenty years, security issues of all kinds have grown in importance to the point that railway companies have had to take note and provide higher management attention within the last years.

The features of the rail sector – the geographical extent of its infrastructure and the traffic volumes using this infrastructure and the political and media repercussions of any attack on rail transport – mean that the railway system (e.g. companies) are prime targets for a variety of criminal activity and a prized target for terrorists, and could be exposed to significant threats.

To face these threats, rail companies had to organise themselves: They have built business oriented security policies and implemented security strategies in partnership with national authorities (e. g. in accordance with ISO 31000).

Apart from the railway system being most robust against security threats compared with other modes of transport, security should not only be based on technical measures but also be combined and completed by advanced methods of working, e.g. implementation of High Reliability Organisations (HRO). A combination of technical, procedural and human measures to protect staff, passengers, freight and assets will also improve security perception.

The European legislative framework bases mostly on the following Directives and Regulations so far:

- Network and Information Directive (NIS)

There is on-going research in the framework of the ARGUS [22, 23] project to which this roadmap may also contribute. Key is the approach of “Embedding security to safety” which shall be applied to all layers and phases of the V – cycle of systems’ development, implementation and operation. It will be unavoidable to link the supply industry to the ARGUS objectives and findings because the development platforms of suppliers can easily be the “penetration gate” of malware.

The CENELEC TC9X Business plan (Railway Applications) will cover cyber security for energy data and on-board communication. Furthermore, CENLEC TC 9X has set up a survey group SC A16 on IT-security with prior focus on CCS and relevance to the entire railway system.

5.3.4 Specific Present Situation Urban Railway Systems « Security »

From the point of view of the Public Transport Operators (PTOs), which are mostly public corporate entities that provide an important public service, security can be seen as having three main aims/functions:

- Protect their corporate assets (staff, infrastructure, equipment, know-how etc.) against intentional threats
- Ensure their primary service (public transport) taking all necessary protection and restoration measures
- Ensure, in cooperation with the police and other relevant authorities, the physical security of their passengers

The main issues/constraints are:

- Costs in equipment, staff and operational overheads
- Service/business continuity
- Legal, regulatory and ethical aspects

The nature of the problem and the complexity of the constraints faced was the reason why both the European Commission - EC - and individual Member States have financed several research projects on various facets of public transport security (see SECUR-ED [16] Deliverable D11.1.2 [17] for a comprehensive list of such projects). These efforts culminated with the SECUR-ED Demonstration project.

The PTO sector representatives had adopted in 2010 an official position [18] stating that a concise and integrated security concept is based on risk assessment, necessary for understanding security needs and prioritising resources. Together with ongoing observation of incidents, the most appropriate security measures can be identified and adapted to the local situation. A variety of possible security layers exists, which can be grouped into three interlinked 'pillars':

- the Human factor;
- Procedures,
- Technology.

In the case of the human factor, staff engaging with the passenger creates a sense of reassurance which cannot fully be achieved by technology. Customers want interaction with real people, either directly or through technological devices. Similarly, only staff can provide direct help during incidents. For the Human Factor to be most effective, staff must be qualified, trained, well-equipped and motivated.

Procedures form one of the three security pillars since the organisation of security should be clear and consistent, including clear lines for alarm, command and control. Security incidents, especially major ones, often happen without warning: emergency and contingency plans must be developed, communicated and drilled in advance in cooperation with all relevant partners.

Last but not least, numerous technologies can be used to enhance security, for example surveillance systems. Proactive use of public address systems and help points demonstrate to customers that there is a human intervention which gives them more confidence. 'Security by design' concepts such as good lighting and clear lines of sight have also been proven as effective. The full potential for technology is huge but can only be realised with procedures and trained staff in place behind it. Machines can never fully replace humans and they will always be managed by staff, but they can help spread human resources more efficiently. No one security measure is enough; it is the balance of security layers from these pillars which can have the best effects.

As part of the SECUR-ED [16] project have been defined "building blocks" of the PTO's security concept which comprises three components (see Figure 4).

Figure 4 The building blocks of public transport security

The setup of a security organisation is essential for determining:

- Who is responsible;
- The responsible party's areas of authority;
- The available resources allocated to the security organisation.

Without these definitions and their ascription to an individual and a defined body within the organisation, the PTO will find it difficult to manage, develop and evaluate its security arrangements.

A risk based security management concept relates to three components in the process and in the organisational security risk management strategy:

- What is the security risk management process?
- What are the security risk management strategies?
- What is the security evaluation process in the organisation?
-

From the organisational standpoint, it is essential for the PTO to assimilate a structured security risk management process that will be based on the structured risk management processes (e.g. ISO 31000 – Risk Management Standard).

Risk mitigation safeguards and policies include four components:

- Manpower trained to perform security tasks;
- Technological and communication systems;
- Physical protection means;
- Procedures (Routine and emergency operating procedures) and policies (e.g. Communication policies and awareness campaigns).

5.4 The Roadmap

5.4.1 Vision on « Safety »

The following trends seem to get dominant in terms of future safety requirements:

- Digitalisation (e.g. Automation, Smart Cities, sharing economy);
- Connectivity;
- Globalisation;
- Environmental conditions (e.g. climate change, extreme weather conditions);
- Liberalisation;
- Smart simplicity;
- Transportation innovation;
- Trade-off between safety and affordability: general economic problems (shortage of money, new deals between safety and affordability, poor profitability for railway service, no acceptance of any accident for the public and authorities) vs. huge and quick investment needs;
- Redesign instead of new procurement;
- Socio-economic mega-trends like demographic change, user behaviour, individualization, customer centricity, transparency, high level of staff performance (competence and resilient capabilities, high standards in training, mental health and intercultural Skills for trans-European demands;
- Regulation/privacy laws (need for confidence);
- Sustainability (e.g. balancing effectiveness with resources);
- Energy availability;
- Human factors (see for further details roadmap “Training an Education”, e.g. competence and resilient capabilities, standards in training, mental health, Train Resource Management and Non-Technical Skills for trans-European demands).

These trends enhance the migration towards a European, if not global, safety culture.

In addition, the progressive migration of the individual modes of traffic towards an integrated intelligent transport system fosters the standardization of technology and processes. As a consequence, safety requirements linked to technical products and processes will become more and more standardized among the various modes of transport.

Furthermore, increased performances require more support by technical assistance for staff up to the point of fully automated systems. Here the precise share and shift of responsibility between technology and humans (staff, passengers, etc.) becomes crucial in normal as well as in degraded operation. Therefore advanced requirements for staff qualification and training need to be addressed as well.

Having all these likely changes in mind, it does no longer seem to be appropriate to limit to railway specific safety performances. The involved stakeholders manage and/ or use various modes of transport and the expectation towards safety becomes naturally a comprehensive, integrated and global one.

To give an example:

> Passenger safety is concerned in the entire chain of services offered by a mobility provider. Therefore the harmonization of safety requirements and processes along the entire chain of services becomes more and more the key. Customer perception will no longer be limited to a “safe train ride” but a safe journey, and it will be up to the mobility provider to combine the appropriate means of transport to achieve an overall optimum towards the customer expectation.

Regarding the main three fields of action in terms of safety, that is the executive power, regulation and standardisation, the changes will be as follows:

- European Railway Agency (ERA) being empowered to more legitimately cover the role, as a unique, Europe wide, authorization and safety certification delivery body as far as the entire European community transport and mobility sector is concerned, encompassing lessons learned from other industries than rail.
- Safety regulation represented by the safety directive with its derived regulation like CSM need to be opened up to the entire transport and mobility sector.
- Safety standardisation shall be clearly distinguished in risk based safety (process) and rule based safety (technology). For risk based safety an intermodal approach need to be invented where finally no railway specific processes should be kept. For rule based safety, the precise and assessable technical requirements for railway specific technology shall be developed and evolved in order to keep the high safety standard of rail while improving competitiveness of rail technology compared with other modes of transport. This addresses especially the integration of commodities (mass technology, e.g. IT) in the railway system.

The areas of action are derived from the following relevant trends for safety.

Table 1 Areas of action related to trends

Trends / Areas of action	Digitalisation	Connectivity	Globalisation	Environmental conditions	Liberalisation	Smart simplicity	Transportation innovation	Trade-off between safety and affordability	Redesign instead of new procurement	Socio-economic mega-trends	Regulation/privacy laws	Sustainability	Energy availability	Human factor
1. Replace personal judgment by clear pass-fail-criteria.	X	X			X	X	X							X
2. Recognition of assessment bodies instead of certification by accreditation scheme			X								X			
3. Safety is from the beginning an EU-wide, if not global, challenge	X	X	X		X		X						X	X
4. Time to market for Innovation shall be significantly reduced	X	X	X	X	X	X	X	X	X	X			X	

Trends / Areas of action	Digitalisation	Connectivity	Globalisation	Environmental conditions	Liberalisation	Smart simplicity	Transportation innovation	Trade-off between safety	Redesign instead	Socio-economic mega-trends	Regulation/privacy laws	Sustainability	Energy availability	Human factor
5. Replace cost and time consuming field tests by simulation	X	X		X		X	X					X		X
6. Safety procedures and methods should benefit from innovation	X	X	X			X	X	X	X					X
7. Re-Balancing active versus passive safety								X	X			X		
8. Adaptation of safety demonstrations accepted in other industries	X	X	X		X	X		X			X	X		
9. Improving Reliability, Availability and Maintain-ability (RAM) aspects in the context of safety	X	X		X			X	X		X		X	X	X
10. Digitalization, automation and autonomous operation	X	X	X			X	X			X	X			X
11. Cross modal safety	X	X				X	X			X			X	

1. **Replace personal judgment by clear pass-fail-criteria. Open the assessment market from assigned assessors to certified assessment bodies**

   Today safety is far too often based on personal judgment of individual persons involved in assessment processes. This hampers interoperability as well as competitiveness of the railways and finally also safety. Therefore a strict approach is desired to replace personal judgment and individual interpretation in all aspects related with technical safety by assessment criteria that are fit for 3rd party assessment.

2. **Recognition of assessment bodies vs. certification by accreditation scheme**

   The permission to certify an entity in charge of maintenance should be limited to an authority on European level or national authorities strictly monitored and guided on European level. The certification by accreditation institutions may bypass the governmental authority and responsibility in terms of safety requirements in processes and organization. Any certification of processes and organization where pass-fail-criteria are not in place in the same level of detail and quality like for technical systems bear the risk to confuse economic ambitions with safety responsibility. Different from 3rd party assessment for technical systems, the assessment of processes and organization should mainly be tasked to recognized bodies. Whether recognition or accreditation applies, the same criteria shall be used. It is common procedure in aviation to allow only state authorities granting certifications for undertakings performing safety related activities. However, clarification of preferred cases for recognition vs. certification should be initiated in the railway domain. There are a number of cases, where in-house conformity assessment is favorable for and established in the sector. EN 17065 is the most appropriate standard for organisations covering only the evaluation process, which includes the assessment of conformity of a subsystem with the requirements set in the relevant TSI. For organisations providing both conformity assessment AND certification (CABs) the well-established standards EN 17020 and EN 17021 are seen as the most appropriate. These standards cover the main activities of a NoBo.

3. **Safety is from the beginning an EU-wide, if not global, challenge: Stop diversity due to national deviation in terms of safety. Foster the shift of safety responsibility from infrastructure to rolling stock for increasing competitiveness**

   It is accepted that the overall safety level is different among member states, stakeholders and depending on the implemented technology. Furthermore, the share of safety contributions between the railway sub-systems is also different due to historical reasons. The EU interoperability regulation aims on harmonization of the safety levels as well as of the balance of safety contributions among the sub-systems. There is a tendency to increase safety up to the highest available benchmark among member states as well as per each sub-system. This jeopardises the competitiveness of the railway system as a whole. Therefore safety shall be understood as a system performance and the distribution of safety contributions among the sub-systems shall

be defined in a target specification. There is potential for a shift of active safety contribution from infrastructure to rolling stock, where the clear way ahead and the safe position of points are the only safety contributions from the infrastructure side and the risk of collision is managed on the rolling stock side. However, clarification of these criteria for a shift should be initiated.

4. **Time to market for Innovation shall be significantly reduced: Innovate the assessment of safety aspects for technical innovation**

   For each technical innovation the process of assessment to place the product on the market shall be accelerated in terms of elaboration and broad agreement from the beginning in order to prevent any delay for the market uptake of this innovative product – without compromising safety.

5. **Replace cost and time consuming field tests by simulation whenever possible**

   The increased availability and quality of relevant data allows for replacing a significant number of field tests by equivalent simulation models and methods in a quicker and cost-effective way. Therefore safety demonstrations shall increasingly be based on simulation rather than testing operationally in field and be recognized as a way of reliable validation.

6. **Safety procedures and methods should benefit from innovation: Smart data and data analytics may replace traditional approaches to ensure safety**

   Key is the information coverage for both technology or processes where safety may be concerned. The enhanced and continuous information allows less additional efforts for checking and maintaining safety up to the withdrawal of fixed inspection intervals.

   A typical application is the condition based and predictive maintenance, where at every time every state of the product or process is known and setting of threshold limits for actions are subject of continuous learning and improvement.

7. **Re-Balancing active versus passive safety**

   Overall availability of information shall allow for intelligent active safety contributions rather than expensive measures for reducing consequences of accidents. Therefore priority shall generally be on improving active rather than passive safety and any attempt in improving active safety should be incentivized by relaxation of passive safety efforts. For example, driver assistance systems on road vehicles indicating the approaching train on level crossings justify the withdrawal of accident scenarios of trains hitting road vehicles. Thus the integration of “heavy metal” solutions for absorbing energy in case of collisions with road vehicles becomes more and more superfluous.

8. Adaptation of safety demonstrations accepted in other industries

Rail up to now had the tendency to differentiate from other industries by creating specific criteria for design and assessment of technical products. As far as products used and proven in other industries are concerned, the adaption of safety demonstrations from these other industries seems to be a big and undisclosed potential not only for cost effectiveness but also for safety improvements as the lessons learnt in other industries can better be exploited.

9. Improving Reliability, Availability and Maintainability (RAM) aspects in the context of safety

Beyond the very narrow scope of technical safety there is a broad area of safety for passengers and freight directly related with reliability and availability of the technical system: failure of a technical system without any safety-related consequences may nevertheless significantly harm passengers or freight.

Examples are technically safe conditions exposing passengers to risks for health (e.g. unintentional train stop on track exposed to high temperatures and shut down of air-condition) or freight to risks for integrity (e.g. damaged protection device of a wagon to cover the load).

Improving the Reliability, Availability and Maintainability (RAM) for the technical system will close the gap between technical safety and comprehensive safety for passengers and freight.

Therefore consideration of RAM related to today's understanding of RAMS has to be strengthened and also research on RAM has to be increased.

10. Digitalization, automation and autonomous operation

Digitalization will cause the development into automation and autonomous operation, e.g. ATO. Therefore the focus of safety shall be enlarged to risks caused by digitalization and automatic operations of systems.

11. Cross modal safety

The railway system is part of the overall mobility chain. Due to increased digitalization in the automotive field railway safety can significantly be increased by optimized interaction between different mobility partners.

An example is the communication between the mobility partners at a level crossing.

5.4.2 Vision on « Security »

The following trends seem to become dominant in terms of future security requirements:

- Digitalisation;
- Connectivity, Internet of things;
- Globalisation;
- Liberalisation;
- Smart simplicity;
- Transportation innovation;
- Socio-economic mega-trends like demographic change, user behavior, individualization, customer centricity, transparency, consumer driven business processes;
- Industry 4.0, Mobility 4.0, Logistics 4.0 (autonomic process, robotics, supply chain, mobility chain, virtual mobility information center, virtualization of costumer services);
- Self-determination (balancing privacy with transparency);
- Regulation/privacy laws (need for confidence);
- Sustainability (e.g. balancing effectiveness with resources).

These trends enhance the migration towards a global security culture.

The railway system shall be an always open and accessible system, integrated in an intelligent transport system providing mobility and logistics up to individual needs of the customers. At the same time a high and reliable standard of security shall be ensured without restricting customers and goods mobility. This shall be provided by a combination of modern security technology (e. g. driven by NIS directive) and processes aiming on increasing security at any phase of the mobility/ logistics process.

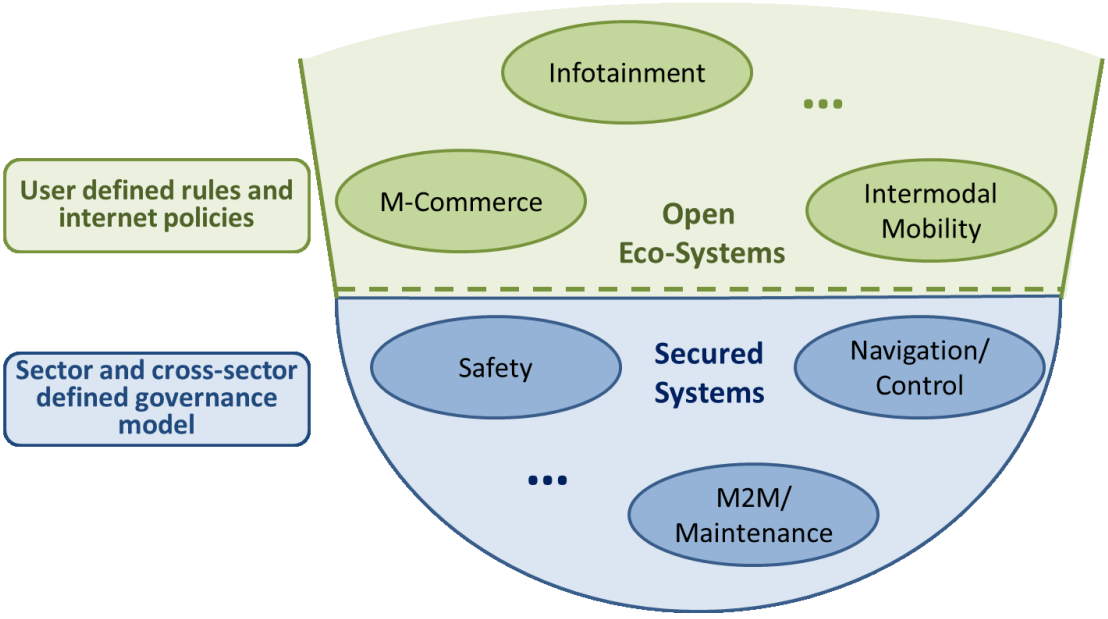

Figure 5 Concept design: Intelligent traffic - application framework

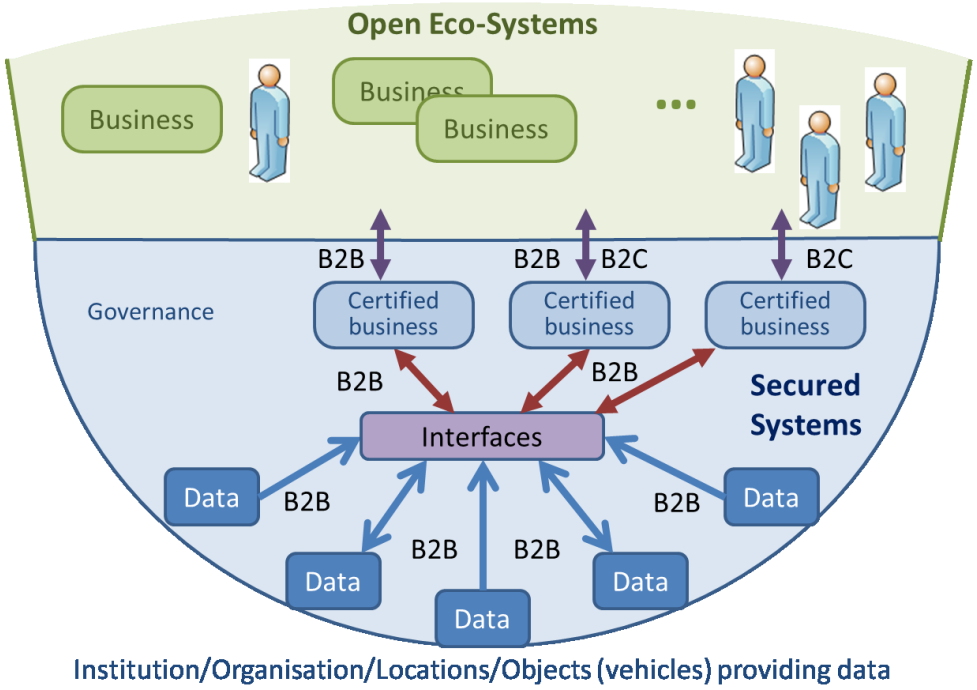

Figure 6 Architecture: Intelligent traffic - application framework

Source of Figure 5 and Figure 6: [11]

Each specific security threat for the railways system should be managed by applying non-rail-specific security measures, if those measures do not compromise the always open access of the railway system. Non-railway specific measures may derive from e.g. European Network and Information Security Agency (ENISA), Federal Office for Information Security (BSI), KRITIS.

Therefore, security policies have to address protection of company critical infrastructures by means of three complementary fields of action, on which future research needs to be based:

- Human factors, covering both staff recruitment, management and training, and possibly the involvement of passengers in their own security. Lasting value might be achieved with their involvement, whether concerning prevention, alarms, interventions, crisis management, tackling a disorder, crisis management and communication etc.;
- Technologies, their development must support staff efficiency; this could be new video-surveillance or image recognition technology, or automatic detection of abnormal situations and suspicious or dangerous objects (explosives or others), help for decision taking.

- Procedures, Regulations (for interoperability), Recommendations and Standards shall establish a coherent approach, including cooperation with public authorities (EU, national, local).

As current focus is on identification on critical infrastructure, there is in addition to the company critical infrastructure a national critical infrastructure defined which only encompasses a very small part of the company critical infrastructure. In detail an infrastructure qualifies to be regarded as national critical infrastructure by the following criterion: Significant impact on the provision of services, which could not be provided by any alternatives during a defined period of time.

It should be noted that all measures dedicated to company critical infrastructure fully cover any aspect of national critical infrastructure.

The security approach shall be not specific for rail from the beginning. Any implemented or available measures to improve security in other sectors than rail shall be considered to be applicable, if not compromising the open access and flexible use of the rail system by its customers. It should be accepted that ownership of data will be more and more difficult to be achieved due to the multi-redundant provision of data from various different sources.

Therefore security should not be based on exclusive knowledge and protection of data, but on open processes that indicate early and in a reliable way any security threat.

By implementing methods well known from the field of safety, security issues can be improved. Therefore all well-known methodologies for risk analysis and hazard identification shall be evaluated for application on security threats (specific requirements for urban rail see chapter 2.5).

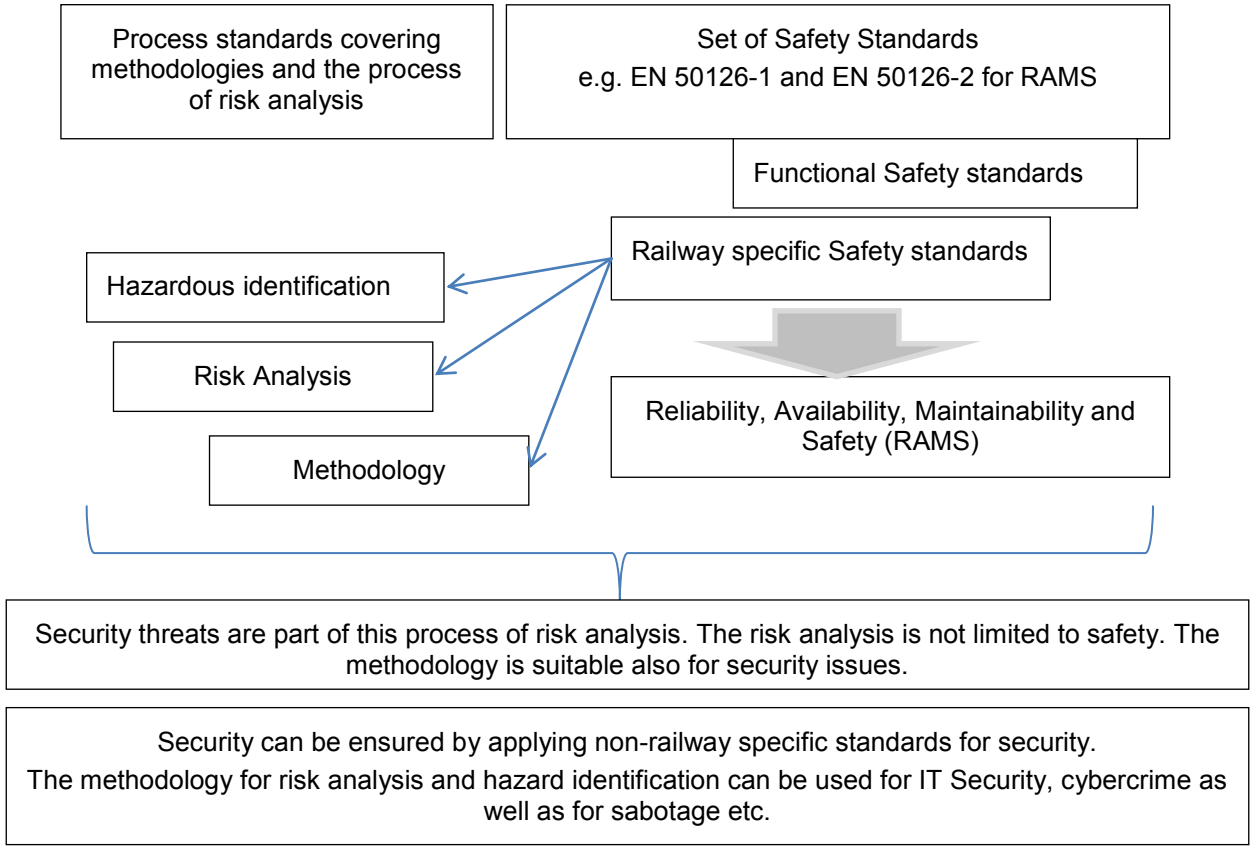

Figure 7 Safety related Standards assist security threats

Thus an important target will also be to share the experiences with other industries. Any measure in terms of IT-security shall be derived from the NIS Directive and be adapted to the specific needs of any project.

Major securities threat categories to be considered especially in research projects:

- Cybercrime (inputs from NIS requirements considering physical and digital protection);
- Unauthorized access / trespassing;
- Lack of cyber protection, especially back doors in embedded components;
- Attacks to the business, e.g. blackmailing;
- Sabotage / Vandalism / Grafitti;
- Obstacle on the tracks;
- Metal theft (inputs from UIC Metal Theft WG and UIC/EC DG MOVE workshops on Metal Theft);
- Aggression and assaults against customers and employees / anti-social behaviour;
- Terrorism / Extremism (input from the UIC coping with terrorism workshop as well EU PROTECTRAIL project);

Regarding security threats, there is no differentiation needed related to the various targets of those threats. Main aspect is the differentiation in threats from inside or outside the company as well as threats of physical or technical origin.

Differentiation of targets of the above mentioned security threats:

Table 2 Differentiations of targets

Threats / Targets	Threats to the company		Kind of threats
	from outside	from inside	
Assets and facilities	x	x	▪ Physical ▪ Technical
Technology (automation, robotics, control system) Telecommunication IT			
People			
Business processes			
Operational processes			

To cope with the above mentioned threats there is a need for improved and differentiated incident management processes based on sound incident scenarios. These processes are allocated to two main tasks:

- Increase of prevention and protection: Prevent attacks from becoming effective;
- Increase of resilience (including Business continuity management processes): Limit the consequences of a successful attack. Enhance preparedness and the response capabilities.

Various areas of actions have been identified and clustered around the two main tasks. They contribute to some extent to the trends highlighted in the vision.

The areas of action are derived from the following relevant trends for security.

Table 3 Areas of action related to trends

Trends / Area of action	Digitalisation	Connectivity	Globalisation	Liberalisation	Smart simplicity	Transportation innovation	Socio-economic mega-trends	Industry 4.0, Mobility 4.0, Logistics 4.0	Self-determination	Regulation/privacy laws	Sustainability
Increase of prevention and protection											
Physical security	x	x				x	x	x	x	x	x
Procedural security	x	x	x	x	x	x	x	x	x	x	X
Perceived security	x	x				x	x	x	x	x	X
Cyber security	x	x	x	x	x	x	x	x	x	x	x

Increase of resilience (including Business continuity management processes)											
Limitation of damage and impact	x	x	x			x		x			
Fall-back level	x	x			x	x		x			
Emergency management	x	x	x			x		X			
Recovery management	x	x	x		X	x		x			

Increase of prevention and protection

- Physical security is usually provided by fencing and locking sensitive assets in order to prevent unauthorised access. This encompasses the design and location of technical components as to prevent the destruction or removal of those components. This includes the physical measures to response on possible attacks, when they appear.
- Procedural security is usually ensured by staff well-trained in security plans and procedures, presence of staff, access limitations and defence strategies. This includes the procedural measures to be prepared to response on possible attacks.
- Perceived security is very much based on customer perception and can be improved by presence of staff, bright, transparent customer areas covered by communication and video surveillance technology. It should be noted that especially on the domain of perceived security the customer expectations have been significantly increased. Setting indicators for perceived rail security at European level remains a challenge.
- Cyber security is compared with all other security challenges the new key security challenge of today and tomorrow. This is because it is global by structure and the benefits of open access means in return attracting enemies with criminal background. The utmost step for protecting a network is its complete isolation from the internet (self-sustaining network), including no interface at all for remote maintenance.

Increase of resilience (including Business continuity management processes):

- Limitation of damage and impact defines all BCM methods, procedures and algorithms for safe-guarding vital functions during and after a successful attack. Damage and impact must be limited by intentionally dropping non-vital functions and associated hardware.
- Fall-back level is the availability of secure and cost-efficient fall-back systems in order to survive a successful attack. Fall-back must be provided either on a functional process level and/ or on a redundant hard-ware basis.

- Emergency management is the capability to quickly cope with a successful attack. It also encompasses the competence to rapidly adapt to permanently changing security hazards.
- Recovery management is the capability to quickly and effectively re-establish crucial business processes.

