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1. Executive Summary

This document is a summary of the key findings and recommendations based on the outcomes of TER4RAIL technical Work Packages (WP 1, 2, 3,) and more specifically Task 1.3, Task 2.1, and Task 3.2.

WP1 Rail innovative research observatory.

TER4RAIL has identified and monitored new opportunities for innovative research and facilitate the cross-fertilisation of knowledge from other disciplines through the Rail Innovative Research Observatory. Permanent contact with other relevant sectors has had a prominent role in importing disruptive perspectives from other disciplines and facilitating interactions.

It is expected that the Rail Innovative Research Observatory will be the basis for the synergies identified by ERRAC's Strategic Research Innovation Agenda (SRIA) which will contribute to a more successful multimodal rail research in Horizon Europe (HE).

WP2 Roadmaps.

TER4RAIL has determined and assessed the existing roadmaps that drive the future of railways and compared them with the interpretations obtained from the observatory. This analysis has indicated the gaps that require to be covered and served as the anchor for the prospective roadmaps. These gaps referred to:

- Lack of a user centredness approach,
- too short-term political approach for railways,
- too low multi-modal approach,
- and too scarce attention to on-demand mobility.

Furthermore, a Delphi panel populated by railway and non-railway experts have issued opinions of the key statements of the current ERRAC Rail 2050 Vision, pointing out divergences between their perceived plausible future of transport and the railways vision. These findings should help to write the next vision for railways of the future, which should pursue more integration with other modes of transportation. For that, engagement at institutional and individual level in non-railway areas should be actively pursued.

WP3 Arguments supporting rail.

TER4RAIL considers railways as the backbone of future European mobility, as stated in the rail sector's European Railway Research Advisory Council's (ERRAC) Rail 2050 Vision published in December 2017, and therefore TER4RAIL has raised arguments to sustain this essential system. To that end, data analysis and statistical reporting were foreseen and conducted. Success stories of railways were told in urban/rural, high speed and freight with large margin of growth, cost advantages in scale economies (while sustainable) together with important societal benefits.

2. Abbreviations and acronyms

Abbreviation / Acronyms	Description
CCA	Cross-cutting activities
CSA	Coordination and Support Action
ERRAC	European Rail Research Advisory Council
FFE	Fundación de los Ferrocarriles Españoles
IP	Innovation Programme
MAAP	Multi-Annual Action Plan
S2R	Shift2Rail JU
UIC	Union Internationale des Chemins de fer
UITP	Union Internationale des Transports Publics
UNIFE	Union des Industries Ferroviaires Européennes
WG	Working Group
WP	Work Package

3. Background and objectives

The present document constitutes the Deliverable D4.3 “Knowledge transfer and exploratory research strategy” a 24-month coordination and support action for transversal exploratory research activities to benefit the railways, within the overall framework of Shift2Rail, which is developing the fundamental building blocks that will allow the creation of the future railway interoperable system.

It is linked to Task 4.2 Exploitation: Knowledge transfer and exploratory research strategy of Work Package 4.

This document provides recommendations regarding the needs, challenges, and possible collaborative research on emerging innovative ideas and key enabling technologies.

4. TER4RAIL Key findings and recommendations

4.1. WP1 Rail Innovative Research Observatory

The Work Package 1 of TER4RAIL project aimed at monitoring, identifying and analysing new opportunities for innovative research for the rail sector. The WP also focused on facilitating interactions that may lead to transversal exploratory research and knowledge transfer. Finally, it included a mapping of existing links between non-rail European Technology Platforms (ETPs) and Public Private Partnerships (PPPs).

With the aim to build a Rail Innovative Research Observatory (RIRO) WP participants organised interactions and shared experiences between the railway sector and other actors willing to boost innovation (regardless of whether they belong to the sector or not). The establishment of these interactions and their content will continue to support the identification of opportunities for innovative research and innovation coming from other sectors.

The basis for this work has been provided by Deliverable 1.1. "A comprehensive map of rail innovative research and key rail stakeholders" and Deliverable 1.2 "A report on the features of the next scenarios: Overview of the rail missions 2050". These two deliverables have identified and prioritized which topics to address and which actors to focus on in Task 1.3: Digitalisation and materials were identified as most important in the medium term. In the more short-term future 5G, automation, batteries, big data and energy were identified and the long-term future topics that are of highest concern are artificial intelligence, automation, power sources and autonomous mobility.

The methodology employed for establishing the above-mentioned RIRO consisted of defining the issues of discussion, the communication channels actions and the interaction between the rail sector and actors willing to boost innovation, e.g. one-to-one contact, integration of dedicated sessions in rail sector meetings and others. A continuously updated Action Plan and close cooperation with S2R and ERRAC stakeholders has guided the development of the work.

