The SETRIS project has received funding from *the European Union's Horizon 2020 research and innovation programme* under grant agreement No 653739

SETRIS PROJECT

DELIVERABLE REPORT

Document identifier:	**SETRIS – D 3.9**
Due Date of Delivery to EC	**31/10/2017**
Actual Date of Delivery to EC	**16/02/2018**
Title:	ERRAC- Update of ERRAC Technology roadmaps' implementation plan
Dissemination level:	**PU**
Work package:	**WP 3**
Lead Beneficiary:	**UIC**
Other Beneficiaries	**UITP, UNIFE**
Document status:	**Final**
Document link:	**N/A**

SETRIS Project coordinated by:

The SETRIS project consortium consists of:

No	Name	Short Name	Country
1	Newcastle University	UNEW	UK
2	European Conference of Transport Research Institutes	ECTRI	Belgium
3	AVL List GmbH	AVL	Austria
4	BMT Group Limited	BMT	United Kingdom
5	Centro National de Competencia en Logistica Integral	CNC-LOGISTICA	Spain
6	The European Earth Friendly Logistics Association AISBL	CO-TREE	Belgium
7	Stichting Dutch Institute for Advanced Logistics	DINALOG	Netherlands
8	German Aerospace Center	DLR	Germany
9	Forum des Laboratoires Nationaux Europeens de Recherche Routiere	FEHRL	Belgium
10	Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung e.v	Fraunhofer IML	Germany
11	Instytut Logistyki I Magazynowania	ILiM	Poland
12	Promotion of Operational Links with Integrated Services	POLIS	Belgium
13	Ships & Maritime Equipment Association of Europe	SEA EU	Belgium
14	Union Internationale des Chemins de fer	UIC	France
15	Union Internationale des Transports Publics	UITP	Belgium
16	The Association of the European Rail Industry	UNIFE	Belgium
17	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	TNO	Netherlands
18	European Organisation for the Safety of Air Navigation	EUROCONTROL	Belgium

Document History:

Version	Date	Modification reason	Modified by
0	20/09/2017	First draft	Johan Marigny (UIC)
1	04/10/2017	Commented by the UITP	Cristina Hernandez (UITP)
2	22/11/2017	Second draft	Johan Marigny (UIC) Cristina Hernandez (UITP)
3	31/01/2018	Integration of the stakeholder review	Johan Marigny (UIC)
4	07/02/2018	Commented by UNIFE	Nicolas Furio (UNIFE)
5	07/02/2018	Commented by UITP	Cristina Hernandez (UITP)
6	15/02/2018	Final review	All
Final	16/02/2018	Formatted document finalised by UNEW	

EXECUTIVE SUMMARY

The purpose of SETRIS is to deliver a cohesive and coordinated approach to research and innovation strategies for all transport modes in Europe. SETRIS vision is to identify synergies between the transport sector European Technology Platforms' (ETPs) strategic and research and innovation agendas (SRIAs) and between these and relevant national platforms. ETPs are industry-led stakeholder forums, recognised by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness (European Commission, 2013). The five transport sector ETPs, in alphabetical order, are:

1. Advisory Council for Aviation Research Innovation in Europe (ACARE);
2. Alliance for Logistics Innovation through Collaboration in Europe (ALICE);
3. The European Rail Research Advisory Council (ERRAC);
4. European Road Transport Research Advisory Council (ERTRAC);
5. Waterborne;

The FP7 Coordination and Support Action, FOSTER RAIL, addressed the key challenges of railways researches of strengthening research and innovation in the railway sector and build a strategy for the European rail research up to 2050. SETRIS offers the opportunity for ERRAC to foster the implementation of the priorities defined in FOSTER RAIL and take a step further by collaborating with other transport ETPs to build the future integrated transport system.

This deliverable D3.9 further complements the work done within FOSTER RAIL WP4 and develops the implementation plans for the ERRAC roadmaps (FOSTER RAIL D4.9, 2016) and provides:

- an overview of EU and national strategies for railways and transport
- an identification of current funding programmes that could support the implementation of ERRAC priorities
- a detailed comparison between ERRAC technology roadmaps and the topics addressed by SHIFT2RAIL and H2020
- a classification of topics (railways/transport, Operation and asset management/ Technology and Innovation / Policy and society / Economy and Business)
- an identification of the barriers which prevent the adoption of innovative technologies and approaches
- recommendations on SHIFT2RAIL2.0 and FP9

TABLE OF CONTENTS:

ACRONYMS AND ABBREVIATIONS

ACARE: Advisory Council for Aviation Research and Innovation in Europe. Air ETP (http://www.acare4europe.com/)

AI: Artificial Intelligence

ALICE: Alliance for Logistics Innovation through Collaboration in Europe. Logistics ETP. (http://www.etp-alice.eu)

ATO: Automated Train Operations

AV: Automated vehicle

BCM: Building Construction Management

BIM: Building Information Management

CCA: Cross-Cutting Activities

CCC: Control Command and Communications

CCTV: Closed-Circuit Television

CEF: Connecting Europe Facility (https://ec.europa.eu/inea/en/connecting-europe-facility)

DAS: Driver Advisory System

EC: European Commission

ECC: European Economic Community

EIB: European Investment Bank

ERDF: European Regional Development Fund

ERRAC: European Rail Research Advisory Council. Rail ETP. (http://www.errac.org/)

ERTMS European Rail Traffic Management System

ERTRAC: European Road Transport Research Advisory Council. Road ETP (http://www.ertrac.org/)

ESF: European Social Fund

ETPs: European Technology Platforms

ETS: Emissions Trading System

EU: European Union

GNI: Gross National Income

GNSS: Global Navigation Satellite System

ICT: Information and Communications Technology

IoT: Internet of Things

IP: Innovation Programmes

IT: Information Technologies

JU:	Joint Undertaking
KMS:	Knowledge Management System
LCC:	Lifecycle cost
MaaS:	Mobility as a Service
NTPs:	National Technology Platforms
PPP:	Public-private partnerships
PRM:	Person with Reduced Mobility
R&D:	Research and development
RAM:	Reliability, Availability, Maintainability
RICG:	UIC Research and Innovation group
S2R:	Shift2Rail
SIL:	Safety Integrity Level
SRRA:	Strategic Rail Research Agenda
SRRIA:	Strategic Railway Research and Innovation Agenda
STRIA:	Strategic Transport Research and Innovation Agenda
TMS:	Traffic Management System
TSIs:	Technical Specifications for Interoperability
US:	United States

LIST OF TABLES

DEFINITIONS

European Technology Platforms: European Technology Platforms (ETPs) are industry-led stakeholder fora recognised by the European Commission (EC) as key actors in driving innovation, knowledge transfer and European competitiveness. ETPs develop research and innovation agendas and roadmaps for action at EU and national level to be supported by both private and public funding. They mobilise stakeholders to deliver on agreed priorities and share information across the EU. (http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=etp).

National Technology Platforms: a National Technology Platform (NTP) was defined in FOSTER RAIL as a sector-led stakeholder forum that develops short to long-term research and innovation agendas and roadmaps for action at national (and EU-) level to be supported by both private and public funding. It should involve all important stakeholders in the sector. For rail, this means among others train-operating companies, infrastructure managers, supply industry, academia/research institutes and users' groups (freight & passengers).

1. INTRODUCTION

The purpose of SETRIS is to deliver a cohesive and coordinated approach to research and innovation strategies for all transport modes in Europe. SETRIS vision is to identify synergies between the transport sector European Technology Platforms' (ETPs) strategic and research and innovation agendas (SRIAs) and between these and relevant national platforms. ETPs are industry-led stakeholder forums, recognised by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness (European Commission, 2013). The five transport sector ETPs, in alphabetical order, are:

- Advisory Council for Aviation Research Innovation in Europe (ACARE);
- Alliance for Logistics Innovation through Collaboration in Europe (ALICE);
- The European Rail Research Advisory Council (ERRAC);
- European Road Transport Research Advisory Council (ERTRAC);
- Waterborne.

The FP7 Coordination and Support Action, FOSTER RAIL, addressed the key challenges of railways researches of strengthening research and innovation in the railway sector and build a strategy for the European rail research up to 2050. SETRIS offers the opportunity for ERRAC to foster the implementation of the priorities defined in FOSTER RAIL and take a step further by collaborating with other transport ETPs to build the future integrated transport system.

This deliverable D3.9 further complements the work done within FOSTER RAIL WP4 and develops the implementation plans for the ERRAC roadmaps (FOSTER RAIL D4.9, 2016). A systemic approach has been adopted to support the implementation of ERRAC roadmaps and advance toward the truly integrated transport system. In order to support the implementation of ERRAC priorities in future research funding programs (FP9, "Shift2Rail 2.0"[1], potential national initiatives etc.), ERRAC research topics have been analysed and classified in regard with the system level they belong to (rail, transport, operation, policy etc.) and topics already addressed by Shift2Rail and H2020 Mobility for Growth calls have been identified. This deliverable also provides recommendations for the future EU funding programmes to facilitate the integration of the railway system into the truly integrated transport system.

[1] « Shift2Rail 2.0 » is used to refer to the program that will follow Shift2Rail and that will be part of FP9

2. ERRAC PRIORITIES

To guide the research effort of the railway sector and the decisions of policy makers and other stakeholders, the *Strategic Rail Research and Innovation Agenda* (FOSTER RAIL D3.2, 2015; onwards SRRIA) was established during the course of FOSTER RAIL as a step change in research and innovation building upon the 2007 Strategic Rail Research Agenda (ERRAC ROADMAP, 2007, onwards SRRA) and following the publication of "RAILROUTE 2050"[2].

Three main sets of themes including overall 10 themes have been identified. The first addresses the attractiveness of rail and public transport and the future demand that the rail sector aims to meet, the second set includes three critical and cross cutting themes within the railway system and finally the third set covers five well-established rail asset-related themes. This thematic arrangement can be briefly described as follows:

Attractiveness of rail and public transport

- Customer experience
- Strategy and economics

A whole system approach

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

Assets

- Control, command, communication and signalling
- Infrastructure
- Rolling stock
- IT[3] and other enabling technologies
- Training and education

Following the structure of this SRRIA, 10 new part-roadmaps have been developed. ERRAC priorities were updated in FOSTER RAIL with the SRRIA, the FOSTER RAIL Rail Business Scenario (FOSTER RAIL D2.6, 2015). These roadmaps are covering the 10 themes identified by the SRRIA and are fully described in the FOSTER RAIL deliverable: *D4.9 Final Technology and Innovation Roadmaps*.