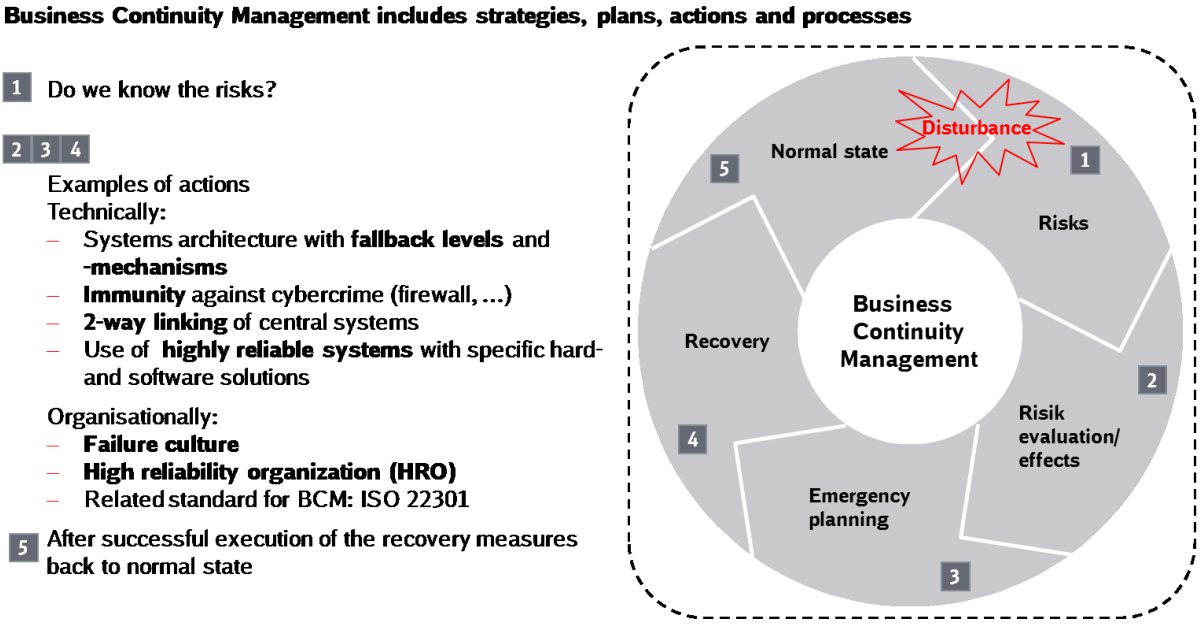

Figure 8 Business Continuity Management includes strategies, plans, actions and processes

5.5 Implementation Plan

5.5.1 Roadmap Development on « Safety »

Table 4 Activities in the areas of action

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
1. Replace personal judgment by clear pass-fail-criteria	Improve applicability of risk based safety approach (e.g. simulation tools)	Development of objective criteria for pass-fail – technical issues (standardisation)	Criteria for assessment are cross accepted between assessment bodies	Short term
		Process definition for integration of all stakeholders in the assessment (ERA)	Cross-acceptance with other industries ensured	Mid term

		Transparency for process and criteria (regulation)	Unambiguous criteria for risk based safety assessment	Short term
2. Recognition of assessment bodies instead of certification by accreditation scheme	Virtual certification	Assign ERA as an assessment body (ERA)	ERA to be operational for assessments	Mid term
		Provide recognition criteria (regulation)	ERA recognizing assessment bodies	Short term

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
3. Safety is from the beginning an EU-wide, if not global, challenge: Stop diversity due to national deviation in terms of safety.	Strict analysis of diverse requirements for the same safety objective	Shift competence from national authorities to EU and/or international level (regulation)	Shorten time to market Remove barriers to innovation	Short term
	Develop methods to reduce unjustified diversity by using tools for big data and data analytics		Quantification of the effects of the safety contribution related to costs	Short term
4. Time to market for Innovation shall be significantly reduced	Develop methods to reduce unjustified barriers to innovation by using tools for big data and data analytics	Develop quick acceptance process for innovations (regulation)	Shorten time to market	Short term
5. Replace cost and time consuming field tests by simulation	Improve applicability of risk based safety approach (e.g. simulation tools)	Provide standards for cross acceptance of simulation tools (standardisation)	Shorten time to market	Short term
	Virtual certification		Quantification of the effects of the safety contribution related to costs	Short term
6. Safety procedures and methods should benefit from innovation	Technology screening for discovering potential innovative safety procedures and methods	Transparency for process and criteria (regulation)	Transfer of best practice into the railway sector	Mid term

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
	Improve predictive maintenance			Mid term
	Introduction of Human Factors Technologies in Safety Process	Monitoring of integration Human Factors requirements in SMS	Technological transfers between the transports modes.	Short term
7. Re-Balancing active versus passive safety	Maximize safety credential of future intelligent transport system	Reduce passive safety provisions and compensate by innovative active safety contributions	Quantification of the effects of the safety contribution related to costs	Mid term

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
8. Adaptation of safety demonstrations accepted in other industries	Best practice screening for discovering potential innovative safety procedures and methods	Provide recognition criteria (regulation)	Accepted safety demonstrations across various industries	Short term
	Join safety research as a partner for leading industries	Reduce railway specific safety standards by adapting general industry standards for safety (standardization)	Reduced variety of safety demonstration methods	Short term
9. Improving Reliability, Availability and Maintainability (RAM) aspects in the context of safety	Research on safety contributions from RAM in a wider scope than technical safety	IEC 62278 to replace EN 50126 (standardisation)	Improving RAM within the Safety aspects of existing standards (e.g. EN 50126)	Mid term
	Research Human Machine and Organizational interface under the RAM frame			Mid term
10. Digitalization, automation and autonomous operation	Safety relevant impacts of automation and autonomous operation	Legal framework has to be improved in order to catch up with new challenges (regulation)	Foster innovation without jeopardizing the current safety level	Mid term
11. Cross modal safety	Support Rail2X and enlarge on global	Application data protocols for rail and	Application of a general industrial	Short term

	level (5G, additional specification of railway and cross modal application protocols)	cross modal (standardisation)	standard for traffic management without any modifications for railway	
	Industry 4.0 requires Law 4.0, today we have Law1.0	Legal framework has to be improved in order to catch up with new challenges (regulation)		Mid term
	Develop safety approach along the entire mobility/logistic chain	Withdraw policy of banning level crossings as soon as safe cross modal communication is available (regulation)	Seamless safety level covering the entire mobility / logistic chain	Long term

The above mentioned targets specific to each area of action are deemed to be effective contributors for improving the common safety targets (CST) in the European Railway System. Therefore the CST's should be monitored and analysed in terms of the effects of the proposed areas of actions.

Before starting research activities derived from this road map a comparison with other research activities in the field of safety should be done to avoid overlaps and double works (e.g. Horizon 2020, 7th Framework Programme).

Roadmap Development on « Security »

Table 5 Activities in the areas of action

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
Increase of prevention and protection				
Physical security	Identification of change of state or location of components Biometric identification and verification without violation of personal rights for the purpose of security of customers, freight and staff. Detection and identification of dangerous material (wappons, explosives etc.)	Privacy laws (regulation) Protection means for unintentional access (e. g. platform edge doors) (standardization)	Reduction of infringements of protected property Prevention of any kind of attacks	Short term Mid term Short Term
Procedural security	maximizing staff efforts in managing and improving security by technical assistance/ support: • increase time for customers and freight care by automation • help identifying security critical situations by IT	Access to information collected by other parties (police, …) for security purpose only, without violating privacy rights (regulation)	Prevention and peduction of attacks to persons, assets and facilities Reduction of consequences of attacks	Mid term
Perceived security	Investigation of future security needs in the light of reduced personal sensitivity and knowledge on the one hand and increased technical security performance on the other hand		Customer Satisfaction Index	Mid term
	The interaction and/or collaboration with social media should be investigated			Short term

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
Increase of prevention and protection				
Cyber security	Analyse the potential of risk based security versus rule based security Improve network architectures in terms of security Hybrid networks (shared versus self-sustaining networks) Encryption methods and management (securing data in open networks) Open source software Improve data interfaces in terms of security Detect anomalies and understand their thread to security (big data and data analytics) Prediction of security threats Future communication platform 5G	Application and revision of NIS-Directive Provision and revision of non-railway specific standards for security in support of safety standards	• Confidentiality • Integrity • Availability • Authenticity (see ISO 31000)	Short term Mid term

Area of action	Activity	Activity	Target	time line
	Research needs	▪ ERA ▪ Regulation ▪ Standardisation		
Increase of resilience				
Limitation of damage and impact	Provision of basic services by self-sustaining networks as parallel networks in addition to public internet: Secured systems for safety, control, M2M, maintenance BCM methods, procedures and algorithms for safe-guarding vital functions by intentionally dropping non-vital functions and associated hardware	Minimum security level for core communication services and platforms	Damage cost in € Keeping business and company alive	Mid term
Fall-back level	Economic and security improvements of fall-back systems (reducing cost for redundancy)	Minimum requirements related to the fall-back level	Damage cost in € Minimising the consequences of attacks	Mid term
Emergency management	Response time and capability regarding limitation of the consequences of an attack	Establishing and optimizing CERT (Computer Emergency Response Team)	Response time to attack Ratio of secured functions to lost functions	Short term
Recovery management	Recovery time and effectiveness regarding re-establishment of crucial business processes	Bench-marking of best practices in recovery management	Recovery time Ratio of secured functions to lost functions	Short term

Before starting research activities derived from this road map a comparison with other research activities in the field of security should be done to avoid overlaps and double works (e.g. Horizon 2020, 7th Framework Programme “Security”, Societal Challenge 7 “Secure Societies.”).

5.5.2 Roadmap Development on « Security » - Needs for Urban Rail Systems

The public transport security concept applied to mass transportation covers three major areas:

- A security strategy, implemented through a structured risk management process involving all relevant stakeholders: Public Transport Operators - PTO, Public Transport Authorities - PTA, Law Enforcement and First Responders - LEFR.
- An organization able to best implement the security strategy at the various levels, including the interfaces with internal and external bodies.
- The procedures that facilitate incident response and business continuity, allowing on a daily basis the security risk mitigation at the appropriate level.

The recommendations presented as main SECUR-ED results [16] cover all these three abovementioned areas.

The sector representatives, through the SECUR-ED project [16], had also highlighted some recommendations for future research which are summarized hereinafter:

- It is necessary to further develop and consolidate the method integrating cyber-security risks13, as it was separately undertaken by the demonstrations during SECUR-ED [16].
- As a future action, an online tool may be developed to improve the access and encourage the usage of a common glossary. It could be taken as an action at the EU level, either through an EU-funded project and/or through a standardization process. The SECUR-ED Glossary [16] could be taken up and used as a living document by the sector.
- For orchestration engines the need for additional research has been identified in order to improve the human-machine interaction.
- Further actions are needed regarding PIS in terms of technical harmonisation and research, especially concerning the integration and utilisation of modern communication tools, such as smartphones.
- Further pilot studies and projects are needed in order to measure and validate more appropriately the impact and benefits of the early warning systems (EWS) for improved operational (security) management which can be integrated with supervision systems.
- Decision support systems need further development and testing efforts. The need for technical harmonisation cannot yet be assessed.
- In the case of “CCTV forensics” and “CCTV and incidents” efforts need to be made in order to make the process more efficient. Software tools for the automated extraction of relevant information are required. In that context, further technical harmonisation is recommended.

[13] Based on ISO/IEC 27005 knowledge.

- Communication systems are widely available on the market and - depending on their cost - can be recommended for a wide application by the sector; further work should focus on improving stability and functioning in emergency situations and with degraded or destroyed infrastructure. Another aspect that may require more attention concerns the protection of communication system against cyber-attacks.
- The intrusion detection domain needs additional research actions – e.g. on how to handle false alarms - as well as technical harmonisation.

There are two other topics that have surfaced during the SECUR-ED [16] project developments and are considered by numerous public transport stakeholders as important subjects that should also be addressed in the future, including through research supported by the EU at the Union level:

- Cooperation in the field of security and emergency management between PTO and LEFR representatives.
- Further research on ethical and societal impacts related to the developments of both security and privacy legislation and practices.

5.6 Visual Roadmap, milestones and deliverables overview

5.6.1 Visual Roadmap « Safety »

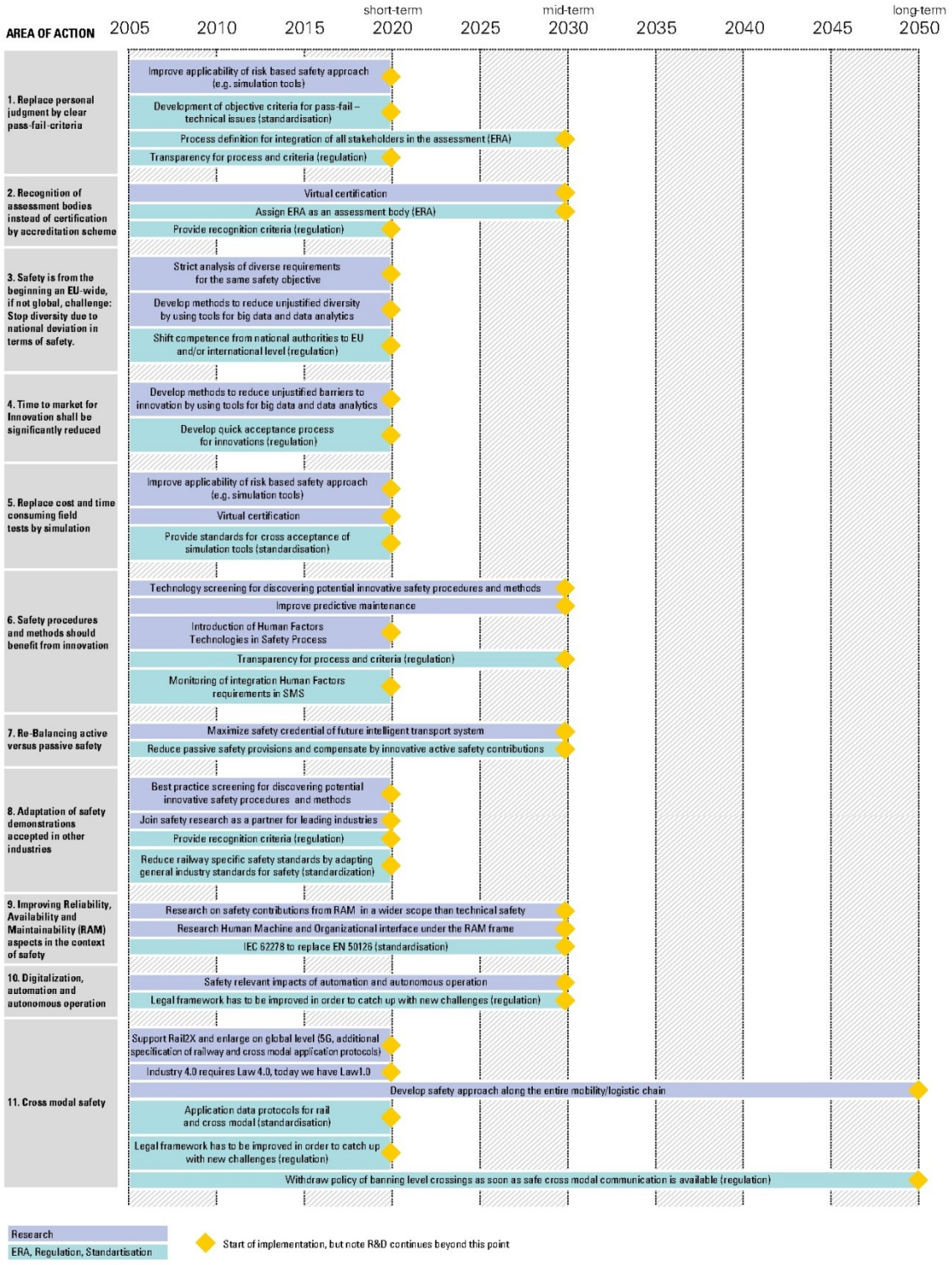

Figure 9 Visual Roadmap Safety, milestone and deliverables overview

5.6.2 Visual Roadmap « Security »

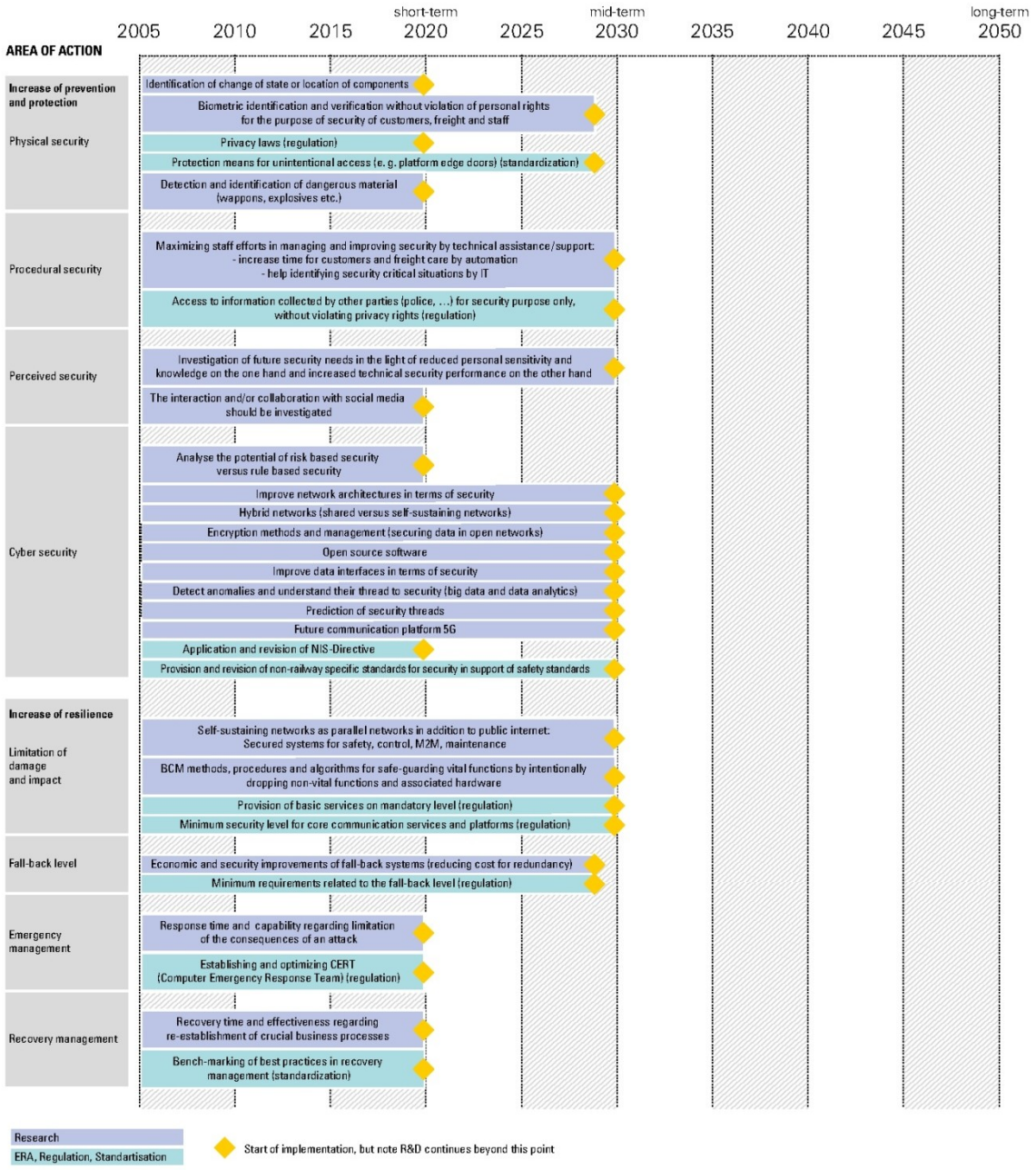

Figure 10 Visual Roadmap Security, milestone and deliverables overview

5.7 Conclusions

5.7.1 Identified Areas of Action on “Safety”

Identified Areas are:

1. Replace personal judgement by clear pass-fail-criteria. Open the assessment market from assigned assessors to certified assessment bodies.
2. Recognition of assessment bodies vs. certification by accreditation scheme.
4. Safety is from the beginning an EU-wide, if not global, challenge:
   - Stop diversity due to national deviation in terms of safety. Foster the shift of safety responsibility from infrastructure to rolling stock for increasing competitiveness.
5. Time to market for Innovation shall be significantly reduced: Innovate the assessment of safety aspects for technical innovation.
6. Replace cost and time consuming field tests by simulation whenever possible.
7. Safety procedures and methods should benefit from innovation:
   - Smart data and data analytics may replace traditional approaches to ensure safety.
8. Re-Balancing active versus passive safety.
9. Adaptation of safety demonstrations accepted in other industries.
10. Improving Reliability, Availability and Maintainability (RAM) aspects in the context of safety.
11. Digitalization, automation and autonomous operation.
12. Cross modal safety.

5.7.2 Identified Areas of Action on “Security”

Identified Areas are:

1. Increase of protection
   - Physical security
   - Procedural security
   - Perceived security
   - Cyber security
2. Increase of resilience (including Business continuity management processes):
   - Limitation of damage and impact
   - Fall-back level
   - Emergency management
   - Recovery management

6. Capacity, performance and competitiveness

6.1 Introduction

Capacity, performance and competetivness for the rail sector means a continuous adoption to new market demands, focusing on the customer experience, new operating plans, co-operative alliances and also technology developments and requirements. To remain competitive and meet the challenge projected by the European society on the rail sector and its importance of transport in Europe, the whole European rail sector must combine and improve its efforts towards the goal of being more efficient and productive while improving the customers' expectations of rail services.

To prove value to present and new customers, rail should capitalis 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.

6.2 Key issues and objectives

The objectives of this Roadmap are to identify, in a structurated way and with a global view on the railway system, the most important topics in capacity, performance and the competetivness. It should be a coherent development with previous and on going projects and the best cost benefit quota.

The priorities defined in the SRRIA can be concreatly specified as:

1. Arrangements maximising capacity on busy corridors and improved system utilization;
2. More reliable system components, leading to a highly reliable system which is a prerequisite for the development of track capacity, reduction of in-service failure;
3. Improved system utilisation, yield management and organizational arrangements, which maximise capacity on busy corridors; business continuity;
4. Optimised real-time traffic management, maximising capacity while conserving energy and minimising inconvenience to the passenger and the freight user;
5. Highly automated railway operation and technical support, including vehicle and infrastructure condition monitoring and maintenance, thereby enhancing Life Cycle Cost efficiency, system resilience, reliability and improving customer service;
6. 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;

Since the objectives are seen as measures to fulfil the priorities of the SRRIA, in a structure suitable for research and innovation, that could mean that some priorities are not included directly, either since they are secondary results or that they simply are not prioritized or are handled in ongoing projects.

The specified objectives in this Roadmap are:

1. Making the infrastructure available for operations.
2. Improving the capability of infrastructure
3. Optimising the operational use of available infrastructure
4. The ability to have effective and extended operation
5. Transport capability

Due to interdepedensies, these five objectives is merged into three Actions in the roadmap chapter:

- Infrastucture availability
- Improved operational use of Infrastructure
- Improved effectivness in operations

6.3 State of the Art and on going research and innovation within and outside rail

Overview

The literature review focused on three principal objectives:

1. The strategic aims and objectives of the European Commission and Member States for transport. For example, for rail - as described in EC White Paper 2011 and Horizon 2020, for other transport modes - as described in the European Transport Platforms (ETP) roadmap for transport infrastructure innovation across transport modes, and for inter-modal transport – as covered in the ECTP Roadmap for cross modal transport infrastructure innovation. This literature identifies the direction and common transport goals across Europe.

2. The vision, strategy and planned work for delivering the railway of the future; for example 10, 20, or 40 years hence. Such issues were covered, for example, in (a) rail industry documents produced by Member States, (b) associations for specific rail engineering disciplines (such as signalling), and (c) other organisations associated with rail transport and/or inter-modal transport that involves rail.

3. Trends and drivers in the European rail industry; including historic and forecast statistics on, for example, the number of passenger km, the number of freight tonne km, and the fleet size and type of rolling stock.

Principal References and Projects

EC White Paper 2011: Roadmap to a single European Transport Area 2050

This Paper sets targets for (inter alia) (a) a reduction in transport-related greenhouse gas emissions, (b) a modal shift of freight from road to rail and/or waterways, (c) a modal shift of medium-distance passenger travel from road to rail, (d) expansion of the European high speed rail network, (e) the completion of the TEN-T core network - including rail links to core airports and core seaports, and (f) implementation of ERTMS.

With the issue of this White Paper, the cornerstone of European transport policy and strategy, the collection of transport statistics for the EU diversified to include information that can help identify and model emerging trends and drivers.

New EC Infrastructure Policy

This reference provides maps of the nine major TEN-T transport corridors that will provide the backbone to the trans-European transport network. To help deliver this network, EC financing for transport infrastructure is to triple, over the period 2014-2016, to €26 billion.

European Railway Traffic Management Systems (ERTMS)

This project will enhance crossborder interoperability across Europe through the creation of a single standard for railway signalling and will also contribute to improving safety and capacity. A press release, in 2013, states that ERTMS is to be in place across the core European rail network by 2030.

European Neighbourhood Policy

The objective of this policy is to avoid divergence between an enlarged EU and its neighbours. The Policy covers a broad range of issues ranging from industrial and competition policy to climate change, and includes energy security, transport, and R&D.

Horizon 2020

It is the EC's latest and largest research and innovation framework programme. One of the aims of this R&D programme is to put Europe at the forefront of innovation in many areas, including transport. The latter does not cover rail transport specifically but the policy states that the vision is to construct a smart, green and integrated transport network. Actions to deliver this policy are to focus on resource-efficient transport, better mobility, less congestion, more safety and security, global leadership for the European transport industry, and forward-looking activities to feed into future policy making.

The associated home page for Horizon 2020 work programme 2014-2015 invites proposals for smart, cost-effective, high capacity, user-friendly rail infrastructure, intelligent mobility management, energy management logistic services, and new generation of rail vehicles.

Rail Route 2050: the sustainable backbone of the Single European Transport Area

As stated by its subtitle (An initial update of the ERRAC Vision for Railway Research and Innovation for the future of rail) this document provides an update of ERRAC's priorities for research and innovation in line with the EC White Paper 2011: Towards a competitive, resource efficient and intelligent transport system for 2050. The document re-iterates the targets given in the White Paper and the trends and aspirations given in others, such as the UIC-CER 2010 Sustainable Mobility Strategy. The ERRAC document provides a comprehensive review of the research and innovation needs for EC funded research to deliver the vision of the White Paper. The priority areas for researchare; intelligent mobility; energy and environment; personal security; safety and homologation; competiveness and enabling technologies; strategy and economics; and infrastructure. The UIC-CER 2010 Sustainable Mobility Strategy identifies trends in the following that are relevant to the operation of a railway; globalisation; demographics; urbanisation; scarcity of energy resources; climate change; limitations of natural resources; biodiversity; individualisation and changes in lifestyle; limited public funding; stronger regulations; and intermodal competition.

Sustrail

The sustainable freight railway: Designing the freight vehicle – track system for higher delivered tonnage with improved availability at reduced cost.

The Sustrail objective is to contribute to the rail freight system to allow it to regain position and market, accounting for the increase of the demand of the total freight transport volumes: 40% (in tonne-kilometres) by 2030 and 80% by 2050 and the shift of 30% of road freight over 300km to other modes such as rail or waterborne transport by 2030 (50% by 2050) as targeted by the European Commission.

Within this framework and motivated by the necessity and opportunity for change in rail transport, Sustrail provides the approach, structure, and technical content to improve the Sustainability, Competitiveness, and Availability of European railway networks thanks to an integrated approach.

Innovations in rolling stock and freight vehicles combined with innovations in the track components will be pursued by adopting a holistic approach, implementing a clear methodology and viable procedures setting up appropriate business cases, ensuring the penetration and the exploitation of the project results by means of effective dissemination activities and cooperating with National and EU authorities in view of future proposals for recommendations to be adopted for enhancing freight transport in the railway context

Spectrum

SPECTRUM - Solutions and Processes to Enhance the Competitiveness of Transport by Rail in Unexploited Markets, explores the market opportunities for transport of low density,

high value (LDHV) goods, utilising new and innovative rail concepts. Focus is on the extension of existing 21st century rail services and more visionary rail logistics services. Early project proceedings set the foundations for detailing concepts by defining technological and operational requirements.

Preliminary research is built upon with an assessment of existing conceptual designs and a shift in focus to assess technical and operational requirements.

SPECTRUM develops a detailed design concept for a high performance freight train that is efficiently lightweight, has driving performance characteristics that facilitate mixed running with passenger services and is capable of accommodating the required types of freight container unit. Design work includes Optimised, lightweight, energy efficient freight wagon structures; High speed running gear, including brakes and vehicle dynamics; electrical systems and coupling arrangements and the handling of freight container units.

Ultimately, at least one demonstrator is produced in order to validate the innovative high performance freight train design solutions developed in the project. Demonstrators such as; the power conversion system that supports the reefers being carried, the running gear that supports high speed operation, critical aspects of the lightweight vehicle structure and the freight handling system are developed. 'Real life' conditions in terms of scale, fabrication, installation maintainability and robustness are replicated.

Capacity4Rail

In 2011, the White Paper on European Transport reasserted how fundamental transport was for society, for the mobility of European citizens and for the growth and vitality of the European economy.

Capacuty4Rail will deliver research that is innovative, prepares rail for the future and takes into account results from previous research projects and programmes. The project builds on previous useable results and will deliver both technical demonstrations and system wide guidelines and recommendations that will be the basis for future research and investment, increasing the capacities of rail networks in the future.

The time used for infrastructure monitoring, maintenance and renewal means 'down time'. New concepts for low maintenance infrastructure, using standardized and "plug-and-play" concepts will be proposed. Non-intrusive innovative monitoring techniques or self-monitoring infrastructure will be investigated, allowing low or no impact on train operations.

The fragility of some key component of the infrastructure system (especially in extreme weather conditions) such as switches may impact the efficiency of the whole system. The resilience of switches to any kind of known failure will be reinforced, as well as the ability of the operation system to recover from incidents.

Capacity enhancements will also be achieved by higher speed freight vehicles, allowing an optimized interleaving of freight trains into mixed traffic, and improved planning models for operation.

Intermodal integration within the global transport system will be improved through enhanced transhipment of passengers and freight.

CAPACITY4RAIL will also look towards 2030/2050, by proposing guidelines for future deployments in the mid-term, recommendations for technologies to de developed and deployed in the long term and investigating the key opportunities for funding these within national and EU funding schemes."

Shift2Rail

This seven year R&D programme of work, due to start in 2015, is concerned with the development and implementation of technological breakthroughs that will help improve rail services across Europe. The project is to be managed by public-private partnership. The project aims to deliver a substantial reduction in the life-cycle cost of rail transport, a substantial increase in rail capacity, and a substantial increase in the reliability of rail transport systems. The programme is focused on five key areas; improved quality of rail services – through the development of a new generation of cost-effective, reliable, high capacity trains, increased rail capacity – through the development of better traffic management and control systems, provision of high quality, reliable rail infrastructure – through the development of lower cost, lower noise, and intelligent infrastructure, provision of integrated ticketing and journey planners – through improvements ininformation technology solutions and services, and more cost-competitive rail services – through the development of improved logistics and inter-modal freight movements.

ECTP Roadmap for cross modal transport infrastructure innovation

In June 2012 it was agreed to form a joint task force, from the various ETPs for road, rail, water and air transport, to develop a roadmap on cross-modal transport infrastructure innovation. The joint task force has started to extract the research and innovation priorities that span the various modes of transport. The focus of the study is the performing infrastructure but in addition to covering the construction and maintenance of physical structures, the scope is to encompass its supporting systems and services, and governance, management and finance.

Moving towards sustainable mobility: A strategy for 2030 and beyond for the European railway sector

This document outlines how the rail sector should be performing, in environmental terms, in 2030 and 2050. It also sets out, for the rail sector, specific targets and objectives to meet by 2030, and more general visions for 2050. The reference includes technical annexes and roadmaps that provide a framework for rail organisations to develop long-term plans to meet the targets.

Living Rail – Challenge 2050: The rail sector visions – how can rail contribute to a Europe worth living in

This reference describes the European rail sector's perception, vision and goals for the railway of 2050. This wide-ranging document considers value for money, performance, safety and security, consistency, capacity, connectivity, sustainable development and personnel.

EUROSTAT and the EU Transport in Figures – Statistical pocket book

These references provide detailed statistical information on European transport, including rail transport. The statistics on rail transport provided in EUROSTAT 2013 are drawn from two sources: that on rail infrastructure, equipment, enterprises and traffic from returns to the Common Questionnaire (Eurostat/UNECE/ITF), and that on rail infrastructure (length – total, electrified, and with two or more tracks) from returns to the REGWeb questionnaire.

The EU Transport in Figures – Statistical pocket book

It gives the following information for freight transport movements within the EU:

• 11% of all the freight was transported by rail, and 45.3% by road.

• In 2011, 420 billion tonne km of freight was transported by rail – much the same as transported in 1997.

• In 2011, 1734.1 billion tonne km of freight was transported by road - compared to 1350 billion tonne km in 1997.

EU transport demands: trends and drivers. Routes to 2050

This document reviews the trends in EU transport, and identifies and analyses the main drivers that will affect the demand for transport in the EU in the long term. This document was produced as part of the project EU Transport GHG: Routes to 2050? that supports the EU's long-term objective for tackling climate change – the strategic target for 2050 is to limit global warming to 2oC. Although new EC policy measures have been formulated, which aim to control emissions from the transport sector, these are not part of a broad strategy or overarching goal. Thus the key objective of that project is to provide guidance and evidence on a broad-based policy framework for controlling greenhouse gas emissions from the transport sector.

Energy trends to 2030

This documents published by the European Commission Directorate - General for Energy in collaboration with Climate Action DG and Mobility and Transport DG provides forecasts of energy use for all transport sectors up to 2030.

NATIONAL STRATEGIES

The Future Railway: The Industry's Rail Technical Strategy 2012.

This document contains the technical strategy for the railway in Great Britain. The document includes a 30 year vision (railway envisaged in 2040) for six key technical areas: control, command and communication; energy; infrastructure; rolling stock; information; and customers. The document was produced on behalf of the GB rail industry by the UK Technical Strategy Leadership Group and therefore represents the collective UK industry view. The document includes high-level roadmaps for each technical area, but few targets against which progress could be measured. The strategy has been well received both in the UK and in Europe where it has been influential in shaping key European programmes, specifically the nascent Shift2Rail Joint Undertaking.

Network Rail Technical Strategy

This document was published in response to The Future Railway: The Industry's Rail Technical Strategy 2012 and outlines Network Rail's (the GB rail infrastructure operator) research and development priorities and opportunities for the next 30 years and contains its strategy for delivering the future vision for the GB railway. The document is closely aligned in structure and scope to the GB industry strategy, but goes into greater detail around the main technical themes, safety, performance, customer experience, capacity, cost-efficiency and sustainability. The strategy includes indicative programmes of work and associated high-level assessments of industry benefits.

Deutsche Bahn Strategy DB2020

The Deutsche Bahn strategy focuses on the period to 2020. The strategy takes into account the customers, employees, environment and society. The "mega trends", which are addressed in the strategy, are globalisation, liberalisation, climate change, shortage of resources and demographic changes. Depending on freight or passenger transport or infrastructure different challenges and future targets are described.

The strategy for freight expects a growing European freight market of app. 2% per year as a mean value. Big risks are the increasing volatility of European markets.