Many kinds of interactions were organized such as the integration of non-rail experts into existing rail events, one of the most prominent ones being the ERRAC plenary where on one occasion cyber security experts were invited to discuss with rail stakeholders. UITP included a session on Urban Scenarios with architects and other non-transport experts into their annual event and UNIFE included TER4RAIL presentations in their Technical Plenary. Other types of interactions were guest presentations at non rail events such as an intervention at the plenary of the European Construction Technology Platform (ECTP) where TER4RAIL was presented. Smaller and informal exchanges were also within the scope of task 1.3 and task partners engaged in several bilateral meetings to update on the TER4RAIL results and identify opportunities for future rail research collaboration.

In addition to the interactions the WP included a cross-sectoral mapping of Shift2rail activities with projects of the non-rail European Technology Platforms and Public-Private Partnerships. These mappings provided a scan of existing links in R&I priorities and ongoing projects between these entities and the rail sector. The approach to these mappings was to analyse for each of the identified ETPs and PPPs the following:

- mention of railways or Shift2Rail in key documents
- analysis of S2R members that are also members of the platform/partnership
- analysis of the non-rail actor financed projects based on a set of key words. Linkage of research and innovation projects directly or indirectly related to railways, and with S2R TDs and projects
- other information considered relevant such as innovation capabilities, interesting organizational or structural information, etc.

It can be said that all mappings reveal some degree of linkage with the rail sector. Some mention rail more directly and have already identified rail as a use case or example which is the case for 5GPPP. Others have clear relevance for the railway sector such as EURobotics where the rail sector can be considered a use case for several applications in the future. The mappings also reveal among other aspects the number of already ongoing projects with relevance for rail as well as working groups that could offer opportunities for the rail sector to engage with.

Going through the different sections included at the mappings, some general conclusions can be drawn:

The fact that all ETPs / PPPs analysed mentioned railways or trains at least in one of their key strategic documents is an indication of the potential connection between their activities and the sectors they represent with the railway sector. There are differences between them with regards to the frequency and relevance of the role played by railways for their policies, agendas and reports. For example, some of them mention railways extensively, such as 5G PPP and ALICE - as railways are an intrinsic part of logistics-, as well as ECSEL and ERTRAC. In others, this connection is made in relation to a specific section, such as the case of ECTP and the area of infrastructures. There are others for which the mention of railways is briefer, but where transport is more widely considered, for example FoF or SPARC. Additionally, Shift2Rail JU is also explicitly mentioned in some documents of ALICE, ECSEL and ECS.

As an example of these interactions the following table summarizes how the analysed ETP/PPP are related to the capabilities of rail.

Capabilities	5GPPP	ALICE	ECSEL	ECS	ECTP	ERTRAC	FoF	SPARC
1. Automated train operation	✓		✓	✓				
2. Mobility as a Service	✓			✓		✓		
3. Logistics on demand		✓		✓		✓		✓
4. More value from data	✓	✓		✓				
5. Optimum energy use			✓	✓			✓	
6. Service timed to the second	✓		✓	✓				
7. Low cost railway				✓	✓		✓	✓
8. Guaranteed asset health and availability			✓	✓	✓			✓
9. Intelligent trains	✓		✓	✓			✓	
10. Stations and “smart” city mobility	✓			✓	✓	✓		
11. Environmental and social sustainability					✓		✓	
12. Rapid and reliable R&D delivery								

4.1.1. WP1 conclusions and Takeaways

The work of the WP1 of TER4RAIL shows the existing links and possible avenues for increased cooperation between non rail actors and the rail research community. These links range from relatively stable cooperation to lose links that have been established some years ago, in some cases no previous links existed. Importantly however thematic links exist to large extend with the railway sector in a large number of cases for topics such as cybersecurity or new materials for example synergies that could be exploited with non-rail research are quite visible.

A valuable contribution has been made by the facilitation of dialogues and exchanges with actors that were not or only to a small extend collaborating with the rail sector. In addition to this, the cross-sectoral mapping of Shift2Rail activities with projects of the non-rail European Technology Platforms and Public-Private Partnerships provides a comprehensive scan of existing links in R&I priorities and ongoing projects between these entities and the rail sector.

Among the most important topics for the rail sector will be issues such as 5G, automation, batteries, big data as well as artificial intelligence, automation, power sources and autonomous mobility.