3. EU AND NATIONAL RESEARCH STRATEGIES FOR RAILWAY AND TRANSPORT

3.1 Transport White paper

In 2011, The European transport policy and strategy were defined in the White Paper *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (COM (2011) 144 final)[4]. The main goal is to achieve a "*Single European Transport Area that ease[s] the movements of citizens and freight, reduce[s] costs and enhance[s] the sustainability of European transport"* while simultaneously addressing the security and safety of transport and the *"quality, accessibility and reliability of transport services".*

[2] http://www.errac.org/wp-content/uploads/2013/11/D9-SRRA-RAILROUTE2050.pdf

[3] Information technologies.

[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:en:PDF

This document envisages a European Transport System which aims at developing:

- Transport and supporting mobility while reaching the 60% greenhouse gas emission reduction target;
- An efficient core network for multimodal intercity travel and transport;
- A global level playing field for long-distance travel and intercontinental freight;
- A clean urban transport and commuting;
- A competitive and resource-efficient transport system: benchmarks for achieving the 60% greenhouse gas emission reduction target.

3.2 Strategic Transport Research and Innovation Agenda (Energy Union)

For the period 2015-2019, the European commission has set 10 political priorities (jobs growth, digital, Energy and climate, internal market, economic and monetary union, EU-US trade, justice and fundamental rights, migration, a stronger global actor, democratic change). Among these priorities, energy and climate specifically addresses transport. The Energy Union[5] is a European priority project set by the European Commission which focuses on the following main aspects:

- **Security, solidarity and trust:** diversifying Europe's sources of energy and ensuring energy security through solidarity and co-operation between Member States;
- **A fully-integrated internal energy market:** enabling a free flow of energy throughout the EU through adequate infrastructure and without any technical or regulatory barriers – an efficient way to secure supply and give consumers the best energy deal;
- **Energy efficiency:** energy efficiency first – improved energy efficiency will reduce our dependence on energy imports, reduce emissions and drive jobs and growth;
- **Climate action – decarbonising the economy:** an ambitious climate policy is integral to creating the Energy Union. Actions include the EU Emissions Trading System (EU ETS), strong but fair national targets for sectors outside the ETS to cut greenhouse gas emissions, a roadmap towards low-emission mobility and an energy policy which makes the EU world leader in renewables;
- **Research, innovation and competitiveness:** supporting breakthroughs in low-carbon and clean energy technologies by prioritizing research and innovation to drive the transition of the energy system and improve competitiveness.

Within the framework of the Energy Union project, the European Commission started a consultation process, involving a wide range of transport stakeholders and experts. The objective was to define a Strategic Transport Research and Innovation Agenda[6] (STRIA), which will outline the steps needed to support and speed-up the research, innovation and deployment process leading to radical technology changes in transport. This document integrates seven thematic transport research areas selected on the basis of their ability to transform and decarbonise the EU transport:

[5] https://ec.europa.eu/commission/priorities/energy-union-and-climate_en

[6] http://ec.europa.eu/programmes/horizon2020/en/news/towards-strategic-transport-research-innovation-agenda-stria

1. Cooperative, connected and automated transport;
2. Transport electrification;
3. Vehicle design and manufacturing;
4. Low-emissions alternative energy for transport;
5. Network and traffic management systems;
6. Smart mobility and services;
7. Infrastructure.

3.3 Shift2Rail

Regarding the European research and innovation and initiatives for railway, the Shift2Rail Joint Undertaking (onwards S2R JU) was created as a public-private partnership in the rail sector, providing a platform for the railway sector with the view to driving innovation in the years to come. Total contributions to the Shift2Rail initiative is EUR 920 million for the duration of the Shift2Rail. This includes the Union financial contribution and the contributions of the founding and associated members. The objective of the Shift2Rail is to implement a programme of research and innovation activities in the railway sector in Europe.

The main key performance indicators of the Shift2Rail are:

- 50 % reduction of the life-cycle cost of the railway transport system through a reduction of the costs of developing, maintaining, operating and renewing infrastructure and rolling stock, as well as through increased energy efficiency;
- 100 % increase in the capacity of the railway transport system, to meet increased demand for passenger and freight railway services;
- 50 % increase in the reliability and punctuality of rail services (measured as a 50 % decrease in unreliability and late arrivals);
- The removal of remaining technical obstacles holding back the rail sector in terms of interoperability and efficiency, in particular by endeavouring to close points which remain open in technical specifications for interoperability (TSIs) due to lack of technological solutions and by ensuring that all relevant systems and solutions developed by the S2R joint undertaking are fully interoperable;
- The reduction of negative externalities linked to railway transport, in particular noise, vibrations, emissions and other environmental impacts.

The S2R JU has developed a strategic Master Plan, which identifies the major objectives of Shift2Rail. Based on those objectives, the Master Plan identifies the main innovations areas that will be required to achieve the overall objectives of the JU. These are structured around five asset-specific Innovation Programmes (IPs) and five cross-cutting themes activities (CCA), which are further elaborated in the S2R Multi-Annual Action Plan (S2R MAAP) (Shift2Rail, 2015):

- Innovation Programme 1 (IP1): Cost-efficient and reliable trains;
- Innovation Programme 2 (IP2): Advanced traffic management and control systems;
- Innovation Programme 3 (IP3): Cost Efficient and Reliable High Capacity Infrastructure;
- Innovation Programme 4 (IP4): IT Solutions for attractive railway services;
- Innovation Programme 5 (IP5): Technologies for sustainable and attractive European rail freight;
- Cross-cutting activities (CCA).

In the revision of the S2R MAAP part A (Shift2Rail, 2017) released the 9th of November 2017, 12 capabilities which represent a concrete target for future research and innovation, have been identified:

- Automated train operation
- Mobility as service
- Logistics on demand
- More value for data
- Optimum energy use
- Serviced time to the second
- Low cost railway
- Guaranteed asset health and availability
- Intelligent trains
- Stations and smart city mobility
- Environmental and social sustainability
- Rapid and reliable R&D delivery

These capabilities are considered necessary to develop for the delivery of an efficient future railway system that fulfils customers' expectations.

Since the launch of Shift2Rail in 2015, rail specific topics are no longer included in the work plan of the funding programme H2020 dedicated to transport: Mobility for Growth. As Shift2Rail is really focused on technology development with a focus on the railway mode, this could negatively impact the development of multi modal solutions integrating railway and research and innovation related to socio-economic and behavioural aspects.

3.4 ERRAC 2050 Vision: Rail- The backbone of Europe's mobility

The *ERRAC 2050 Vision: Rail- the Backbone of Europe's mobility* (ERRAC, forthcoming) describes the vision and objectives of the whole railway sector- railway operators, infrastructure managers, manufacturers and research organisations - until to 2050. The vision stated in the document is that "In 2050, rail transport in Europe is the backbone of an intermodal "Mobility as a Service" within cities and beyond, for both passengers and goods, meeting the needs of customers, EU citizens and society. The suppliers and service organisations of the European rail industry are recognised as the world's thought leaders for railway products and services.". Building upon this vision , the documents identifies future and current challenges and opportunities of the railway mode and key enabling technologies which could lead to new paradigms such as autonomous train operations, intelligent assets lifecycle management: whole-life asset approach, protecting the environment and the energy supply, ensuring safety and security and digital rail industry supply chain management. This strategic document will be updated regularly in order to always appropriately reflects the current vision the railway sector.

3.5 National priorities

In the deliverable *D3.8 ERRAC-Alignment of ERRAC priorities with national rail strategies*, national research priorities have been collected in 8 EU member countries (Austria, Czech Republic, Latvia, Poland, Portugal, Romania, Spain, United-Kingdom) and 1 associate country (Norway). It has been noted that all countries have elaborated a strategic plan for transport and, in most cases, a specified plan for the railway transport mode. The challenge regarding energy, sustainability and climate change is also addressed by all transport strategic plans of all countries. As for exclusive rail topics, infrastructure is included in all strategic plans. Railways infrastructures of western European countries are aging and require more maintenance, and infrastructures of eastern European countries need to be modernized and developed. This is therefore an issue that needs to be tackle across Europe. Most of eastern countries prioritize modernisation and infrastructure development over research and

innovation. Thus, it is important for the eastern countries to efficiently implement their modernisation and development program for infrastructure taking in account technological, environmental and financial aspects.

4. METHODOLOGY

4.1 Analysis framework

This document adopts a systemic approach to enable the implementation of ERRAC roadmaps and advance toward the truly integrated transport system. The European funding programme H2020 and the joint undertaking Shift2Rail are grandly contributing to the achievements of ERRAC priorities. However, the application of the ERRAC roadmaps is going beyond the horizon 2020 and promotes a long-term vision toward 2050. In order to support the implementation of future European funding programmes (framework programme 9, "Shift2Rail 2.0" etc.) or foster national initiatives, it is required to clearly define and integrate the railway system within the transport system but also its connections with other non-transport systems. The thematic approach of the ERRAC roadmaps is completed in this deliverable with a systemic approach which will help stakeholders and policy makers to better comprehend the challenges of the future railway system. The topics of the ERRAC roadmaps have been linked to 4 cross-cutting areas in which positive impacts should be expected if the topics are implemented:

- Operation and asset management;
- Technology and Innovation;
- Policy and society;
- Economy and Business.

To ensure both clarity and exhaustiveness, each cross-cutting area includes two related aspects, thus the entire system is covered but non-necessary multiplication of areas is avoided.

It is also important to define at which level the topics of the ERRAC roadmaps should be investigated. In other words, if it would be more beneficial to explore an ERRAC topic at the level of the railway system or the transport system. Therefore, the topics of the ERRAC roadmaps have also been classified in accordance to the system level they belong to:

- Railway;
- Transport.

Another important aspect is the identification of topics not included in the Shift2Rail work programme. In this implementation plan, ERRAC topics not or not sufficiently covered by Shift2Rail are listed for each ERRAC roadmap. The interest of this work is twofold: to support the current Shift2Rail programme but also to provide reference points for future research programmes. The topics not covered by Shift2Rail will be in red and the topics covered but not sufficiently will be in orange. The topics appropriately covered by Shift2Rail will not be not mentioned.

4.2 Recommendations

Based on the outcomes of *D3.8 ERRAC-Alignment of ERRAC priorities with national rail strategies* and the analysis of the research and innovation topics defined by the ERRAC technology roadmaps, the section 7 of this document provides a list of research and innovation topics addressing the future challenges of the railways and the transport sector in general. The topics are proposals for the Framework Programme 9 and "Shift2Rail2.0".

The ERRAC Community has been consulted for the review of research and innovation topics. The results of the questionnaire answers received from ERRAC community members are detailed in appendix A.