The protection of the environment is a key subject in the strategy for all assets and transport modes and it is expected to increase the acceptance of the railway system and strengthen the "green" position of its customers. Flexibility with respect to economic trends and changes is identified as a central success factor of the railway.

Plan de Infrastructuras, Transporte y Vivienda PITVI 2012-2024

This document, published by the Spanish Government (Ministry of Public Works), presents the strategic vision for all means of transport (rail, road, air and maritime transport), and also for housing. The document establishes the criteria to plan and prioritize the future investments in transport until 2024.

For railways, the targets identified in the document are to increase efficiency and competitiveness, to increase sustainability, to achieve a seamless chain of transport with other means of transport (intermodality), to increase the efficiency and market share of freight traffic and to contribute to the cohesion of the Spanish regions. Some of the specific actions included in the plan include increasing the maximum length of trains up to 750m and the maximum load up to 22.5t in some lines to adapt them as European corridors.

Plan Estratégico para el Impulso del Transporte Ferroviario de Mercancías en España
This document produced by the Spanish Government (Ministry of Public Works) describes the actions that should be taken to move from the 2010 market share for rail freight transport (4.1%) to 8-10% in 2020. To achieve such targets the plan envisages liberalisation of the market, an increase in transport efficiency, the creation of logistical platforms, the adaptation of some railway lines to meet freight requirements and the use of emerging technologies, among others.

Estrategia Logística de España

This document describes the strategy for Logistics in Spain. It meets the vision of the PITVI 2012-2024 plan and sets a roadmap for the future years to increase of efficiency of the transport, the inter-modality between modes of transport, etc. in order to enhance the logistic role of Spain in Europe. To achieve that, the document reveals a list of actions such as the creation/improvement of multimodal logistic platforms. Regarding the specific plans for railways, it envisages the creation of specific high capacity corridors, increase the priority of freight trains when allocating slots, extending the rail network, etc.

Zielnetz 2025+

The strategic concept of ÖBB Infrastruktur AG is Zielnetz 2025+ (Target Network 2025+). The overall goal is to shift transport volume from road to rail with ambitious target setting such as 40% increase in freight volume, 30% increase in train-kilometres and a 25% percent increase in passenger volume by 2025+. This is expected to avoid 11.1 million truck-loads in Austria and increase the number of passengers from 240 to 300 million. Regarding ERTMS the strategy is to equip all major corridors (TEN-T) as well as new and refurbished lines.

Czech Republic Transport Policy Priorities

The following priorities follow from the global goal and are interlinked:

• Achieving a suitable modal split by ensuring equal conditions on the transport market

• Ensuring quality transport infrastructure

• Ensuring financing in the transport sector

• Improving the transport safety

• Supporting transport development in regions.

Turkish State Railways Strategies

The TCDD strategy focuses on 2023-2035 period. In order to render TCDD more effective and efficient and to increase its share in passenger and freight transportation, projects such as high speed line construction, investments in conventional lines, renewal projects of existing lines and rolling stock, Electrification, Signalization and Telecommunication (EST) projects, new rolling stock procurement and establishment of logistic centres are being carried out.

TCDD's major goals are as follows:

• Increasing the railway lines to 31,000 km by constructing 6,000 km new fast line between 2023 and 2035.

• The development of the railway industry and the marketing of railway products internationally.

• To improve intelligent transport systems and infrastructure for providing the railway network integration with other transport systems and development of international combined transport and effective supply chain management.

• Ensuring the completion of the railway lines and connections in the Straits and Gulf Crossing between the continents of Asia, Europe and Africa as a major rail corridor.

• Updating the legal and structural legislation in line with EU legislation for regulation of rail transport activities.

• Increasing the rate of railway passenger transport to 15% and freight transport to 20 %.

6.4 The Roadmap

For the development area a single concrete action has been identified evaluating its priority taking in account several aspects such as:

- Cost Benefit Ratio;
- Timeline;
- Number of field and sector involved;
- Innovation grade and existing technology;
- Reliability in the existing system;
- Repetibility;

- Sustainability.

Increased Infrastucture availability

Even if an ever-open railway would be the ideal situation the railway community must face unplanned unavailability due to incidents and breakdowns and planned unavailability due to monitoring, maintenance and renewal of the assets. Furthermore the physical characteristics are not always optimas for the market request.

The unplanned unavailability can be:

- Unexpected breakdown due to lack of maintenance
- Inefficient maintenance
- Excessive time to recover from incidents
- Natural hazards
- Malicious acts

The planned unavailability can be:

- Time for building and installation
- Time for monitoring
- Maintenance needs
- Time requested for intrusive maintenance operations
- Time for renewal operations

Knowledge requirements in order to progress in these areas are:

- Anticipate the maintenance needs in terms of volume and nature:
  - Knowledge of the asset actual condition;
  - Knowledge of degradation laws of components;
  - Development of appropriate monitoring strategies and tools.

- Enhance the efficiency of corrective maintenance:
  - Appropriate tools and procedures for corrective actions, including staff training;
  - Improve preventive maintenance;
  - Limit maintenance needs and facilitate maintenance from the design stage.

- Reduce vulnerability
  - Improve knowledge of failure modes of components;
  - System designs for more resilience;
  - Protection against attacks;
  - Reduce time for track installation and renewal;
  - Development of modular infrastructure subsystems;
  - Development of plug-and-play components and subsystems;

- Easy test of components after installation.

- Reduce capacity consumption for monitoring and maintenance:
- Simplification of components;
- Development of non-intrusive / remote monitoring and maintenance strategies and tools.

- Improve and harmonise life expectancies of assets:
- Reduce detoriation;
- Improve repair and preservation techniques (bridges).

Action: Dynamic Infrasructure Management System

Based on the above knowledge, the following steps can be seen:

1. Digitalisation of components

The degradation laws of the components, their measurement, knowledge and digitalization is the first step to be made in order to create the rules in the Dynamic Maintenance System. Each time a component is substitute or maintained the interventions have to be registered and reset in order to assure always the right comparation from the expected and the real conditions of each of them.

2. Preventive monitoring

Preventive monitoring can be provided implementing different technologies such as:

- Internal track self diagnosis: the single components are able to measure their own state and to transmit the data to the system continuosly and simultaneously for each point of the infrastructure.
- Developed the usage of train sensors and imaging scanners to be installed in trainset and locomotives able to measure the required physical Factors.
- Possible use of drones or other independent moving monitoring equipment. Each item registers and transmits data continuously.

3. Data format and elaboration

All the data registered by the monitoring tools have a specific standardized format and are transmitted and elaborated in the system that compares the real status of each component to their theoretical one, registers eventual discrepancies and prioritises the interventions.

4. Dynamic Mainenance planning

The system is able to prioritise all the interventions and to plan them. Furthermore it is able to quantify the needed resources to assure the safe and regular needed maintenance operations.

5. Installing and testing operation

In order to be able to plan and to quantify the needed resources, the system has also to know each different intervention of installing, reneawling and testing component and in particular:

- Needed time to execute each activity
- Cost of each intervention
- Resources to be used
- Training and compentences state of art of the employers
- Working bases position and time needed to be able to intervene

Improved operational use of Infrastructure

The current practical usable capacity is often reduced to less than 50% of the maximum theoretical capacity offered by the infrastructure because of several constraints.

Knowledge requirements in order to progress in these areas are:

- Signalling margins
- Operating margins
- Speed limit margins
- Differential speeds and braking curves
- Dwell time on platforms
- Timetabling operations

Actions in order to progress in this area are:

1. Limitation of signalling margins

- Migration toward moving blocks and cab signalling
- Minimised headways
- Improvement of freight train manoeuvrability:
- Homogenous speed for freight and passenger trains
- Improved breaking performance,
- Improved acceleration performance

2. Reduce operational margins

- Setting traffic priorities according to real needs.
- Improve resilience of traffic management to perturbation
- Assistance to driver for real-time optimized speed curves/ATO

3. Automated timetabling

- Optimisation of priorities
- Optimal accounting for train capabilities and constraints
- Optimal allocation of remaining slots

4. Timetable resilience and recovering performance

- Computer-assisted or automated fast re-scheduling after perturbation

Improved effectivness in operations

ACTIONS:

1. Improved intermodal performance

- Improved communication betweens modes to anticipate and facilitate temporary modal transfer
- Smart management of goods along seamless multimodal transport chain
- Standardized data format
- Communicating trains

2. Reduction of dwell times and turnbacks

- Improved information to passengers
- Improved capacity of passenger platforms, multiple drop-off platforms
- Reversible trains
- Driver substitution
- Facilitation/automatision of brake testing

3. Operate longer more productive trains

- Automatic coupling in yards and in lines
- High performance braking
- Remote control of distributed locomotives
- Remote monitoring of train condition
- Improve flexibility with load standardisation and multi-purpose wagons
- Flexibility of mixing shipments of smaller sizes and different nature
- Network wide management of trains rather than line wide management

4. Improve the resilience of rolling stock

- Improve failure resistance and reduce baking-induced damage to vehicles nd infrastructure.
- Automated inspection system for rolling stock

5. Dynamic “Train to Train” communication

- Data format that must be elaborated have to be standardized
- Data exchange of static technical characteristics and the real time.
- Communication between all the trains in circulation on the network via radio, satellite or GSM-R.
- Indirect communication passing through the Ground Infrastructure based on dynamic data transfer that informs the infrastructure about the static technical characteristics and the real time.
- Real time traffic management having the control of the network and introducing an IT system able to manage automatically any situation.
- Driver Assistance Systems allowing the train drivers to optimize the capacity and the energy consumption
- Automated Train Driving, with or without driver, optimizing the total system efficiency and productivity.
- Automatic, and/or virtual, coupling of trains sharing the same path at least for a part of their itinerary without the need to be stopped.

6.5 Implementation Plan

The implementation planning must take into account on-going and planned projects. The major European level planning is in Shift2Rail. In som cases there are thinkings on follow-ups to Shift2Rail, however rather unspecified. This roadmap can in parts facilitate the discussion about these.

The implementation plan, not fully developed, is split into three workstrams;

1. Shift2Rail
2. A potential future large program
3. Separated workstreams

In the S2R several of the project ideas shown here are described are elaborated much more in detail and aims.

Increased Infrastucture availability

For “Increased Infrastucture availability”, the developments in Shift2Rail IP 3 are partly addressing this and will be partly be solved there. This does however not change the roadmap, since it is to cover the entire field.

The implementation plan for development beyond Shift2Rail, in future programs or separate workstreams can be done as follows:

- Survay on maintenance systems in other fields (medicine, high tech, start up companies) in order to check existing IT system already managing this kind of process.
- Define the list of all information needed and their fomat for components, resources and operations.
- Identify the optimal monitoring system thanks to a cost benefit analysis on the possible ones.
- Test the technology on a specific sysem and line.
- Produce a cost benefit analysis on the implementation of this technology.

Improved operational use of Infrastructure

For “Improved operational use of Infrastructure”, the developments in Shift2Rail IP 2 are addressing this and will be partly be solved there. This does however not change the roadmap, since it is to cover the entire field.

The implementation plan for development beyond Shift2Rail, in future programs or separate workstreams can be done as follows:

- Survay on exixting technology and systems that could be applied to the concept;
- Define the data and their format;
- Identify the possible technology to be used;
- Simulate the use of this technology in different lines to measure the saved capacity;
- Cost Benefit analysis on the implementation.

Improved effectivness in operations

For “Improved effectivness in operations”, the developments in Shift2Rail IP 1, 2 and 5 are partly addressing this and will be partly being solved there. This does however not change the roadmap, since it is to cover the entire field.

The implementation plan for development beyond Shift2Rail, in future programs or separate workstreams can be done as follows:

- Define the information that must be collected and test system.
- Check the actual vehicle and infra management.
- Identify best practice in similar systems, such as metropolitan transport networks.
- Produce a cost benefit analysis on the implementation of this technology.

6.6 Conclusions

The area is Capacity, performance and the following competetivness are very important for the rail sector. It has significant and realistic reachable goal, as shown in the roadmap. The need to further elaborate these is necessary, and to see what will be produced in Shift2Rail.

As a general next step, a sector wide gathering must be done, to pinpoint the exact development stages.

7. Energy and environment

7.1 Introduction

Transport plays a key role within the economy and society: transport systems are of crucial importance for the competitiveness of any nation or regional economy as well as for the mobility of its citizens. However, while they bring significant benefits to society there are also substantial costs. The current growth of the transport sector is far from being sustainable. “In Europe it is the only sector with uninterrupted and rapidly growing energy consumption and CO2 emissions, and is now responsible for around 23% of total EU greenhouse gas emissions"[14].

The current transport system is a heavy burden for the environment and the health of citizens, and continues to move in the wrong direction. In this context, rail has the capability to play a key role in any sustainable transport system by offering efficient transport with low environmental impact, and these strengths need to be articulated in the political decision-making process. Rail already has a strong focus on how to continuously improve its sustainability performance. But of course rail is not the only transport mode working on new solutions to reduce its ‘whole-life’ environmental impact from construction, through to operations and end-of-life. Other modes continue to seek improvements to their environmental performance, and rail manufacturers, infrastructure managers, and operators all have to put strong emphasis on working together and improving performance in order to remain the least polluting major mode of surface land transport without affecting passengers experience (reliability, punctuality and others). Thus, a long term strategic approach is needed: one that forms an efficient answer to the challenges of the future and that allows a solid base on which to build. This strategy is based on a long-term vision and has two main target points in time: 2030 and 2050. At a first glance this time frame seems to be long. But the railway sector has very long life cycles; part of today’s “new technology” is likely still to be in operation towards year 2050. Furthermore, new strategies for reducing greenhouse gas emissions are being developed that foresee 2050 as the target date. Even more, some of the basic research and ideas of nowadays could be part of the 2050 rail research priorities and/or challenges: it is called “innovation (value) chain For typical train sets the time from idea to production, operation until end of life is in the range of 30-50 years. Even though this structure might also change in the decades to come in order to improve rail performance and competitiveness, it is not too early to think, plan and act now for the performance of railways in 2050.

[14] UIC IEA Railway Handbook Eneergy Consumption and CO2 Emissions 2014

7.2 Key issues and objectives

Energy supply is a critical function in the rail system both for traction power and for heating, ventilation and air conditioning – HVAC-, lighting and other operational needs improving the the effectiveness of the transport services and the safety and comfort of travellers. Rail must become a system that relies much less on the consumption of fossil-sourced energies. This may come about via the vehicle, via the energy supply and storage systems, through more effective engines than need less energy for achieving the same results (vehicle techonology),, more efficient and sustainably-sourced electrification of the various railway systems (including energy regeneration and harvesting technologies), or by the use of alternative sources of renewable energy and storage systems.

- Deployment of Smart Grids according to the latest research and developments in the electricity supply/consumption system will allow rail to reduce consumption, costs and emissions coming from electricity promoting rail as a central actor in the electricity supply chain connected to other actors as electric vehicles or buildings.

- The development and deployment of resilient and efficient energy distribution schemes will involve smart grid solutions, energy harvesting devices and improved energy self-sufficiency.

- The rail sector will look at new combustion technologies, efficient transmission systems and exhaust after treatment that will ensure that rail diesel traction will remain more environmentally friendly in the future. Electrification of remaining lines is also one of the many approaches that should be taken, although rail diesel propulsion is still expected to play a major role for the European transport system in the coming years.

- The European rail sector has long recognised that noise from rail activity needs to be further reduced. The sector will aim to ensure that noise and vibrations will no longer being considered a problem for the railways in the future – meaning that noise levels will be socially and economically acceptable and allow for 24-hour passenger and goods operations.

- The management of the rail system for minimum energy use and better traffic management based on the development of new technologies will enable energy savings and better overall railway system efficiency.

- Rail will also pay particular attention when addressing in energy used in non traction activities. Stations, terminals and other railway installations and trains will use their own renewable and environmentally-friendly energy sources wherever this is feasible. This is a challenge especially for urban rail operated underground which requires improving the comfort of passengers on-board trains and in stations (HVAC) as well as their accessibility to/from the trains (escalators, lifts and so on). In addition, rail stations will reduce mobility requirements placed in city centers and offering services, working as a

hub of activities for rail clients. Rail terminals should become an intermodality area (transport node). Soft transport modes should be considered in their offer.

- Railways will develop a climate resilient transport mode dealing with climate change threats, with research into the effects and management of weather, water, heat impacts on infrastructure. Rail will be able to lead adaptation to climate change in the transport sector as an integrated mode of transport.

The promotion of environmentally friendly and efficient rail transport of passengers and goods is a key objective in Europe. In that framework, transparent environmental systems analyses should be promoted, to improve citizens' information (for instance, informing about their carbon footprint). Public documents as the White Paper on transport and authorities policies must improve societal understanding of the environmental advantages offered by the railway system in comparison with competing modes of transport.

7.3 State of the Art and on going research and innovation within and outside rail

a. Shift2Rail

SHIFT2RAIL 2016 - 2022

Shift2Rail (S2R) represents an unprecedented research investment in rail for improving the travel offer, the quality and cost effectiveness of the European railway system as a whole. By aiming to strengthen the attractiveness of rail to end users, these projects accelerate the integration of customer-led requirements and technologies as innovative business solutions. S2R pave the way towards a sustainable transport system for future generations in while reinforcing European leadership in designing, constructing, operating and maintaining the railway system. S2R has been conceived for closing the gap between operational needs, research & innovation efforts and industrialisation processes.

The Shift2Rail Joint Undertaking is a public-private partnership between the EC and major European rail stakeholders, with the aim of bringing about a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system.

The S2R is divided into five Innovation Programmes (IPs), each addressing a major rail area, as follows:
IP1 – Cost-efficient and reliable trains, including high capacity trains and high speed trains
IP2 – Advanced Traffic Management & Control Systems
IP3 – Cost Efficient and Reliable High Capacity Infrastructure
IP4 – IT Solutions for Attractive Railway Service

IP5 – Technologies for Sustainable and Attractive European Rail Freight

Energy and Sustainability is one of the cross cutting themes that be covered by all Innovation Programs.

7TH FRAMEWORK PROGRAMMES FOR RESEARCH AND TECHNOLOGICAL DEVELOPMENT (FP7)

CLEANER-D (2010-2013)

Was a partly European Commission funded project that aimed to develop, improve and integrate emissions reduction technologies for diesel locomotives and rail vehicles. Its target was to achieve emission levels below the limits established by the new European Directive 2004/26/EX and to evaluate innovative and hybrid solutions for the best possible contribution to reductions in CO2 emissions.

MERLIN (2012-2015)

MERLIN's main aim and purpose is to investigate and demonstrate the viability of an integrated management system to achieve a more sustainable and optimized energy usage in European electric mainline railway systems, benefiting of the latest technological progress on smart grids. MERLIN provided an integrated and optimized approach to support operational decisions leading to a cost-effective intelligent management of energy and resources through:

- Improved design of railway distribution networks and electrical systems and their interfaces
- Better understanding of the influence of railway operations and procedures on energy demand
- Identification of energy usage optimizing technologies
- Improved traction energy supply
- Understanding of the cross-dependencies between technological solutions
- Improving cost effectiveness of the overall railway system
- Contribution to European standardisation (TecRec)

Where MERLIN's results are being implemented, an overall reduction of the energy consumption of 10% is expected.

RIVAS (2011-2013)

RIVAS aimed at reducing the environmental impact of ground-borne vibration while safeguarding the commercial competitiveness of the railway sector. For several areas of concern vibration should be reduced to near or even below the threshold of perception. The project's goal was to provide the tools to solve vibration problems for surface lines by 2013. The project aimed to contribute to relevant and world leading technologies for efficient control of people's exposure to vibration and vibration-induced noise caused by rail traffic. RIVAS focused on low frequency vibration from open lines but its results may be implemented to suburban, regional and high-speed operations. RIVAS delivered:

- Assessment of the benefits of mitigation measures in terms of human response and agreed protocol for the evaluation of annoyance and exposure to vibration.
- Agreed measurement protocols to assess and monitor the performance of anti-vibration measures.
- Agreed protocol to characterize vibration response properties of soils
- Guidelines for track and vehicle maintenance geared towards low vibration
- Mitigation measures for ballasted and slab track.
- Guidelines for the design of transmission mitigation measures under the track.
- Guidelines for the design of low vibration vehicles

ACOUTRAIN (2011-2013)

ACOUTRAIN "Virtual certification of acoustic performance for freight and passenger trains "simplify and improve the acoustic certification process of new rolling stock, in particular relating to the TSI Noise. Today the need of conformity assessment for a new vehicle according to the TSI Noise represents a significant element of both cost and time to market due to the need to carry out expensive and time consuming tests. The goal of the proposed project is to speed up the product authorisation by introducing some elements of virtual testing while retaining the same degree of reliability and accuracy. A successful simplification of the TSI conformity assessment process would result in a strengthening of the competitiveness of the European railway sector. The risk of not developing such a simplification would be that the expense of excessive certification of new products could hamper the introduction of new innovations. The major outcome of the ACOUTRAIN project was a new certification process including some elements of virtual testing. This be ready for inclusion in the next "full revision" of the TSI Noise, planned in 2013.

OSIRIS (2012-2015)

For many transport modes, energy reduction strategies can be effectively formulated at the level of the vehicle. New technologies can therefore be introduced to a vehicle and the direct energy savings can be readily quantified. However, this approach is not suitable for urban rail, where it is not sufficient to consider only the energy performance of vehicles; the energy associated with the infrastructure, as well as the influence of the mode of operation are to be considered too. What is needed, and what has been lacking so far, is a holistic approach for the reduction of energy consumption for urban rail systems embracing vehicles, infrastructure and operation, as proposed by OSIRIS "Optimal Strategy to Innovate and Reduce energy consumption In urban rail Systems". The project started from the definition of Key Performance Indicators and Standard Duty Cycles to measure energy consumption in urban rail systems. Then, rather than focusing only on specific technologies, it addressed the issue from the system-level ensuring that progresses on energy reduction are substantial. The effectiveness of solutions and their full potential have been proven by simulations and pilot tests.

PREVIOUS FRAMEWORK PROGRAMMES FOR RESEARCH AND TECHNOLOGICAL DEVELOPMENT

RAILENERGY (FP 6)

The overall objective of the FP 6 project "Railenergy" is to cut the energy consumption in the railway system thus contributing to the reduction of life cycle costs of railway operation and the CO2 emissions. The project target is to achieve a 6% reduction of the specific energy consumption of the rail system by 2020. This is envisaged to be done by addressing the energy efficiency of the integrated railway system and to investigate and validate solutions ranging from the introduction of innovative traction technologies, components and layouts to the development of rolling stock, operation and infrastructure management strategies.

UIC PROJECTS

ARISCC (2011)

The UIC project ARISCC (Adaptation of Railway Infrastructure to Climate Change) explored in detail the strategies of European railways on natural hazard management, and found out which of them were developing strategies for climate change adaptation. The project produced a wide number of good practice case studies in the management of a wide range of weather and climate related natural hazards such as flooding, severe storms, landslides, rock fall and avalanches. Using this as a basis, ARISCC produced a guidance document on how to integrate long-term climate forecasts into natural hazard management. All the results of ARISCC, including a case study database, are available on UCI website.

Zero CARBON RAILWAYS (2012)

Recent data showed that European railways used in 2009 nearly 30% of renewable electricity, with a significant increase in the last years (UIC/IEA 2013). Decarbonization of electricity mix is one of the drivers for CO2 emission reduction: the higher the percentage of electricity from renewable sources used for traction, the lower is the CO2 emitted in the atmosphere. In parallel to the growth in renewable energy production, the voluntary use of renewable electricity by companies has also been growing at fast pace.
The UIC project was a result of of an intense year working spent on consulting related stakeholders (IEA, EEA, DG Energy…) and UIC Experts from the Energy Efficiency and CO2 Emissions Expert Network in order to agree on a common approach when reporting on Carbon performance internally and at sector level.

ENERGY DRIVERS (2013)

This project had the following goals:
1. Examine the progress towards the 2020-2030 targets for energy consumption and CO_2 emissions set by UIC and CER, and whether those targets should in any way be adjusted;

2. Evaluate in what measure green electricity instruments such as Guarantees of Origin (GO) and Renewable Electricity Certificates (REC) contribute to the evolution towards the emissions targets, and explore whether there are any differences if those instruments are not taken into account (i.e. the electricity production mix is used);
3. Determine which railway companies have contributed the most to the progress towards the environmental objectives fixed for 2020 and 2030;
4. Investigate which drivers have contributed to the decrease of specific energy consumption and CO2 emissions in the past years and in what measure;
5. Identify the drivers which influence the evolution of specific energy consumption and CO2 emissions in future years.

National PROJECTs

TRaCCA – Tomorrow's Railway and Climate Change Adaptation (2012-2016)
The project aimedto enhance knowledge on climate change impacts on Brithish railways. The work is funded by RSSB and Network Rail through the FutureRailway programme, as part of the undertaking, commissioning and managing of research and innovation programmes to provide knowledge for decision making now and for the future, and promoting step changes to deliver the Rail Technical Strategy.
SA2VE (2006-2012), National project funded by the Spanish Ministry of Science and Innovation.

Advanced Energy Storage System (SA2VE)
The objectives of SA2VE are the use of energy coming from braking trains by recovery, as well as the improvement of the load curve of the substation. Given high energy costs, the SA2VE project aims to use the braking energy of trains, which is not used by other trains on the network and therefore is dissipated in braking resistances. This energy could reach values of up to 20% of energy consumed. A storage system has been designed and built for the kinetic energy that comes from braking trains (KESS, Kinetic Energy Storage System). In developing this system several prototypes have been built that have culminated in the prototype Omega (W), capable of storing 200 MJ of energy and transferring it to a power of 500 kW, becoming the largest kinetic energy storage system within the world.

INVERFER (2011-2013), Spanish National Project
Development of the first reversible substation in ADIF's conventional network of 3000 V dc, with the installation of an Energy Recovery Equipment in Substation La Comba, Málaga – Fuengirola suburban Line. The energy produced by the regenerative braking of a train, if not used by other nearby trains, is returned and re-injected into the supply network, leading to a saving for the Malaga-Fuengirola line has been estimated at 12% of total consumption, approx 1,000 MWh per year.

FERROSMARTGRID, National project funded by the Spanish Centre for the Development of Industrial Technology (CDTI). Innterconecta Programme 2012-2014.

The project involves the creation of a smart grid for energy management in the railway sector. This network integrated the actions of the trains that are connected to it, in order to achieve efficient, reliable and sustainable power. To achieve the objective of the project, it is necessary to address interoperability between different urban and interurban systems of transport electrically integrated through intelligent nodes interacting with the user in the railway stations. This investment aims to develop a demonstrator that allows optimal power management of the system, as well as interoperability with other urban and interurban transport systems, integrated electronically through intelligent nodes, and interacting with the user in the railway stations environment.

FERROLINERA (2010-), Spanish National Project

The Ferrolinera project aims to promote the development of urban electric mobility by using the energy recovered from the braking trains and the integration of auxiliary support systems based on renewable energy through electric vehicle recharge points connected to the railway network.

The project started as Ferrolinera 1.0 at Adif's energy laboratory in Madrid, integrating the storage of train brake energy in a flywheel and photovoltaic support system, which was implemented in a parking lot roof designed to hold the recharge point. The concept continued as Ferrolinera 2.0, which comprises two projects. The first one uses the energy recovered from the braking trains through the high-speed catenary, feeding the first public recharge point at Malaga station since November 2011. Electric vehicle charging operations with energy from the railway system are currently being performed at this station. The second project, known as Genera, created a prototype of a mixed wind-photovoltaic generation system that can be used in the charging operation and which is located at Adif's Railway Technology Centre in Malaga.

ELECRAIL (2007-2011), National project funded by the Spanish CEDEX, Ministry of Development

Inventory and systematic analysis of all possible measures to reduce energy consumption on electric railways and exploitation of regenerative braking. These measures are set alongside one another, analysing incompatibilities, differential advantages and the applicability to each specific case. The area in question is rail passenger transport, but covering segments which produce most traffic and investment: high speed, metropolitan railways and commuter train systems. Adjustable simulation models are developed to analyse consumption reduction strategies involving the efficient design of both railway timetables and train operation. Particularly focussed on the operation of high speed lines, and specific models for metropolitan lines and commuter trains. The results of these simulation-based studies have been tested in two actual cases.

ENERTRANS (2006-2008) National project funded by the Spanish CEDEX, Ministry of Development

Enertrans research project develops a model for the estimation and homogeneous comparison of energy consumption (and associated emissions) in different vehicles and modes of transport. The calculation procedure is multipurpose, versatile and reliable for measuring the sensitivity of consumption and emissions to diverse variables which could be the object of a technical or regulatory decision aimed at reducing the environmental impact of transport. It is also suitable for identifying the reasons for consumption and emission differences between vehicles or modes of transport. It includes a common consumption calculation procedure adapted to physical phenomena which takes into account not only the vehicle's mass, but also its size; and it introduces the concept of "equivalent stop due to speed reduction", which in many modes of transport is fundamental, given that it explains an important part of the energy consumption.

7.4 The Roadmap

Energy Efficiency and Carbon Emissions

Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. Road transport alone contributes about one-fifth of the EU's total emissions of carbon dioxide (CO2), the main greenhouse gas. While emissions from other sectors are generally falling, those from transport have continued to increase until 2008 when transport emissions started to decrease on the back of oil prices, increased efficiency of passenger cars and slower growth in mobility. More than two thirds of transport-related greenhouse gas emissions are from road transport, with private vehicles contributing to this significant growth The EU has policies in place to reduce emissions from a range of modes of transport, such as including aviation in the EU Emissions Trading System (EU ETS) and CO2 emissions targets for cars.

Europe needs to reduce its (import) dependence for all fossil fuels. By using electricity, which can draw its power from a range of sources, rail is the only major transport mode not entirely dependent on fossil fuels; and especially in the case of urban rail. According to latest UITP estimations, total consumption of urban rail (41 metros/141 lines and 177 LRT systems/1074 lines) in Europe is 11 000 Gwh per year. Expressed in kWh per passenger-kilometer, urban rail is 7 times more energy-efficient than automobile in urban environment. Any modeal shift from cars to trams and metrois therefore mechanically translate into massive carbon-dioxide, pollutant emissions and energy reductions.

Rail is the most emissions-efficient major mode of surface land transport. Transport final energy consumption in the EU28, as a sector, ascended to 351.7 Mtoe, for 2012, where

7,0 Mtoe were related to rail. It means the 2% of the transport energy consumption.[15] The electrified rail system is the only major means of transport that is immediately compatible with renewable energy.

The electrified rail system is the only major means of transport that is immediately compatible with renewable energy; electric trains offer the possibility of practically carbon-free transport. On average, Green House Gas emissions from freight rail are 8 times less than by road and almost 7 times less than inland shipping. For passenger transport, emissions from rail are nearly 5 times less than travelling by road, and 6.7 times less than flying. Rail transport also brings important co-benefits, including green jobs, social inclusion, high safety standards, improved air quality, reduced congestion and greater bio diversity.

In the case of cities, the rail (Metro, tram and Light Rrail, regional & suburban rail) has been the best solution for all energy efficiency and carbon emission targets, alongside the 'soft' transport modes (walking, cycling, etc.) before other public transport modes such as buses, and in complementarity with new services such as car sharing schemes. This is because it provides an alternative mobility option to private vehicles which is sustainable and needs to be build on a core of public transport, with rail options playing a key role in cities across Europe.

Cities worldwide having the "best" liveable, green and high socio-productive system have an integrated mobility system with public transport at its core. It is important to note that public transport's carbon footprint has an inverse relationship to the global carbon footprint. This means that the world's GHG emissions will decrease if public transport's footprint increases. As such, if we are to address raising emissions we need maintaining and developing more public transport infrastructure and services (in better coordination with "feeding" modes).

Public transport's GHG emissions can be broken down into two categories: GHG emitted directly or indirectly by public transport operations, and GHG emissions avoided in the region as a result of its operations. The net of carbon that is avoided is a result of:

- Mode Shift - Avoided car trips through more use of public transport, walking and cycling.
- Land Use - Infrastructure and urban form are strongly linked to climate mitigation. As urban areas become denser and rely more on public transport and intelligent multi-level buildings, CO2 emissions are reduced.
- Congestion Relief - Reduced fossil fuel emissions as a result of reduced congestion and improved mobility.

[15] EU Transport in figures, Statistical Pocketbook 2014

There are many examples that highlight the climate benefits of using more public transport. A good example is the Paris case: by using RATP's multi-modal public transport services, passengers consume on average five times less energy and emit between 2 and 50 times less greenhouse gas emissions than if travelling by car. In 2011, the use of RATP services saved the emission of 2,7 million tonnes of CO2 equivalent [16].

In 2012 in EU27[17], out of the total 56,.8 blnbillion journeys registered, 44% were made by rail (trams & light rail 14%, metro 16%; subrurban and regional rail 14%). And this share is set to grow, given the continuous investments in metro and light rail systems throughout the EU.