To work on these topics the rail sector and ERRAC in particular could benefit from making use of the cooperation possibilities with organisations such as the 5G Public Private Partnership (5GPP), Alliance for Logistics Innovation (ALICE), European Cyber Security PPP (ECS) and several other identified.

4.2. WP2 Roadmaps

The WP2 of TER4RAIL consisted to review, support, and improve the sector roadmaps in order to prepare for the subsequent iterations of the roadmapping process.

The need for a higher share of railways in the European mobility was self-evident when considering the increasing pressure European institution place on the transport sector to maintain high mobility levels while reducing the burden on the environment vis a vis the Greenhouse Gases emissions.

In the context of ERRAC 2050 vision, TER4RAIL WP2 members provided a comprehensive vision of the strategic planning of the rail sector by a review of the key roadmaps. They provided an explanatory framework with the chronological development of transport roadmaps, including a detailed review of the most relevant roadmaps published. Furthermore, TER4RAIL WP2 partners identified relevant gaps in the roadmaps, which are impeding the achievement of ERRAC vision of railway as the backbone of sustainable European mobility.

WP2 partners also developed and followed a thorough methodology articulated in three steps and characterised by data collection and data analysis.

Firstly, the research focused on data collection from transport experts through interviews, the Delphi study carried out in Task 2.1, the World Café activity and group discussions. In parallel with the data collection, the research carried out an analysis of the roadmaps published by the ETPs. The roadmaps were collected and monitored to create a database containing the keywords with higher frequency. Lastly, the research identified the nature of the gaps by using the database as a filter for the data resulting from the interaction with transport experts.

As a result, the research clustered the identified gaps in the following four areas:
- **Railway users.** The ETPs underestimate citizens individual needs, while their roadmaps fail to adopt and understand the needs and habits of the prospective users. The lack of a user centredness approach, together with the lack of inclusion of mobile apps and of adequate service quality policy are acting as inhibitors to the sector shift from a “production culture” to a “service culture" which is currently driving the market.

- **Policymakers.** The analysis of roadmaps suggests the long-term vision for the rail sector is often not supported by the necessary actions, due to lack of short-term benefits for the policymakers. The current roadmaps do not stress adequately the needs for political support in the development of connectivity, infrastructure and hard technologies.

- **Multi-modal approach.** The multi-modal approach is heavily included in rail-based roadmaps, while other transport sectors fail to adopt such vision. However, the role of exponential technologies and specific safety and security measures in providing an effective multi-modal approach is often overlooked in the current roadmaps.

- **On-demand mobility.** The roadmaps do not stress the importance of on-demand mobility services in boosting public transportation. However, on-demand mobility affects the everyday life of European citizens, thanks to new technologies able to assist the end-user by supporting the phases of booking, trip planning and connectivity. Although the role of technology is also expected to be central in the multimodal approach and in the context of railways users, it is rarely mentioned in the current roadmaps.

Each area present recommendations to improve the status quo and thus achieve the ERRAC vision. In particular, it is recommended to integrate the perspective of social-oriented aspects into the roadmaps to be able to understand which barriers prevent the modal shift to rail. Similarly, a stronger and sustained government involvement might be able to overcome the difficulties in adopting a long-term vision. Furthermore, this research stresses the importance of including the rail sector and the multi-modal approach in other transport sectors, which are currently not incorporating rail in their research priorities. Lastly, the enhancement of on-demand mobility services, currently lacking, might be able to support declining public transportation in rural areas.

In conclusion, despite the analysed roadmaps belonging to the state of the art, the identification of certain gaps must be seen as a valuable finding for the transport sector. This WP showed which obstacles rail has to overcome to become the sustainable backbone of an energy-efficient transport chain for both passengers and freight. Within the context of sustainable mobility, rail has the chance to provide an integrated and efficient transport system. A sustained modal shift to rail will also act as a major driver for de-carbonisation of the transport sector, meeting the objective of the Green Deal without sacrificing the European mobility levels.

All along the project duration, a **Delphi** survey was conducted to determine if the rail stakeholders believed in the Rail Vision 2050 document and specifically agreed with the statements contained within the document. This was important as the next generation of this document was to be the basis of a Strategic Research and Innovation Agenda (SRIA) for Rail. The Delphi survey revealed the consensus and the dissent in relation to the statements.

While there were issues with rail freight, rail and public transport are clearly the solution to provide mobility for passengers. By 2050, rail will still be the safest mode with zero casualties, and this was recognised and valued by European citizens. Rail will be the backbone of urban mobility with rail considered as the mass transit solution. In cities there will be new energy-efficient station designs. Free access to data from all providers for all modes and all asset and service providers must be shared across the European rail stakeholders, preserving the requirements of some of the parties' privacy. Native speakers in urban areas across Europe will have easy tailored access to mobility services but not non-native speakers.