5. UPDATE OF ERRAC IMPLEMENTATION PLAN

5.1 Funding programmes

5.1.1 Shift2Rail

The Shift2Rail activities, with a total of 920 M€ of budget, are carried out through collaboration between stakeholders in the entire railway value chain, also outside the traditional rail sector, including SMEs, research and technology centres and universities. End of 2015, the Shift2Rail calls 2015 and 2016 have been successfully launched. The S2R JU has selected 15 proposals for the open calls representing a total budget of 26.1M€. The 27 S2R JU members have presented project proposals for the 13 call topics reserved to them, requesting a funding of 63 M€. For the 2017 call for proposals, 17 grants the 27 S2R JU Members presented 7 projects, requesting a funding of 40.6M€. For the open call for non-JU members, 10 proposals were selected for a total amount of funding of 19.5M€. It is overall 45 research projects initiated by Shift2Rail from 2015 to 2017. Many technology related topics of the ERRAC roadmaps are addressed by Shift2Rail as the following table shows:

Table 1: Topics of Shift2Rail calls 2015-2016-2017 linked with ERRAC priorities

IP	S2R Topics	ERRAC Roadmap
IP1	S2R-CFM-IP1-01-2016 – Development of concepts towards the next generation of traction systems and management of wheel/rail adhesion	X
	S2R-CFM-IP1-01-2017 - Development of new technological concepts towards the next generation of rolling stock, applied to major subsystems such as carbody, running gear, brakes, doors and modular interiors	X
	S2R-CFM-IP1-02-2016 – Development of new technological concepts, standard specifications and architectures for train control and monitoring, with specific applications in train-to-ground communications and high safety electronic control of brakes	X
	S2R-OC-IP1-01-2016 – Tools and methodologies supporting the development of next generation traction systems, and brakes	X
	S2R-OC-IP1-01-2017: Innovative materials & modular design for rolling stock applications	X
	S2R-OC-IP1-02-2016 – Technology feasibility studies supporting the development of next generation TCMS, and safe control for brakes	X
	S2R-OC-IP1-02-2017 - Tools, methodologies and technological development of the next generation of running gear	X
IP2	S2R-CFM-IP2-01-2015 – Start-up activities for advanced signalling and automation System	X
	S2R-CFM-IP2-01-2017 - Enhancing railway signaling systems thanks to applying satellite positioning; developing an on-board safe train integrity; applying formal methods approach and standardised interfaces, and enhancing traffic management system (TMS) functions	X
	S2R-OC-IP2-01-2015 – Threat detection and profile protection definition for cyber-security assessment	X

IP	S2R Topics	ERRAC Roadmap
	S2R-OC-IP2-01-2017 - Operational conditions of the signaling and automation systems; signaling system hazard analysis and Global Navigation Satellite System (GNSS) characterization along with formal method application in railway field	X
	S2R-OC-IP2-02-2015 – IT virtualisation of testing environment	X
	S2R-OC-IP2-02-2017 - Energy harvesting methodologies for trackside and on-board signaling and communication devices. adaptation of already existing technologies for developing a purely on-board train integrity	X
	S2R-OC-IP2-03-2015 – Technical specifications for a new adaptable communication system for all railways	X
IP3	S2R-CFM-IP3-01-2016 – Research into enhanced track and switch and crossing system	X
	S2R-CFM-IP3-01-2017 - Smart system energy management solutions and future station solutions	X
	S2R-CFM-IP3-02-2016 – Intelligent maintenance systems and strategies	X
	S2R-OC-IP3-01-2016 – Research into new radical ways of changing trains between tracks	X
	S2R-OC-IP3-01-2017 - Smart metering and asset management of railway systems	X
	S2R-OC-IP3-02-2017 - Future stations and accessibility (IP1 and IP3)	X
	S2R-OC-IP3-03-2017 - Satellite and autonomous monitoring systems	X
IP4	S2R-CFM-IP4-01-2015 – Shopping, booking and ticketing of multimodal travel solutions	X
	S2R-CFM-IP4-01-2017 - Technical framework for attractive railway services	X
	S2R-CFM-IP4-02-2015 – Travel companion and tracking services	X
	S2R-CFM-IP4-02-2017 - IP4 overall integration and demonstration	
	S2R-OC-IP4-01-2016 – Interoperability framework governance, ensuring its market uptake and sustainability	
	S2R-OC-IP4-01-2017 - Smart technologies for improved travel companion and trip tracking	X
	S2R-OC-IP4-02-2016 – Interoperability framework converters	
IP5	S2R-CFM-IP5-01-2015 – Development of functional requirements for sustainable and attractive European rail freight	X
	S2R-CFM-IP5-01-2017 - Real-time information applications and energy efficient solutions for rail freight	X
	S2R-CFM-IP5-02-2015 – Start-up activities for freight automation	X
	S2R-CFM-IP5-03-2015 –Freight propulsion concepts	
	S2R-OC-IP5-01-2015 – Freight Automation on lines and in yards	X
	S2R-OC-IP5-01-2017 - Real-time yard and network management	X
	S2R-OC-IP5-02-2015 – Improved vehicle/train dynamics	X
	S2R-OC-IP5-03-2015 – Intelligent freight wagon with predictive maintenance	X
CCA	S2R-OC-CCA-01-2015 – Long-term needs of different actors in the railway sector	X
	S2R-OC-CCA-01-2017 - Smart maintenance and human capital	X
	S2R-OC-CCA-02-2015 – Energy usage, generation and saving approaches.	X
	S2R-OC-CCA-03-2015 – Noise reduction methodologies	X
	S2R-OC-CCA-04-2015 – Safer infrastructure – improved object detection and prevention of safety critical events and integrated mobility	X

Shift2Rail has already addressed a consequent number of challenges and topics of the ERRAC roadmaps. Shift2Rail covers mostly technological topics but not exclusively (human capital, long-term needs of the actors of the railway sector). Nevertheless, the approach of the Shift2Rail topics is mainly focused on "Business to Business" solutions. Shift2Rail currently lacks topics which comprehensively and consistently explore the needs of the final "Consumer" (passengers, producers or distributors of goods, society etc). Most of the topics propose to develop innovative technology based on the current scientific and technological advancements but rarely propose to investigate the needs of the final "Consumer" to build innovative solutions. This could explain why human factors and social sciences are not often included in the scope of the Shift2Rail topics.

5.1.2 Horizon 2020

H2020 Mobility for Growth is the section of H2020 addressing the challenges of the transport system. At the moment, this document is written, two H2020 calls 2014-2015 and 2016-2017 have been published and finalized and the last one 2018-2020 is still upcoming. For the Mobility for Growth call 2014-2015, a total of 558.5 M€ of budget were envisaged and for the call 2016-2017, 437.5 M€ were planned. These figures include project topics dedicated to all transport modes. The Mobility for growth topics addressing exclusively railway topics represented a budget of 52 M€ in the call 2014-2015 and were considered as undertaken by Shift2Rail for the following Mobility for Growth calls.

The call topics of the Mobility for Growth work programme related to the ERRAC priorities have been listed in the table below.

Table 2: Topics of H2020 Mobility for Growth calls 2014-2015 and 2016-2017 linked with ERRAC priorities

H2020-Mobility for Growth	Topics linked to ERRAC roadmap Topics
RAIL	MG.2.1-2014. I²I – Intelligent infrastructure
	MG.2.2-2014. Smart rail services
	MG.2.3-2014. New generation of rail vehicles
SAFETY	MG.3.5-2016. Behavioural aspects for safer transport
URBAN MOBILITY	MG.4.1-2017. Increasing the take up and scale-up of innovative solutions to achieve sustainable mobility in urban areas
	MG.4.3-2017. Innovative approaches for integrating urban nodes in the TEN-T core network corridors
	MG.4.4-2016. Facilitating public procurement of innovative sustainable transport and mobility solutions in urban areas
	MG.4.5-2016. New ways of supporting development and implementation of neighbourhood-level and urban-district-level transport innovations
	MG.5.2-2014. Reducing impacts and costs of freight and service trips in urban areas
	MG.5.5-2015. Demonstrating and testing innovative solutions for cleaner and better urban transport and mobility
LOGISTICS	MG.5.1-2016. Networked and efficient logistics clusters
	MG.5.2-2017. Innovative ICT solutions for future logistics operations
	MG.5.3-2016. Promoting the deployment of green transport, towards Eco-labels for logistics
	MG.5.4-2017. Potential of the Physical Internet
	MG.6.1-2014. Fostering synergies alongside the supply chain (including e-commerce)

H2020-Mobility for Growth	Topics linked to ERRAC roadmap Topics
	MG.6.3-2015. Common communication and navigation platforms for pan-European logistics applications
INFRASTRUCTURE	MG.7.1-2017. Resilience to extreme (natural and man-made) events
	MG.7.2-2017. Optimisation of transport infrastructure including terminals
	MG.7.1-2014. Connectivity and information sharing for intelligent mobility
SOCIO-ECONOMIC RESEARCH	MG.8.1-2014. Smarter design, construction and maintenance
	MG.8.1-2016. Research, technology development and market trends for the European transport manufacturing industries
	MG.8.2-2014. Next generation transport infrastructure: resource efficient, smarter and safer
	MG.8.3-2015. Facilitating market take up of innovative transport infrastructure solutions
	MG.8.3-2016. Assessing future requirements for skills and jobs across transport modes and systems
	MG.8.4-2015. Smart governance, network resilience and streamlined delivery of infrastructure innovation
	MG.8.4-2017. Improving accessibility, inclusive mobility and equity: new tools and business models for public transport in prioritised areas
	MG.8.5-2017. Shifting paradigms: Exploring the dynamics of individual preferences, behaviours and lifestyles influencing travel and mobility choices.
	MG.9.1-2015. Transport societal drivers
	MG.9.2-2014. User behaviour and mobility patterns in the context of major societal trends
	MG.9.3-2014. Analysis of funding schemes for transport infrastructure
	MG.9.4-2014. Research, technology development and market prospects for the European transport industries

5.1.3 Connecting Europe Facility: Transport

CEF Transport is the funding instrument to realise European transport infrastructure policy. It aims at supporting investments in building new transport infrastructure in Europe or rehabilitating and upgrading the existing one. CEF Transport focuses on cross-border projects and projects aiming at removing bottlenecks or bridging missing links in various sections of the core network and on the Comprehensive Network as well as for horizontal priorities such as traffic management systems. CEF Transport also supports innovation in the transport system in order to improve the use of infrastructure, reduce the environmental impact of transport, enhance energy efficiency and increase safety.
€24.05 billion are made available for the transport sector under the CEF programme for the 2014-2020 period.