In the case of both urban and mainline, rail has further positive impacts on the environment: land occupation of rail lines is inferior to that of roads, while the capacity is higher and the lifespan longer. This means that the environmental impact is lowered (both directly/on-site and in terms of the materials used to build and maintain such systems), something that is crucial in the city landscape. Moreover, rail systems are one of the main tools for shaping cities and ensuring large urban renewal. Many cities have introduced pedestrian areas or have extended green spaces, based on light rail and metro developments, The best example for such an urban renewal policy is France – with 25 new light rail/tram systems created within the same number of years (since the mid '80s) – and the model is currently being replicated by other countries both within and outside the EU. For example, Metro São Paulo, Brazil, the second largest system in South America, which is expanding its network from the present 75 km to 225 km in 2025.

It is expected that the demand per working day shall grow from 4,4 million daily boarding passengers nowadays to 6,9 million in 2018 which is estimated to prevent the emission of CO2 equivalent of more than 1,35 million tons of CO2 per /year in 2018 against 820 ,000 tons/year which is currently being avoided. Projects in Europe will also help to encourage a modal shift, for example: in Munich, Germany, the new 2,7 km tramway is expected to save 245 tonnes of CO2 in 2016[18]; in Dresden, Germany, new services save 23 tonnes of CO2 per day; and in the metropolitan area of Granada, Spain, the light rail line will cater for an extra 4 million travels per year, which will see a reduction in 15% of car use and 10% fewer emissions. In Austria, the expansion in the tram and regional train system of Innsbruck will also reach completion in 2020, saving 1,405 tonnes of CO2 emissions annually.

[16] http://www.ratp.fr/en/ratp/c_5084/climate-change

[17] [17] UITP Statistics Brief, Local Public Transport Trends in the EU, June 2014

[18] https://www.mvg.de/en.html

The electrification of railway transport has a double benefit for reducing carbon intensity: it increases energy efficiency and also provides access to low emission factors associated with electric power. With the development of renewable electricity sources the electric emission factor has the potential to be reduced to zero.

It is important to note the policy trend towards road transport electrification (both public and private transport) within cities driven by European policy goals. For instance the Transport White Paper has a key goal that there will be no more conventionally-fuelled cars in cities by 2050. Urban rail networks such as metros can play a key role in supporting electrification of the road transport network. For example, a project on the Madrid Metro is developing an innovative system for the smart management of the direct current grid of the trains and of the associated systems and devices of the metro (traction substations, fixed accumulators, possible inverters), by introducing power feed points for electric cars into the grid, in such a way as to maximise the harnessing of the energy regenerated by the trains during braking and the overall efficiency of the system.

"Since 1975 rail passenger activity has grown by 130% and freight by 76%. Over the same period we have seen an improvement in energy efficiency. Specific energy consumption has decreased by around 50% from 1975 to 2011 for both for passenger (51% improvement) and freight (47% improvement). This trend indicates a decoupling between energy consumption and transport activity, with the volumes on rail constantly growing and the energy consumption remaining basically stable. The inclusion of rail in the transport chain shows how decoupling in transport sector is possible, rail is the backbone of intermodal chains in terms of sustainability and energy efficiency."[19]

Furthermore, the latest UITP statistics have shown that witin the EU (plus Norway and Switzerland) demand for regional and suburban railway (RSR) services in the last decade has increased by over 30% to reach 8 900 million trips per year. The RSR accounts for 90% of the total number of rail passengers and 50% of the total number of passenger-kilometers per year[20]. And since the RSR services generally cover the communtign activities, a shift towards rail services can therefore reduce the general transport energy consumption, pollution and congestion.

[19] UIC IEA Railway Handbook Eneergy Consumption and CO2 Emissions 2015

[20] UITP Regional and Suburban Railways Market Analysis Update, 2016 (pag; 20)

EU current and future Policy

1. EC White paper on transport

Rail contribution for decreasing GHG emissions is contained in main global and regional strategies as the White Paper on Transport of the European Commission.

The European Commission made clear in the Transport White Paper 2011 that the EU's transport system is not sustainable that change is essential if the GHG reduction targets the White Paper outlined for 2030 and 2050 are to be met. "More resource-efficient vehicles and cleaner fuels are unlikely to achieve on their own the necessary cuts in emissions. They need to be accompanied by the consolidation of large volumes for transfers over long distances," it said. This would mean greater use of transport modes that can easily carry large numbers of passengers such as rail, and multimodal solutions for freight that rely on waterborne and rail modes for long-hauls.

The Transport White Paper stipulates that the majority of medium-distance passenger transport should be by rail by 2050. Specifically, 30% of road freight over 300 kilometres should shift to other modes such as rail or waterborne transport by 2030, and more than 50% should shift by 2050, facilitated by efficient and green freight corridors.

Modal shift targets of the 2011 Transport White Paper are central to the delivery of Europe's overall goals of cutting greenhouse gas emissions, achieving energy security, and relieving congestion. These ambitious modal shift targets require appropriate infrastructure to be developed. Furthermore, fair conditions for inter-modal competition have to be secured, which could be achieved with pricing policies i.e. infrastructure pricing; internalisation of local external costs; climate and energy policies; and taxation.

UITP analysis has shown that technology alone will not achieve the intermediary objectives of the Transport White Paper, however by doubling the market share of urban public transport would decrease emissions by 20% by 2030 while delivering simultaneouslyationaly a range of other sustainable development benefits, such as more jobs, reduced congestion, air pollution, fewer traffic fatalities and so on which all pose a significant cost to society and national economies.

In this framework, in July 2014 the European TAG (Transport Advisory Group) consider, in its "Consultation of the Horizon 2020 Advisory Groups" that some of the future key challenges related to the transport should (still) consider an environmental focus. It includes:

- Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility) and using transport as an enabler of urban renewal.

- Achieving the required level of climate change, air pollution and noise mitigation in the transport sector.
- Reducing transport's dependence on fossil fuels through improvements in energy efficiency and a switch to alternative energy sources.

2. European Council Targets on Carbon and Energy Efficiency

The "Europe 20202 strategy" is the EU's growth strategy for the coming decade, to develop the EU area as a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should be driven through a set of five ambitious objectives - on employment, innovation, education, social inclusion and climate/energy - to be reached by 2020.

EU council agreed on 23 October 2014 the domestic 2030 greenhouse gas reduction target of at least 40% compared to 1990 together with the other main building blocks of the 2030 policy framework for climate and energy, as proposed by the European Commission in January 2014. This 2030 policy framework aims to make the European Union's economy and energy system more competitive, secure and sustainable and also sets a target of at least 27% for renewable energy and energy savings by 2030.[21]

In 2010 UIC and CER developed the Sustainable Mobility Strategy – "Moving towards Sustainable Mobility: Rail Sector Strategy 2030 and beyond – Europe". The Goal was to adopt a unified Strategy of the rail sector in Europe that was endorsed by European members of UIC, CER, EIM and UNIFE to strengthen coordination, speed and direction of actions and ensure the widest possible acceptance within the rail industry.

According to this frame of energy efficiency and low carbon promotion, rail advantages on GHG emissions and energy consumption plays a major role to present railways as a sustainable alternative to competitor modes. On this frame the European Railways Comunity, leaded by UIC and CER, has commited to reduce their energy consumption and carbon emissions to face the challenge of climate change and energy dependency.

Short-Medium Term: by 2020 European railways will cut specific GHG emissions by 40% compared to 1990 levels for freight and passenger transports. For 2030 the EU railways will reduce their specific final energy consumption from train operation by 30% compared to the base year 1990; measured per passenger-km (passenger service) and gross tonne-

[21] http://ec.europa.eu/clima/policies/2030/index_en.htm

km (freight service). Reducing the specific CO2 emissions by 50% and the total ones by 30% compared to 1990 as baseline year.

Long Term: the European railways will strive towards halving their specific final energy consumption from train operation by 2050 compared to the base year 1990; measured per passenger-km (passenger service) and grosse tonne-km (freight service). The vision for the carbon emissions in 2050 is to have free carbon services by the introduction of renewable energies.

So far specific energy consumption has been reduced by 19.6% in the passenger sector and by 21.5% in the freight sector in the period 1990 – 2013. Therefore the specific energy consumption of the European railway sector for passenger and freight is in line with the targets set for 2030 as with this pace of energy reduction the target will be achieved. Regarding Carbon Targets the current reduction of specific carbon emissions is 39% whilst the freight performance of specific GHG has decresed by 44%.

There have been various factors contributing to the reduction in the CO2 emissions and energy consumption of rail in recent years: these include the increased energy efficiency of railway services, further electrification of lines, and a reduction in carbon intensity of the electricity production by the power supply sector. Improved IT systems (and especially command, control and signalling systems) have also provided a better service at the same or even reduced energy consumption, and also improving the network management. Exhaust emissions and noise, in contrast, have largely relied on technical innovation within the sector, so change has been more challenging due to the long lifespan of many technical systems.

There are huge perspectives for the growth of the energy meters market, as most of the responding railway are integrating (or planning to integrate) energy meters in virtually all their trains. The development of energy metering systems (due to the development of energy bills adapted to the real consumption of energy by the consumers, Railway Undertakings, Stations, etc) confirms that there are ways for a more efficient use of energy. This is adding to the already existing progress in reducing energy consumption on-site (buildings, maintenance facilities, other operations, etc.). The urban rail sector has been leading this approach due to its high energy needs (numerous and large enclosed space, often underground, long operating hours, etc.), as well as due to the more stringent contracts between operators and the (transport) authorities. In the decades to come, these trends will play a crucial part in enhancing the environmental performance of rail further: Energy efficiency will continue to increase through improved technology and service efficiency (occupation rates and load factors). Further electrification will occur – both in term of the electrification of existing lines and the development of more urban rail lines and new low carbon propulsion technologies will replace diesel traction by electric traction or other less carbon-intensive propulsion concepts.

Furthermore, the growth, scalability and ever reducing costs of renewable energy installations will facilite the production of energy on-site by rail operators. Numerous overground buildings that the rail stakeholders represent a significant potential source of renewable energy, especially in the case of installing solar panels. Historically, rail operators – both urban and mainline – have also been producers of electricity, often acting as suppliers to entire communities. While this situation is not foreseeable in the next decades, the rail sector can still play this role in smaller and targeted cases. The best example is again provided by urban rail, where the surplus energy (harvested and/or saved from different 'internal' sources) can be used for the further greening and electrification of transport. In many countries in the EU and beyond the systems are being transformed to redirect this surprlus energy to charging points for EVs. It is a glaring example of the fact that rail can not only support other public transport means, but can also contribute to the harmonious development of the entire (urban) transport system. The potential of the rail sector, wisely used and maximized by the newly-developed technologies, could therefore lead not only to its success, but also to a good cooperation with the road sector.

More railway operators will actively demand green energy and shift to CO2-free energy sources, as European and national regulation facilitates more renewable and carbon-free electricity coming onto the market. The UIC Zero Carbon Project develops the reporting of Guarantees of Origin (GOs) according to the latest standard produced by the GHG Protocol. Renewable Energy is an important part of the UIC strategy fro 2050, and many railways already source a proportion of their energy from renewable sources. This project aims to avoid concerns by external stakeholders about accounting this energy as zero carbon with a solid accountability system. It is a subject that is politically and strategically important for UIC and its members.

The European rail sector has doubled its use of renewable electricity between 2005 and 2010, now accounting for 28% of all electric traction. Decarbonization of electricity mix is the main driver of reducing GHG emissions: the higher the percentage of electricity from renewable sources used for traction, the lower the CO2 emissions produced.

3. Energy Union Strategy

On this frame the Energy Union Strategy of the European Commission. The Energy Union package published on 25th February 2015 by the European Commission intends to establish a European-wide union for sustainable energy production, transportation and consumption in all its forms (electricity, gas, oil, new energy sources ...). Such a large scale of course encompasses all modes of transportation, particularly in emissions reduction.

However, the Energy Union puts a strong focus on empowering the consumer in its energy-consumption. This point highly concerns rail as a major consumer of energy and action needs to be undertaken on that basis along others within the package. Many other aspects linked to climate and energy will directly influence rail which has to be prepared to contribute.

The package incorporates the Communication "A framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy" [22] "The Paris Protocol – A blueprint for tackling global climate change beyond 2020"[23] "The Paris Protocol – A blueprint for tackling global climate change beyond 2020" [24] "Achieving the 10% electricity interconnection target, Making Europe's electricity grid fit for 2020"[25].

4. Energy Efficiency Directive 2012/27/EU

The Energy Efficiency Directive is a further legal tool for energy efficiency and the cycle of assessment / improvement. It is a key tool to implement more energy efficient equipments for buildings, maintenance centers and transport services in the EU countries, including the requirements of investments in energy efficiency actions according to some legal national frames. Performance and actions will be reviewed by audits (external and/or internal) with an improvement cycle.

Energy audits shall comprise a detailed review of the energy consumption profile of buildings or group of buildings, industrial operations or installation, including transportation depending on the national transposition of the Directive.

This Directive will be the operational frame for the improvement, performance on energy efficiency in the short-mid term across the EU countries.

5. European Innovation Partnership (EIP) on Smart Cities

The EIP on Smart Cities brings together cities, industry and citizens to improve urban life through more sustainable integrated solutions. This includes applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, intelligent use of Information and Communication Technologies (ICT), etc.

The partnership was launched in July 2012 and its overarching goal has hence been formulated thus:

[22] [COM(2015) 80 final] and its Annex, the Communication

[23] [COM(2015) 81 final] and its Annex, the Staff Working Document

[24] [SWD(2015) 17 final] and the Communication

[25] [COM(2015) 82 final] and its Annex

This partnership strives at a triple bottom line gain for Europe: a significant improvement of citizens' quality of life, an increased competitiveness of Europe's industry and innovative SMEs together with a strong contribution to sustainability and the EU's 20/20/20 energy and climate targets. This will be achieved through the wide-reaching roll out of integrated, scalable, sustainable Smart City solutions – specifically in areas where energy production, distribution and use; mobility and transport; and information and communication technologies are intimately linked.Smart cities should be regarded as systems of people interacting with and using flows of energy, materials, services and financing to catalyse sustainable economic development, resilience, and high quality of life; these flows and interactions become smart through making strategic use of information and communication infrastructure and services in a process of transparent urban planning and management that is responsive to the social and economic needs of society.The European Innovation Partnership for Smart Cities and Communities aims to make this possible by accelerating the market uptake of smart city solutions. To this end the Partnership seeks to engage stakeholders at various levels from cities and regions, industry, SMEs, and research in order to create critical mass. Smart solutions triggered by the Partnership should contain elements of ICT, energy, and transport/mobility. The solutions should be scalable and replicable and aim at ultimately contributing to and possibly out-performing the EU's 20/20/208 climate action goals by increasing energy efficiency, increasing the use of renewable energy sources and reducing energy consumption and green-house-gas emissions. A core policy feature of the EIP is to address sustainable urban mobility. The strategic implementation plan (SIP) of the EIP contains a vision for sustainable urban mobility and outlines a number of priority steps that should be undertaken in smart cities:

- a first priority is to reduce and avoid demand for emission-intensive transport modes while facilitating the increased mobility of people, goods and information and ensuring that efficient transport is devised around smart integrated infrastructure and mobility planning.
- Secondly, a shift from more energy intensive and environmentally harmful modes of transport to less polluting, better integrated and more efficient modes is required, for example public transport, favouring efficient logistics and non-motorized modes.
- Thirdly, reduced impact can be achieved through improved, cleaner transport technology and policy solutions, driven by better management of mobility. Zero- and low-emission vehicles will connect with each other, with infrastructure and with "the smart grid".

Urban transport strategies and new public-private actions will "get sustainability done" in towns, cities and region. Already, a number of Member States, regions and cities have set up initiatives in electric transport and mobility. Clearly urban rail systems will play a key role in taking forward this approach to sustainable urban mobility in smart cities.

Climate Change adaptation

According to the 5th Assessment Report of the IPCC, higher frequencies and intensities of extreme weather events are expected in the future. Climate Change events like increases in average temperature, wider differences in temperature within the same geographical area ,sea level rise and changes in precipitation patterns will seriously affect the railway sector. Higher temperatures and higher frequencies of heat waves are likely to have a direct effect on the rail buckles or the catenary system to collapse. Extreme weather events can cause floods or landslides that can lead to a diversified range of consequences from delays to human fatalities and major infrastructure damages. And even more, low probability events must be considered from a security point of view.

As smooth and effective operations of the railway system heavily rely on heavy infrastructure such as bridges, tunnels and embankments, adapting it to new climate conditions require a substantial economical effort from national authorities. Those assets are in fact designed to last around a century or more and initial investments have usually a very long return rate. Therefore an anticipatory planning that considers future climate conditions is now necessary in order to maintain costs for adaptation acceptable.

Railways benefited from considering the rail system as a whole rather than conducting specific action for each component. This scope lets railways to identify the impacts of climate change, their timeframe and vulnerability of zones; to priority adaptation measures, based on the identified impacts; and to assess the priority measures and selection, consistently with the overall strategy, adopting low-regret measures, which cost–benefit balance remains positive independently from the pace of climate change.

Without an integrated adaptation strategy and adaptive action, the present resilience of railways could prooveto be insufficient in the near and midterm future. Therefore European railways will work to develop a proactive adaptation strategy and systematically build up adaptive capacity. The strategy should comprise short term as well as mid-term and long term adaptation goals and measures and has to take into account affordability. The guiding principle of the integrated strategy should be the three R:

- Readiness - To be well prepared for extreme weather events;
- Resilience - To systematically increase the resilience of the whole system;
- Recovery - To have contingency plans allowing for fast and full recovery.

EU current and future Policy

1 2030 Framework for Climate and Energy Policies:

The Communication was adopted in January 2014 as a future policy and not as a fully finalized package. New targets for 2030 were agreed by the October European council for GHG emissions, Renewable Energy, Energy Efficiency and, for the first time, energy interconnectivity. As a response, ERRAC members have responded by preparing

targeted plans in order to meet and even go beyond these requirements..CER presented the political timeline that started with the 2008 climate and energy package, which lead to 2020 targets. Similar legislative developments are expected for the period 2015-2016. These concern a major revision of the EU ETS, Renewable Energy Directive and Energy Efficiency Directive. Currently the only legislative proposal is on introducing a Market Stability Reserve into the EU ETS. The Council conclusions included a paragraph on transport sector. CER Position Paper advocates the creation of a Transport Pillar within the Framework.

Exhaust emissions

"Around 80% of European railway transport takes place using electric traction"[26], while the remainder is diesel traction from which local air pollution is a significant source of pollution. Diesel engines have potential to further reduce their emissions of nitrogen oxides (NOx) and particulate matter (PM) – the two primary emission problems.
Diesel engine technology is under pressure from many sides due to its reliance on fossil fuels as well as the local emission pollutants mentioned. New technologies such as hybrid solutions or even carbon-free propulsion concepts in the long term would be part of the solution. As explained already in section 3.5 the targets adopted were:

By 2030 the European railways will reduce their total exhaust emissions of NOx and PM10 by 40% in absolute terms even with projected traffic growth compared to base year 2005.
The European railways will strive towards zero emission of nitrogen oxides (NOx) and particulate matter (PM10) from non-electric trains by 2050.

The main reason for setting air pollution target is to minimise or even avoid the risk that railway exhaust emissions could become a barrier or even inhibit future railway transport growth, especially for urban agglomerations with high population density. In the current unsustainable transport situation railway transport could contribute significantly to overall society objectives if rail is capable and enabled to take over traffic from other modes of transport, mainly private road transport and air transport – for personal mobility and freight transport. The overall sustainability of railway transport is reflected in the low external costs compared to other modes of transport. It includes economical cost, environmental cost and others
In order to reach these exhaust emission targets, a number of measures have to be developed and implemented in major parts of the rolling stock as well as for operational planning and supporting measures (information, communication). This will be described under milestones and activities following the analysis of the situation.

Abatement methods to address air emission in metros include washing of railroad; filtration of air; platform screen doors; more electrical braking (less mechanical braking can reduce

[26] Clean Euorpean Rail-Diesel, 2013 D5.1.2 Sustainability Study – Update, 2013

brake wear); less/softer braking on platforms; and air conditioning on trains which reduces PM10 inside them; compulsory technical inspection of the vehicle:

- I. Infrastructure development and maintenance: Preventive irrigation for building activities and ballast maintenance (batting), special and mandatory covers for aggregates, schedules and rules avoiding strong winds, etc…

These will be described under milestones and activities following ttthe analysis of the situation

EU current and future Policy

The political focus on rail exhaust emissions has been quite significant since the Non Road Mobile Machinery Directive (2004/26/EC or simply 'NRMM') was updated to include diesel multiple units and locomotives. Before their inclusion in the NRMM, rail emissions were regulated by the UIC leaflet 624. The problem for exhaust emissions has mainly been the existing fleet of often very old diesel tractive units which have considerably contributed to overall emission levels in local urban settings e.g. from stand still in depots or at terminal stations. This has added to the myth of diesel operation being old fashioned and not significantly improving. In reality tremendous improvements have happened which are now also slowly being acknowledged at the political level. Further improvement will come from the introduction of stage IIIB of the NRMM.

Railways will be influenced by the future development of energy and CO2 prices which could lead to significantly higher operational costs. This will allow for other and more energy efficient technologies to be implemented. The main problem however is that the costs of new, clean engines are quite high due to the small market and the high migration costs from road to rail. For new rolling stock it is less of a problem but for existing rolling stock there is often no business case for the railways to exchange their engines if the vehicles are way beyond the middle of their expected life span. The positive implications of having reached the exhaust emission target for traction is that the rail sector can demonstrate its sustainability performance to customers as well as governments and thereby receive increased support for further investments in railway infrastructure as well as upgrades to handle the growing capacity needs.

The main technical measures to reach the 2030 target are not known at present – but some prototypes in various stages exists for stage IIIB due in NRMM in 2012. Technical measures to reduce exhaust emissions from railway operation can basically be split into two parts:

1) Exhaust emission improvements in the diesel traction chain
2) Alternative traction types

One barrier (risk) for exhaust emission is the long lifespan of rail vehicles which prevents a fast implementation (NOx and PM performance improvement) with regards to exhaust emission measures. The UIC already established and updated a trustworthy exhaust emission data to the current energy and CO2 database in order to keep track of the performance improvement from here to 2030 and 2050.

It should however be noted that in cities, public transport is a key solution to address local pollutions from the transport sector, but due to the fact that air pollution is a transboundary problem linked to may other sectors many of the gains made at the local level with public transport can be undermined by other sectors, such as the power or agriculture sector. As such, effective measures have to be strengthened that enable Member States to comply with the Ambient Air Quality Directive (2008/50/EC), in particular for the proposed revision of the National Emissions Ceilings (NEC) Directive, with binding and ambitious emission ceilings for 2025 and 2030 to guide Member States efforts on air pollution and to better coordinate measures under the NEC Directive and the Ambient Air Quality Directive.

Noise

EU current and future Policy

Noise is a consequence of all major modes of transport, and is one of the key concerns for people living near transport infrastructure. Half of the EU's urban population is exposed to noise levels high noise levels above 55 decibels (dB) as a result of transport (mostly road traffic). In European cities with populations over 250 000, almost 70 million people are exposed to long-term average road traffic noise levels exceeding 55 dB Lden (a weighted average noise over 24 hours that marks the threshold for excess exposure). At night, more than 48 million people in the same urban areas are exposed to long-term average road noise levels higher than 50 dB Lnight (the EU threshold for excess exposure at night time).

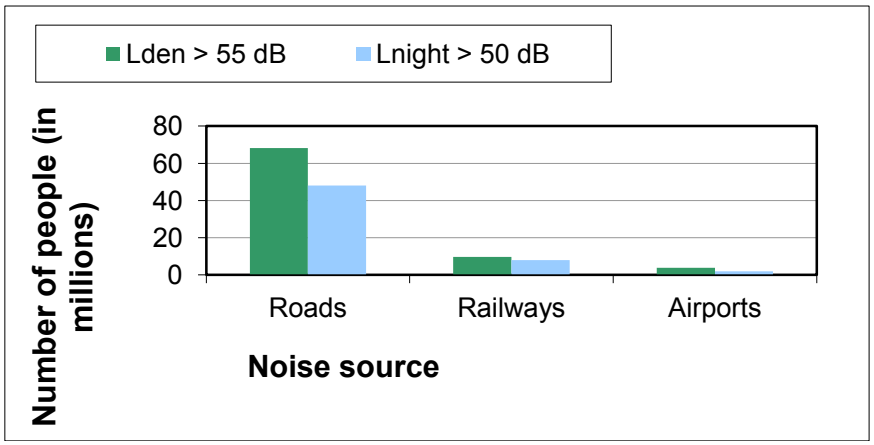

Figure 1.Exposure to transport noise in urban areas in Europe (EU-27 plus Norway and Switzerland) Source: EEA 2007, Noise Observation and Information Service for Europe

Current EU legislation distinguishes between noise creation (the emission of noise at source, best tackled on an EU-wide level), and noise reception (what to do once noise has been emitted, best addressed at national, regional or local levels). The current EU requirements to control rail noise at source are set out in TSIs (Technical Specifications for

Interoperability) on high speed rail, rolling stock and noise, and impose strict noise limits on new or upgraded rolling stock.

The main EU legislative instrument for providing a coherent overview on dealing with noise reception is the 2002 Directive on Environmental Noise. This requires that Member States must calculate noise exposure levels, publish noise maps, and adopt Action Plans to prevent or reduce noise exposure where necessary. Using data so far provided, the World Health Organisation (WHO) has estimated that at least one million healthy life years are lost each year due to road traffic noise alone in Europe.

The *White Paper* entitled "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system" published by the Commission in 2011 has the declared goal of developing a CO_2-free transport industry.

By 2050, key goals will include a 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport. More specifically for the rail sector, the White Paper indicates that:

- 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.
- By 2050 rail should substantially expand its modal share over medium and long distances for both passenger and freight.

With respect to the cost associated with the impacts of noise and local air pollution, the Commission intends to develop a common approach for the internalisation of these external costs to be applied across the entire transport system.

There is a serious challenge for the rail sector to reduce noise at reasonable cost. Reducing noise is important to ensure the social acceptance of higher volumes of rail traffic, whilst managing the cost of noise mitigation is important to prevent any harm to the rail sectors' competitiveness. These are both important issues if the rail sector is to Increase its market share and through this to improve the overall environmental impact and sustainability of the transport sector.

The European Commission has a range of policies designed to foster the development of a single European railway. In support of this, a set of common technical specifications, known as Technical Specifications for Interoperability (TSIs) have been developed by the European Railway Agency (ERA).

The Noise TSI (Regulation 1304 of 26 November 2014 known as TSI NOI) sets out noise limits for new rail vehicles in addition to renewed or upgraded wagons. These include stationary, starting and pass-by noise for all types of rolling stock, as well as noise limits

for the level in the driver's cab. Provided that it complies with these requirements, it is not possible for a Member State to refuse access to a rail vehicle on the basis of its noise performance.

The European Directive on the Assessment and Management of Environmental Noise (2002/49/EC), known as the Environmental Noise Directive, intends to support a harmonized approach across the EU Member States & increase public awareness of noise exposure. It requires Member States to publish strategic noise maps every five years starting from 2007. These enable the assessment of the exposure of citizens living in agglomerations (large urban areas) and close to major transport infrastructure to noise from road, rail and air transport in addition to industrial sites.

The directive also requires the drafting of Action Plans, these should be designed to prevent and reduce environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

The directive does not replace national legislation; in particular it does not affect the national capacity to set limit values for the maximum allowable exposure of citizens. This capacity is considered to be subject to the so-called subsidiarity principle[27] (article 5 of the Treaty on European Union).

In its 7th Environmental Action Plan, the Commission announced the objective, by the year 2020, to move the exposure to environmental noise significantly closer to the World Health Organisation recommendations. Moreover, a refit process has been launched, evaluating the so-called regulatory fitness of the Directive. Elements to be evaluated are the effectiveness, efficiency, coherence, relevance, added value and prospect of the legislation. The conclusions of this refit process are expected not earlier than by the end of 2016.

7.5 Implementation Plan

Energy Efficiency and Carbon Emissions

The management of the rail system for minimum energy use and better traffic management based on the development of new technologies will enable energy savings and better overall railway system efficiency.

[27] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:ai0017

Efforts should concentrates on different parallel lanes according to their technology readiness level as follows:

Lane 1: **Rolling Stock**

Lighter Trains;

Hybrid traction;

EE Auxiliaries.

On this topic the application of the TecRec 100_001 about Specification & verification of energy consumption of railway rolling stock plays a central role as an energy standard for rolling stock procurement, agreed by operators (UIC) and manufacturers (UNIFE), produced under the frame of the Railenergy project (2006-2010), valid since March 11th 2010. This norm integrates the evaluation of rolling stock, in some types of infraxtructure and operation conditions, setting as objectives the harmonized framework for generating comparable energy performance values for rolling stock, supporting benchmarking and improving the energy efficiency.

Smart Trains capable of performing: (i) an integrated management of the traction and auxiliaries and (ii) of responding to the requirements of the smart grid control center(s). These technologies are crucial for the implementation of railways smart grid, since the infrastructure itself is not able to perform many of the control actions required in real operation.

Lane 2: **Infrastructure**

Smart Grids

Energy Supply

Increasing the traction power supply voltage

Braking Energy Recovery

Energy utilization in AC traction power supply system by introducing Power conditioning

Lane 3: **Operation and management**

Traffic Flow Management

Implementation of a communication between Traffic Management Systems and Driving Advisory System that include real time changes in Time Table in order to reach the optimal solution for detected conflicts.

Regarding these two lanes and the new Smart Grids Infrastructure and its relation to other rail subsystems the current MERLIN Porject to be finished at the end of 2015 includes as main objectives that:

MERLIN Project will provide an integrated and optimised approach to support operational decisions leading to a cost-effective intelligent management of energy and resources. The interface between rolling stock and smart grids infrastructure will be regulated by the output standards of the project.

A further step on this topic will be the deployment and the implementation of smart grids in the rail infrastructures connected to the current operations of European railways Smart management of the consumption power peaks in the substations.

Integration of the electrified railway systems with the existing electricity markets.

Lane 4 : **Support and Communication**

UIC will monitor the progress towards the targets guaranties transparency and accountability, towards competitors, stakeholders and decision makers. To ensure that all objectives are met, the Environment Strategy Reporting System has been launched. It is an integrated management system, officially used from September 2012. Through support and communication (training activities, further studies) UIC will collect and share implemented energy efficiency actions developed in the European railway community.

On this topic UIC analyzes the European Rail performance in order to provide a follow-up of the set targets. Furthermore, UIC developes actions on communication of sustainability rail advantages as Train to Paris, to show the international community sustainability of rail, for the next COP21 to be held at the end of 2015 in Paris, UIC will get together in the same days trains coming from different European cities.

Climate Change adaptation

The ERRAC members will develop a climate resilient transport mode dealing with climate change threats, with research into the effects and management of weather, water and heat impacts on infrastructure
The future role of railway infrastrucutres in strengthening and improving the adaptation of their asset to climate change will include the following measures and actions:

- Facilitate and coordinate knowledge sharing e.g. by running research projects or hosting best practice workshops and supporting common methodologies;
- Facilitate the development of appropriate metrics for impact and vulnerability assessment;
- Support the development of appropriate governance approaches for adaptation.

Multi modal, complex transport chains and their total associated activities such as production or logistics activities could be halted, and the daily routines of millions of

citizens could be altered; and if vulnerable infrastructures are serving regions with already limited accessibility alternatives, they could compromise their development prospects.

The transport system is interconnected and it is an indispensable service making other economic and social activities possible. Therefore, adaptation of transport systems to climate change requires a wide perspective. This suggests strongly integrating climate change adaptation of the transport system with efforts in other sectors and policy areas. In addition, there will be a need to embed adaptation into broader transition strategies of our society, rather than leaving it to be implemented by single stakeholders like infrastructure managers, operators or regulating authorities in the transport sector.

Rail best practices examples for assessing and gaining resilience in France, Germany, Austria or Spain have shown how transport is able to face the challenge of the Adaptation to Climate Change. The latest report of the Environmental Energy Agency Highlighted these actions showing how rail is ready to face this global challenge.

Urban environments are particularly vulunerable to the impacts of climate change and governments can impose legislation to assess the impacts that climate change could have on their assets such as metros. For example, in the UK, the Climate Change Act 2008 and the Mayor's draft Climate Change Adaptation Strategy requires TfL to demonstrate its approach to assessing and planning for the impacts of the changing climate. TfL has assessed and evaluated the future climate impacts on its assets and services, such as the London Underground, Docklands Ligh Rail, Overground rail network, referencing the latest generation of climate projections. The report that TfL was required to submit to the regulator sets out a snapshot of TfL's current position relating to climate change adaptation and outlines future work. TfL's work on this front will be progressively developed as part of the risk management system. The report presents TfL's approach for assessing climate related risks on its assets and services and how these are likely to change over time. There are a number of elements of London's transport network that have the potential to be affected by weather related events, which can become more frequent or of higher consequence in the longer term. The principal risks that have been identified are from flooding, high temperatures, low temperatures and drought.