The common themes that were exploited were:

- Market orientation;
- Cost, competition and efficiency;

- Leadership, political issues, lobbying, government intervention for good or ill;
- Lack of seamlessness for many reasons;
- Inadequate speed of reaction/investments compared to Asian competitors;
- Lacking technical/technological innovations and skills;
- Language barriers;
- Different regulations barriers in EU rail space;
- Info, data availability sharing and management;
- Safety and security issues;
- Accessibility and capacity;
- A limiting of scope from universal visions to urban, native and backbone

The results of the Delphi Study are synthetised in the table below:

Agree	Synthetised Statement
96.30%	In 2050 importance of cost in railways
92.59%	In 2050 rail still in timetables, no tailor-made journeys
88.89%	In 2050 European rail stakeholders sharing data to participate in data economies
87.72%	In 2050 rail freight units communicate with each other
85.96%	In 2050 rail users have internet access
84.21%	In 2050 rail is the backbone of urban mobility
84.21%	In 2050 rail sector is fully into the economy of data
84.21%	In 2050 rail still the safest mode with zero casualties
81.48%	In 2050 non english speakers have easy acces to mobility services in EU
78.95%	In 2050 rail is the backbone of long distance mobility
77.78%	In 2050 still need of capital investment for railways
77.19%	In 2050 autonomous and intelligent rail vehicles operate in European railway network
74.07%	In 2050 asiatics (led by China) are leaders of railway products and services
73.68%	In 2050 rail is core part of city planning
73.68%	In 2050 stations are energy efficient and easy accesible providen interchange across modes
73.68%	In 2050 rail is fully integrated with logistics multimodal chains being its backbone
71.93%	In 2050 rail sector handles cyber-secruity threats in cooperation with other sectors
70.37%	In 2050 people feel safe in rail services
66.67%	In 2050 rail responds to individual demands delivering tailor made solutions of mobility in cooperation with other modes
63.16%	In 2050 rail vehicles are aware of themselves and can adjust journeys to meet demand
62.96%	In 2050 rail still very vulnerable to terrorism
55.56%	In 2050 still a fragmented EU posing difficulties for mobility
55.56%	In 2050 rail is able to have fully smart and autonomous vehicles operating, but only in cities
55.56%	In 2050 rail is the backbone of freight in EU
51.85%	In 2050 national railways not integrated with neighbours, and even worse with other modes
51.85%	In 2050 sharing data economy by railways threatens privacy
48.15%	Few rail smart vehicles in low useage lines in 2050
29.63%	In 2050 rail not able to be driven by user aspects

Figure 1 Delphi Study results

4.2.1. WP2 conclusions and Takeaways

The EU is facing the challenge to provide sustainable, satisfactory and affordable mobility. In this context, the EU mobility roadmaps play a fundamental role in designing the future of the Union's transportation.

Our research aimed at answering the question about which misalignments and gaps characterize the

EU mobility roadmaps and whose trends which are not mentioned should be included to ensure rail will be the backbone of the future European mobility.

The data show the mobility roadmaps lack focus on certain topics which are instead essential for achieving ERRAC vision. These topics are related to the following four topics: the necessity of adapting citizens' needs, user acceptation and integration of railways; the influence of short-term policy on transport developments over the long term; the absence of a multi-modal mindset in every transport sectors to integrate railways; and the need for tailored and on-demand mobility in railways.

Additionally, the research highlighted comparability in some of the keywords mentioned in the transport roadmaps. This characteristic is expected to lead to an accelerated pace in the development of the following five topics: cross-sectoral and cross-disciplinary research; information management systems; physical transport network; safety and security; and digitalization and interconnection of the rail network. Regarding the degree of connection between transport modes, this research showed two important findings. On one side, the transport experts focusing on multi-modal approach and seamless transport networks emphasize that the railway sector must achieve more collaborations with other transport modes, especially with road transportation. On the other side, non-rail roadmaps frequently lack to mention in their respective transport vision the opportunities arising from collaboration or integration with railway services. Such a characteristic strongly hinders the process of establishing the future European mobility with rail as a backbone.

The investigation and research on key trends within the European transport roadmaps allow the output of task 2.2 to provide a robust foundation for Task 2.3 and Task 2.4. The research undertaken within Task 2.2 developed an overview of the roadmap shortcomings published by the key stakeholder. These shortcomings have been defined as gaps in the European transport and railways visions. Despite while the roadmaps still belong to the state of the art, the identification of certain gaps should be seen as a valuable finding for the transport sector.