5.1.4 Other public funding programs

The following categories of funding have been considered as public funding programmes (FOSTER RAIL D4.9, 2016):

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

The main sources are the European Structural and Investment Funds (EU Regional policy) :

- 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 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) invests in people, with a focus on improving employment and education opportunities across the European Union. For 2014-2020 the ESF focuses 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, 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 inter-modality, 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. 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. There are also lending possibilities, 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 EEC EU members. The EBRD is involved in supporting ICT, transport & infrastructure and general manufacturing.

The state funding comes in two major channels:

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

5.1.5 Private funding possibilities

The main methods to obtain private funding for rail R&D 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. 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.

This point highlights the fact that research and innovation should not be only limited to technological topics and that innovation is needed in railway project finance. Innovative ways of financing are required to increase the bankability and de-risk railway projects in order them attractive to private investors.

5.2 Classification of the ERRAC technology roadmap topics

5.2.1 Customer experience

The railway sector wishes to offer to all its customers a set of services that can meet 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 create the necessary "bridges" with other transport sectors in order to enable the creation of the truly seamless door-to-door trip.

In the following table, the topics of the ERRAC customer experience roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 3: System table of the customer experience roadmap

ERRAC ROADMAP: Customer experience	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Rapid reaction to queries - response time to enquiries in terms of service availability, routes, schedules, pre and end haulage satisfying customer demands	X		X	X	Rail
Customer needs and expectations including protection of privacy, and translation into functional service requirements			X	X	
Mobility and local behaviour of individuals and firms			X	X	
Key asset protection - Train security perception	X		X		
Key asset protection - Station security perception	X		X		
Human factors - Passengers and other users security perception	X		X	X	
Detection Systems - No intrusive sensors and no time spent in security check	X				
PRM[7] - Mobility for all	X	X	X		Transport
Land use improving the spatial appeal to passengers of the urban environments in which transport hubs are located			X		
Measuring customer satisfaction and involving customers in service design and operation				X	
Procedures, regulations and standards - Privacy and personal freedom protection			X		

5.2.2 Strategic and economics

The overall vision of the rail stakeholders regarding strategy and economics is to find innovative solutions 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.

In the following table, the topics of the ERRAC Strategic and economics roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

[7] People with Reduce Mobility.

Table 4: System table of the strategy and economics roadmap

ERRAC ROADMAP: Strategy and economics	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
General wagon issues. New transhipment technologies and operational concepts for low cost terminals	X	X			Rail
Improving local integration of land-use, transport and environment	X		X		
(New) charging and pricing policies strategies			X	X	
Adaptation of the existing railway system to the new climate conditions		X			
Assess the (socio) economic direct and indirect impact of rail use and rail infrastructure developments, both positive (network extensions) and negative network closures			X		
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			X	X	
Development of TEN-T missing cross border links with efficient green co-modal nodes	X	X			Transport
Spatial planning for mega hubs freight villages necessary for development of co-modality and long-distance transportation, new designs and layout	X	X			
Urban green logistics associated to the mega hubs and freight villages	X				
Land-use and spatial planning around sustainable efficiencies of public transport			X	X	
Integrating interchanges with urban policies (land use planning, economic development, smart cities, etc.)			X		
Framework for stakeholders' involvement in greater exchange of information on urban freight delivery				X	
New city logistics concepts, taking into account the impact of societal changes on commercial behavior and goods delivery in urban areas				X	
Network management strategies, integrated with sustainable urban mobility plans	X		X	X	
Evaluation of models efficiency and network management tools and policies			X	X	
Integration of an all modes and mobility options, and of a greater variety of network management tools, in network management systems				X	
Modal choice and travel behaviour : mobility demand management			X	X	
Mobility management and social networks			X	X	
Consistent data collection and exchange on urban mobility and development and use of harmonised models supporting data		X		X	

ERRAC ROADMAP: Strategy and economics	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
analysis, land use and transport forecasts, cost-benefit and multi-criteria economic analysis and decision-making					
Analyse and understand user behavior throughout the different stages of mobility in order to better reply to his needs while at the same time improving the business models			X	X	
Studies to promote the introduction and charging of the different transport modes according to the environmental impact costs			X	X	
Extreme climate events and resilience		X			
Procedures, regulations and standards - PPP			X		
Procedures, regulations and standards - International Security Organisations	X		X		

5.2.3 *Safety and security*

Railway safety should adapt to the paradigm shift towards the full integration of the railway into an intelligent intermodal transport system without jeopardizing the local and global safety of the system. Regarding railway security, the future research needs are mainly based on the following complementary priority areas: Human Factors, Technologies, Common procedure & regulations and cooperation with authorities.

In the following table, the topics of the ERRAC Safety and security roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 5: System table of the safety roadmap

ERRAC ROADMAP: Safety	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Introduction of human factors technologies in safety process	X				Rail
Research human machine and organizational interface under the RAM[8] frame	X	X			
Safety relevant impacts of automation and autonomous operation	X	X			
Research on safety contributions from RAM in a wider scope than technical safety				X	Transport
Industry 4.0 requires law 4.0, today we have law1.0			X		
Develop safety approach along the entire mobility/logistic chain	X	X			

[8] Reliability, Availability, Maintainability.

Table 6: System table of the security roadmap

ERRAC ROADMAP: Security	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Biometric identification and verification without violation of personal rights for the purpose of security of customers, freight and staff		X	X		Rail
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;	X	X			Rail
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	X	X			Rail
Detection and identification of dangerous material (weapons, explosives etc.)		X			Transport
The interaction and/or collaboration with social media should be investigated			X	X	Transport
Business Continuity methods, procedures and algorithms for safe-guarding vital functions by intentionally dropping non-vital functions and associated hardware	X	X			Transport
Analyse the potential of risk based security versus rule based security	X		X		Transport
Hybrid networks (shared versus self-sustaining networks)	X	X			Transport
Prediction of security threads		X			Transport
Economic and security improvements of fall-back systems (reducing cost for redundancy)				X	Transport
Response time and capability regarding limitation of the consequences of an attack	X				Transport
Recovery time and effectiveness regarding re-establishment of crucial business processes	X			X	Transport

5.2.4 Capacity, performance and competitiveness

Capacity, performance and competitiveness 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.

In the following table, the topics of the ERRAC Capacity, performance and competitiveness roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 7: System table of the capacity, performance and competitiveness roadmap

ERRAC ROADMAP: Capacity, performance and competitiveness	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Established and revised (as appropriate) 'degradation laws' that provide increasingly accurate actual and predicted states for railway assets	X				Rail
Fully autonomous operation	X	X			
Implement, or associate with a globally integrated, freight booking service and associated freight management systems that is able to maximise duty cycles and minimise the running of empty freight wagons	X				
Innovation to expand the throughput of freight terminals, especially exploiting autonomous and intelligent freight handling systems	X	X			

5.2.5 Energy and environment

The leading position of the railway transport in term of energy use and environmental impact has not been a stimulus to improve energy efficiency. In general, railway energy efficiency has remained substantially stable over the last 20 years. Some technological improvements have been offset by the increased consumption of auxiliary in passenger services. Meanwhile, in other modes of transport where the cost of energy is a very important part of the total costs, significant efforts have been made to improve efficiency, so that the advantage of the train has been reduced in latest period. The promotion of environmentally friendly and efficient rail transport of passengers and goods is a key objective in Europe. In the following table, the topics of the ERRAC Energy and environment roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shif2Rail are in red and the topics covered but not sufficiently are in orange.

Table 8: System table of the energy and environment roadmap

ERRAC ROADMAP: Energy and environment	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Hybrid traction: innovative technology applied to improving diesel fuel engines is required, along with the development and incorporation of hybrid energy solutions that maximise operational effectiveness. Energy resources, especially their resilience and availability for traction drive are a focus for innovation and in reducing the rolling stock contribution to environmental impact		X			Rail
SMART Grid: Delivery of managed energy distribution systems that maximise efficiency and report, in a qualitative manner, are required to in order to demonstrate effective energy usage thus a Pan-European approach to SMART Grid technology and innovation is envisaged.	X	X			
Advanced Traction Energy Supply: Sustained and efficient energy. Supply for rolling stock traction is critical for railway operations and innovative and technological advances in electrical energy distributions, development of higher voltage systems is anticipated, plus an increasing ability for regenerated energy to be returned to the grid.		X			
Non-traction energy: Innovative ways are required to support the belief that there is considerable potential for locally generated and renewable energy resources to be used to power local non-traction systems, especially at stations and terminals; further, excess energy could be used/sold for local consumption.		X			
Traffic flow management: Innovative ways for energy reduction and environmental impact through integrated traffic management	X				
Communications between TMS & DAS: Develop systems that increase the energy efficiency of driving through DAS supported driving and real time links with TMS		X			
Noise and vibration: There is a need to reduce noise and vibration levels across the railway and reduce associated impact on the environment. This is a pre-requisite for 24 hour operation		X			
Energy Efficient auxiliaries: Technology and innovation to reduce energy consumption of on-board systems (heating, lighting, etc.) are needed.		X			Transport
Climate change: Increased incident of weather extremes and climate change will impact the railway; technology and innovation is necessary to provide climate resilience and the ability to operate and recover from extreme weather related events. Technologies that protect infrastructure and trains from heat, water (rain, snow, ice, flood, etc.), and allowing a degree of end-to-end journey provision are sought	X	X			

5.2.6 Control command and communications

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. The railway transport is recognised as the safest mode of transport. 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.

In the following table, the topics of the ERRAC Control command and communications roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 9: System table of the control command and communication roadmap

ERRAC ROADMAP: Control command and communications (CCC)	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Need to have an open architecture to reduce energy consumption cost-effective design	X	X		X	Rail
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		X		X	

5.2.7 Infrastructure

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. Safety is always a key issue, a better rail infrastructure requires less maintenance, and hence a safer environment for users as well as the workforce.

In the following table, the topics of the ERRAC Infrastructure roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 10: System table of the infrastructure roadmap

ERRAC ROADMAP: Infrastructure	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Novel materials, exploiting the potential of, for example, low carbon footprint materials, emerging materials (e.g. graphene, foam metal) and the increased use of recycled materials		X			Transport
Adoption of new processes and technologies such as nanotechnology, biotechnology		X			
Increased use of building information management (BIM)		X			

5.2.8 Rolling Stock

A large part of the attractiveness of the railway transport is based on the perception of the rolling stock 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 rolling stock 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).