Infrastructuture maintenance
Rail companies adopting meteorological alerts system can adapt operations, and services and maintenance. It is especially interesting for the less accessible areas that can be located in more extreme weather areas, such as the Pirinees or the Alps Cooling or heating can be adjusted or transport operators can provide advanced information to their users, anticipating changes in their service performance. This enables passengers as well as freight operators to adapt their plans or find alternative transport options. Such measures can also improve the quality of services and have positive co-benefits for the companies, for the transport sector and for the society and economy in general terms.

Next steps:
The future role of UIC and UITP in strengthening and improving the adaptation of railway infrastructure to climate change will include the following measures and actions:

- Facilitate and coordinate knowledge sharing e.g. by running research projects or hosting best practice workshops and supporting common methodologies;
- Facilitate the development of appropriate metrics for impact and vulnerability assessment;
- Support the development of appropriate governance approaches for adaptation.

Rail companies adopting meteorological alerts system can adapt operations and services. Cooling or heating can be adjusted or transport operators can provide advanced information to their users, anticipating changes in their service performance. This enables passengers as well as freight operators to adapt their plans or find alternative transport options. Such measures can also improve the quality of services and have positive co-benefits for the companies, for the transport sector and for the society and economy.The European railway community supports a strong and credible EU ETS. As major consumers of electricity, rail transport may in future be significantly affected by (probably) high allowance prices as a result of a policy of internalization of external costs. CER and UNIFE accept that this will be the result of a policy of internalisation of external costs that they have always advocated. Nevertheless, fair treatment between modes of transport must become a reality: internalisation of external costs must apply in a fair and balanced manner across all transport modes.

The EU legislation on the EU ETS (Directive 2009/29/EC) established the goal of completely phasing out free allocation by 2027. From 2013, auctioning is the main method of allocating allowances for the power generation sector; however certain sectors are still benefiting from free allocation. "*The energy intensive industry sectors for example received 80% of their allowances free of charge in 2013. Auctioning will increase to 70% for the manufacturing sector by 2020. In the aviation sector, however, only 15% of allowances will be auctioned over the 2013-2020 period*"[28].

After 2020, a global market-based mechanism is planned to govern minternational aviation emissions, but no clear strategy has been outlined yet. This stop-go approach to aviation emissions is a concern for the rail sector given direct competition between high-speed rail and short-haul aviation. In general the railways are and will be paying for the extra costs of the ETS that are passed on by the power generation sector. Road transport, the most CO2 emitting mode, is not included in the ETS. Competition between road and rail is correspondingly distorted. The rail sector believe that road transport fuels need to be included, subject to auctioning like the other sectors, or subject to measures of an equivalent effect.

[28] CER UNIVE POSITION PAPER A 2030 Framework for Climate and Energy Plicies, 2014

Noise

From an early stage, railway companies were concerned about their noise performance. They have long stated their willingness to take the necessary actions, provided that there is a level playing field with competing transport modes like road, inland shipping and airplanes.

In the early nineties, in a common effort under the direction of UIC and CER, they invested in research to better understand railway noise. It was found that cast iron brake blocks applied on the wheel treads would cause high levels of surface roughness and therefore rolling noise. For many years the only low noise brake blocks available were the so-called K-blocks which have a different friction performance to cast iron blocks. However, in order to achieve a compatible braking performance when wagons using different brake blocks were coupled in the same train it is necessary to make further expensive changes to the braking system of wagons fitted K-blocks. The total cost of replacement brake blocks and changes to the braking system has proved to be prohibitively expensive for most rail companies and prevented the wide scale retrofitting with K-blocks.

In the STAIRRS project, carried out in the late 90-ies, various noise control options were compared in terms of their cost and efficiency to reduce noise. It was found, that the most cost efficient solutions would include retrofitting, i.e. replacement of the cast iron blocks, of the existing freight fleet. The least cost efficient solutions would include erecting noise barriers. The conclusion of STAIRRS was reconfirmed in a UIC study in 2013 [9].

The conclusions of STAIRRS paved the way for the Action Plan, agreed and published by the railway umbrella organizations (UIC, UIP, UIRR, CER and Unife). The action plan focused efforts on the following objectives:

- Focus on reducing noise from rail freight. This was causing the main noise problems due to night time operation (with a legal penalty in the noise exposure level) and use of noisy cast iron brake blocks;
- Retrofit the main part of the European wagon fleet with low noise brake blocks;
- In order to maintain the level playing field economic support from public bodies, preferably from the European Union, was required to compensate for the costs associated with the retrofitting. This would include both the investment for the retrofitting and possible increases in operational cost due to higher wheel wear and brake block price.

The latter point turned out to be the difficult one. European Union Member States were not allowed to support the Action Plan financially, due to European State Aid rules. The European Commission did not want to engage in supporting the initiative. The railways, by

that time, had been split up into train operating companies and infrastructure management organizations. Notably, thanks to direct funding by the Swiss federal government, retrofitting using K-blocks was completed for the Swiss wagon fleet in 2012.

As a solution the railways launched a program to develop a new type of brake block, the LL-block, that could achieve a similar friction performance to cast iron blocks, but with a smoother wheel surface. This would allow simple substitution with cast iron blocks (without major changes to the braking system) and therefore low cost retrofitting. The UIC EuropeTrain project successfully concluded in 2013 following which three LL-blocks have been approved for use.

Some cost increase remains due to purchasing the LL-blocks, actual retrofitting work, changes in wheel wear & more frequent inspection and servicing.

The Action Plan turned out to be successful:

- For passenger trains, new rolling stock can be equipped with disk brakes,
- For stationary noise, the NOI TSI would be fulfilled by new locomotives and multiple units,
- For new freight vehicles K-blocks would be applied,
- For existing freight vehicles in international traffic, LL-blocks would be considered, provided that sufficient incentive was provided
- For new track, optimized rail pads would be selected
- For existing track, the rolling surface would be well maintained

Railway noise measures can be divided into two main categories: rolling stock-related measures such as modified brakes or damped wheels, and infrastructure-related measures such as rail dampers and noise barriers. The larger potential lies in treating the noise problem at source, which is recognised as the most effective solution both in technical and economical terms.

The biggest challenge in the rail sector is the noise caused by the large remaining fleets of older freight wagons (passenger traffic is considered to be less of a problem). Since 2006, new and upgraded wagons have to have been equipped with low-noise brake blocks, but tens of thousands of older freight wagons continue to operate using cast iron brake blocks, which in turn cause rough wheels and rails. The noise generated by them is considered a particular nuisance in densely populated central European countries such as Netherlands, Germany and Switzerland.

Retrofitting existing freight wagons with low-noise ‘LL’ brake blocks offers a noise reduction potential of 8-10 dB. This impact is particularly beneficial at night when a major percentage of freight trains operate. However, there are significant costs involved in retrofitting existing wagons, and this measure is expected to cost between €1-4 billion to retrofit all existing wagons.

To ensure that LL-blocks could be safely fixed onto new wagons and would be effective, the rail sector commissioned the €15 million EuropeTrain project. The test train consisted of 32 wagons fitted with LL-blocks, and spent over a year running on loops experiencing the most extreme weather conditions found in Europe.

7.6 Visual Roadmap, milestones and deliverables overview

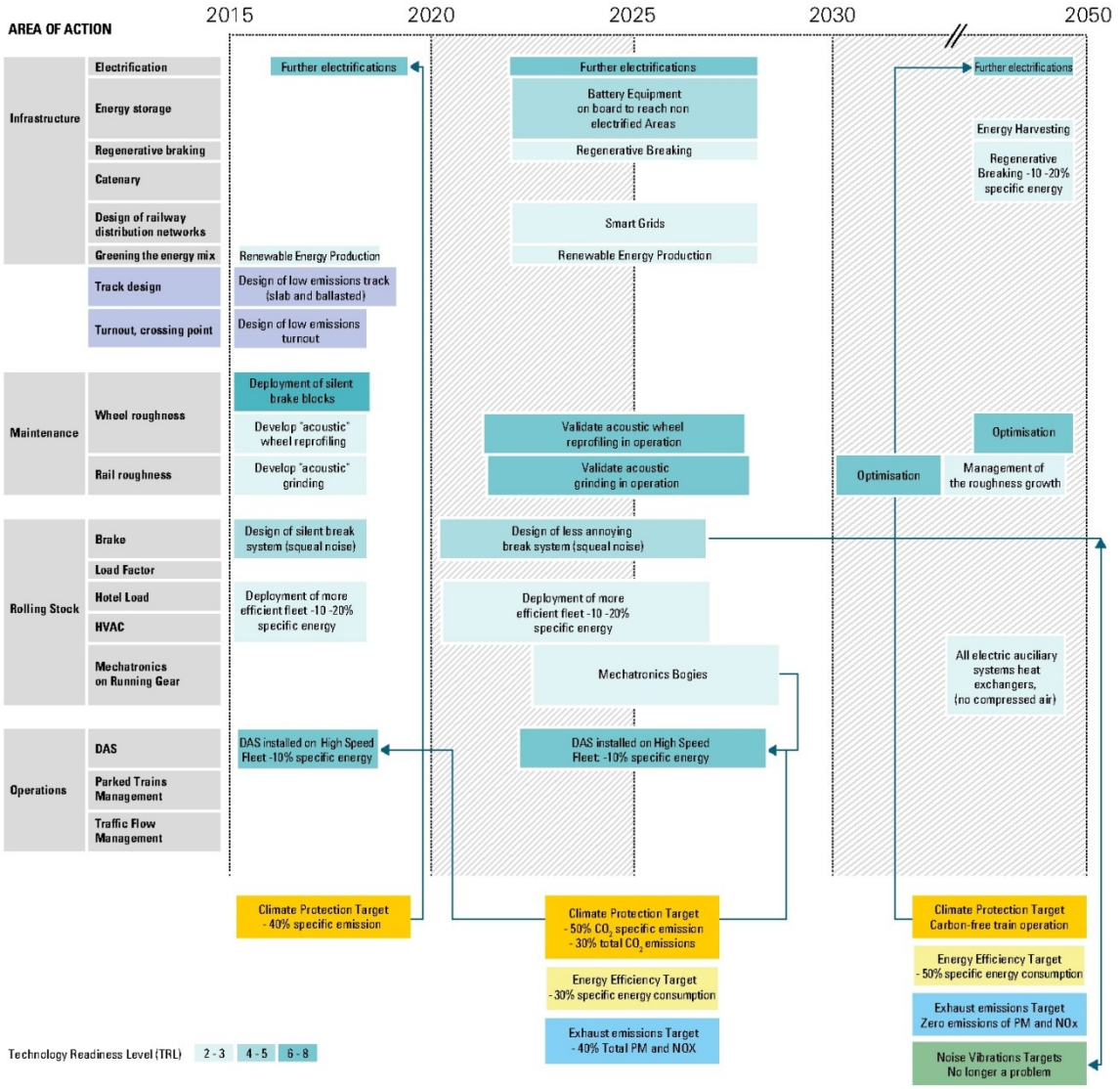

Fig. 1 - Visual Roadmap, milestone and deliverables overview

7.7 Conclusions

Rail role in energy and sustainability topics is a key one to ensure energy efficiency, energy empowerment, low carbon growth and adaptation to climate change in the EU countries.

Current frame of EU policies and projects go on the way of modal shift to rail promotion, but main challenges on energy independency, renewables implementation and climate change adaptation require going beyond on this strategy.

The implementation of the announced actions of this roadmap contributes to reduce energy bill of EU economies whilst a reduction of GHG emissions will be ensured.

8. Control, command, communication and signaling

8.1 Introduction

Control, command and communication is linked to a number of other roadmaps, and in particular to four other themes: “rolling stock”, “security & safety” (ensuring secure communication between signals and train drivers), “IT & other enabling technologies” and also “capacity, performance and competitiveness”, since this is a major part of the holistic, system-wide approach to rail research.

This is a very specific subject. The control, command and communication systems are pivotal to increasing the efficiency and safety of transport networks and operations.

The railway operates under a flexible, real-time intelligent traffic management system, maintaining the current high level of safety. Trains ru+n 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. Secure 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.

8.2 Key issues and objectives

The key issues and objectives of this roadmap are:

• Increase capacity through real-time intelligent traffic management systems;

• Reduce energy consumption;

• Increase operational flexibility;

• Reduce life cycle costs through cost effective standard design, test, installation and maintenance of signalling and communications → need of an open architecture;

• Dedicate a frequency bandwidth or at least give the priority to urban railway;

• Keep the current level of safety in the rail networks and ensure cybersecurity while increasing networked interconnections;

• Improve customer quality for both passengers and freight companies in the transition between transport modes;

• Improve performance in terms of reliability and punctuality as well as information (e.g. traffic information/disturbances);

• Enhance interoperability;

• Maintain the international competitiveness of European companies.

8.3 State of the Art and on going research and innovation within and outside rail

3.3.1 FP7

There was several research activities linked to the topic covered by this roadmap developed in the FP7:

• A set of specifications for a new generation of interlocking systems was defined and made directly exploitable for its implementation.

• A model of the complete on-board ERTMS system behaviour to eliminate interpretation differences was developed, along with new tools to include the dynamic behaviour of the wireless interfaces and fault injection techniques in the external and internal interfaces for the safety assessment, making the field-testing certification more efficient.

• Research on a novel positioning system based on the combination of different techniques proved useful for other industrial sectors (multi-antenna assembly to reduce multi-path effects, combination of information sources such as GNSS, UMTS and GSM-R).

• Research on the analysis of the similarities / differences of the required functionality of ETCS and CBTC systems, to determine the achievable commonality level of architecture, hardware platforms and system design.

3.3.2 H2020

• Research on the development of technologies that will overcome hurdles to innovation in the field of railway vehicles as part of a longer term strategy to revolutionise the rolling stock of today, whose results will contribute to the increase of the operational reliability and to the reduction of the life cycle costs. In particular, research is being focused on technological innovations in 8 different areas: traction and power electronics, train communications, car bodyshell, running gear technologies, brakes, train interiors, noise and vibration and energy performance.

• Research on intelligent infrastructure to increase capacity and reliability, as well as reduce life cycle cost, through the adoption of a whole system approach linking infrastructure re-design with asset maintenance, traffic and energy management.

• Research on infrastructure challenges affecting large number of people and the large geographical proportion of Europe (especially countries of recent accession) that are served by conventional rail lines.

3.3.3 Relevant Development – EU or International Bodies

The European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI) are all three the European Standardization Organisations - ESOs (EU level).Their close collaboration between CEN and CENELEC was consolidated by the creation of a common CEN-CENELEC Management Centre (CCMC). There are already some existing European standards (EN) on the topic of Command, Control and Signalling systems in railways.

The close collaboration between the three ESOs and the rail representatives associations was consolidated by the creation of the Joint Programming Committee for Rail – JPC-R – also known as Sector Forum Rail. Together, CEN, and CENELEC and ETSI provide a platform for the development of European Standards and other technical specifications across a wide range of sectors, including specifically the information and communication technologies sector (ICTs). A wider joint initiative is the CEN-CENELEC-ETSI Coordination Group 'Smart and Sustainable Cities and Communities' (SSCC-CG). Moreover, both CEN and CENELEC have their own working groups that address various topics connected to this specific transport area.

ETSI is working on different technological clusters, some directly addressing transport (ITS), while others covering transversal topics that are relevant for the transport system (Radio, Quality of Service, NFV, Smart Cities, etc.)

Very recently, following the setting-up in 2013 of a platform for European rail infrastructure managers ("PRIME") aiming at exchanging views and shaping a common vision on several rail policy areas, e.g. ERTMS deployment and implementing acts under Directive 2012/34/EU, DG Mobility and Transport (DG MOVE) of the European Commission launched in July 2015 a similar platform for European rail passenger and freight operators, called the "RU Dialogue" (the first Plenary meeting is planned for October 2015). The initiative responds to a request from railway operators. The topics covered include: Digital Railways; Rail freight corridors, including the implementation of the TEN-T corridors; International dimension: challenges faced by cross border rail passenger operators, including infrastructure charges, transparency of the costs structure.

As for urban rail, UITP in coordination with UNIFE created in 2011 a "Spectrum User Group" – SUG – to address the specific needs of CBTC systems regarding the allocation of a bandwidth dedicated to urban rail in the 5,9 GHz spectrum. The SUG collaborated with ETSI for producing a draft "System Requirement Document" – SRDoc- on "Electromagnetic compatibility and Radio spectrum Matters (ERM); Spectrum requirements for Urban Rail Systems" sent mid-2012 to ETSI. The draft SRDoc has been processed through ETSI and a final SRDoc approved in October 2014 as TR_103111v010101p. End of October, the SUG contacted the CEPT/ECC about the ETSI

works, and the ECC SRD/MG analysed the ETSI SRDoc and the SUG request. On 17 February 2015 the ECC sent a "liaison statement [Doc. FM(14)094 Annex 42] from WG FM to ETSI TC ERM on request to consider Urban Rail Systems as part of ITS". A dedicated ETSI Working Group has been created which shall produce recommendations by the end of 2015 for consideration by ECC early 2016.

The International Level

The equivalent organizations of CEN/CENELEC at the international level are the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Some of the most relevant activities performed within these frameworks are to be found in the ISO/TC 204 Intelligent transport systems, in the ISO/IEC JTC 1 Information technology, and in the IEC TC9 Electrical equipment and systems for railways.

A particular case is the Institute of Electrical and Electronics Engineers (IEEE). This organization has its own, recognized Standards' Association (IEEE-SA), while at the same time also supporting R&I activities including the transport sector.

3.3.4 Relevant Research & Technologies outside Rail

- GNSS (Galileo): satellite-based services as a cost-efficient way for Train Control Systems;
- ECC/ITS initiatives for the reservation of bandwidth for safety applications for traffic management, the most relevant such initiative at the EU level being the Spectrum Users' Group mentioned in 5.4.

8.4 The Roadmap

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, enhanced train location knowledge (e.g. on-board/trackside-less train location and train integrity) and its impact in capacity, environmental gains (i.e. limiting pollution) and operational costs.

Signalling is a crucial element for train operations, as it enables trains to run safely on railway lines. Being guided, often at high speed, on fixed rails, trains are uniquely susceptible to collisions. In the 19th Century, the lack of signalling equipment frequently led to accidents on railway lines – a stark contrast from today, where rail is recognised as the safest mode of transport.

Over time, signalling has evolved from a strictly safety-related feature to a means of increasing line capacity and traffic. For example, the high-performing signalling systems available today allow for reduced headways between trains, enabling more traffic to flow on an existing line, thus becoming a key tool to improve performance and the overall competitiveness of the sector.

Challenges

Affordability

Control and command systems are today too expensive. This means that we have an affordability problem. An example is that small and medium operators risk being put out of business due to the high costs for retrofitting their locos with new equipment. The railways have to press down its cost base and one cost driver is C&C.

A partial solution to the cost dilemma is:

- Control command systems fully modularized with well-defined interfaces between the modules, where each module is safety certified and online tests minimized to almost zero. Each module also has a well-specified function which enables that supplier independent systems can be designed. This would open up the market, lead to economies of scale and reduce costs.

Increase capacity

CCS (Control, Command and Signalling) can help in increasing capacity through intermediate signals that inform the driver about future conditions, for example permitting the reduction of speed at a specific point.

CCS equipments can make the most of current assets through the study and analysis of new systems with new parameters that positively affect performance, reliability and capacity. By reducing the need for infrastructure-based equipment, new CCS systems should be able to increase capacity in a very cost-effective way through real-time intelligent traffic management systems.

In addition, a new generation of Automatic Train Operation (ATO) will increase capacity and minimise energy consumption.

Finally, the development and validation of high capacity, low cost, highly reliable signalling system based on moving block principles, as well as further exploration of the concept of virtual coupling/uncoupling in order to maximise the flexibility of train operations are key.

Energy efficiency and sustainability

CCS systems can reduce life-cycle costs through cost effective standard design, test, installation and maintenance of signalling and communications infrastructure and on-board equipment. Here there is a need for an open architecture, whereby reduction in energy consumption can be attained.

Driver assist systems are also relevant, since many studies have shown that, depending on the style of the driver, there can be changes in the energy consumption of the train. Traffic management systems with onboard optimization systems can be helpful in this regard.

Reliability and punctuality

New radio-based control systems allow for less signal failures, one of the greatest problems that cause train delays in many places. Since these systems also allow for trains to run closer to each other, punctuality and capacity are both enhanced.

Interoperability

Trains that have on-board databases stored should be able to run autonomously, while the on-board system identifies the position of the train and brings about speech checks based on the data of the route, controlling the speed. At the same time, while the system is safer and less dependable on external physical signals, the cost of infrastructure should decrease.

Safety and security

Keep the current level of safety in the rail networks and ensure cybersecurity while increasing networked interconnections are pivotal for the future of the sector.

Achieve the optimal level of cybersecurity against any significant threat for the signalling and telecommunications systems, especially central traffic control systems and an automation system is key.

Also, achieve a GSMR improvement for safety relevant communication links to increase their security resistance and increase with high availability is important, and will result in an increased situational awareness for trains safety, preventing collisions, derailments, and rail switch errors.

Other objectives:

• Achieve an “automatic breaking test, the parallel breaking control” and the “automatic setting of the ETCS (OBU)” after a new train composition leading to a significative enhancement of the breaking capacity of passenger and the freight trains independently of their composition or length. This way, all the wagon will break at the same time (and the same for the release of the breaking), winning a great amount of time.

• Achieve a “permanent completeness checking” that is needed to evaluate to ETCS level 3 equipment (without any on line train detection systems) => SIL4 issues.

• ETCS Level 3 requirements including the “operation principle” and the “management of the degraded modes” and different conditions of use/environment.

• ETCS level 3: trains on time in theory, but no more than 16 managing the entries/exits.

• Create software able to translate the different signalling languages of all countries.

8.5 Implementation Plan

3.5.1 Shift²Rail

The Shift2Rail Joint Undertaking is a public-private partnership between the European Commission and major European rail stakeholders, with the aim of bringing about a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system.

The S2R is divided into five Innovation Programmes (IPs), each addressing a major rail area, as follows:

IP1 – Cost-efficient and reliable trains, including high capacity trains and high speed trains

IP2 – Advanced Traffic Management & Control Systems

IP3 – Cost Efficient and Reliable High Capacity Infrastructure

IP4 – IT Solutions for Attractive Railway Service

IP5 – Technologies for Sustainable and Attractive European Rail Freight

IP2 is directly linked to the topic of control, command and communication, and focuses on activities to support the rapid and broad deployment of advanced traffic management and control systems by offering improved functionalities and standardised interfaces, based on common operational concepts, facilitating the migration from legacy systems, decreasing overall costs, adapting it to the needs of the different rail segments as well as to the needs of a multimodal smart mobility system.

In order to achieve these objectives, eleven research and innovation topics have been produced focused on:

- Smart, fail-safe communications and positioning systems: develop an interoperable path to modern multi-vector mobile communications and provide ability to use networks as a service, develop a fail-safe, multi-sensors train positioning system, boosting the quality of train localization;

- Traffic management evolution: advanced traffic management systems should be automated, and they should be combined with Driver Advisory Systems (DAS) and automation functionality to allow for predictive and dynamic traffic management;

- Automation (complementary approaches for mainline and urban domains);

- Moving block (MB) and train integrity;

- Smart commissioning and testing: develop a framework for zero on-site testing using simulation tools and subsystem and product implementation in interconnected laboratories of different parties;

- Virtual coupling;

- Cybersecurity;

3.5.2. H2020

In order to fill the gap between ERTMS needs for safety critical applications and European Global Navigation Satellite Systems (EGNSS) services, a characterisation of the railway environment and of GNSS performances assessment in that environment is a must. This is covered by some research already ongoing on the application of GNSS in ERTMS, which shall lead to significant economic benefits through reduction of trackside equipment, reduction of maintenance, increase of availability and performance. This shall also make ERTMS more competitive in comparison with competing systems in the world market, leading to increased business opportunities for the European signalling and space industry.

3.5.3 Other public funding programs

The following categories of funding have been considered as public funding programmes:

1. The different EU sources of funding;
2. The state (national/regional) sources of funding.

EU-Level Funding

Concerning R&I, a specific source of funding is the EU programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME), which supports SMEs for: access to finance in the form of equity and debt, access to markets, framework conditions for the competitiveness and sustainability of Union enterprises, etc.

The ERA-NET scheme, created to develop and strengthen the coordination of national and regional research programmes, is also to be considered.

The other EU main direct funding sources, which can be accessed directly and indirectly for R&I are the European Structural and Investment Funds:

• The European Regional Development Fund (ERDF), which aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions. The ERDF focuses its investments on 4 key thematic priorities: innovation and research; the digital agenda; support for small and medium-sized enterprises (SMEs); the low-carbon economy. It is the most important EU fund that support R&I. ERDF will manage the bulk of R&I funding.

• The Cohesion Fund, aiming to reduce economic and social disparities and to promote sustainable development. It is supporting the ‘Connecting Europe Facility’. Moreover, a significant part can be allocated to general environmental activities: energy efficiency, developing rail transport, supporting intermodality, strengthening public transport, etc. Rail stakeholders can use part of these funds for transport-related research, but this also depends both on the national legal framework and the future EU-related developments in the field of research funding.

Furthermore, there are EU grants in support of projects or organisations which further the interests of the EU, or contribute to the implementation of an EU programme or policy.

The state funding comes in two major channels: the various national and/or regional schemes that support R&D&I development and the involvement of foreign states (or state-owned organizations) in major research activities through: loans, grants, capital market investments, etc.

There is also a specific category of public funds available for R&I, the source being the generically termed IFIs (International Financial Institutions) whose owners and/or shareholders are generally national governments.

The most important is the European Investment Bank (EIB). The aim of this bank is to offer favourable lending and other types of financial support to a number of projects, mostly in the EU. The lending is mostly done in order to enhance the implementation of EU policies and goals. Innovation and transport are among the bank's two main targets.

Another institution is the European bank for Reconstruction and Development (EBRD) which also supports different sectors through lending, other financial mechanisms, counselling, etc. The bank has been created to support the former Communist countries in their transition, hence its funds are (mostly) available to CEE EU members. The EBRD is involved in supporting ICT, transport & infrastructure and general manufacturing.

Of the IFIs at the wider international level, the best example is the World Bank Group which through its different branches, supports, finances and advises different projects, reforms, funding schemes, etc.

3.5.4 Private funding possibilities

The main methods to obtain private funding for rail R&I (in addition to those pledged by the already-involved stakeholders) are the following:

- Other private companies that wish to enter the market, including private equity investors in major companies or major research projects;
- Public-private partnerships (PPPs) for major and expensive research topics;
- Loans from banks;
- Drawing funds from the capital markets (either from private companies or PPPs) for major projects;

Even though the rail environment generally does not offer high returns of investment in a short period of time, these developments are becoming attractive for these sources of

private funding, due to the increasing effort put into this topic (ERTMS deployments in Europe and abroad, more metro systems built or upgraded with CBTC systems, etc.).

This is one of the topics where the rail sector clearly needs to put more effort into developing the right solutions for both urban and mainline rail sectors. It is also one of the sectors where rail cannot rely too much on the support of other domains, except the IT systems. Consequently, most of the needs have to be addressed by the sectors stakeholders directly.

Given the fact that these systems are ultimately providing valuable information for many of the rail sectors' business cases (e.g. the ticketing), all these developments need to be ready to interact with the tools and systems of other stakeholders and business partners, in order to ensure openness and the development/use of as many open-source, adaptable technical solutions as possible, in order to enable a real "plug-and-play" solution.

8.6 Visual Roadmap, milestones and deliverables overview

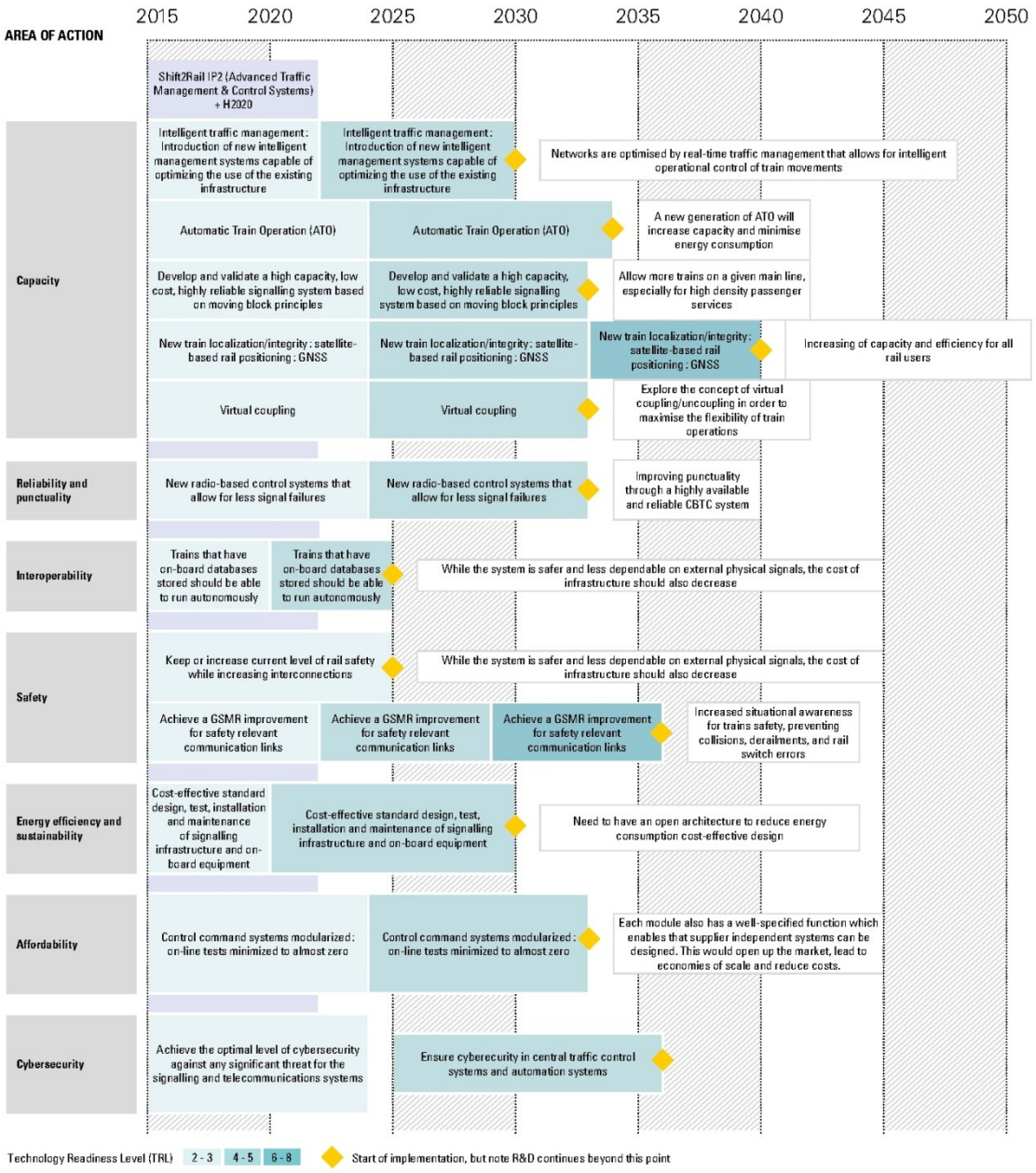

Fig. 1 - Visual Roadmap, milestone and deliverables overview

8.7 Conclusions

When the railway operates under a flexible, real-time, interconnected (with all other transport modes), intelligent traffic management system, it can maintain a high level of safety and also increase efficiency, throughput and capacity drastically.

The control, command and communication systems are pivotal to increasing the reliability of rail transport operation, from urban and suburban systems to high speed and intercity applications.

Integrated control, command and communication systems with improve life cycle costs up to 50%.