Task 2.2 has shown a small glimpse of the potential that rail has to become the sustainable backbone of an energy-efficient transport chain for both passengers and freight. As the shift towards sustainable mobility requires an integrated and efficient transport system as well as secure and clean energy, research demonstrates that a modal shift to rail will act as a major driver for de-carbonization of the transport sector. It is therefore essential to continue informing and advising policymakers and railway operators alike, to continue the trend towards and a sustainable, inclusive and future transport.

There are issues with rail freight, but rail and public transport are clearly the solution to provide mobility for passengers. We will present below some recommendations to increase the share of rail freight and passenger mobility:

Freight:

In order to increase use of rail freight and for rail to become the backbone for freight, it is imperative that it addresses some fundamental issues; namely cost competitive, asset utilization and customer facing connectivity. These service user aspects are the important challenges that need to be addressed in order for rail freight to raise expectations and to enable the shift of freight from road to rail.

It is also expected that rail freight transport units will be able to communicate with each other as well as with the infrastructure and operational. This expectation will not become a reality without significant investment and development of the appropriate communication standards towards the

intelligent freight train which will communicate over the next generation communication system.

A very challenging target that will need significant support is to move from competitive rail freight to rail taking the lead and becoming the backbone of an intermodal Mobility as a Service for freight. The freight business has not yet been consolidated but there are opportunities with sea transports that lead to success for rail. Intermodal transport with a rail backbone is the segment with a great potential. To achieve this potential there must be investment in terms of capital but also essential research. One way of improving intermodal mobility to improve rail provisions in terminals and close to ports.

Passenger mobility:

With respect to passengers, rail and public transport clearly are the solution to provide mobility. This belief builds on rail's existing credentials and credibility as the most environmentally friendly form of mass land transport with an excellent safety record. In 2050 rail will still be the safest mode with zero casualties and this is recognised and valued by European citizens. This opportunity is enhanced by the fact that passengers across Europe are to access real time personal communication continuously, before, throughout and after the journey. This situation will only improve as passengers demand connectivity and entertainment through their mobile devices.

One issue that will hold back seamless services is that national rail services do not integrate seamlessly with rail services available in neighbouring countries. This situation must be addressed by research into standards and data sharing. Without serious consideration of this aspect, integrating seamlessly with all other available transport modes would seem unrealistic.

The flagship for passenger services is rail at the backbone of urban mobility with rail considered the mass transit solution. With large numbers comes the responsibility for protection and improvement of service but also the revenue to provide intelligent stations at the heart of smart cities, being life-centric places to work, meet and communicate. This improvement is considered as a given and it is believed that the expected innovation in mass transit will lead to rail being fully intelligent, operating autonomous vehicles circulating in cities with the offer further from the city centre being less focused on mass transit and with the innovation such as pods being researched and developed for the final stages of the journey. These pods or fully smart vehicles may be self-regulating by 2050 in traffic, negotiating vehicle-to-vehicle and vehicle-to-X to determine movement priority and resolve potential conflicts at junctions in the network and reacting to unexpected situations.

Especially in cities there will be new energy-efficient station designs in Europe. They will provide easy access and seamless interchange across all transport modes, enabling railways to manage growing passenger volumes and mobility demands funded by the secondary spend in stations.

Free access to data from all providers for all modes and all asset and service providers must be shared across the European rail stakeholders as a part of the data economy. An additional challenge is to have a harmonised system architecture and data organisation able to support the challenges listed above in an open, interoperable way whilst preserving the requirements of some of the parties' privacy in terms of data confidentiality. A commitment needs to be made to managing the growing volume of data in Europe contributing to the data economy. Tools will need to be jointly developed for the collection, analysis interpretation and prediction of passenger flows. Passenger information needs to be automated to provide consistent up-to-date

information, supporting fast, well informed travel choices and aiding decisions. This will all benefit rail as a business.

Europe has a number of languages and native speakers in urban areas across Europe will have easy tailored access to mobility services. The same is not true for non-native speakers and therefore research should be conducted into the use of smart systems to assist non-native speakers.