In the following table, the topics of the ERRAC rolling stock roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 11: System table of the rolling stock roadmap

ERRAC ROADMAP: Rolling stock	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
EE Auxiliaries - Optimisation and development of intelligent management auxiliaries		X			Rail
Innovative propulsion - Implementation of hydrogen fuel cell of RAMS/LCC[9] incl. the aspect of hydrogen production & storage		X			

[9] Lifecycle cost

ERRAC ROADMAP: Rolling stock	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Energy and Environment - Environmental friendly and energy efficient HVAC		X			
Freight and Urban Mobility - Interfaces and complementarities: New techniques and vehicles for urban freight delivery	X				
Safety - Train collisions preventions and effects mitigation (active and passive safety)	X	X			
Energy and Environment – Eco-procurement specifications and harmonisation			X	X	Transport

5.2.9 *IT and enabling technologies*

"IT and enabling technologies" is a very broad, complex and very fast-moving area. The societal demand coming from the end-users makes the adoption of these technologies vital for the future of the rail sector. 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 and providing the tools to manage heterogeneous data are essential. In the following table, the topics of the ERRAC IT and enabling technology roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by SHhift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 12: System table of the IT and enabling technologies roadmap

ERRAC ROADMAP: IT and enabling technologies	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Safety/security - Powerful algorithms in closed-circuit television (CCTV)		X			Rail
Urban - New city logistics concepts for freight and urban mobility	X		X	X	
Urban - Governance for integrated ticketing	X				
Urban - New tools and products for traffic and travel information	X			X	
Urban - Privacy and security aspects			X		
Safety/security - EU procedures, regulations & standards			X		
Safety/security - Guarantee for privacy and personal freedom protection			X		Transport
Safety/security - New sensors against terrorism attacks		X			

5.2.10 Training and education

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.

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.

In the following table, the topics of the ERRAC Training and education roadmap which are not fully included in the new Shift2Rail MAAP (Shift2Rail, 2017) are listed and classified in accordance with the methodology described in section 5. The topics not covered by Shift2Rail are in red and the topics covered but not sufficiently are in orange.

Table 13: System table of the training and education roadmap

ERRAC ROADMAP : Training and education	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Trends in technical systems, production and operational methods and industry structure - Value added and changes in volume trends, employment trends		X		X	Rail
Technical competences - New dimension to skills development		X		X	
Existing railway higher education programs - Inventory of current railway higher education programs				X	
Bridging the gaps between knowledge production in Higher Education institutions and required know-how in the different industrial environments - Gaps between knowledge production in Higher Education institutions and required know-how				X	
Demand for railway higher education by the industry				X	
Training and education for top management in the sector				X	
Develop a Knowledge Management System (KMS) Analyse and to compare the existing competences, tools and facilities for railway education and research				X	
Periodically collect the research results and educational options provided by the associated EURNEX institutions (universities and research centers) and all other universities in Europe.		X			

ERRAC ROADMAP : Training and education	Operation & Asset management	Technology & development	Policy & Society	Economy & business	Level
Skills development and changing trends in staff requirements. Global trade			X	X	Transport
Legal competences			X		
Operational cooperation - Market areas, customer demands, liberalization, related passenger and freight services				X	
Advanced training courses - New technological professional profiles			X	X	
International legislation and market liberalization			X	X	
Explore advanced training courses in different settings				X	
Lifelong learning actions addressing emerging technologies - Recovering current staff to new organisational and emerging skill needs				X	
Create innovative programs for "proficiency" through innovation		X		X	
Promote higher flexibility, tailored contents, operational and practical subjects for educational courses in the rail sector, and also in the more general transport domain				X	
Promote and / or reinforce the interaction between educational establishments and industry - "trusting partnerships" between academia and practitioners on job coaching of practitioners (e.g. "seed planting" approach). Promote full and unhindered mobility of students, professors / teaching staff, and industry professionals				X	
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			X		
Knowledge from basic disciplines (e.g. mathematics, statistics) in order to enable analysis and management of complex systems				X	
Specific and high-level knowledge related to the various transport disciplines. Experience in project management with development of leadership, mediation and communication skills				X	

5.2.11 Summary table

In the previous system tables, topics not covered by Shift2Rail were identified. The topics not covered by Shift2Rail mainly related to the transport system do not really belong to the scope of the JU programme. Thus, the following table lists only ERRAC topics relevant for the railway system not covered by Shift2Rail. It is important to note that not all topics were sufficiently or clearly detailed and some could be grouped as they are addressing similar topics. Therefore, these topics have been reviewed and included when relevant to Section 7: Recommendations.

Table 14: Summary table of topics not covered by Shift2Rail belonging to the rail system

ERRAC ROADMAP: Customer experience
Mobility and local behaviour of individuals and firms
Key asset protection - Train security perception
Key asset protection - Station security perception

ERRAC ROADMAP: Strategy and economics
Improving local integration of land-use, transport and environment
(New) charging and pricing policies strategies
Adaptation of the existing railway system to the new climate conditions
Assess the (socio) economic direct and indirect impact of rail use and rail infrastructure developments, both positive (network extensions) and negative network closures
ERRAC ROADMAP: Safety
Introduction of human factors technologies in safety process
ERRAC ROADMAP: Security
Biometric identification and verification without violation of personal rights for the purpose of security of customers, freight and staff
ERRAC ROADMAP: Capacity, performance and competitiveness
Implement, or associate with a globally integrated, freight booking service and associated freight management systems that is able to maximise duty cycles and minimise the running of empty freight wagons
ERRAC ROADMAP: Energy and environment
Advanced Traction Energy Supply: Sustained and efficient energy. Supply for rolling stock traction is critical for railway operations and innovative and technological advances in electrical energy distributions, development of higher voltage systems is anticipated, plus an increasing ability for regenerated energy to be returned to the grid.
Non-traction energy: Innovative ways are required to support the belief that there is considerable potential for locally generated and renewable energy resources to be used to power local non-traction systems, especially at stations and terminals; further, excess energy could be used/sold for local consumption.
ERRAC ROADMAP: Rolling stock
Energy Efficient Auxiliaries - Optimisation and development of intelligent management auxiliaries
Innovative propulsion - Implementation of hydrogen fuel cell of RAMS/LCC incl. the aspect of hydrogen production & storage
Energy and Environment - Environmental friendly and energy efficient HVAC
Freight and Urban Mobility - Interfaces and complementarities: New techniques and vehicles for urban freight delivery

6. BARRIERS

Some of main barriers which prevent the adoption of innovative technologies and approaches, leading to the achievement of ERRAC roadmaps, have been identified.

6.1 Regional disparities

The regional disparities in terms of economic performance and infrastructure development in Europe implies disparities in terms of priorities in various economic areas, the area of transport included. As it has been observed in *D3.8 ERRAC-Alignment of ERRAC priorities with national rail strategies*, most of European eastern countries prioritize modernisation and infrastructure development over research and innovation. For instance, the development and implementation of digital technologies are not always included in the transport policies and strategies of some eastern countries, often more considered as a way of improvement for established modern transport systems rather than as a game changer which will bring high added value.

6.2 Return of investment

Why should we implement innovations if things seem to work perfectly well? In the railway sector, as well as in many industries, the global transformation of the market and environment is not always enough to trigger the adoption and implementation of innovation. The main reason being, that with the implementation of innovation often comes high investment in term of costs and time. Therefore, if the return of investment is not high enough or not demonstrated, the chance of adoption of an innovation remains low. As it has been observed in the energy sector, in some cases, even with a support from policies and regulations, innovative technologies were not implemented on a large-scale due to the uncertainties of their return of investment.

6.3 Safety

Safety is one of the major issue of the railway sector, railway operators undertake every day the responsibility of the life of millions of passengers. In railway safety, it is difficult to divide the railway system into independent subsystems and not consider it as whole. This is due to the high interdependence which exists between railway system components. Therefore, any implementation of innovative technology can have a direct or indirect impact on safety. This high system dependence also implies that an increase of complexity of the global system, which could be expected from the implementation of innovative technologies, can lead to the increase of complexity of the system safety analysis and in some cases, can jeopardize the safety of the entire system.

6.4 Capabilities

The development of digital technologies, such as big data for instance, raises novel issues about privacy and ethics. Impacts on interconnected fields are to be expected when implementing innovative technologies. These issues can be tackled but it requires capabilities and expertise not always possessed by the technology provider or user. If not addressed appropriately, it could lead to major concerns and discourage future initiatives.

6.5 Regulation

"The industry 4.0 requires laws 4.0". As for Member States, in general terms, transport policies do not provide sufficient support to the development and deployment of innovative technologies.

EU transport policy could further address how innovative technology might contribute to a faster, more cost efficient, durable and sustainable development of the whole transport system. For example, in the field of transport infrastructure, the environmental positive impact is well addressed in the regulation but other factors such as durability, performance during service life and conservation are not appropriately considered.

7. RECOMMENDATIONS

Building upon the outcomes of *D3.8 ERRAC-Alignment of ERRAC priorities with national rail strategies* especially the national disparities observed in this study, the recommendations of this document address the following aspects:

- **"Shift2Rail2.0":** topics which are not currently covered by Shift2Rail that should be studied and implemented at the level of the railway system. These topics are key for the enhancement of the attractiveness and competitiveness of the railway sector;

- **Framework Programme 9**: topics which are relevant for the whole transport system that would grandly contribute to the achievement of a truly integrated transport system.

Topics are **not** present in a prioritized list.

7.1 "Shift2Rail 2.0"

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

- **Management of obsolescence** in urban rail systems: how to achieve conciliation of different life cycles of sub-sytems and their components. Standardised and modular „plug-and-play" architecture for urban rail sub-systems allowing lean design, improved reliability and automated maintenance and reduced overall LCC;
- **Enhanced communication of intelligent trains:** communications between trains, between train and infrastructure and between train and passenger/freight customers;
- **New "intelligent" materials** with self healing properties and ability to change properties in response to an external stimuli;
- **Alternative propulsion concepts** such as fuel cells, hybrid powered tractions;
- **Rolling stock homologation process** - define one european homologation process for railways of European Community's level (objective of the on-going implementation of the Technical Pillar of the Fourth Railway Package). Virtual certifications/simulations is essential in the future;
- **Alternatives to Diesel Engines:** A number of different technologies that may provide an alternative to diesel propulsion in non-electrified lines are already under development. These need to be evolved to the point that technical and economic feasibility can be shown before that they are fully recognized as legitimate substitutes of diesel traction;
- **Reduced Energy Consumption:** The trains' energy consumption of both mainline and urban railways is influenced by many different factors, and therefore a number of complementary technological developments should be carried out in order to reduce it;
- **Noise Reduction:** Because noise is a complex technical issue, there is an increasing need of improving prediction and analysis methods, especially for bridges and tunnels. These which may later on support the identification of the most suitable noise mitigation measures, and in many cases allow predicting performance accurately during the design phase;

IP2 - Advanced Traffic Management and Control Systems

- **Automated train operation**: Technical solutions to migrate from existing train/track GoA1 environments up to GoA2 or GoA1/2 up to GoA3/4;
- **Automated train operation without additional infrastructure**: Signal detection/recognition by a sensor system, Regularity framework for approval has to be developed in parallel;
- **Advanced Traffic Management (TMS) functions**: Develop new solutions in order to have the capability of interactions with other transport modes, defining standard interfaces for communication of multimodal data. Increase the automation level in order to react dynamically to variation in the demand of transport. Integrate new connected services in order to optimize and extend the standard TMS functionalities;
- **Advanced safety solutions:** V2V cooperative alert solutions to ease the interaction of different transport modes with railways;
- **Next Generation of ERTMS**: Starting from existing ERTMS Standard and new advanced technologies define a more integrated System including also new functionalities and features for interoperability of European Community's level railways;

- **Frequency bandwiths for urban and suburban railways**: To investigate possible protocols of radio spectrum use in the 5,9 GHz range, in line with open and dedicated bandwiths approaches in order to guarantee the priority for CBTC safety critical applications. To analyse how urban rail non-safety applications, which could be shared within the 5,8-5,9 GHz spectrum, could use a part of ITS (existing or new) set of standards. Last, investigation are needed to define business models for the use of LTE for CBTC (data) and for operations (voice, video, passenger information, maintenance data);
- **New generation of CBTC (2.0)**. Research allowing for development of modular sub-systems and components.