9. Infrastructure

9.1 Introduction

Vision & priorities

- Europe has an integrated transport infrastructure, enabling a single European rail area. This integrated transport infrastructure system for the 21st century would be advanced, affordable, reliable and will deliver increased capacity to be acceptable to Europe's citizens.
- The system will be optimised in terms of performance, and would adequately enable and support the advancements in other systems, processes and technologies involved with the seamless movement of people and freight through the various transport modes[29].
- Operation and maintenance of network infrastructure is reliable, supportive of customer needs, cost effective, sustainable, adaptable to future requirements and resilient to hazards by bringing together cost effective innovative technologies and concepts such as automation and intelligent materials.
- 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 freight 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. The railway regulations will not be major cost drivers.
- Rail system infrastructure is designed to be intelligent and self-learning. It should adopt relevant infrastructure technologies from other sectors.
- Intelligent infrastructure will be fatigue and wear resistant; system components will be monitored autonomously in real time. The use of new operational and track engineering techniques across the network will reduce the need for intrusive maintenance and greatly improve 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 and autonomous analysis and decision support) will enable the establishment of timely and right first time maintenance. This will ensure that there is minimisation of system interruption and maximisation of product availability to the customer.
- Freight customers will have easy access to terminals. Terminals will manage throughput and loading and unloading operations swiftly. Optimising processes for train preparation will reduce the noise and vibration and so social nuisance from terminal operations and increase efficiency. Primary, secondary and tertiary

[29] "*TOWARDS A PERFORMING INFRASTRUCTURE",* Roadmap for Cross-modal transport infrastructure innovation

terminals are combined for furthering of efficient multimodal logistics chains.

9.2 Key issues and objectives

The main drivers are cost effectiveness, reliability and flexibility, delivered by:

- Increased infrastructure resilience.
- Reduced costs and maximise track availability by non-disruptive inspection and targeted timely maintenance interventions.
- 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 components, pre-fabricated modules can offer significant improvements in performance and reductions in investment and operational costs.
- Development of intelligent infrastructure maintenance and inspection and defect detection technologies carried out at commercial speeds.

9.3 State of the Art and on going research and innovation within and outside rail

The road transport sector accounts for the majority of the freight-tonne and passenger kilometers. The rail sector accounts for approximately 7% of the passenger market and about 17% of the inland freight market[30]. According to the European Commission, the freight volumes are expected to almost double and passenger volumes by almost 50%.

Although rail offers a significant opportunity to meet this demand of increasing mobility within the constraints of reducing greenhouse gas emissions, the European rail network faces an ever improving threat from other transport modes. For a variety of reasons Road and Air transport modes have been reducing their costs to the end user, improving safety and reliability, reducing emissions and improving fuel economy at a rate far beyond that of the rail industry.

The liberalisation of the transport market has also led to the emergence of low cost air carriers and road hauliers. This has led to an increased competitive pressure on the rail business.

The factors above have combined to increase the competitiveness of the other transport sectors and they are beginning to make significant inroads into the rail sector. A good

[30] EU Transport in Figures, Statistical Pocketbook 2014, tables 2.2.3 and 2.3.2.

illustration of this is the loss of rail freight market share and the increasing use of air transport for intercity travel. Innovations and new technology will only increase this threat as the arrival of autonomous vehicles will potentially change the how people commute and would remove a big obstacle from road haulage (the limit on driver hours, recorded by tachographs). To tackle this threat the railways of Europe need to be more frequent, cheaper to use, more reliable, greener and much more convenient for the customer (both passenger and freight). Rail must also enhance its present role in co-modality. This cannot be achieved by pushing the current system, we need innovations and new technology. But, we also need to embrace non-rail specific technology, such as big data, autonomous systems, robotics and smart materials. However, technology alone will not take the industry all the way. In competitive non-rail industries RTD spending is used to gain leverage. The rail industry need to develop and embrace both RTD spending and competition to evolve.

So the drivers come down to cost, availability, environment and climate. If costs are getting lower for other transport modes such as roads, what are the societal incentives for backing rail as a mode of transportation? Although automonous vehicles will be a reality in the near future, rail can still be seen as a backbone for fast, efficient mass rapid transportation. Cities evolve around networks of railway lines. More people can be transported on shorter time due to the fact that rail is a controlled mode of transportation. In contrast to cars and truck, decisions are not taken subjectivey through individual drivers, but rather via a controlled system. In addition, the use of common transportation e.g. rail, releases spending capacity as people do not have to cater for their own vehicle, thus enabling a more affluent life-style.

But the railway has to respond to the threat of other transport modes by means of new business models that are enabled or supported by technological advances. Harmonization of regulatory frameworks e.g. safety and environment should also be enacted in order to achieve a level playing field between the modes. Funding the changes required in the rail industry will also need to be innovative and consider whole cost rather than short term cost of purchase.

The European Comission has backed RTD in a number of fields and it would be useless to repeat all projects here. However, to set the scene a few successful projects from different industries are highlighted to demonstrate that similar challenges that the rail sector faces exist elsewhere.

The road sector has through a number of initiatives such as the Strategic European Road Research Programme (SERRP) and the Forever Open Road Programme developed roadmaps for roads in the 21st century. National programs include the Norwegian Ferry Free E39, the French PREDIT 1- 4 and Route 5 Generation (R5G) programmes, Germanys Roads in the 21st Century and the Dutch program Innovation

Estafette, Knowledge for Climate (INCAH) and the Swedish national RTD programmes featuring Bridges & Tunnels, Geotechnics and Road and Railway Construction and Maintenance have all contributed. From the North American continent, the US Exploratory Advanced Research programme (EAR) is worth mentioning. All these initiatives cover to some extent similar challenges the Rail sector faces.

Rail specific roadmaps indicating state-of-the-art and visions include the Rail Technical Strategy Europe and the Challenge 2050, the rail sector vision. More specific initiatives are the Network Rail Technical Strategy 2013 and the UK Track 21 and Track to the Future (UK EPSRC funded) programmes. The Scandinavian 8 million City is an example of a project indicating that through the use of high-speed rail services, cities such as Oslo, Gothenburg, Malmoe and Copenhagen could be connected to for a single city and boost economic development.

With the support of the European Commission, a number of front-end initiatives have been completed throuh Framework Programmes. On the infrastructure side the FP6 Sustainable Bridges, explored bridges and tunnels. Through FP7, the initiatives MAINLINE, AUTOMAIN and SUSRAIL targeted rail infrastructure maintenance. The FP7 SST.2013.5-3 'Innovative, cost-effective construction and maintenance for safer, greener and climate resilient roads' call hosted the ERA-NET Plus Infravation Scope, although targeting the road sector, similar challenges exist for the rail infrastructure. The most recent initiative is the H2020 Shift2Rail Joint-Technilogy-Initiative, where the European Commission, rail industry and infrastructure providers jointly explore and develop technology for the net 10 to 20 years.

The construction process is getting more and more important. It is not all about what we do, how we do things often decides success or failure. From the aeronautical and automotive industries, the FP6 Virtual collaborative enterprise – VIVACE and SuperLightCar – SLC projects, indicate that the rail industry can adopt principles from elsewhere. Specific from the construction sector, the FP6 - INPRO - Open Information Environment for 'Collaborative Process Throughout the lifecycle of a building' explored the use of BIM, and further the FP7- PANTURA – 'Low-disturbance sustainable urban construction' programme, targeted construction projects in urban areas and other challenging environments.

The Roadmap for Cross-Modal Transport Infrastructure Innovation was created to connect specific roadmaps from various sectors, ERTRAC, ERRAC, ACARE, ECTP and WATERBORNE.

9.4 The Roadmap

Rail infrastructure managers face a number of challenges to maintain and improve the rail transport network. It could be resource efficiency, e.g. better quality, improved recycling and use of a circular-economy. Accessibility is a key issue for the rail transport network as it differs from the road transport system where diversions due to construction, inspection and maintenance can be easily achieved. Cost-efficiency is related to more value for the taxpayers money, e.g. by adopting a life-cycle perspective. Safety is always a key issue, a better rail infrastructure require less maintenance, and hence a safer environment for users as well as the workforce.

Therefore major drivers for both existing and new railway lines includes the environment, cost efficiency, reliability and flexibility using ICT31 as an enabler. One thing is for sure, “Infrastructure” shapes mobility32 and rail has a central role in this process. In the following roadmap, the word “infrastructure” is used as an umbrella definition for parts such as track structures, earthworks, bridges, tunnels, stations and associated components and areas.

Basically four corner-stones apply for the area infrastructure; methods & processes, materials, sensors & communication and legal & finance. Following the Roadmap for Cross-modal Transport Infrastructure Innovation33, we can adopt three interrelated domains:

- Construction and maintenance of infrastructure
- Infrastructure based supporting systems and service
- Governance, management and finance of the infrastructure

<u>Construction and maintenance of infrastructure</u>

As most of the rail infrastructure in Europe is existing and represents a massive investment by society, an important issue that arises is: how we shall take care of this investment?

In the case of new infrastructure it is quite clear that building infrastructure in the same way as the past is not an option. Instead the industry has to look for novel construction concepts using novel design methods. We envisage that rail and construction industries are influenced by other sectors where cost and production are included into a holistic

[31] ICT – Intelligent Communication Technology

[32] WHITE PAPER, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, SEC(2011) 391 final

[33] Roadmap from the ERTRAC-ERRAC-Waterborne-ACARE-ECTP Task Force, Version: formally endorsed by the ETPs involved, June 30, 2013

concurrent design and manufacturing process, and that BIM[34] (Building Information Modelling) is used throughout the project for an integrated project delivery. New design concepts have adopted DFMA[35] and Lean principles. Automation and robotics will be heavily used and new technologies such as 3D-printing will be a major element in the manufacturing of construction elements, both on and off site. A new factory design using rolling manufacturing units could be envisaged.

On the material side we anticipate the use of new materials and material components through multi-material technologies where the material has been chosen based on function rather than traditional preference and also includes new repair strategies. Ideas such as nano- and biotechnology could be developed to increase both resistance and resilience. Concrete technology will have evolved to include the use of non-virgin and recycled material as ballast and the introduction of new materails such as graphene as a fibre reinforcement have taken place. The development of manufacturing techniques, rail products and alternative materials that provide greater reliability and cost efficiency from reduced wear and tear, contributing to a reduction in carbon usage, has started. Modular standardized components for simplification of upgrades and RAMS-design will also contribute to cost effective whole life cycle cost and performance.

A resillient, environmentally sustainable railway will also need to consider:-

- A greater understanding of whole system carbon impact and development of low carbon materials and processes
- LCA and LCC for accurate assessment of different renewal and maintenance options and choice of new concepts
- Reduced environmental impact, e.g. include noise and vibration in early design stages
- Explore possibilities to reduce virgin materials
- Recycling strategies and reduced use of black listed materials and minimised waste & industrial by-products.
- Climate change and climate resilence – through adaptable, automated and weather resilient structures offering real time observation e.g. hydrophobic materials and treatments
- Lower maintenance costs, free from from earthworks failures with longer asset life and a reduction in the impact of climate change (extreme weather conditions) on the network
- Energy transfer
- Intelligent structures for energy harvesting
- Design to avoid energy use

[34] BIM – Building Information Modelling. BIM is not an IT-project. It is a way of working and relating information.

[35] DFMA – Design For Manufacturing and Assembly

Maintenance of existing infrastructure is vital for infrastructure managers. Not only does it have to be within the available funds, it also has to be carried out smoothly, not disturbing the rail transport system. Maintenance is driven by inspection / monitoring, planning, decision support and intervention.

Zero intrusive maintenance and thorough Root-Cause-Analysis, right first time diagnosis and fix of problems are essential to achieve network capacity at a cost effective level. Keeping the infrastructure operational as long as possible becomes a key activity. Life-time extension of existing infrastructure is perhaps one of the biggest challenges. A system problem is the varation of times of life for different components. A balanced system has assemblies made up of components with equal life spans, thus enabling a simpler and more efficient maintenance scheme.

An example from a track engineering point of view is that, innovative track designs for better geometry, reduced tamping and improved longevity, can achieve a reduction in whole-life costs associated with improved design, installation, operation and maintenance.

Controlling infrastructure condition is connected to infrastructure costs. By using non-intrusive inspection techniques, preferably via autonomous / robotics systems monitoring, RCM[36] data for maintenance decision will result in a reduction of unplanned maintenance. We forsee self-repairing structures for an incremental degree of operation and automation and robotisation of inspection and maintenance. Evidently the infrastructure of tomorrow will be designed for predictive maintenance. This will be achieved by:-

- Linking real time asset management monitoring with the traffic management system giving a greater available capacity with the existing assets and increasing asset service life at minimal costs
- More efficient, accurate monitoring of the asset to detect faults and inform decision making, building on Intelligent Infrastructure programmes will improve:-
    - durability, stability & safety
    - track foundation solutions
    - increased loading capacity
- Virtual Construction and Design (VCD) will provide methods & tools for system performance optimisation and decision support. The technology could also be used in conjunction with augmented reality both on and off site.

<u>Infrastructure based supporting systems and service</u>

[36] Remote Condition Monitoring

The demand of today and tomorrow is a 24/7 resilient railway. In addition, increased demand of reliability and maximized capacity set the boundaries for condition based intervention. The right action at the rigt time at the right place to deliver the right network availability calls for a connected infrastructure - asset management tools and methods for condition based intervention.

One way of achieving this is by the use of Smart Infrastructure, such as intelligent materials with certain material characteristics and embeded sensors / actuators *e.g.* piezo-ceramics or shape memory alloys that can be used for adaptive material systems with integrated electronics to create oposing measures and / or sense the infrastructure or component condition and also self-diagnostic structures using “materials by design”.

Other technologies include mechatronics, which may unlock new design concepts in areas such as self-adjusting switch and crossings design. Adapting intelligent rolling stock unlocks the possibility of real time infrastructure condition monitoring. All these measures aim at reducing ad hoc maintenance to increase network availability via the ability to test and evaluate new and innovative structural instrumentation techniques against known conditions and parameters.

Network flexibility will result from:

- Service levels attuned to customer expectations;
- Efficient redundancy management in case of severe disruptions caused by extreme weather events or other force majeure through real time cross mode integrated emergency management systems.

A holistic approach for system level optimisation will result from:

- A multidisciplinary approach to identify critical design drivers;
- Introducing cost as an independent design variable;
- The development of socio-economic investment models for sustainable rail infrastructure development and interoperability;
- Using infrastructure as part of societal and spatial planning for a future sustainable society;
- Use of big/open data (Internet of Things).

<u>Governance, management and finance of the infrastructure</u>

An obvious goal is low-cost solutions. However, low-cost is not equal to low quality, it should be read as affordable for society. These solutions may not be the cheapest initial purchase price, so consideration needs to be given to incentivise the adoption of whole life cost and sustainable solutions. Such a goal can be achieved by revisiting the construction & procurement process and introduce cost management processes such as target costing, where early cost planning and supplier involvement, minimization of total

cost of ownership, and value-chain analysis are conducted. To support these changes it is vital to understand underlying factors that form procurement practice. Typical questions that need to be answered include:

- The influence of knowledge transfer on procurement units and on system level;
- How influence of societal and cultural normes, procurement rules, court descisions, policies, individual preferences and resource limitations governes procurement?;
- Exploring the role of organisational networks, public support functions and research to develop current procurement practice;

In short, development of contracts and finances beyond PPP[37] and BOT[38] is both required and recommended. In connection to functional requirements on new designs used in the tender process, performance based maintenance could also be explored from a contractual point of view.

Thus to understand infrastructure from a rail perspective, RTD needs to address:

- A greater understanding of whole-system energy and carbon impacts (Energy);
- Advanced manufacturing and construction concepts;
- Project delivery linked to legal & financial considerations, including digital models;
- Novel concepts and track designs beyond the conventional (ballasted and ballastless systems);
- Explore the boundaries between track and bridge;
- Increased track resilience and cost efficiency through improved / novel design and materials;
- Reduced cost, maximised track availability, improved safety of earthworks and improved safety of bridges, tunnels, structures and buildings by non-disruptive inspection and targeted timely maintenance interventions.

In the near future we need to investigate the opportunities to optimise interfaces through a differentiated railway (Whole Systems Approach) that could enhance capacity for individual routes and may offer more consistent, simplified and higher performing platform to train interfaces.

We need track and civil engineering infrastructure which achieves:

- Workforce safety improvements;
- Real-time monitoring of assets to provide early warning of potential safety impacts on train operations and to allow adequate planning time to obtain the

[37] PPP – Private Public Partnership

[38] BOT – Build Operate Transfer

optimum intervention opportunity with minimum disruption;

- Non-disruptive inspection and maintenance interventions to reduce costs and improve the safety of infrastructure assets;
- Smart modular structural systems;
- Optimised infrastructure-train interface.

We need to continue the development of decision support tools which analyse infrastructure data and improve the whole-system infrastructure reliability (Whole System Approach).

Network capacity at a system level will result from:

- Flexible real time intelligent traffic management delivering on customer expectations;
- In cab signalling and traffic management;
- Real time information in control centres of location, speed, braking and acceleration of trains for optimization of operational performance and on-time management;
- Include economic incentives and track & access charges.

A critical aspect of achieving our vision for infrastructure is to manage capacity at stations, these are addressed under other themes and include:

- The accommodation of more passengers without increasing station size. Solutions need to be identified to extend capacity without the need for larger spaces; (includes rolling stock capacity and access, route capacity, service frequency, passenger demand, car parking and multimodal options etc.);
- Understanding the changes to station design needed to cope with intensive train service patterns (includes service disruptions, special events, security etc.).

9.5 Implementation Plan

There are a number of research programmes underway across Europe including Horizon 2020 (including Shift2Rail and other themes) that consider rail technology both directly and indirectly as part of general infrastructure calls and other areas such as autonomous systems. To implement change in the railway across Europe, further thought should be given to increasing the technology readiness levels from core research to a fully implementable system or technology.

It is clear that early research has attracted significant funding, but beyond TRL[39]4 significant challenges remain. In the UK for example, the Government has initiated a number of programmes via EPSRC[40] and Innovate UK[41] (general applications) and rail specific bodies such as RIA[42] to help form partnerships between academics and industrial partners to overcome this technology level valley of death. Through VINNOVA[43], the Swedish innovation agency, a number of innovation platforms in strategic areas including transport & environment, and service & ICT have been launched, but none are rail specific. A specific target group for Innovative Small and Medium-sized Enterprises has also been formed. By tradition in Sweden, RTD cooperation is fostered through a triple helix model between the industries, academia and government agencies. From an infrastructure perspective such co-operations exist for bridges and tunnels, geotechnics and earthworks, track-structures and railway engineering in general.

Within Horizon 2020 there are also opportunities to push technology towards implementation via the Fast Track to Innovation scheme. Through the FP7 ERA-Net Plus initiative a pooled research fund on infrastructure innovation, INFRAVATION[44], has been launched. The idea is to bring innovations out to the field through higher TRL.

Ultimately the new technology will be developed sufficiently for commercial and industrial organisations to fund the implementation and roll out in to the railway system across Europe.

It is important to select standardisation areas that do not impede development. Interfaces between systems and sub systems must clearly defined, this includes modular plug&play components. Other areas for standardisation could include:

- Remote conditioning monitoring through NDT[45];
- Principles for automated maintenance;
- Self-learning principles;
- Management system for redundancy planing;
- Interface for building with modules;
- Track forms;
- Switches construction;
- New materials including rail & wheel;
- Intelligent rolling-stock;

[39] TRL – Technology Readiness Level, http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

[40] ESPRC - The Engineering and Physical Sciences Research Council , https://www.epsrc.ac.uk/

[41] https://www.gov.uk/government/organisations/innovate-uk

[42] RIA – Rail Industry Association, https://www.riagb.org.uk/

[43] http://www.vinnova.se/en/

[44] INFRAVATION – INFRAstructure innoVATION, http://infravation.net/

[45] NDT – Non Destructive Testing

- Container modules.

9.6 Visual Roadmap, milestones and deliverables overview

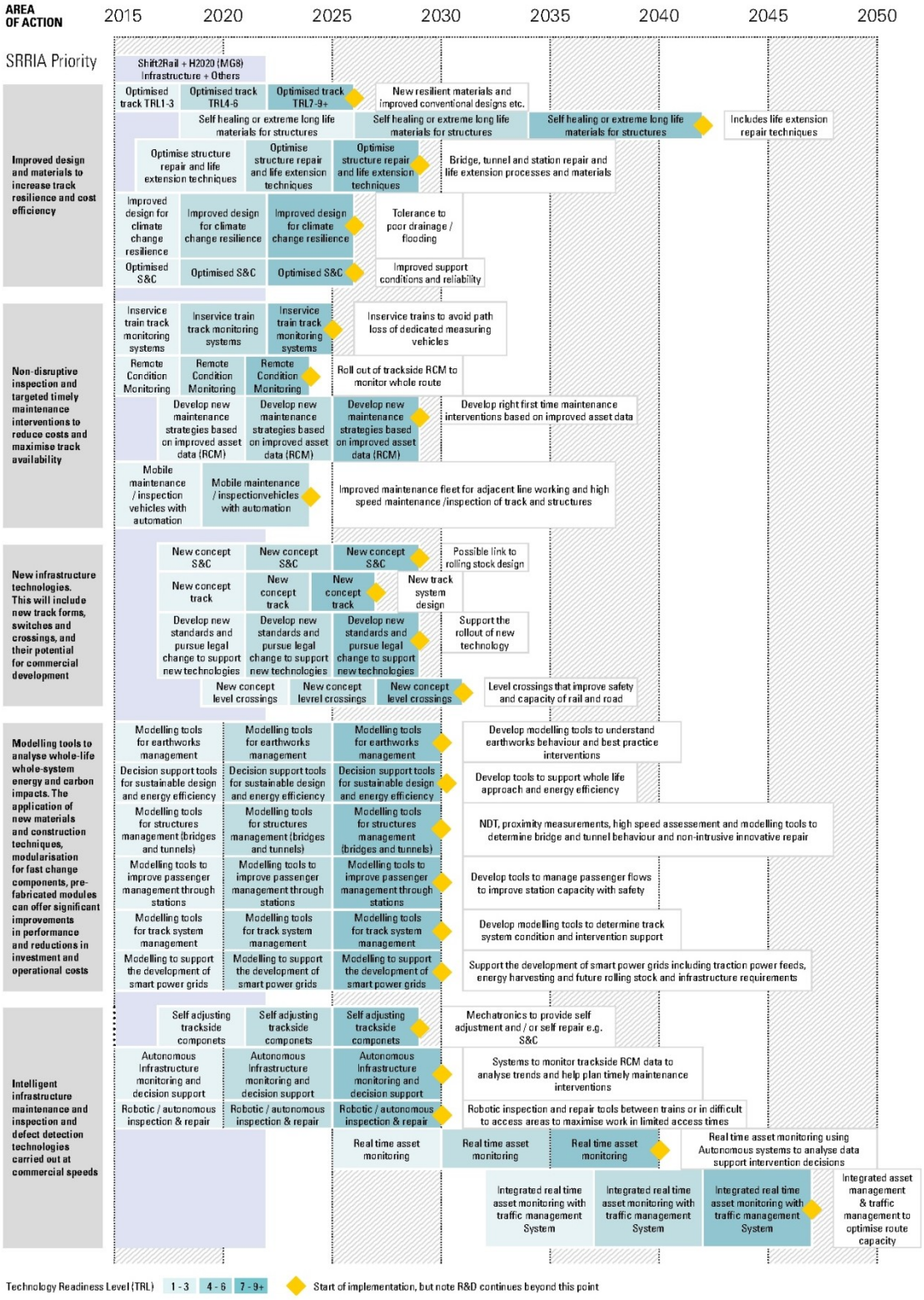

Fig. 1 - Visual Roadmap, milestone and deliverables overview

9.7 Conclusions

Infrastructure continues to be the major cost driver for the railway system. Inspection, maintenance and renewal are currently very time and labour intensive. Increasing customer demand for longer operating hours will only drive down the opportunity to gain track access, whilst the increase in capacity will drive up degradation rates, both combining to drive up cost.

New technology will be essential to correctly identify issues as they develop allowing a timely, right first time intervention to be completed at the best operational time to minimize disruption. New materials and techniques will allow for longer component life and with the introduction of autonomous and robotics we will be able to undertake inspection and maintenance between trains in complete safety for passengers and track workers.

Complete knowledge of the behavior and condition of the infrastructure will allow the maximum capacity at the best reliability and ultimately this information should integrate with the traffic management system to provide a seamless end to end journey for customers. A relevant cost effective railway is one that will survive long into the future.

Finally, the key-stone to master future maintenance and construction of rail infrastructure is a deep understanding of not only the design, development and construction phases, but the governance, management and finance of the infrastructure is equally important.

Thus to understand infrastructure from a rail perspective, RTD also needs to address:-

- The influence of knowledge transfer on procurement units and on a system level.
- The role of organisational networks, public support functions and research to develop current procurement practices.
- Contracts and finances beyond PPP and BOT.
- Project delivery linked to legal & financial considerations, including digital models.

10. Rolling stock

10.1 Introduction

The major interactions that a passenger experiences with the Railway System are with the Ticketing, the Station and the Rolling Stock (RS). RS is the “sub-system” in which a passenger spends most of his rail travel time. A large part of the attractiveness of the railway transport is based on the perception of the RS by the passenger. Thus, Rolling Stock is key for the provision of quality, accessible and reliable rail services as well as for the competitiveness of the sector.

Besides that passenger-centric thrust, the next generation of RS must meet other demands regarding the environment (reduced energy consumption and noise emission), safety (to continue to be the safest mode of transport), capacity (to cope with the increased demand for travel while offering a high level of comfort to passengers), performance & competitiveness (to become a more reliable and cost effective way of transport), interoperability (to comply with changing regulations to create the European railway system and/or to allow to dispatch a fleet among different lines of the same network, depending on the rail market segment).

Technology is what, in most cases, provides solutions to answer to those drivers.

As noted in the SRRIA, high-capacity modular rolling stock with efficient new generation braking, traction and bogie designs, use of lightweight and recyclable materials and information systems have a strong innovative potential to improve customer services and reduce life-cycle cost.

To provide attractive, affordable and quality rail services, the vision outlined by the SRRIA in this case is the following:

- Railway will be the first choice of travellers as RS will offer a high level of comfort and services and a digitally connected environment.
- Facing tougher competition from other ways of transport (e.g. buses), the cost per seat of the railway mode will decrease drastically as the fare level is one of main drivers of passenger’s choice. For example:
    - Lighter trains causing less track damage;
    - Energy efficient train operations;
    - Reduced maintenance costs.
- The drastic increase of the operational reliability of critical trains subsystems (e.g. doors and accessibility devices) resulting from targeted technical development, will deliver an overall better service to increase rail’s attractiveness for passengers.
- Reduced noise and vibration source emissions as well as the impact of remaining levels of annoyance will allow a better society acceptance.

- Reduced emission of harmful material, especially particulate matters through optimisation of operations (e.g. Vehicle braking, traction and running processes). The waste and recycling potential aspects should also be taken into consideration.
- For freight traffic, faster, flexible, lighter freight trains with improved performance enable rail to deliver the reliability (e.g. automatic brake test capability) and cost-competitiveness that are key to exploiting market segments until now largely untapped by rail or taken over by the road sector during recent years. 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.

10.2 Key issues and objectives

The priorities are:

- Offering more spacious travelling environment for passengers;
- Increasing vehicle operational reliability;
- Improving vehicle performance through enhanced braking and flexible coupling and by addressing technologies for better accessibility in order to reduce dwell times;
- Reducing vehicle life cycle costs (including procurement and retrofitting) through the combined effect of simpler and more generic and standardised architectures (including interfaces between train sub-systems), less energy consumption (e.g. more energy efficient sub-systems, lighter vehicles and higher level of braking energy recovery),cheaper and more agile certification processes and less maintenance costs;
- Environmentally friendly rolling stock with special emphasis in the reduction of the emission of noise and vibrations and mitigation of their impact;
- Extending the benefits of LCC reduction to the infrastructure through the development of track-friendly rolling stock technologies;
- New paradigms for cost efficient freight rolling stock designs with improved capacity and optimised weight and suitable functionalities for different types of freight;
- Adapting/revisiting RS standards and norms to increase the competitiveness of the railway transport system.

10.3 State of the Art and on going research and innovation within and outside rail

a. Shift²Rail

The Shift2Rail Joint Undertaking is a public-private partnership between the EC and major European rail stakeholders, with the aim of bringing about a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system.

The S2R is divided into five Innovation Programmes (IPs), each addressing a major rail area, as follows:

IP1 – Cost-efficient and reliable trains, including high capacity trains and high speed trains

IP2 – Advanced Traffic Management & Control Systems

IP3 – Cost Efficient and Reliable High Capacity Infrastructure

IP4 – IT Solutions for Attractive Railway Service

IP5 – Technologies for Sustainable and Attractive European Rail Freight

IP1 is directly linked to rolling stock, and focuses on the design of reliable, comfortable, affordable and accessible trains, in order to attract more passengers in the future while reducing system costs and enhancing interoperability.

In order to achieve these objectives, an indicative list of priority research and innovation activities has been produced, focused on:

- Train interiors: to offer a premium comfort to the passenger, including accessibility aspects, noise and vibrations.

- Doors and intelligent access systems: to speed-up safely passenger exchanges at stations and to improve operational reliability and robustness.

- Traction: new semiconductor technology to reduce weight, noise and energy consumption and to increase reliability.

- Brakes: safer and better performing brake systems with lower life cycle costs and noise levels for all weather conditions.

- Train Control and Monitoring System (TCMS): reducing the number of components, optimising the architecture and integrating safety critical functions.

- Carbody-shell: Lighter and aerodynamic carbody-shell structures, reduced life-cycle costs.

- Running gear: reduced infrastructure/wheel wear and damage as well as energy loss.

IP5 is also linked to rolling stock, on wagon design and including new bogie solutions, running gear for higher speed, lower noise, running stability, lower wear and tear, intelligent safety sensors, disc brakes, power-pack and generator aiming at reduced overall costs/high safety.

b. FP7

• CLEANER-D (2009-2013) aimed to develop, improve and integrate emissions reduction technologies for diesel locomotives and rail vehicles. The main goals of the project were to demonstrate the feasibility and the reliability in service of railway rolling stock powered with diesel engines compliant to the requirements of stage III-B of the Non-Road Mobile Machinery (NRMM) European Directive.

• EURAXLES (2010-2013) aimed to bring the risk of failure of railway axles to such a minimum level that it will no longer be considered as a significant threat to the safe operation of the European interoperable railway system.

• MARATHON (2011-2014) investigated the integration of rolling stock technologies combined with innovative operating patterns in order to provide freight services based on longer heavier and faster trains.

• TRIOTRAIN (2009-2013) was a cluster of integrated research projects which aimed at further promoting interoperability by increasing virtual certification, i.e. replacing testing by simulation and proposing a simplification of the authorisation processes through an optimised mix of field testing, mock-up testing and simulation.

• RIVAS (2011-2013) aimed to reduce the environmental impact of ground-borne vibration.

• SUSTRAIL (2011-2015) aims to contribute to a new era in increased competitiveness of the rail freight sector by adopting a holistic approach, implementing a clear methodology and viable procedures for a combined improvement in both freight vehicles and track components.

• ACOUTRAIN (2011-2014) aimed at simplifying and improving the acoustic authorization of new rolling stock by introducing virtual certification procedure, in particular relating to the TSI Noise.

• EUREMCO (2011-2014) aimed to harmonise and reduce the certification process of rail vehicles against Electromagnetic Compatibility (EMC).

• OSIRIS (2012-2015) aimed to develop Optimal Strategies to Innovate and Reduce energy consumption In urban rail Systems (OSIRIS) by implementing technological and operational solutions and tools, while testing/demonstrating/assessing their individual and combined benefits in real case scenarios.

• ECUC (2012-2016) aims to prove that linear eddy-current brake (ECB) is an effective solution for increasing the braking capacity of new high speed trains.

• REFRESCO (2013-2016) aims to reduce energy consumption of railway rolling stock through new materials such as composites and light metallic alloys, which will consume less energy and help reduce the emissions of rail transport.

c. H2020

The call “Mobility for Growth” invited proposals against the topic “New generation of rail vehicles” (MG.2.3-2014), aiming to deliver a reduction of up to 40% in life cycle costs of rolling stock products, an increase in passenger train capacity up to 15%, reductions of downtime by increased reliability (up to 50%), a reduction of energy consumption (up to 30%) and an improvement in environmental performance, whilst delivering superior performance in terms of overall service quality, safety and customer experience in rail transport.

The following topics are covered:

- Development and integration of higher-performance technologies for critical structural components.

- Traction, command-control and cabin environment applications (e.g. new materials, smart power and wireless technologies).

- Design and production solutions (e.g. modular, "commercial off-the-shelf" or adaptive concepts).
- Innovative solutions to extend vehicle lifetime.
- Technologies to ensure interoperability through better Electro-Magnetic Compatibility (EMC) between the railway vehicles and the electrical installations of the network.
- Development of innovative, modular and customisable solutions for comfortable and attractive train interiors.

ROLL2RAIL (2015-2017): ROLL2RAIL aims to develop key technologies and to remove already identified blocking points for radical innovation in the field of railway vehicles as part of a longer term strategy to revolutionise the rolling stock for the future. In particular, Roll2Rail focuses on technological innovations in different subsystems of the vehicles which, each and all together contribute to achieve the desired impact at vehicle level and whole railway system level improving capacity, reliability, efficiency, comfort and LCC. The project expects innovations in 8 different areas such as traction and power electronics, train communications, car bodyshell, running gear technologies, brakes, train interiors, noise and vibration and energy performance.

d. National research

Austria

The research Projekt “eHybridlok” focuses on the development of an e-hybrid locomotive. For trips without an overhead cable, a hybrid shunting locomotive will be powered by a battery pack or with hydrogen, with both systems to be recharged when operating with the overhead cable. Energy and maintenance, costs, noise and exhaust fumes should all be significantly reduced.