4.3. WP3 Arguments supporting rail

The overall objective of this WP was to collect, analyse and elaborate a certain amount of available data and statistics regarding the rail's advantages/benefits in Europe, in order to have a clear picture of the current "as is situation". This picture has formed the basis to support the analysis for future trends/scenarios related to rail passengers and freight mobility in order to facilitate the understanding of their impact on some identified variables, being them societal, environmental or economic. This impact was finally measured qualitatively and, when possible, quantitatively, strengthening the arguments supporting rail as backbone of the European society of the future. Comparisons with other transport modes such as road, air and waterways have been powerful tools utilized to give a clearer and more efficient picture of these benefits and of the role that rail can play in the European society in the years to come. Digitalization and new technologies' evolution have been taken into account since they are shaping consistently every citizen's and every user's everyday life.

The ambition of rail is to become "backbone of the Europe's sustainable multimodal transport system of the future, both for passengers and freight".

The analysis of the current situation of the rail ecosystem and trend projections, plus the significant case studies addressed in deliverable D 3.2, already supported such ambition. WP3 partners incorporated considerations and recommendations made from previous visionary projects with a 2050 rail horizon focus such as Spider Plus, MARATHON, SPECTRUM, D-RAIL and Living Rail.

The progress in the desired directions seems to be somewhat slower than the objectives assumed in the 2010 Transport White Paper targets. In particular, national contributions appear to be behind the ambitions detailed in D.3.1 deliverable "Data Collection/As is situation".

In order to reinforce and justify positive perceptions of rail progresses, samples of recent virtuous actions have been summarized by exemplary categories:

- High speed rail & cross border developments,
- Local transport & smart mobility,
- Incentives & pricing policies,
- Network & infrastructure,
- Fleet & Rolling stock.

The strengths and weaknesses of the rail ecosystem were then combined with external forces or "drivers of change" that have already been identified and are expected to influence evolutionary change in the next few decades.

The strengths of the rail Ecosystems are the result of its positive relevance in the EU mobility system, the environmental and services dimensions, its highly extensive network and sub-systems, and their overall synergy.

In the last decades, rail has continued to build capabilities despite limited traffic gains but creating the conditions for accelerated growth in the near future. The successful experiences in virtuous countries and the demonstrated continuity of efforts, has allowed us to identify several strengths to be further exploited and expanded if rail is to become a pillar of European mobility.

Sustainability and cost competitiveness are major strengths achievable whenever economies of scale can apply. This potential will increase further after technology innovations. Technology is expected to improve efficiency, safety and security substantially supporting customers' seamless experiences. The co-modal redefinition of mobility can attract new traffic in a number of business segments. rail infrastructure has both bottlenecks to be solved and significant free capacity, to be exploited with relatively limited "hard" and "soft" investments in order to achieve additional capacity relatively soon.

ICT, especially in exponential technologies, while having huge impact in all mobility segments, will facilitate co-modality (and therefore the role of rail), providing integrated offerings supporting seamless users' experience.

Rail will benefit from several industrialization and scale factors; price differential for users will incorporate increasing taxation for less sustainable modes and externalities. Harmonized infrastructural charges will occur partially as a consequence of this.

Rail freight, not only traditional long-distance transport, but also medium and short distances shows potential applying co-modal approaches. Within the various types of "Physical Internet" and other ICT enablers, combined transport has many new & relevant opportunities.

The terrible appearance of COVID 19 introduced new considerations likely to increase the points of strength of the rail system in general, but certainly favouring International rail Intermodal Transport compared to its main competitor the "road modality". Here drivers' crossing border operations associated to health control and quarantine seem to be an obstacle. Several Press articles and editorials have already underlined this situation.

Metro and light rail solutions are expected to be in good shape for increasing their role. In particular in urban space there is no alternative better solution (walking and biking excluded). Sustainability is a major strength. Increasing urbanization will create better condition for Metro & light rail because of better scale factors and less acceptance of congestion consequences of Road alternatives.

Passenger business is a natural space for growth. While most of the positive patterns are related to HSR innovation, lot of potential can be identified also in more traditional services both in serving commuting and local traffic and in serving other traffic segments. Being the investments planned according to new co-modal thinking, they are beneficial to the entire rail system, including freight and metropolitan needs.

There are still Weaknesses to face in the rail industry. The long lead time of any innovation has been unavoidable because of the rail complexity, the combination of 27 individually managed systems together with the network extension. The European uniform "Rail Space" is an objective

yet to be achieved. High investment requirements are part of this complexity. Service performances can be a weakness unless new service policies enabled by the upgrading of operational capabilities, new processes of communicating and customer relationship management, allow to turn this weakness into a strength. The difficulties of the integration process with reference to liberalization, harmonization of regulations, infrastructural charges, etc… are part of the picture. Some EU countries participate to the European progress at different speed and conviction. In rail, unlike road, the service performance is as good as its weakest link and some Countries seem to be unaware of this, penalizing the whole rail ecosystem.