IP3 - Cost-Efficient and Reliable High-Capacity Infrastructure

- **Innovative modular track and wayside**, in order to reduce the time of installation of a new line (urban domain, possibly extended to some main lines)
- **3D innovative BIM technologies for railways (infrastructure, suprastructure and stations)**, from design and BIM to 3D acquisition of the existing as built;
- **Internet of Things and Artificial Intelligence for enhanced health asset management (high TRL),** explore the use of Internet of thing and Artificial Intelligence for smart monitoring and maintenance;
- **Assess the (socio) economic direct and indirect impact of rail use and rail infrastructure developments**, both positive (network extensions) and negative network closures;
- **New and advance types of infrastructure**: New and advanced types of infrastructure might use new design principles and therefore not be compatible with the existing system. New advanced concepts are in this case only applicable for new lines which are standalone and do not need to be integrated with existing lines or network;
- **New materials and sustainability**: Focus is the use of new materials and closed cycle waste management systems towards 100% level of recycling;
- **Working methods and robotisation**: Both for maintenance, building new infrastructure and renewals, working methods can be improved in order to be more efficient and less costly.
- **Whole system approach for the reduction of railway operational and infrastructure costs:** New models to deliver efficient and affordable infrastructure, rolling stock and railway operation allow the rail mode to be viable in areas of low demand and to compete for new transport links. Design, service solutions, technologies draw inspiration from other sectors such as light rail, automotive and aviation.

IP4 - IT Solutions for Attractive Railway Services

- **Mobility as a Service enabled by the Interoperability Framework technology and Governance**. Mobility as a Service deployment in Europe needs different levels of integration to become a reliable and sustainable alternative to private mobility. Integration should be at information, booking and payment, service offer and governance levels. Interoperability Framework and sematic web technologies as well as travel shopping, booking, travel companion can be the missing components that enable a fully interoperable mobility ecosystem at urban and extra-urban level;
- **Seamless and customized end to end journeys**: Provide Rail Customers (passenger and freight) with seamless, efficient and cost-effective end to end journeys, whatever the mode of transportation. Integration of both passenger and freight railway services into a single European end2end jorney area with other modes of transportation to provide multimodal, seamless, efficient and cost-effective trip for all types of customers;

- **Multi Modal Planning**: Provide an intelligent and adaptive multi-modal traffic management system to Operators to provide seamless end to end journeys to customers (passengers and freight;
- **Accessibility for all**: Provide improved access to passengers of varying age, social categories, culture and language, life characteristics and level of mobility, taking into account the acceptance of innovative technical solutions at both urban and inter-urban level;
- **Combined implementation of Internet of Things and Artificial Intelligence technologies (high TRL)** to provide efficient capture, storage, management and interpretation of data.
- **Toward a fully intelligent and integrated railway system:** From design to end-of-life, the entire railway value chain is efficiently managed through a continuous flow of information, with intelligence at each level of the system to ensure flexibility and real-time responsiveness. Rail vehicles, infrastructure and command and control systems are fully digitalized and element is also endowed with the ability to perform goal-oriented tasks with a high degree of autonomy (TRL should be highest as possible).

IP5 – Technologies for Sustainable & Attractive European Rail Freight

- **Integrating freight trains in high-intense passenger operations** to ensure fast and seamless movements of multimodal cargo through the rail network;
- **Automated yards, intermodal hubs, ports and cross-modal interchange locations** connect the rail system into the multimodal logistic chain;
- Implement, or associate with a globally integrated, **freight booking service and associated freight management systems** that is able to maximise duty cycles and minimise the running of empty freight wagons;
- **Spatial planning for mega hubs freight villages** necessary for development of co-modality and long-distance transportation, new designs and layout;
- **Freight Mobility** - Interfaces and complementarities: New techniques and vehicles for urban freight delivery;
- **Implement, or associate with a globally integrated, freight booking service** and associated freight management systems that is able to maximise duty cycles and minimise the running of empty freight wagons.

Cross-Cutting Activity

- **Working area 3.1 (Safety):**
  - **Software SIL[10] demonstration:** The operation of automated rail systems has to cope with very strict safety requirements. A study could enlarge the scope of the formal „proof" method to the whole system so that it could be used for the global safety assesment of the systems (urban and mainline domains);
  - **Fire safety** as a safety and secured topic to qualify exactly what are the major risks (related to materials, components, sub-systems including rolling stock) and to improve their mitigation (through design, operation and maintenance of assets);
  - **Intrusion detection**, a particularly -but not exclusively- relevant field for fully automated rail systems, needs additional research actions as well as technical harmonisation;
  - **Better inclusion of human factors and organisational aspects in railway safety;**

[10] Safety Integrity Level

- **Safety functions using Artificial Intelligence** and challenges regarding rolling stock validation and homologation;
- **Cyber-security:** Assure protection against cyber-attacks**.**

- **Working area 3.2 (Standardisation):**
  - Research preparing for **standardisation of interface between Platform Screen Doors (PSD)** and the **operating system** of automated lines using CBTC – *Operational topic*;
  - Development of **open architecture and standard interface EAM** (Extranet Access Management) **softwares** able to „plug and play" multiple data source from various sub-systems sensors and equipment from multiple suppliers;
  - **Standardisation of the loading gauge UIC/UE28**:; increase of the wagons' productivity (volume and mass) ; automated loading and unloading systems;
  - **Validation/homologation of systems based in new digital technologies** (e.g. Artificial Intelligence).

- **Working area 3.3 (Smart maintenance):**
  - **Broken rail detection**: broken rails so far detected by a combination of human checks and/or track circuit detection. How could the new tehnologies provide innovative broken rail detection methods in a way which would ensure safe train operation? This is particulary important for the development of fully automated utban rail systems operated on steel wheel;
  - **Remote diagnostics and maintenance automation**: Innovative technologies to gather rail assets condition data to collect & share real time equipments status data while the train is in operation adressing both urban and mainline;
  - **Management of obsolescence** in urban rail systems: how to achieve conciliation of different life cycles of sub-sytems and their components. Standardised and modular „plug-and-play" architecture for urban rail sub-systems allowing lean design, improved reliability and automated maintenance and reduced overall LCC;
  - **Collaboration tools:** The extend of the supply chain, requires new solutions supporting collaboration-enabled maintenance, service and support from the various partners involved. Collaboration solutions should support maintenance training, field inspections, maintenance actions and repairs, on-site or and in the field;
  - **Maintenance 2 GO**: Maintenance 2 GO should be seen as an initiative, rather than an objective. As an initiative, it is the driving force to enable transformations and lead towards improvements needed to increase the availability, especially in situations where 24/7 availability is required;
  - **Maintenance organisation**: Automated digitalized platforms for the management of railway assets will be able to support decision making in order to optimize the resources utilization, planning prognostic, risk and condition-based maintenance interventions;
  - **Maintenance execution**: Whilst the effort to reduce the maintenance, almost inevitably there is still the need for inspection, maintenance and repair actions. In these cases, the use of autonomous and intelligent robots will become more and more common place, especially in places with low accessibility and for unsafe or difficult activities for the personnel.

- **Working area 4 (Smart mobility):**
  - Feasibility of **mixed operation** between regional level semi-direct and omnibus trains and assessment of their impact on the operation of the most loaded rail line section.
- **Working area 5.1 (Energy):**
  - **Energy-efficient HVAC systems**: HVAC can require up to 50% of total energy consumption due to frequent stop-and-go operation and multiple wide doors. To offer competitive comfort to pasengers, HVAC/cooled ventilation is no longer an option. There is great potential for energy savings contributing to overall energy efficiency of railways;
  - Further operational **development, validation and testing of the standardised duty cycles** conceptualised and developed for urban rail. High efficent modelling tools to optimize the energy consumtion of a line;
  - **Advanced Traction Energy Supply**: Sustained and efficient energy. Supply for rolling stock traction is critical for railway operations and innovative and technological advances in electrical energy distributions, development of higher voltage systems is anticipated, plus an increasing ability for regenerated energy to be returned to the grid;
  - **Non-traction energy**: Innovative ways are required to support the belief that there is considerable potential for locally generated and renewable energy resources to be used to power local non-traction systems, especially at stations and terminals; further, excess energy could be used/sold for local consumption;
  - **Global analysis of energy efficiency:** Exhaustive analysis of the energy efficiency of the different components of the railway system.