France

The research project “Mimosa” focused on the development of new aero-acoustic methods for high-speed train noise prediction.

5.5 Relevant Research & Technologies outside rail

- Use of composite materials, already common in the aeronautic and the wind power sectors.
- Nanotechnologies
- Alternative propulsion energy sources, including hydrogen and natural gas
- Multi-senses vehicles – innovative solutions for people with mobility impairment
- IT-related developments

10.4 The Roadmap

The priority topics identified by the previous ERRAC roadmaps had been reallocated according to the new SRRIA Roadmap titles.

Below is an outline of the main topics for the “Rolling Stock Roadmap”, structured according to a number of sub-themes. In the case of rolling stock some overlaps exist, especially with the “Customer experience” roadmap as well as with the “Energy and environment”, “Safety” and “Strategy and economics”.

The indicative timeline of these research proposals is also indicated between brackets.

• Offering more spacious travelling environment for passengers

- Adaptive interiors configuration for different types of passengers (family activities, mobile office and group travel) and constant evolution (time scale of week, season and society) of the demand (Medium Term)
- Improvement of interior acoustic comfort for passengers (Medium & Long term)

•Increasing vehicle operational reliability

- New more reliable components and technologies (Medium &Long Term);
- More reliable architectures for key sub-systems (Medium Term);
- PHM (prognostic and health management) system (Short& Medium Term);
- Research in condition-based maintenance regimes (Short& Medium Term).

• Improving vehicle performance

- Advanced braking (Medium &Long Term);
-Flexible coupling between consists (Medium &Long Term);
-Better accessibility to reduce dwell times (Medium &Long Term)**.**

• Reducing vehicle life cycle costs (including procurement and retrofitting) through the combined effect of simpler and more generic and standardised architectures (including interfaces between train sub-systems), less energy consumption (e.g. more energy efficient sub-systems, lighter vehicles and higher level of braking energy recovery),cheaper and more agile certification processes and less maintenance costs. The obsolescence/life cycle of certain RS parts is also included:

- Hybrid Traction: Multiple power sources including energy storage on-board (Medium Term).
- EE Auxiliaries - Optimisation and development of intelligent management auxiliaries (Short Term).
- Future generation of power semi-conductors beyond SIC (Silicon carbide) e.g. diamond (Long Term).

- Innovative Propulsion - Implementation of hydrogen fuel cell of RAMS/LCC incl. the aspect of hydrogen production & storage (Long Term).

- Energy and Environment - environmental friendly and energy efficient HVAC (Short and Medium Term).

• Environmentally friendly rolling stock with special emphasis in the reduction of the emission of noise and vibrations and mitigation of their impact:

- Improved prediction methods and design solutions to reduce aero acoustics noise of high speed trains (Medium Term).

- Reduction of N&V annoyance towards exterior (Medium & Long term).

• Extending the benefits of LCC reduction to the infrastructure through the development of track-friendly rolling stock technologies.

• New paradigms for cost efficient freight rolling stock designs with improved capacity and optimised weight and suitable functionalities for different types of freight:

- General wagon issues - Modern wagon concepts with low noise, track friendly and more reliable bogies. Increased speed capability with no increased track attrition. Incentivisation of track friendly equipment (Medium Term).

-Freight and Urban Mobility: Interfaces and complementarities: New techniques and vehicles for urban freight delivery (Medium & Long Term).

•Urban, Suburban and Regional

- Competitiveness and enabling technologies - innovative constituents increasing RAMS whilst decreasing LCC (Short & Medium Term).

- Competitiveness and enabling technologies - Tram-train (Medium & Long Term).

- Competitiveness and enabling technologies - Innovative design, devices and constituents (Medium & Long Term).

- Research in condition-based maintenance regimes (Short & Medium Term).

Adapting/revisiting RS standards and norms to increase the competitiveness of the railway transport system.

- Energy and Environment - Eco-procurement specifications and harmonisation (Medium Term) allowing e.g. for easier recycling of materials.

- Eco-design label for rolling stock - Based on key criteria covering significant environmental aspects: Energy-CO2, Materials, Noise (Medium Term).

- Pursuing virtualization of certification/homologation (Medium Term).

Improving Safety and Security

- Safety - Train collisions preventions and effects mitigation (active and passive safety) (Medium Term).
- Safety – Enhanced vehicle preventive maintenance (short and medium-term).

10.5 Implementation Plan

a. SHIFT²RAIL

The Shift2Rail Joint Undertaking is a public-private partnership between the European Commission and major European rail stakeholders, with the aim of bringing about a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system.

The S2R is divided into five Innovation Programmes (IPs), each addressing a major rail area, as follows:

IP1 – Cost-efficient and reliable trains, including high capacity trains and high speed trains

IP2 – Advanced Traffic Management & Control Systems

IP3 – Cost Efficient and Reliable High Capacity Infrastructure

IP4 – IT Solutions for Attractive Railway Service

IP5 – Technologies for Sustainable and Attractive European Rail Freight

IP1 is directly linked to the Rolling Stock topics and has the following objectives:

1. Increase the physical capacity of vehicles and promote the enhancement of transport capacity of railway lines.
2. Reduce the travel disruptions for passengers by increasing operational reliability and availability of vehicles, either through the use of fundamentally more reliable components or system/subsystem architectures.
3. Reduce life cycle cost of the vehicle (reduction of maintenance, energy consumption …) and of other subsystems interfacing with the vehicle (reduction of track damage …).
4. Increase energy efficiency of the vehicle and reduce vehicle mass.

In order to achieve these objectives, seven research and innovation topics have been produced focused on:

- Traction Systems;
- Train Control and Monitoring System;
- Carbody Shell;
- Running Gear;
- Brake Systems;

- Doors and Access Systems;
- Train Modularity In Use.

b. H2020

H2020 does not plan any others opportunities that Shift2Rail to implement the research activities described in the Rolling Stock Roadmap. However ERRAC expects that some H2020 funding (not allocated to Shift2Rail) will also be planned for Rail Rolling Research in the next H2020 calls.

c. Other public funding programs

EU-Level Funding.

Concerning R&I, as already mentioned in the clause above, another specific source of funding is the EU programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME), which supports SMEs for: access to finance in the form of equity and debt, access to markets, framework conditions for the competitiveness and sustainability of Union enterprises, etc.

The ERA-NET scheme[46], created to develop and strengthen the coordination of national and regional research programmes, is also to be considered.

The other EU main direct funding sources, which can be accessed directly and indirectly for R&I are the European Structural and Investment Funds[47]:

- The European Regional Development Fund (ERDF)[48], which aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions. The ERDF focuses its investments on 4 key thematic priorities: innovation and research; the digital agenda; support for small and medium-sized enterprises (SMEs); the low-carbon economy. It is the most important EU fund that support R&I. ERDF will manage the bulk of R&I funding.
- The Cohesion Fund[49], aiming to reduce economic and social disparities and to promote sustainable development. It is supporting the 'Connecting Europe Facility'. Moreover, a significant part can be allocated to general environmental activities: energy efficiency, developing rail transport, supporting intermodality, strengthening public transport, etc. Rail stakeholders can use part of these funds for transport-related research, but this also depends both on the national legal framework and the future EU-related developments in the field of research funding.

[46] http://cordis.europa.eu/fp7/coordination/about-era_en.html

[47] http://ec.europa.eu/regional_policy/thefunds/index_en.cfm

[48] http://ec.europa.eu/regional_policy/thefunds/regional/index_en.cfm

[49] http://ec.europa.eu/regional_policy/thefunds/cohesion/index_en.cfm

Furthermore, there are EU grants in support of projects or organisations which further the interests of the EU, or contribute to the implementation of an EU programme or policy[50].

The state funding comes in two major channels: the various national and/or regional schemes that support R&D&I development and the involvement of foreign states (or state-owned organizations) in major research activities through: loans, grants, capital market investments, etc. A lot of research in the rolling stock field is currently funded with the help of national programmes.

There is also a specific category of public funds available for R&I, the source being the generically termed IFIs (International Financial Institutions) whose owners and/or shareholders are generally national governments.

The most important is the European Investment Bank (EIB)[51]. The aim of this bank is to offer favourable lending and other types of financial support to a number of projects, mostly in the EU. The lending is mostly done in order to enhance the implementation of EU policies and goals. Innovation and transport are among the bank's two main targets.

Another institution is the European bank for Reconstruction and Development (EBRD)[52] which also supports different sectors through lending, other financial mechanisms, counselling, etc. The bank has been created to support the former Communist countries in their transition, hence its funds are (mostly) available to CEE EU members. The EBRD is involved in supporting ICT, transport & infrastructure and general manufacturing.

Both EIB and EBRD have widely supported the acquisition of rolling stock (urban rail regional and suburban, mainline) in European countries – both within and outside the EU.

Of the IFIs at the wider international level, the best example is the World Bank Group[53] which through its different branches, supports, finances and advises different projects, reforms, funding schemes, etc.

d. Private funding possibilities

The main methods to obtain private funding for rail R&I (in addition to those pledged by the already-involved stakeholders) are the following:

- other private companies that wish to enter the market;
- public-private partnerships (PPPs) for major and expensive research topics;
- loans from banks;
- drawing funds from the capital markets (either from private companies or PPPs) for major projects;

[50] http://ec.europa.eu/contracts_grants/grants_en.htm
[51] http://www.eib.org/about/index.htm
[52] http://www.ebrd.com/home
[53] http://www.worldbank.org/en/about

- private equity investors in major companies or major research projects.

Even though the rail environment generally does not offer high returns of investment in a short period of time, these developments are becoming attractive for these sources of private funding, due to the increasing effort put into this topic. Rolling stock developments (and investments) are one of the more profitable and appealing rail market segments for investments, due to:

- the new technologies on the market (HSR, ERTMS, CBTC, new light rail and tram-train systems, etc.);
- the increase in ridership demand (mostly urban, suburban and regional market segments);
- the need to replace obsolete fleets with more modern, comfortable, safe, secure and appealing products;
- the fact that rolling stock generally represents the most 'attractive' part of the rail (technical) environment.

Nevertheless this is a topic where the rail sector clearly needs to put more effort into developing the right solutions for both urban and mainline rail sectors – and solutions that could fit both domains. It is also one of the sectors where rail can rely extensively on the 'support' of other domains. Rolling stock manufacturers should thus be able to pick the most convenient 'low hanging fruit' from numerous other sectors (e.g. automotive aeronautics, IT, new materials, etc.). Consequently, the needs have to be addressed by the sectors stakeholders while learning and adapting/integrating solutions from other domains, including through partnerships and other associative forms. It is one of the few sectors in the rail field where the stakeholders should, in certain aspects, allow other domains to progress and then adapt the results, thus saving a significant amount of time and resources.

Given the fact that these assets are ultimately key tools for many of the rail sectors' business cases, all these developments need to be ready to interact with the tools and systems of other stakeholders and business partners. There is a need to ensure a certain openness of some systems and the development/use different adaptable technical solutions, in order to enable a real "plug-and-play" offer – especially for the customers (both individual and companies).

10.6 Visual Roadmap, milestones and deliverables overview

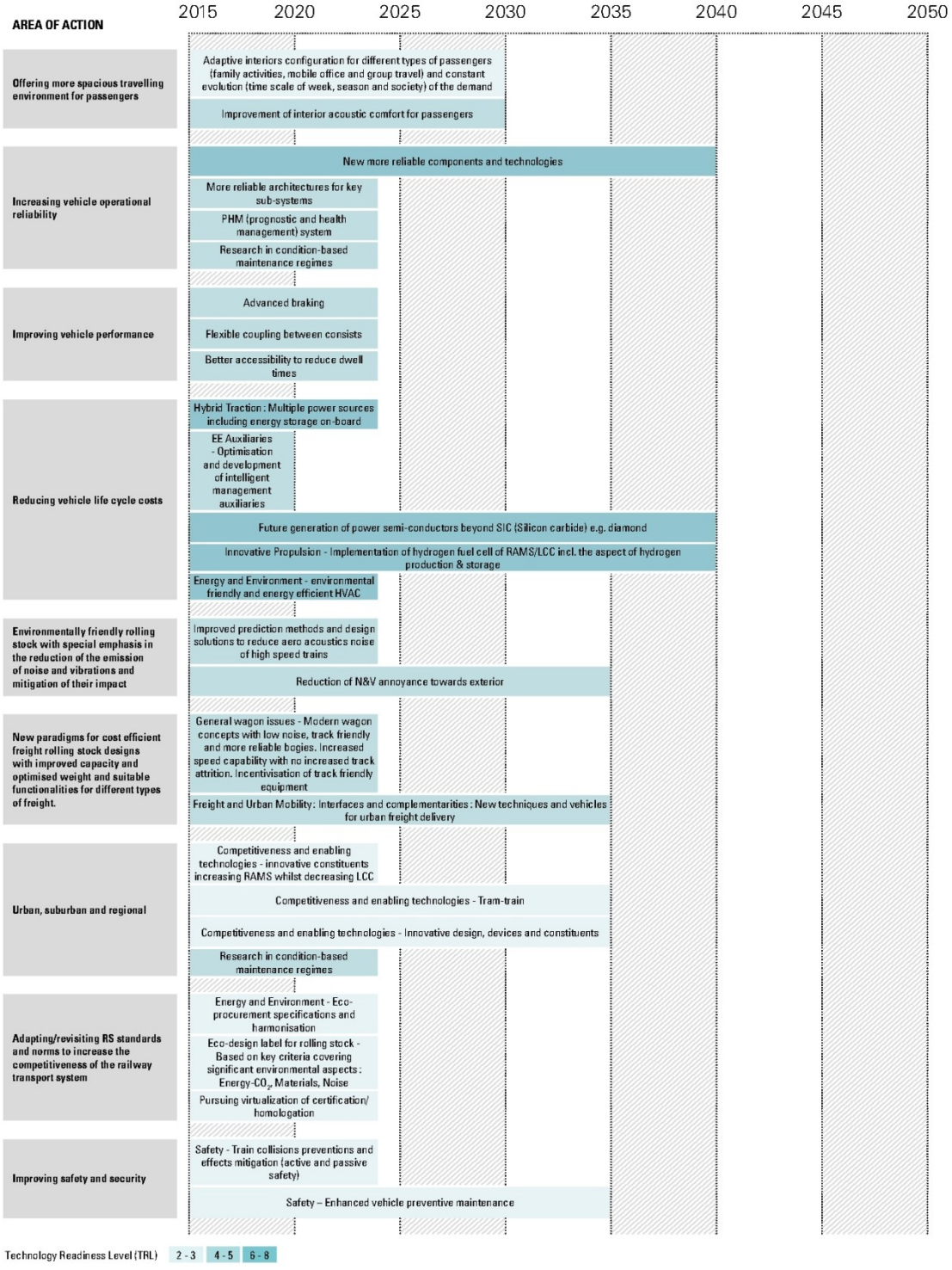

Fig. 1 - Visual Roadmap, milestone and deliverables overview

10.7 Conclusions

Key main drivers have been identified for establishing the Rolling Stock Roadmap.
The passenger/user driver is the attractiveness of rail travel for passengers and goods to offer a high level of comfort and services in a fully digitally connected environment so that the rail way of transport becomes the first choice.

Rolling Stocks offering adaptative interiors configurations in a low noise environment along with increased operational reliability (more efficient Prognostic and Health Management processes; more reliable components and sub-systems based on emerging new technologies) are key to increase the attractiveness of rail transport system. As travel fare is an essential component of travel choice, the reduction of vehicle life cycle costs (less energy consumption; simpler and more generic and standardized architecture; less costly and more agile certification processes; efficient maintenance) is of paramount importance. This applies to new build as well as to retrofit of RS.

With the foreseen increase of travel demand, the Railway infrastructure will have to operate more trains. For a better society acceptance of rail operations, the environmental footprint has to be decreased, especially the reduction of noise and vibrations but also in terms of more energy efficient trains that are a component of the overall railway energy intragrid.

Some of the topics identified in this Roadmap are going to be tackled by SHIFT2RAIL but not all, especially those with a longer prospective i.e. beyong 10 years. For example, the future generation of power seconductors beyond the Silicon Carbide technology (diamond), energy solutions from a hydrogen society, etc…

Adapting/revisiting RS standards and norms will be a continuous quest to decrease acquisition cost of RS in order to increase the competitiveness of the rail transport. This is covering eco-procurement specifications and harmonization, eco-deisgn label and, not the least, pursuing virtualisation of certification/homlogation.

11. IT and other enabling technologies

11.1 Introduction

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 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: its absolute commitment to safety, 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 technological and organisational arrangements maximising capacity on busy corridors and improving the railway system using the new possibilities given by the "railways digitalisation" or "IT and other enabling technologies", the priorities are:

- More realtime resilient, adaptative and available railway system components, leading to a highly performant system which is a prerequisite for the development of track capacity and network performances; business continuity, optimised by IT based real-time traffic management, maximising capacity, conserving energy and minimising inconvenience to the passenger and the freight user; reduction of in-service failure.
- IT innovations foster highly adaptative and (semi)automated railway operation and technical support, including vehicle and infrastructure, as for operation that for condition monitoring and maintenance, thereby enhancing system resilience, including facing cyber attacks from different origins, reliability and cost efficiency and improving customer service.
- Digitalisation and IT innovation technologies will lead for the railways, IM's, RU's and suppliers to a major Culture change in order to operate the railway, to maintain a safe, secure and available traffic, to promote continued improvement of every aspect of the passenger's trip and of the freight shipper's experience along the supply chain.

Of course, the digitalisation, IT and other enabling technologies is closely linked to the cluster on the attractiveness of rail and public transport, since one of its key goals is to improve the quality of the passengers' door-to-door journey. It is also linked, to a lesser extent, to capacity and competitiveness, as well as control, command, communications and signaling, when it comes to ensuring reliability and punctuality.

Rail is a very fragmented sector where the life cycle of the products and equipments is very long, several decades for most of them. The diffusion of IT and enabling technologies is still at the very beginning and sometimes slower than in other transport sectors. But things are moving, and passengers, always connected, more and more demanding in terms of real time information and support, in-time capacity of choice and tailored services, but at the same time also asking for more reliability, punctuality, resilience and flexibility, will impose similar IT standards to the rail sector.

The vision outlined by the SRRIA is the following:

- Rail embraces all technologies that enable new forms of information and communication. It encourages the design and use of interoperable systems architectures taking into account the railway specificities (safety, security, especially for signaling linked functions) and the integration of information systems throughout Europe. This helps to manage large volumes of data over the life of assets.
- The railways have to define a co-ordinated approach to the standardization and the management of the information needed to run and maintain the operational railway system. The inter-connected signaling systems, on board and in the ground, will give the possibility that trains are traced and tracked in real-time through all stages of transit, whatever the mode. The web of transportation things connects all the assets, allowing much better monitoring of the whole rail system, with preventive and predictive maintenance and flexible adaptation of the different components. Freight is traced, tracked and monitored 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 and personalised information keeps the passenger abreast of the varying alternatives, including inter-connection with other modes, should journey problems arise.

It could be extended with the additional main trends:

- The continuous increase of computing power due to parallel computing, cloud computing, and new programming paradigms is offering new opportunities for real time monitoring and control of the whole rail system.
- The real time localization of travelers, assets and goods, while repsecting the relevant regulatory framework, s allowing better prediction, more reliability, and a better adaptation between the offer and the demand sides. Galileo and/or Egnos systems are also providing additional features (e.g. PRS and Safety of life services), allowing the use of satellite positioning for safety critical train functions.
- Significant progresses are made especially in the field of mobile applications, and smart devices and wearables are massively adopted by travellers for communicating, gaming, audio/video media and web browsing during journeys. Improvement of the traveller experience is coming from new applications and services, exploiting all the potential of man-machine interfaces, mixed realities, smart devices, ambient

intelligence, big-data and cloud computing, geo-positioning, environment sensing (including through crowd sourcing, social networks, and the ubiquitous 'web of things') and others.

- Information technology is bringing a general shift from hardware to software, providing more complex functions, and a new balance and more flexibility between local and remote intelligence: more computing power in the sensors displaying only relevant information, more complex signaling automatic systems and at the same time, huge back office computing power, often cloud based, reducing the complexity of on site equipments. With improved data interoperability, big-data, linked data and business analytics are gaining insights that inform business decisions and can be used to automate and optimise business processes.

Following this vision, and taking into account the maturity of the technologies as well as the characteristics of the sector, we can highlight some priorities:

- Adopting architectures which allow the easy adoption of new technologies with stable rules for functional requirement layers (IT should be a technical enabler for interoperable systems but should remain independent of the business rules);
- Selecting IT technologies which allow interoperable services whilst limiting impacts on existing systems, without prerequisites for further standardization (e.g. semantics web and linked data technologies);
- Defining 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;
- Introducing new technologies to manage the transmission, capture, storage and communication from new sources such as sensors, video cameras, tablets and other personal devices;
- Capability of generating knowledge from data through data mining and analytics tools;
- Guaranteeing the necessary security level when managing sensible information (personal or from organization): data protection and security should be assured;
- Increasing computing performances for real time train control and traffic management systems, fully integrated with traffic related source of information (i.e. maintenance, trains, asset status);
- Targeting an integrated mobility management, thanks to accessible and interoperable data sets, which allows covering the operational and maintenance systems for Infrastructure Managers and Railways Undertakings including urban transport and city logistics.

Finally, there must be a level playing field between the different transport modes (rail, air, bus) and one must anticipate the impacts of other innovative transport modes such as car-sharing and autonomous vehicles and soft transport modes. The economical balance of

local, regional or long distance public transport systems is going to be threatened in the short or mid-term. Moreover the costs linked to rail interoperability obligations may jeopardize competiveness of certain transport modes compared to those that do not have such obligations but are real mobility alternatives for passengers.

11.2 Key issues and objectives

The main drivers are interoperability, improved customer experience and seamless access of services, and increased knowledge of the system status for better reliability and flexibility:

- Foster interoperability within rail (all the segments), but also with other transport modes, without further standardization, while preserving the legacy systems;
- Supply to the end-users an instantaneous access to services. The new paradigm which is expected by the travellers is that the travel experience is the product, and IT technologies should mask the complexity of the transport ecosystem;
- Develop a better knowledge and optimize the rail business rules thanks to the digitalisation of the rail sector resulting in huge amount of heterogeneous data;
- Develop new or improved services thanks to big data and linked data (e.g. from standard maintenance to preventive and predictive maintenance; new travelers' management patterns, etc…);
- Foster highly adaptative and (semi)automated railway operation and technical support, including vehicle and infrastructure, for operation and maintenance;
- Use a reliable live tracking and monitoring system for freight, including inter-connection with other modes (the whole logistic chain is necessary to be covered), and enhancing the safety in freight transportation;
- Improve customer experience through the implementation of new services addressing all aspects of the travel whatever the mode of transport, including the possibility of ancilliary services;
- Improve the transport offer with business analytics providing personal feedback on preferences and behavior of customers and also on arising events affecting travel plans and on acceptability of the solutions offered;
- Contribute to the development and implementation of active infrastructures and smart vehicles/rolling stocks (V2V, V2G and V2H), thus making a link with the electrification of the road sector and at the same time putting rail at the core of the electrification (land) transport trend.

11.3 State of the Art and on going research and innovation within and outside rail

"IT and enabling technologies" is a very broad and fuzzy theme, drived by new life paradigms - people are increasingly nomade and always connected - and fast moving technologies - communication (4G+; 5G), internet, data management (big data, linked data, business analytics), augmented reality, positioning systems, etc.

The increase need of reliability and the societal demand coming from the end-users make the adoption of these technologies absolutely vital for the future of the rail sector.

Concerning the usage of these technologies in the rail sector, the most ambitious and clear initiative is certainly Shift2Rail, the now running public-private partnership between EC and major European rail stakeholders, which aims to bring modal shift in order to achieve a more competitive and resource-efficient European transport system.

Shift2Rail is divided into five Innovation Programmes (IPs), each addressing a major rail area.

IP4 (IT Solutions for Attractive Railway Services) is directly linked to the theme ”IT and other enabling technologies”, and focuses on the need to achieve a full seamless multimodal travel experience, where the customers must be able to easily plan and purchase door-to-door journeys through ticketless and multi-application solutions that guarantee interconnectivity no matter where the traveller roams.

The innovation activities proposed by this IP4 are based in three broad topics:

- Technical framework: identify, formalise and document requirements and solution engineering specifications for interoperability using unambiguous semantic web technologies and open architecture and standard service interfaces.
- Customer experience applications: develop secured customer experience applications including customer preferences, itineraries, preselected payment means, and giving access to additional services such as en-route assistance and re-acommodation, guidance to PRMs or passenger right information, by exploiting the potential of new man-machine interfaces and increasing the interaction between the traveler and the rail system.
- Multimodal travel services: develop one-stop-shop solutions and applications for multi-modal shopping and ticketing enabling integrated door-to-door itineraries.

IP5, addressing the freight is also linked to this IT-topic and other enabling technologies.

The innovation activities proposed by this IP include Cargo Tracker and other IT solutions related to Integrated Mobility Management. The IT and enabling technologies focus mainly on Access and Operation:

- Collection and processing of combinations of different transport chains for individual transport units (“door to door planning system”)
- Combination of border crossing train path allocation and slots, including "codesharing" of train paths, e.g. by long trains
- Provision of real time data
- Improvement of the interoperability and maintained safety, reducing barriers to interoperability and preventing safety from being misused for discrimination of RUs
- Promotion of market opening
- Creation of incentives for product innovation and service quality networks
- Vitalisation of the wagon load market
- Sharing of train and marshaling yards capacity

IP2, addressing “Signaling” is also linked to this IT and other enabling technologies topic, mainly through: GNSS positioning, new Traffic Management System (based on data access and data management), and new communications systems.

And this is also true for IP3 (Infrastructure), where maintenance, also based on data access and data management, is extensively addressed, and IP1 with TCMS (Train Control management system, with new IT architecture, secure access to data, and wireless communication).

Very closely linked with Shift2Rail, we can also mention the H2020 lighthouse projects currently running: IT2RAIL project answering to the call “Mobility for Growth” against the topic “Smart Rail Services” (MG.2.2-2014), aiming at conceiving and prototyping an on-line, mobile, suite of integrated facilities providing a whole new traveller experience throughout the journey. This project is developed by some of the partners of Shift2Rail IP4 and addresses the same vision and strategy (in a reduced scope), providing the first results that should be further developed in Shift2Rail.

Another lighthouse project, IN2RAIL is against the topic “I²I – Intelligent Infrastructure” (MG.2.1-2014). One of the objective is to reconcile business and operational requirements (namely customer service, capacity, speed, timekeeping, energy, asset management) with real-time field and asset condition monitoring and intelligent traffic planning (including cross-border), to deliver normal or near-normal services during all but the most exceptional circumstances, with a view to ensuring a minimum impact on services delivered. The Roll2Rail project aims to develop key technologies and to remove identified blocking points for innovation in the field of railway vehicles/rolling stock of the future. All the results will be further developed, leading to demonstration into Shift2Rail IP1.

But there is also some older FP7 transport initiatives and projects which contributed of the IT new trends:

- CREAM (2007-2011) and TIGER/TIGER DEMO (2009-2013) aimed at providing a set of tools (telematics like GPS NavMaster, IT systems like Train Monitor) to improve freight transport by integrating a consistent, interoperable mix of technologies and processes from risk assessment to full scale implementations.
- IFM (2008-2010) aimed to make public transport more user-friendly by facilitating seamless accessibility to different public transport networks, providing travellers with common styles of contact-less cards which can be used for multiple transport products in different European geographic areas and for sustainable modal switching.
- INTERCONNECT (2009-2011) aimed at reducing the environmental impact of passenger transport by encouragement of integration, co-operation and, where appropriate, competition in the provision of local connections, paying attention to land, air and maritime modes. The range and applicability of specified solutions, which were tested in the project case studies, made use of policy measures like integrated pricing and ticketing, improved links and interchanges, infrastructure pricing, strategic planning, information and marketing.
- SECUR-ED (2011-2014) aimed at providing a set of tools to improve urban transport security by integrating a consistent, interoperable mix of technologies and processes from risk assessment to complete training packages.

It should also be noted that the sector has been working on interoperability solutions on a voluntary basis for several years. FSM (Full Service Model) is an industry initiative (RU, GDS, Traveling agencies) aiming at defining technical specifications allowing interoperable distribution systems for the European railways. Similarly, the Smart Ticketing Alliance (STA) gathers representatives from

several European ticketing standards (especially ITSO, VDV-KA and Calypso), working on the best way to ensure interoperability between the different ticketing standards.

UIC has edited some vision papers directly linked to this theme of IT and other enabling technologies. In complementarity and in coherence with the previous research actions, UIC has directed and/or realized many research programs directly linked to this theme of IT and other enabling technologies, focusing on the need to improve the performance of the raiway services, especially the traffic capacity, the asset management, the safety and the security aspects. A short list of the recent or on going projects:

- SATLOC: definition and realization of an ERTMS level 3 based on satellite localization (GPS and GNSS…), industrial computerized units (SIL2), virtual balises, and innovative communication links. The system will be soon in operation in Roumania;

- Lowcost ERTMS for regional lines: demonstration line in Sweden, the final functional requirement will be soon exhaustively formalized;

- ARGUS: analyse of the security issues introcuced by the use of IT network linked with IT critical signaling systems.

- SECRET: analyse the possibilities of the electromagnetic perturbation or intrusion into IT signaling systems and/or IP telecommincations links

- SMILE: definition of the functional and physical generic interface between an existing interlocking and an ERTMS Level 2 or Level 3 RBC.

- ETCS technical Feedback: realization of a confidential and technical feedback with railways having ERTMS line in operation, from the design to the in operation and maintenance status;

- FRMCS: formal and generic definition of the future radio radio link for ERTMS equipements;

- Balance between Maintenance and Renewal for signaling system (IT system especially);

- Detection of broken-rail with detecting trains by innovative IT systems;

- Detection, localization, speed measurement by IT innovative TC…

IT is a transversal topic, and many initiatives developed in other areas may have direct applications in the rail sector:

- GNSS (Galileo): satellite-based services as a cost-efficient way for Train Control Systems and en-route assistance services
- Advanced IT, namely big data processing and analytics, which provides new tools which can be applied in the transport sector.
- Web technologies, allowing access to functions considered as services.
- New Communications Technologies (e.g. RFID)
- Internet of things
- Enhanced reality and HMI
- Innovative solutions for people with mobility impairment
- Etc…

11.4 The Roadmap

The priority topics identified by the previous ERRAC roadmaps had been reallocated according to the new SRRIA Roadmap titles.

Below is an outline of the main topics for the “IT and other enabling technologies Roadmap”, structured according to a number of sub-themes. In the case of this theme some overlaps exist, especially with the “Control, command, communication” roadmap as well as with the “Customer experience” and “Strategy and economics”.

The indicative timeline of these research proposals is also indicated between brackets.

- T0 = It has been already covered.
- T1 = Immediate.
- T2 = 2015
- T3 = 2020
- T4 = 2030
- T5 = 2050

Freight:

- Intelligent traffic management - Introduction of new intelligent management systems capable of optimizing the use of the existing infrastructure (T0-T3 / Part of Shift2Rail IP2 & IP5);
- Intelligent traffic management - ERTMS level 2 and 3 - implementation of low cost compatible solutions for freight trains (T0-T3);
- Freight waggon telematics (T0 / Partly part of Shift2Rail IP5, after the start of Shift2Rail it can be checked which topics have to be handled in follow up programmes as they could not be handled in Shift2Rail due to budget limitations). e.g. Single wagons - Tagging standardisation (RFID) of wagons telematics (small specific topic);
- Automation – prerequisites for automated loading-/unloading of waggons (respective installations on waggons, planning & controlling systems) and/or automated coupling-/de-coupling, automated controls/train ready messages) (T0 / due to budget limitations only minor part in Shift2Rail IP5 / rest T2-4);
- Logistic services - Rapid reaction to queries - response time to enquiries in terms of service availability, routes, schedules, pre and end haulage satisfying customer demands (T0 / Part of Shift2Rail IP5);
- Fleet Management - Reduction of empty running and repositioning of equipment (T0);
- Fleet Management - Open standard rail freight management of ICT packages compatible with other operators - enabler of train planning and collaborative approach (T0-T2);

Passenger:

- Development of a digital interoperability framework – based on web semantics technologies, it allows the decoupling of interoperability mechanisms from the application layers, and is a key condition to foster multimodal interoperability without further standardization (T2-T3, part of Shift2Rail IP4);
- EU wide deployment of a multimodal interoperability framework (T4);

- Seamless multimodal travel experience - Harmonization of shopping, booking, ticketing and travel information, ticketless journeys (EU level) interoperable with local transport fare management systems (T0-T3, part of Shift2Rail IP4);
- Passenger Experience - Enhanced access to all travel services and ancilliary experiences, including shopping/booking/ticketing, but also information, en-route assistance and re-acommodation, trip-tracking, and additional services related to the journey. (T0-T3, part of Shift2Rail/IP4);
- Development of business analytics tools for a better use of traveller' journeys information in order to adapt the offer and the demand (T0-T3, part of Shift2Rail/IP4);
- Improving traffic mobility management. Disruption and recovery management, on-demand/offer (T3-T4).