Identification of "drivers of change" contribute to point out Opportunities and Threats to the strategic scenario, suggesting ways to leverage Strengths and to mitigate risks related to Weakness. The overall impact of drivers of change is expected to play in favour of the increasing role of rail within the growing mobility demand.

The positive impact mainly includes (Opportunities):

- All modes will improve their sustainability patterns, but rail is expected to keep its advantages especially in terms of energy efficiency and emissions of pollutants versus Road and Air. Moreover, sustainability is becoming a central issue. COVID 19 may accelerate the transition towards smarter/responsible mobility due to increased environmental and safety/security awareness. The environmental dimension with the growing youth unrest driving towards energy conservation and the Planet resources respect, will be a driver for using more rail compared to other fossil fuels depending modes.
- Acceleration of policy developments in favour of public transport can be expected. Fiscal policies will favour more sustainable modes and rail centrality in co-modal perspective
- Growing demand patterns in future projections are expected better fitting rail (scale economies, intercontinental exchanges, urbanization, …)
- Public/private investments and new business models advantaging light assets and innovations, assume a growing role.
- Resiliency and mobility growing R&D capabilities are expected to develop effective solutions for managing dynamics
- Co-modal integration may benefit of long term more efficient time/space planning

Main bottlenecks and constraints to monitor include (Threats):

- Rail is a high capital-intensive business. Public resources are limited, and this represents a bottleneck.
- The EU Commission continuous efforts for the establishment of a genuine single market with adoption and implementation of the Commission Directives for achieving a fully interoperable systems are sometimes finding obstacles due to local interests of limited vision.
- Faster reaction of other modes to adopt ICT and exponential technologies and other dynamics

All these elements summarized with the SWOT (Strengths, Weaknesses, Opportunities, and Threats) methodology.

New requirements coming from Covid19 experience and the transition period from pandemic to the "new normal", have not been elaborated in their impacts. The impact and analysis of Covid-19 is too recent to be easily integrated within the project time frame.

Rail has much greater development potential for EU Society beyond the "Declared Opportunities". The "weaknesses" existing in rail services for many years, are mostly self-generated inside the system itself. If the EU Institutions together with the member States would undertake actions to achieve the uniformity of intents, objectives and modular organization as defined in the EU Railway Packages, the weaknesses would transform themselves in positive elements with benefits to EU Society beyond those currently evidenced.

4.3.1. WP3 conclusions and Takeaways

SWOT methodology have been applied at the rail overall ecosystem as a summary after the exercise application to the individual sub systems as defined in the previous WP3 deliveries.

The strategic objective towards identification of Strengths, Weaknesses, Opportunities and Threats is defined as "Rail to become the backbone of the Europe's sustainable multimodal transport system of the future, both for passengers and freight".

The time horizon is intended to be the year 2050.

In this perspective:

- With focus on "internal" competition frame of the rail Industry towards other modes
  - **Strengths** are the characteristics of the rail industry to be leveraged, being relative or absolute advantages, that justify the ambitions to play a substantial role in the overall mobility and support strategies having such a target
  - **Weaknesses** are the characteristics of the rail Industry to look after, being unfavourable, that may put at risk the achievement of the strategic objective. Nevertheless, appropriate actions may allow to turn some weakness into strengths.
- With focus on "external" comprehensive environment where the rail industry competes
  - **Opportunities** are the drivers of change that could exploit the advantages of rail
  - **Threats** are elements whose dynamics could cause trouble for the strategic objective.