- **Working area 5.2 (Environment):**
  - **Reduction of wear and tear, noise and vibrations**: where and how to achieve improvements in urban rail systems (urban domain, possibly extended to some main lines);
  - **Adoption of 'circular economy' principles** enables the railway to move towards 'zero-waste' operation;
  - **Development of climate services** for the adaptation of .railway infrastructure to climate change

- Other:
  - **Digitization of the supply chain (Industry 4.0):** Digital manufactuing process, exchange of digital informaiton in the supply chain, new materials, modularity, additive manufacturing, virtual and rapid prototyping.
  - **Autonomous units**: Deeply optimize capacity of infrastructure as well as connecting of rail traffic with other modes of transport. Provide a highly integrated traffic system for nearly door-to-door travel on demand by maximum use of rail infrastructure with high safety level and high riding comfort and high punctuality of the transport of passengers and goods.
  - **Innovative PPP structuring for rail infrastructure procurement**: the Railway sector must find new ways to reverse backlogs in infrastructure spending, renew their rolling stock and invest in more capacity or new projects in order to tackle the growing demand. The global trend confirms the emergence of private sector partnering as a serious component to railway infrastructure financing and management, where

models such as PPPs constitute a promising solution to attract private participation. However, there are many examples from the rail sector that illustrate the difficulty of setting successful and well-structured PPPs. Private participation possibilities are numerous, and additional PPP schemes could be explored for the structuring of financial deals, including infrastructure and rolling stock, urban rail, signaling etc

7.2 Framework Programme 9

- **Combination rail - AVs**[11]: the new concept combined with the development of the automated vehicles could be a potential game changer of the traditional public transport. In such a model, (urban) rail plays a critical role as the backbone of mobility along the most heavily patronised corridors, and it is even more important that the quality of rail service delivery be excellent in order to convince large segments of the travelling public to rely on the MaaS cocktail of mobility.
- **Improved operation with traditional public transport and interchange hubs**: Delivering seamless travel experience in urban areas is a challenge as most travel patterns will involve the use of several carriers, modes and postentially companies. Interchange and intermodality can be further improved from infrastructure, ticketing and information viewpoints.
- **Cyber-protection:** Additional and novel approaches to cyber-protection should be encouraged and developed: identification of threat, assessment and definition of mitigation means and contingency processes, possibly in synergy with other sensitive sectors
- **Increase the overall system security level without jeopardizing mobility (**security controls, ...) -fast & non-intrusive safety controls in accordance with ethics, health and privacy requirements: biometric identification, non-radioactive scanning and detection and identification of dangerous material
- **Multimodal transport service timed to the second. Real-time data exchange between transport modes (supply side) for coordinated improvement** of both operations and maintenance: situational awareness, synchronization of different transport modes in real-time providing door to door travel and end to end logistics services, supports service operation timed to the second. This results in increased and enhanced operational flexibility and contributes to a more robust, resilient and reliable service as well as faster recovery from service disruption. Important issues of availability, integrity, confidentiality and privacy need to be carefully addressed as well as cyber security".
- **Sustainable and ethical procurements** which includes the carbon footprint, with a whole life approach and focus on inputs to the system, recycling, transport of materials, renewable energy, operations and disposals.
- **Human-centered studies to identify measures aiming to improve the perception of security** at multimodal hubs, railway stations (urban and inter-urban), rail vehicles and to facilitate intervention and evacuation for safety and/or security reasons.
- **Enhance the resilience of the transport system**: Business continuity methods, procedures and algorithms for safe-guarding vital functions by intentionally dropping non-vital functions and associated hardware, recovery time and effectiveness regarding re-establishment of crucial business processes, economic and security improvements of fall-back systems (reducing cost for redundancy), technological and human factor centred solutions.

[11] Automated vehicles

- **Regulatory framework adapted to the transport system 4.0** which encourages the implementation of innovation with respect to environmental, ethical and safety requirements. Address. How innovative technology might contribute to a faster, more cost efficient, durable and sustainable development of the whole transport system? For example, in the field of transport infrastructure, the environmental positive impact is well addressed in the regulation but other factors such as durability, performance during service life and conservation are not appropriately considered.
- **Using social networks** to support security and crisis management in accordance with ethics and privacy requirements
- **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 model
- **Investigation of the effectiveness of eco charging of transport modes** according to their environmental impact
- **Public health impact of transport:** analysis of negative and positive impact on public health and related socio-economic aspects of transport modes
- Encourage incentives and explore innovative solutions to **foster the shift from fossil fuel transport to sustainable transport** (goods and passengers)
- **Innovative financing shemes for transport infrastructure:** Analysis of funding mechanisms & risk sharing challenges, Definition of innovative operation/asset/service value development opportunities, financing shemes and PPP structuring patterns

8. REFERENCES

SETRIS, D3.8 ERRAC-Alignment of ERRAC priorities with national rail strategies, 2017

FOSTER RAIL, D3.2 Strategic Rail Research and Innovation Agenda, 2015
http://www.errac.org/wp-content/uploads/2013/07/FOSTER-RAIL_WP3_3-2_UNI_SRRIA-Final_for_Uplooad.pdf

ERRAC ROADMAP, Strategic Rail Research Agenda, 2007

FOSTER RAIL, D2.6 Updated Reference Rail Business Scenarios, 2015
http://www.errac.org/wp-content/uploads/2013/07/FR_D2_6_Final_for_Upload.pdf

COM (2011) 144, WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, 2011
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:en:PDF

FOSTER RAIL, D1.4 Developing links and coordination strategies between ERRAC, EU and national technology platforms. Recommendations for the future, 2016

FOSTER RAIL, D4.9 Final Technology and Innovation Roadmaps, 2016
http://www.errac.org/wp-content/uploads/2013/07/FR_WP4_UIC_D4-9_Final_for_upload.pdf

SHIFT2RAIL, S2R Multi-Annual Action Plan, 2015

SHIFT2RAIL, S2R Multi-Annual Action Plan part A, 2017

ERRAC, ERRAC 2050 Vision: Rail- the Backbone of Europe's mobility, forthcoming

EU Regional Policy, http://ec.europa.eu/regional_policy/thefunds/index_en.cfm

9. APPENDIX A: STAKEHOLDER REVIEW OF THE ERRAC COMMUNITY

Questionnaire:

Rolling Stock

Please rate the importance of the following topics for the future railway/transport system?

	Not important at all	Slightly important	Moderately important	Very important	Extremely important	No opinion
Management of obsolescence in urban rail systems : Standardised and modular „plug-and-play" architecture, improved reliability and automated maintenance and reduced overall LCC	○	○	○	○	○	○
Enhanced communication of intelligent trains: communications between trains, train and infrastructure and train and passenger/freight customers	○	○	○	○	○	○
New "intelligent" materials with self healing properties and ability to change properties in response to an external stimuli	○	○	○	○	○	○
Alternative propulsion concepts such as fuel cells, hybrid powered tractions	○	○	○	○	○	○

In your opinion, what other topics currenlty not sufficiently addressed and related to rolling stocks would be of importance for the future railway/transport system?

Your answer

Infrastructure

Please rate the importance of the following topics for the future railway/transport system?

	Not important	Slightly important	Moderately important	Very important	Extremely important	No opinion
Innovative modular urban track and wayside, in order to reduce the time of installation of a new line	○	○	○	○	○	○
3D innovative BIM technologies for railways from design and BIM to 3D acquisition of the existing as built	○	○	○	○	○	○
Internet of Things and Artificial Intelligence for enhanced health asset management (high Technology Readiness Level)	○	○	○	○	○	○
Assess the (socio) economic direct and indirect impact of rail use and rail infrastructure developments, both positive (network extensions) and negative network closures	○	○	○	○	○	○
Broken rail detection: broken rails so far detected by a combination of human checks and/or track circuit detection	○	○	○	○	○	○

Broken rail detection: broken rails so far detected by a combination of human checks and/or track circuit detection	○	○	○	○	○	○
Remote diagnostics and maintenance automation: Innovative technologies to gather rail assets condition data to collect & share real time equipments status data	○	○	○	○	○	○
Development of open architecture and standard interface EAM (Extranet Access Management) softwares able to „plug and play" multiple data source from sensors and equipment from multiple suppliers	○	○	○	○	○	○

In your opinion, what other topics currenlty not sufficiently addressed and related to infrastructure would be of importance for the future railway/transport system?

Your answer

Control, command, communication and signalling

Please rate the importance of the following topics for the future of the railway/transport system?

	Not important at all	Slightly important	Moderately important	Very important	Extremely important	No opinion
Frequency bandwiths for urban and suburban railways: To investigate possible protocols of radio spectrum use in the 5,9 GHz range	○	○	○	○	○	○
New generation of CBTC (2.0). Research allowing for interchangeability development of sub-systems and components	○	○	○	○	○	○
Research preparing for standardisation of interface between Platform Screen Doors (PSD) and the operating system of automated lines using CBTC	○	○	○	○	○	○

In your opinion, what other topics currently not sufficiently addressed and related to control, command, communication and signalling would be of importance for the future railway/transport system?

Your answer

Logistics

Please rate the importance of the following topics for the future railway/transport system?

	Not important at all	Slightly important	Moderately important	Very importante	Extremely important	No opinion
Integrating freight trains in high-intense passenger operations to ensure fast and seamless movements of multimodal cargo through the rail network	○	○	○	○	○	○
Automated yards, intermodal hubs, ports and cross-modal interchange locations connect the rail system into the multimodal logistic chain	○	○	○	○	○	○
Implement freight booking service and freight management systems that are able to maximise duty cycles and minimise the running of empty freight wagons	○	○	○	○	○	○
Spatial planning for mega hubs freight villages for development of co-modality and long-distance transportation, new designs and layout	○	○	○	○	○	○
Freight Mobility - Interfaces and complementarities: New techniques and vehicles for urban freight delivery	○	○	○	○	○	○

In your opinion, what other topics currently not sufficiently addressed and related to logistics would be of importance for the future railway/transport system?

Your answer

Mobility as a Service

Please rate the importance of the following topics for the future railway/transport system?

	Not important at all	Slightly important	Moderately important	Very important	Extremely important	No opinion
Feasibility of mixed operation between regional level semi-direct and omnibus trains and assessment of their impact on the operation of the most loaded rail line section	○	○	○	○	○	○
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 model	○	○	○	○	○	○
Mobility as a Service enabled by the Interoperability Framework technology and Governance: semantic web technologies, travel shopping, booking etc enabling an nteroperable mobility ecosystem at urban level	○	○	○	○	○	○
Combined implementation of Internet of Things and Artificial Intelligence technologies (high Technology Readiness Level) to provide efficient storage, management of data etc	○	○	○	○	○	○

Combination rail - Autonomous Vehicle: the new concept combined with the development of the automated vehicles . In such a model, urban rail plays a critical role as the backbone	○	○	○	○	○	○
Improved operation with traditional public transport and interchange hubs: Delivering seamless travel experience in urban areas is a challenge as most travel patterns will involve the use of several carriers, modes and companies	○	○	○	○	○	○
Multimodal transport service timed to the second. Real-time data exchange between transport modes for coordinated improvement of both operations and maintenance: situational awareness, synchronization etc	○	○	○	○	○	○
Enhance the resilience of the transport system: Business continuity methods, procedures and algorithms for safe-guarding vital functions, recovery time, human factor centred solutions etc	○	○	○	○	○	○

Regulatory framework adapted to the transport system 4.0 which encourages the implementation of innovation with respect to environmental, ethical and safety requirements.	○	○	○	○	○	○

In your opinion, what other topics currently not sufficiently addressed and related to mobility as a service would be of importance for the future railway/transport system?

Your answer

Energy & Environment

Energy and Environment: Please rate the importance of the following topics for the future railway/transport system?