Main line:

- ERTMS-level 3 fully implemented on core axis (TEN-T) - Development and implementation of processes and ICT tools for time tabling and operational traffic management (T0-T5);
- GNSS used as positioning system fully compatible with ETCS (T3-T5);
- Signaling in the cloud, with limited ground equipments: the train knows (GNSS or other sensors) its position, communicate it to the ground, and the train movement is controlled remotely thanks to an overall traffic management system (T5).

Urban Mobility:

- Freight and Urban Mobility: Interfaces and complementariness - New city-logistic concepts (T0 – T4);
- Integrated Urban Mobility Systems and Governance;
- Interoperable ticketing, traffic and travel information: governance aspects and interoperable innovative technologies, tools and products (T3 – T4);
- Innovative technologies, tools and products - Interchangeable and/or interoperable innovative technologies, tools and products, for traffic and travel information (T0 - T4);
- Integration of ticketing and charging services:
    - Interoperability for customers through multi-applications on a single support: create a Pilot operation in a number of Member States in preparation for wider roll-out (T3);
    - Develop a Common EU portal and Common Product Templates supporting an extension of the "IFM Brand" (T2-T3);
    - Create a common EU-IFM application (T2-T3), and develop a commercial and technical framework for the sales and settlement of EU-IFM Products (T3);
    - Extend functionalities to facilitate inter-modality and Demand Management (T1);
    - Engage and merge with existing IFM Systems and other ITS services and transport modes (T0-T2);
    - Engage with applications for electromobility related services (T3);
    - Security and privacy framework for contactless payment (T3);
    - (New) charging and pricing policies strategies (T2-T3);

Urban, Suburban and Regional Rail:

- Competitiveness and enabling technologies - Innovative ITS for operation management (T1-T4);
- Personal safety/security - ITS for passenger security and safety (T0-T3);
- Competitiveness and enabling technologies - Information management (databases, dynamic control of information) (T3-T4);

Improving safety and security:

- Security - Procedures, regulations and standards - Privacy and personal freedom protection (T0 – T2);
- Security - Procedures, regulations and standards – Passengers security passive measures (T0–T3);
- Security - Detection Systems - No hindering sensors (T0 – T2);
- Security - Detection Systems – CCTV (T0 – T2);
- Cybersecurity (T2-T3);
- Safety: Preventive and predictive management (T1-T4);

Strengthening competitiveness:

- Economics - Decision support tools for asset management (T0 – T4);
- Optimising the use of network – Travel demand management (T0-T4.

11.5 Implementation Plan

The implementation plan is based on existing and future initiatives, and specifically:

- Shift2Rail: will address most of the themes in the timeframe T0-T3 (see above);
- Other H2020 initiatives in the frame T0-T3:
    - On big data (PPP big data);
    - Digitalisation around Digital SERA;
    - Security and cybersecurity are top priorities as the rail infrastructures are considered critical infrastructures;
    - Other national public programs.
- But we could also rely on CEF (Connecting Europe Facility - EU funding instrument), which applies not only for rail infrastructure but also for the deployment of Digital Service Infrastructure projects, aiming at the creation and/or enhancement of interoperable and internationally compatible core service platforms, accompanied by generic services for digital service infrastructures. This is in particular perfectly adapted for the deployment of the “Interoperability framework” developed in Shift2Rail IP4, and could leverage the Shift2Rail developments in order to achieve a bigger market uptake. (T4 – T5).
- A lot of initiatives coming from the ITS (intelligent transport system) sector are directly applicable to rail, on (extended) traffic management systems (road and rail), on multi-modality, etc… (T0-T3).
- Additional initiatives come from the GSA, with respect to the positioning systems applied to the rail signaling (T0-T4).

11.6 Visual Roadmap, milestones and deliverables overview

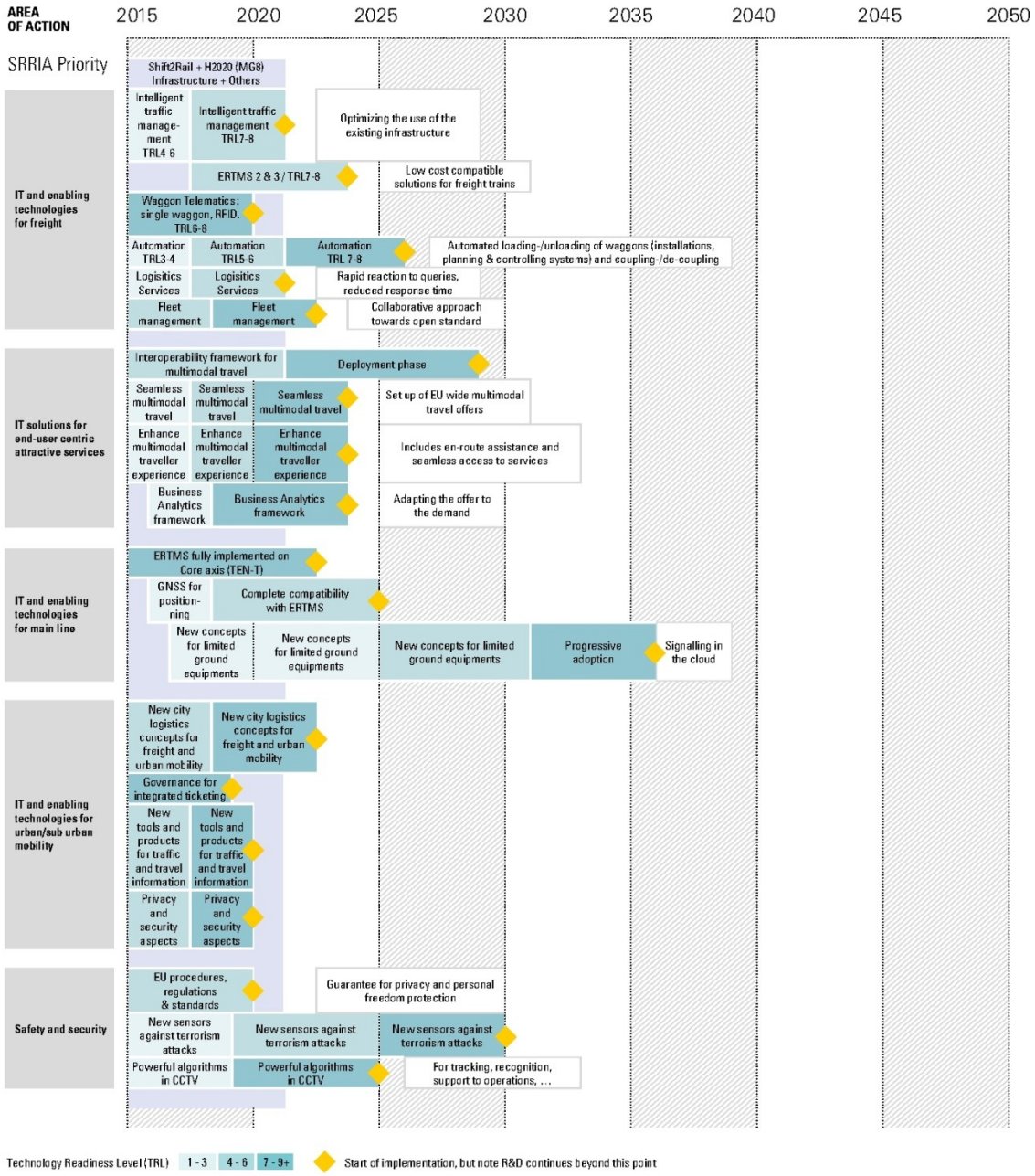

Fig. 1 - Visual Roadmap, milestone and deliverables overview

11.7 Conclusions

“IT and enabling technologies” is a very broad and complex topic, due to the fact that this sector is a very fast moving one and that people always want to be connected, even when traveling. Even if the diffusion of these technologies in the rail sector is slower than in other transport sectors, the societal demand coming from the end-users makes the adoption of these technologies absolutely vital for the future of the rail sector.

These changes will impact all the segments, and all the operational aspects, depending on their resistance to change: the segments which are not fully standardised and/or not safety related will be impacted first.

All functions and services directly in contact with the end-users are already fully impacted and will continue to move very quickly (e.g. travel information).

The operations (maintenance, control, overall management) can get huge benefit of the new data technologies (big/linked data and analytics) to drastically reduce LCC and increase reliability.

The capacity for the rail to become an integrated part of the overall mobility landscape is a key success factor for the future, and the IT technologies, contributing to enhance interoperability without additional standards and providing the tools to manage heterogeneous data are essential: welcome in the Digital Railways area.

12. Training and education

12.1 Introduction

The Railway sector is presently a rapidly developing and changing sector in its various main market segments (High Speed Rail; Regional Rail; Suburban Rail; Light Rail; Metro; Freight ...). The railways and their staff are facing crucial changes that will determine the future of this important sector. These changes occur in technological, demographic, structural, legal and regulatory domains.

The purpose of training and education is to contribute 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 to make railways a more competitive and innovative sector and the offer of skills coming out of the different research based education and training institutions across Europe.

Europe needs rail and rail needs research, development and innovation, which in turn require skilled and motivated staff at all levels as agents of change in an increasingly complex, multidisciplinary and transdisciplinary environment.

A partnership for innovation, skills development and jobs is envisaged to mobilize support and help the different players work together to spread ownership and excellence.

The sector is getting increasingly impacted by new processes and technological changes, and complex simulation tools and ICT applications are getting more and more important. These trends will play an important role in regard to future skills.

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

Training and skills development is a necessary pre-condition for the success of both the European Research challenges and the everyday needs that the railway sector is facing. Training and education initiatives offer an effective way to nurture collaboration across the sector by:

- Providing access to industrial sector and promote knowledge transfer processes from academia and research institutions through specific actions and research based training and education initiatives.
- Provide the dissemination of experience and best practices among the stakeholders of the same sector, in order to learn from the lessons of each other.

- Fostering collaboration and joined-up thinking by facilitating sustainable partnerships involving the sector, SMEs, academia and R&D institutions.
- Facilitating cross-fertilization from other sectors aiming to intermodal integration by cooperating with ETPs and other stakeholders from the transport sector.

12.2 Key issues and objectives

The transport industry in general and the rail sector in particular demand a mix of competencies from present and future transport researchers. This demand is changing, reflecting the current and future needs (environmental protection, new materials, new technology, new energy sources, etc.). Presently, the educational programs being offered at transport courses do not in general meet in a systematic manner these requirements.

Several sources of competences gaps are identified:

- Gap between the competences that the employees need and the actual competences of the students (i.e. to what extend are the student's competences actually useful in their working daily activities?).
- Gap between the knowledge the companies need in a rapidly changing sector and the actual competences of the employees (i.e. to what extend do the employees' competences actually fit in their companies' competences requirements and to what extent life-long learning practices are implemented).
- Gap between the knowledge the universities generate and the actual competences of the students (is the knowledge generated in the research transferred in the courses?).
- Gap between the know-how the companies need and the knowledge the universities have (i.e. the universities' research and teaching activities of relevance for the companies).
- Closer cooperation between academic institutions and end-users is needed in order to inform and train appropriate personnel for transport research and offer them competitive work conditions.

Key objectives in training and education activities are:

- Forecasts of the skills that the railway sector will need and analysis of gaps in skills;
- Enhance and expand access to railway educational programs and courses;
- Enhance educational quality in the railway area (academic, stakeholders);
- improve cooperation between the railway sector and educational institutions to put forward courses not offered by existing institutions;
- Develop e-learning based courses and promote the production of course materials;
- Promote Joint PhDs using bilateral and multilateral programs;
- Promote joint international MSc programs in different rail related areas;

- Develop and deliver short training courses (STC);
- Facilitate sustainable partnerships involving the sector, SMEs, academia and R&D institutions envisaging knowledge transfer and fostering innovation processes.

12.3 State of the Art and on going research and innovation within and outside rail

Skills and jobs are of vital importance for the future of the European economy and have recently gained increasing attention, both at national and EU level.

The transport sector is one of the most important sectors for the European economy. Its importance stems not only from its size but also from the fact that it plays a crucial role in connecting other economic actors with each other.

The transport industry in Europe directly employs around 10 million people and accounts for about 5% of gross domestic product (GDP). Effective transport systems are fundamental for the European companies' ability to compete in the world economy. Logistics, such as transport and storage, account for 10–15% of the cost of a finished product for European companies.

The transport sector is characterized by a great diversity and different transport modes that come with different technologies, regulations, challenges and know-how and skills requirements. Rail transport (passenger and freight) includes subway, metro and tram systems,regional services, intercity and cross border operations of which high-speed trains become a new passenger travel paradigm.

The employment structure and work organization in the transport sector is dominated by large (and often monopolistic) companies (such as air and rail transport) whereas in the important freight transport by road segment small companies predominate.

In order to attract the next generation of rail professionals the interest of young people has to be sparked off. This means to start early with age-relevant specific attractiveness initiatives while embracing individual and societal benefits (clean sector, technology driven and appealing career opportunities).

The transport sector has a gender issue when it comes to employment and recruitment, and a paramount source of future labor shortage in the transport sector will be retirement. [1]

Partnerships for innovation, skills and jobs, in connection with technology platforms, industrial high level groups, as well as clustering initiatives are being promoted at both European and national level.

Existing partnerships for innovation, skills and jobs generally show a number of characteristics, which include:

- Involvement of all relevant actors, ranging from companies, research organisations, education and training institutes to public administration and others;
- Cross-sectorial approach: even though partnerships may be assigned to a specific sector, they often work across different business sectors. This may be the case of urban public transport and rail freight where successful business involve in a cooperative manner technology, services, logistics, operators and shipping agencies;
- Cross-thematic approach, i.e. linking innovation, skills and jobs;
- Inclusion of general human needs into the partnership strategy: human needs, such as housing, health or mobility can be part of the formulated partnership vision or strategy;
- Long term commitment of actors (members);
- Joint problem solving, i.e. working on problems that cannot be met by one member alone leading to the European dimension of the training and education challenges.

Major underlying drivers are now identified as leading to the development of new skills coping with emerging job profiles: globalization and world trade, natural resources availability and prices, technology developments (ICT and technology for planning, surveying and monitoring and innovative rail products), demand for clean and safe transport, regulations, safety policies and vehicle legislation, etc..

A number of strategic options may involve different measures at different levels of the training, education and skills development chain:

- Recruiting staff with appropriate levels of education with specific majors better suited to the needs of the sector and offered in Higher education institutions;
- Training employed workers and tailoring their skills, design and offer new courses either in-house or outsourced;
- Improve the image of the sector and the attractiveness of pursuing careers in the different railway sub-sectors, and promote a stronger cooperation with industry (internships, visits and.visiting lecturers)
- Exploitation of the Marie Curie instruments in cooperation with industry is an illustrative example with a potential strategic impact at European dimension.

During the past 15 years a number of initiatives and policies have been taken at European level to promote education and training activities in general (unfortunately not specifically for the field of Transport). The most notable of these are the following [5]:

2000 – Initiation of the concept of the European Research Area (ERA);

2007 – EU's Green paper aiming to deepen and widen the ERA, by i)removing the institutional and national barriers hampering free movement of researchers and ii) improving their working conditions and widening their career prospects;

2012 – EU Communication: “A Reinforced European Research Area Partnership for Excellence and Growth”, aiming at deepening and re-ensuring the removal of barriers to researcher mobility, training and attractive careers for an open labor market for researchers [7];

2000 – 2013: Several other initiatives and actions by a number of relevant organisations such as the COST programme, iInitiatives by Networks of Excellence (NoEs) (e.g. HUMANIST, EURNEX, NEARCTIS), initiatives by research associations such as ECTRI, Erasmus, Erasmus Mundus, etc.[3] and [4].

At the level of the EU, the transport research education and training issues are addressed collectively within the overall education and training activities of the “Excellent Science” pillar of the Horizon 2020 programme of the Union. These are primarily carried out through the well-known Marie Skłodowska-Curie (or simply Marie Curie) programme. This programme is considered by the academic and research communities as successful.

It is worth mentioning that in the ETRA report [5] the training activities that take place with the support of the Marie Curie programme should be complemented by relevant actions that could be supported by the rest of the H2020 activities, most notably through the process of funding and implementation of collaborative research in general. In this respect it is proposed that the main collaborative research pillar of the “societal challenges” research of the H2020 programme could include some funding for actions (through projects) in the following areas:

- Promoting short courses as well as training workshops in various subjects related to specific research topics developed in specific research projects;
- Activities within research projects that provide training materials, short training courses and / or publishing textbooks. Such activities could be given some sort of priority in funding especially when this is done with involvement of leading international academic organizations;
- Projects doing solely the above could also be funded in specific sectors that are considered as particularly important;
- Concerted attempts and suggestions at benchmarking (for Transport courses and training material and curricula) have been made over the past decade mainly through EU funded research projects in the FP6, FP7, and now in the H2020 programme. Two of them merit special mention here: the DETRA project (Developing the European Transport Research Alliance) [8], and the MORE and MORE2 projects (MObility patterns and career paths of REsearchers).
- A sector specific initiative, the Rail Uni Net (Railway UniversIty Network – a global network (http://railtalent.org/what-it) which was created under the aegis of the UIC TALENT project (www.railtalent.org) is taking a certain number of initiatives such as summer schools and developing a portfolio of continuing development courses.
- Also In the frame of the TALENT project, which main purpose is to attract and retain the best talents in the rail industry, an e-learning platform has been developed in order to support the continuous development courses set up in co-operatipon with Rail Uni Net. [9].

12.4 The Roadmap

1. Characterisation of skills and competence needs

Together with ERRAC iassociations, members of EURNEX, and other relevant European universities and research institutions, the future topics on training and education in the rail sector will be identified as:

- State-of-art and current trends in the development of technically and operationally inter-dependent systems, production methods and industry structure, value added and changes in volume trends, employment trends;
- Internal competition between modes (and even within mode sectors), which give a new dimension to skills development and changing trends in staff requirements while the legal and regulatory environment is becoming also more relevant requiring specific skills and knowledge in specific issues e.g. those in the safety domain;
- Trade globalization giving also new dimensions to skills development and new challenges in staff requirements
- Technical competences associated with: professional intervention across different railway assets; appraisal of the level of intervention in technical careers; new emerging technology products and services such as Galileo, GSM, IT, environmental efficiency; systems engineering, man-machine interfaces and human factors, signaling systems, innovative and modular RS, modern infrastructure maintenance, sensor technologies and asset management methods;
- Competences in the legal domain: interoperability directives, safety rules, certification of rail staff, environmental policies, working conditions, etc.;
- Competences in procedures and operational cooperation in different market areas: competition, social objectives, customer demands, cross border operations, liberalization, low fare airlines, globalization, freight logistics and related passenger and freight services.

2. Higher education offer

Based on the results of the SKILLRAIL, RIFLE, TURNRAIL and NEAR2 projects, there is still a need to:

- Update and develop a comprehensive inventory of current railway higher education programs and activities in the E.U. and the rest of the world,
- To determine the demand for railway higher education by the operators, infrastructure managers, transport authorities and the industry, both quantitatively and qualitatively. Establish a web-based railway education forum as a tool for stakeholders to provide input and suggestions.
- Appraise current educational offers and define major guidelines at BSc and MSc levels bridging the gaps between knowledge production in Higher Education institutions and required know-how in the different industrial environments.

- Establishment of training and education for top management in the sector. The main features of such programs include:
  - Running efficient and safe rail system while respecting the rules of competition;
  - Focus on strategic directions, critical technologies, needs and aspirations of customers;
  - Forward strategies ensuring rail as the backbone of a sustainable European transport system;
  - Legal and institutional contexts;
  - Features of the future rail passenger and freight services, standardisation and interfaces.

3. Advanced Training courses

Universities and research centres working together with railway manufacturers,railway operators and infrastructure managers at international (EU projects) or national (national programmes) levels, have developed methods, tools, instruments, test specifications and sometimes test facilities as well as any kind of scientific activity tailored for the railway sector.

Several times and in several national or international projects a know-how transfer from other industrial sectors or other transport modes have been used and specified for the railway sector introducing new technologies or new techniques in technological and in the economic and legislation areas. This opportunity and the outcomes of projects are often not well disseminated and exploited while they can be suitably introduced in high level training courses and related tools and instruments.

Short training for high skilled jobs can be targeted to all kind of railway stakeholders in order to develop competences standardized or recognized at international level, enabling to comply with EU and international requirements and legislation, and also with the high-tech innovations under development/implementation in railway services.

The creation and development of a portfolio of short training courses for high skilled jobs constitutes a benchmark for the rail training system which mainly answers to the following needs:

- To create professional profiles able to operate in the technological changes provided recently by the signalling, communication, IT systems introduced in the railway sector;
- To create professional profiles in the international legislation and market liberalization under implementation in the railway sector;
- EU universities and research centres must continue to develop a Knowledge Management System (KMS) in order to analyse and to compare the existing competences, tools and facilities for railway education and research. The EURNEX

pole of excellence “Education & Training” created the EURAIL Virtual University which is providing a centralized Learning Management System;

- Explore advanced training courses in different settings according to the industry needs and taking into consideration the target audiences: in-house tailored courses for specific companies; summer courses for university students, open advanced courses targeted to larger groups of industry specialists and PhD students;
- Lifelong learning actions aimed to address emerging technologies and recover current staff to new organisational and emerging skill needs;
- Learning programmes fully exploiting current virtual learning environments, and e-learning technologies to explore networking of specialists and expose novices and specialists to real operational situations. E-learning classes can be provided to suit needs and timescale in the current climate travel and tight training budgets. To help still meet training needs the e-learning courses can be developed to complement the live class. The e-learning courses may run over different class periods or may allow students to be exposed to recorded classes in after work periods and weekends. E-learning classes are ideal for companies with a group of engineers requiring training.

4. EURAIL – The European Railway University

The SKILLRAIL project has launched the EURAIL “European University of Railway”. As a corporate service of EURNEX, its main mission is associated with the creation, dissemination and transfer of knowledge within the railway sector. By addressing the needs of the sector the European University of Railway- EURail will provide the conditions to disseminate the social and industrial benefits of training and education in the railway sector and to develop, at European level, high quality training and education activities for the railway community of tomorrow.

Based on knowledge, experience and people from "real" universities in Europe, EURail is virtual in nature and aspires to foster, at European level, excellence by gathering and networking the different relevant organizations and institutions around an educational project suitable to the needs of the European Rail sector. EURail’s unique feature is this concentration of high-level knowledge and expertise in one single sector/problem-oriented institution. It is expected that EURail will form a coherent community able to define lines of actions and conduct sustainable business in close liaison with the Network of Excellence EURNEX.

The first objective is to unite the efforts of the different railway stakeholders seeking to share information and training. EURAIL must be supported to periodically collect the research results and educational options provided by the associated EURNEX institutions (universities and research centres) and all other universities in Europe.

5. Meeting expectations of end users

- Create innovative programs for “proficiency” through innovation, bringing together, field expertise, teaching, research and knowledge development by academicians, practitioners and students.
- Promote higher flexibility, tailored contents, operational and practical subjects for educational courses in the rail sector, and also in the more general Transport domain.
- Promote and / or reinforce the interaction between educational establishments and industry, through:
    - “trusting partnerships” between academia and practitioners to develop regular problem solving workshops and research projects and Strategic alliances for on job coaching of practitioners (e.g. “seed planting” approach).
    - Promote full and unhindered mobility of students, professors / teaching staff, and industry professionals.
    -

6. Exploitation of standardisation potentials

Due to the internationalisation in the train transport sector and the need for technical unification of the existing network it will be necessary to constantly adapt the knowledge and skills of the employees. To ensure international standards as well as the required mobility of labour a European recognition of skills and a corresponding adaptation of national initial vocational training is recommended for train drivers and stewards of the sector. The European Qualification Framework can provide a common basis for the European transport sector to pursue this aim. Social partner organisations, the European Commission and companies and training providers should adopt the European-wide validation system for the sector and develop a special certification system.

This would also support trans-national mobility within in the sector and enhance a common rail transport market.

7. Harmonised European Transport/Rail PhD

A relevant major recommendation of the project DETRA (http://detra.fehrl.org/) was the need for a commonly defined “European Doctorate (PhD) in Transport” and the need to define specific guidelines for such a PhD format.

A commonly features, the defined “European Doctorate (PhD) in Transport” would provide, among other, acquisition of:

- Knowledge from basic disciplines (e.g. mathematics, statistics) in order to enable analysis and management of complex systems;
- specific and high-level knowledge related to the various transport disciplines;
- Experience in project management with development of leadership, mediation and communication skills.

Stakeholders that should take the initiative for the design and implementation of such a EU PhD transport/rail are:

- Universities in charge of PhD programs;
- Research centres hosting PhD students;
- Networks of Excellence (NoEs) that encourage training and mobility activities;
- Sector organizations with the ability to pool expertise and knowledge from their various members
- Industries capitalising on researchers' know-how and abilities, and of course
- The relevant governmental bodies.

12.5 Implementation Plan

To carry out all the proposed road mapping activities several lines of financial support must be sought in the framework of SHIFT2RAIL, H2020, Member States funds, Structural Funds, other public funding and self-sustained business oriented activities with private support funding.

Grants from different institutions and financial bodies – the EU, the EIB, the EBRD, etc. - can also be accessed by partnerships between the academia and the transport practitioners (operators, infrastructure managers, industrial manufacturers) in order to set-up these training and educational initiatives.

12.6 Visual Roadmap, milestones and deliverables overview

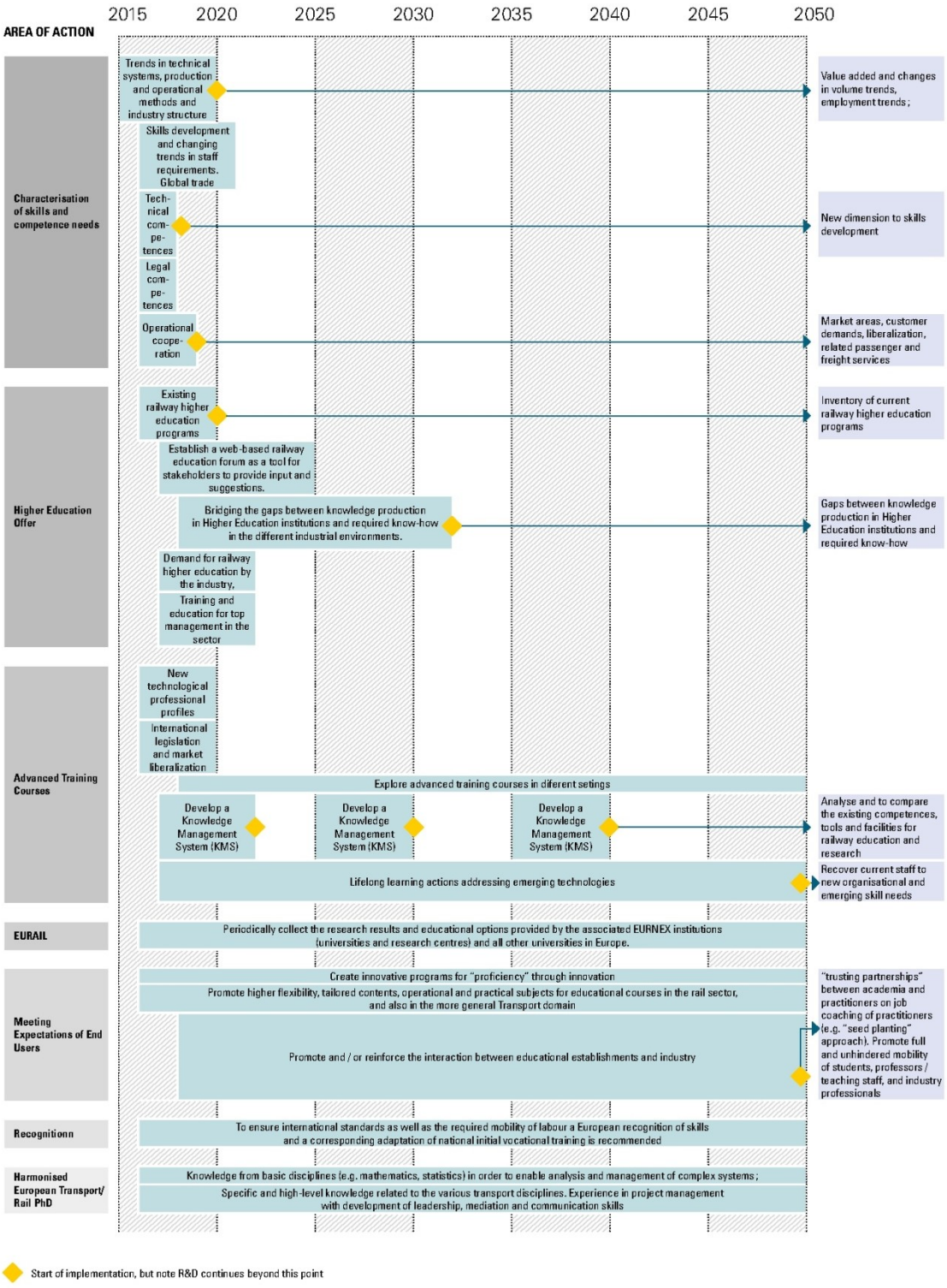

Fig. 1 - Visual Roadmap, milestone and deliverables overview

12.7 Conclusions

Training and Education aim to contribute to the enhancement of the railway sector by fostering a better match between the human resources needs to make railways a more competitive and innovative sector and the offer of skills coming out of the different research based education and training institutions across Europe. In this context the proposed activities do not aim to develop new research but simply develop a matching function that is to bring the existing knowledge near the existing needs for a successful synergy.

The proposed activities also contribute to disseminate the social, economic and industrial benefits of education and research in the railway sector, and promote the idea that society needs advanced technologies and further education as applied to a highly innovative and technological developed sector.

In line with the ETRA paper on Training and Education issues, the following final recommendations are offered:

- Create new innovative research based “postgraduate” programs through bringing together: teaching, research and industrial needs by enhancing cooperation of academicians, practitioners and researchers;
- Create new or complement existing transport educational “offers”, through:
    - New courses and programs (more flexible, not focusing on fundamental disciplines only and taking into account the changes in the business environment and technology developments);
    - Specialization courses offering higher flexibility, tailored contents, operational and practical subjects; and through offerings well designed and coordinated at European level;
    - Courses for top management in transports and railway addressed to high level managers in the transport sector, including manufacturers, technology providers, operators, logistics, authorities;
    - Lifelong Learning and Vocational Training courses.
- Continue to support and strengthening the EURNEX – EURAIL, RAIL UNI NET and TALENT and similar agencies and initiatives exploring their synergies and complementarities in the preparation and organization of short training courses and other collaborative initiatives at European level;
- Establish a web-based portal associated with EURAIL including portfolios of course offers, industry and academic specialists engaged in T&E activities, course materials;
- Reinforce University-Industry (Operators, manufacterers and infrastructure managers9 interaction, through:
    - Partnerships between academia and practitioners to develop programmes and problem solving content;
    - Creating strategic alliances for on-job coaching of practitioners;

    - Promoting mobility of students, teachers and industry professionals further and above all in a coordinated and fully transparent way.
- Improve the Marie-Curie programme through:
    - Providing funding for supervisory activities in hosting institutions, i.e. for tutoring or academic supervision of the hosted researchers;
    - Increasing the allowable percentage of commercial work that a Marie Curie programme supported researcher can undertake for the institution he/she is placed with. This will give the individual researcher the necessary commercial experience and skills, and possible IP benefits and will help manage the hosts' institutional costs especially for organisations with no Government funding;
    - Increasing the incentives to encourage stronger and more commercially oriented research institutions to provide highly skilled researchers as "stagers" to lesser developed or developing research organizations;
    - Supporting the creation of a pan-European database of researchers per sector (in our case for the railway sector). Such database would be useful for more efficient and widespread transport research mobility all around.
- Promote transport education and specialization within the university students and graduates;
- Promote networking of young transport professionals in order to strengthen "specialism" and also get them to know more about other specialists and be open to collaboration with them;
- "Educate" the transport employers on the need to facilitate and promote the further lifelong education and training of their employees.

Finally, work towards establishing some harmonized and well specified transport degrees, starting with the "European Transport /Rail PhD.