	Not important at all	Slightly important	Moderately important	Very important	Extremely important	No opinion
Energy-efficient HVAC systems: HVAC can require up to 50% of total energy consumption due to frequent stop-and-go operation and multiple wide doors	○	○	○	○	○	○
Further operational development, validation and testing of the standardised duty cycles conceptualised and developed for urban rail. High efficent modelling tools to optimize the energy consumption of a line	○	○	○	○	○	○
Advanced Traction Energy Supply: Sustained and efficient energy. Supply for rolling stock traction, operations and innovative and technological advances in electrical energy distributions	○	○	○	○	○	○
Non-traction energy: Innovative ways to locally generate and use renewable energy resources to power local non-traction systems	○	○	○	○	○	○

Reduction of wear and tear, noise and vibrations: where and how to achieve improvements in urban rail systems	○	○	○	○	○	○
Adoption of 'circular economy' principles enables the railway to move towards 'zero-waste' operation	○	○	○	○	○	○
Development of climate services for the adaptation of railway infrastructure to climate change	○	○	○	○	○	○
Sustainable and ethical procurements which includes the carbon footprint, with a whole life approach and focus on inputs to the system, recycling, transport of materials, etc	○	○	○	○	○	○
Investigation of the effectiveness of eco charging of transport modes according to their environmental impact	○	○	○	○	○	○

In your opinion, what other topics currently not sufficiently addressed and related to energy and environment would be of importance for the future railway/transport system?

Your answer

Safety & Security

Please rate the importance of the following topics for the future railway/transport system?

	Not important at all	Slightly important	Moderately important	Very important	Extremely important	No opinion
Software SIL demonstration: enlarge the scope of the formal „proof" method to the whole system so that it could be used for the global safety assesment of the systems (urban and mainline)	○	○	○	○	○	○
Fire safety as a safety and secured topic to qualify exactly what are the major risks (related to materials, components, etc) and to improve their mitigation (design, operation and maintenance of assets)	○	○	○	○	○	○
Intrusion detection, a particularly -but not exclusively- relevant field for fully automated rail systems, needs additional research actions as well as technical harmonisation	○	○	○	○	○	○
Cyber-protection: Additional and novel approaches to cyber-protection, identification of threat, assessment and definition of mitigation means and contingency processes	○	○	○	○	○	○

Increase the overall system security level without jeopardizing mobility -fast & non-intrusive safety controls in accordance with ethics, health and privacy requirements	○	○	○	○	○	○
Human-centered studies to identify measures aiming to improve the perception of security at multimodal hubs, railway stations (urban and inter-urban), rail vehicles	○	○	○	○	○	○
Using social networks to support security and crisis management in accordance with ethics and privacy requirements	○	○	○	○	○	○

In your opinion, what other topics currently not sufficiently addressed and related to safety and security would be of importance for the future railway/transport system?

Your answer

Results:

14 people answered the questionnaire. The could be answered anonymously, but the possibility of providing contact and geographic information was given. 8 people answered the questionnaire anonymously, 6 people indicated their country which were France (2), Germany (1), Belgium (1), Spain (1) and Czech Republic (1).

To validate by the greater ERRAC community, the topics identified in deliverable D3.9, the following rating scale were used:

Level of importance	No opinion	Not important	Slightly important	Moderately important	Very important	Extremely important
Rating scale	Not considered	0	1	2	3	4

Topics having a rating between Moderately important and Extremely important will be kept.

The average and standardised rate by topic are the following:

Rolling stock	Rating
Management of obsolescence in urban rail systems : Standardised and modular „plug-and-play" architecture, improved reliability and automated maintenance and reduced overall LCC	**3,0**
Enhanced communication of intelligent trains: communications between trains, train and infrastructure and train and passenger/freight customers	**3,5**
New "intelligent" materials with self healing properties and ability to change properties in response to an external stimuli	**3,2**
Alternative propulsion concepts such as fuel cells, hybrid powered tractions	**3,3**

Rolling stock topics are rated between **Very important** and **Extremely important**.

The following extra topics were proposed:

"Rolling stock homologation process - define one european homologation process and apply cross acceptance"

"Cybersecurity and validation/homologation of systems based in new digital technologies (e.g. Artificial Intelligence)"

Infrastructure	Rating
Innovative modular urban track and wayside, in order to reduce the time of installation of a new line	**3,0**
3D innovative BIM technologies for railways from design and BIM to 3D acquisition of the existing as built	**3,5**
Internet of Things and Artificial Intelligence for enhanced health asset management (high Technology Readiness Level)	**3,4**
Assess the (socio) economic direct and indirect impact of rail use and rail infrastructure developments, both positive (network extensions) and negative network closures	**3,4**

Broken rail detection: broken rails so far detected by a combination of human checks and/or track circuit detection	**3,2**
Remote diagnostics and maintenance automation: Innovative technologies to gather rail assets condition data to collect & share real time equipments status data	**3,8**
Development of open architecture and standard interface EAM (Extranet Access Management) softwares able to „plug and play" multiple data source from sensors and equipment from multiple suppliers	**3,3**

Infrastructure topics are rated between **Very important** and **Extremely important**.
No extra topic was proposed.

Control, command, communication and signalling	Rating
Frequency bandwiths for urban and suburban railways: To investigate possible protocols of radio spectrum use in the 5,9 GHz range	**3,0**
New generation of CBTC (2.0). Research allowing for interchangeability development of sub-systems and components	**3,0**
Research preparing for standardisation of interface between Platform Screen Doors (PSD) and the operating system of automated lines using CBTC	**3,0**

Control, command, communication and signaling topics are rated between **Very important** and **Extremely important**.
No extra topic was proposed.

Logistics	Rating
Integrating freight trains in high-intense passenger operations to ensure fast and seamless movements of multimodal cargo through the rail network	**3,0**
Automated yards, intermodal hubs, ports and cross-modal interchange locations connect the rail system into the multimodal logistic chain	**3,3**
Implement freight booking service and freight management systems that are able to maximise duty cycles and minimise the running of empty freight wagons	**3,5**
Spatial planning for mega hubs freight villages for development of co-modality and long-distance transportation, new designs and layout	**2,8**
Freight Mobility - Interfaces and complementarities: New techniques and vehicles for urban freight delivery	**3,7**

Logistics topics are rated between **Moderately important** and **Extremely important**.
The following extra topics were proposed:
"Standardisation of the loading gauge UIC/UE28 ; increase of the wagons' productivity (volume and mass) ; automated loading and unloading systems"
"a world wide uniform datasystem for all modes is necessary"

Mobility as a Service	Rating
Feasibility of mixed operation between regional level semi-direct and omnibus trains and assessment of their impact on the operation of the most loaded rail line section	**2,4**
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 model	**3,4**
Mobility as a Service enabled by the Interoperability Framework technology and Governance: semantic web technologies, travel shopping, booking etc enabling an nteroperable mobility ecosystem at urban level	**3,4**
Combined implementation of Internet of Things and Artificial Intelligence technologies (high Technology Readiness Level) to provide efficient storage, management of data etc	**3,4**
Combination rail - Autonomous Vehicle: the new concept combined with the development of the automated vehicles . In such a model, urban rail plays a critical role as the backbone	**3,3**
Improved operation with traditional public transport and interchange hubs: Delivering seamless travel experience in urban areas is a challenge as most travel patterns will involve the use of several carriers, modes and companies	**3,4**
Multimodal transport service timed to the second. Real-time data exchange between transport modes for coordinated improvement of both operations and maintenance: situational awareness, synchronization etc	**3,8**
Enhance the resilience of the transport system: Business continuity methods, procedures and algorithms for safe-guarding vital functions, recovery time, human factor centred solutions etc	**3,3**
Regulatory framework adapted to the transport system 4.0 which encourages the implementation of innovation with respect to environmental, ethical and safety requirements.	**3,1**

Mobility as service topics are rated between **Moderately important** and **Extremely important**.
The following extra topic was proposed:
"global analysis of the energy efficiency"

Energy and Environment	Rating
Energy-efficient HVAC systems: HVAC can require up to 50% of total energy consumption due to frequent stop-and-go operation and multiple wide doors	**3,0**
Further operational development, validation and testing of the standardised duty cycles conceptualised and developed for urban rail. High efficent modelling tools to optimize the energy consumption of a line	**2,7**

Advanced Traction Energy Supply: Sustained and efficient energy. Supply for rolling stock traction, operations and innovative and technological advances in electrical energy distributions	**3,3**
Non-traction energy: Innovative ways to locally generate and use renewable energy resources to power local non-traction systems	**3,3**
Reduction of wear and tear, noise and vibrations: where and how to achieve improvements in urban rail systems	**2,7**
Adoption of 'circular economy' principles enables the railway to move towards 'zero-waste' operation	**3,3**
Development of climate services for the adaptation of railway infrastructure to climate change	**3,0**
Sustainable and ethical procurements which includes the carbon footprint, with a whole life approach and focus on inputs to the system, recycling, transport of materials, etc	**3,3**
Investigation of the effectiveness of eco charging of transport modes according to their environmental impact	**3,3**

Energy and environment topics are rated between **Moderately important** and **Extremely important**.
No extra topic was proposed.

Safety and security	Rating
Software SIL demonstration: enlarge the scope of the formal „proof" method to the whole system so that it could be used for the global safety assesment of the systems (urban and mainline)	**3,0**
Fire safety as a safety and secured topic to qualify exactly what are the major risks (related to materials, components, etc) and to improve their mitigation (design, operation and maintenance of assets)	**2,7**
Intrusion detection, a particularly -but not exclusively- relevant field for fully automated rail systems, needs additional research actions as well as technical harmonisation	**3,3**
Cyber-protection: Additional and novel approaches to cyber-protection, identification of threat, assessment and definition of mitigation means and contingency processes	**4,0**
Increase the overall system security level without jeopardizing mobility -fast & non-intrusive safety controls in accordance with ethics, health and privacy requirements	**3,0**
Human-centered studies to identify measures aiming to improve the perception of security at multimodal hubs, railway stations (urban and inter-urban), rail vehicles	**3,0**
Using social networks to support security and crisis management in accordance with ethics and privacy requirements	**2,0**

Safety and security topics are rated between **Moderately important** and **Extremely important.**
No extra topic was proposed.

The following topics were proposed to the question “In your opinion, what topics currently not sufficiently addressed should be tackled on the very short term for the future railway/transport system?”:
“human and organisational factors for a better inclusion of these in the future of the systems “
“Public health impacts (negative and positive) of transport”
“standardisation”
“we need more inter modal activities,h may be world wide”
“to encourage people to use rail instead of cars”
‘Financial aspects’
"1. Virtual simulation and validation (homologation).
2. Safety functions using Artificial Intelligence will create new challenges regarding rolling stock validation and homologation."