4.3.1.1. Rail Freight

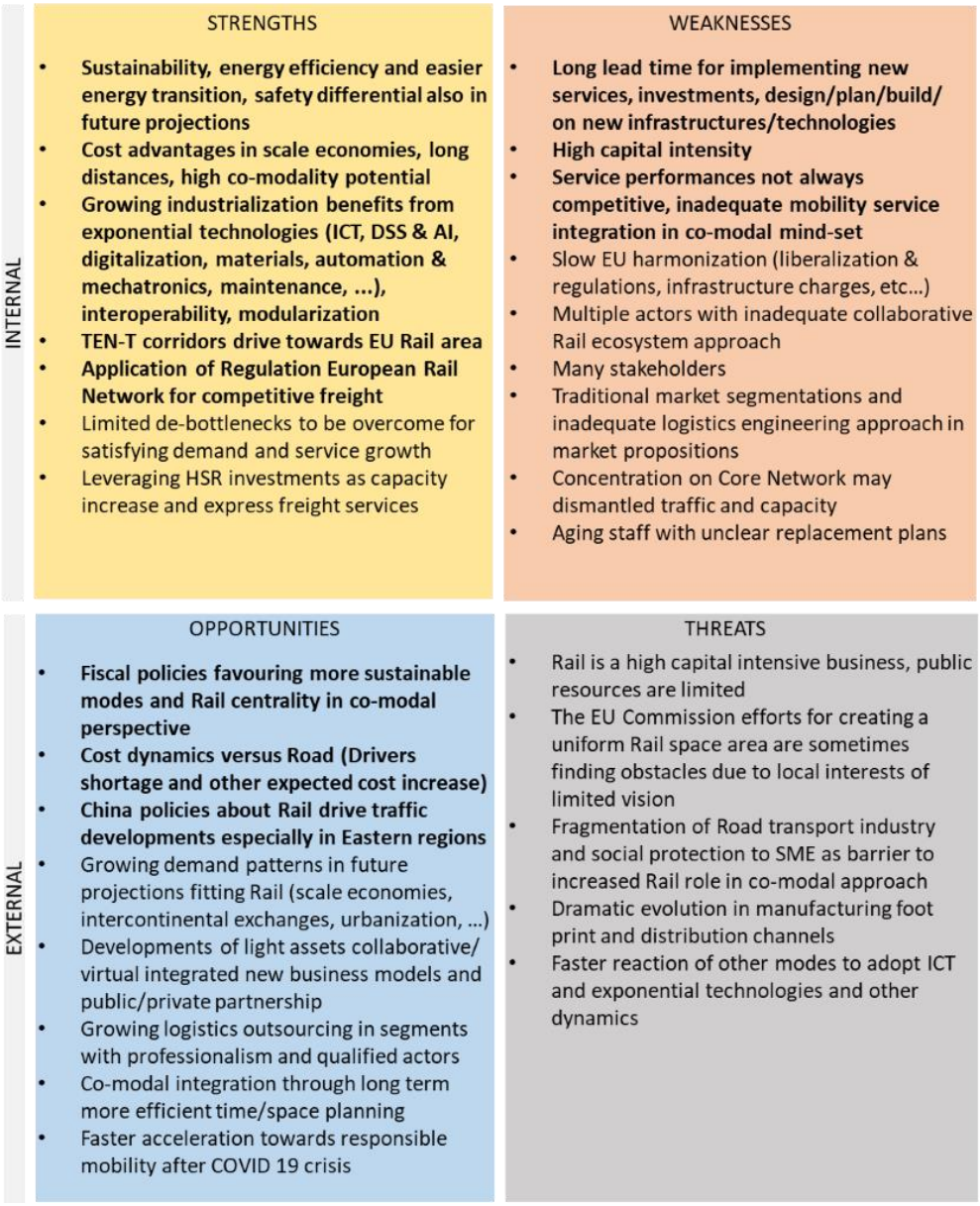


Figure 2 - SWOT Freight – Source: New Opera (2020)

Freight and logistics have a natural space of growth for rail, based on capabilities built with continuity over decades, allowing to identify a number of strengths. In fact, not only long-distance transport, traditional target for rail transport still shows a potential to growth, but also medium and even short distances, especially in the co-modal redefinition of mobility, can unveil new relevant segments of business. Infrastructure has significant free capacity, to be exploited with relatively limited investments (ports, longer trains, bottlenecks) while a number of additional factors – notably technology applications - are expected to improve cost performances and luckily also sustainability, safety and security. Technology may enable new business models beneficial for

better use of capacity (as for instance smart contracts and dynamic pricing) as well as enhanced operation planning.

There are still in the rail industry weaknesses to face of which the long lead time of any innovation is unavoidable because of the complexity of a huge ecosystems with dense structure of correlations. High investment requirements are part of this complexity. Service can be a weakness, unless new service policies together with new processes allow to turn it into a strength.

The drivers of change are expected to influence the external conditions in an overall positive way.

Main opportunities are related to cost differential, expected to grow and features of trade that should better fit rail. Being trade for its nature international, national barriers should be more easily overcome (versus passenger segments) and the pressure of Belt & Silk is a great example of that.

Threats cannot be under evaluated as well. Unfortunately, investments and regulations are mainly oriented by policies and continuity of efforts. The intensity and pace of development are largely outside the control of the rail Industry. Also, the fragmentation of the Road transport industry and the social implication of relevant modal shift may be a barrier to an effective implementation of co-modal mobility of goods. EU countries in the East of Europe as first option they started to finance motorways constructions and road trucking.

4.3.1.2. Tram & Metro (Light Rail + Metro ridership and infrastructure)

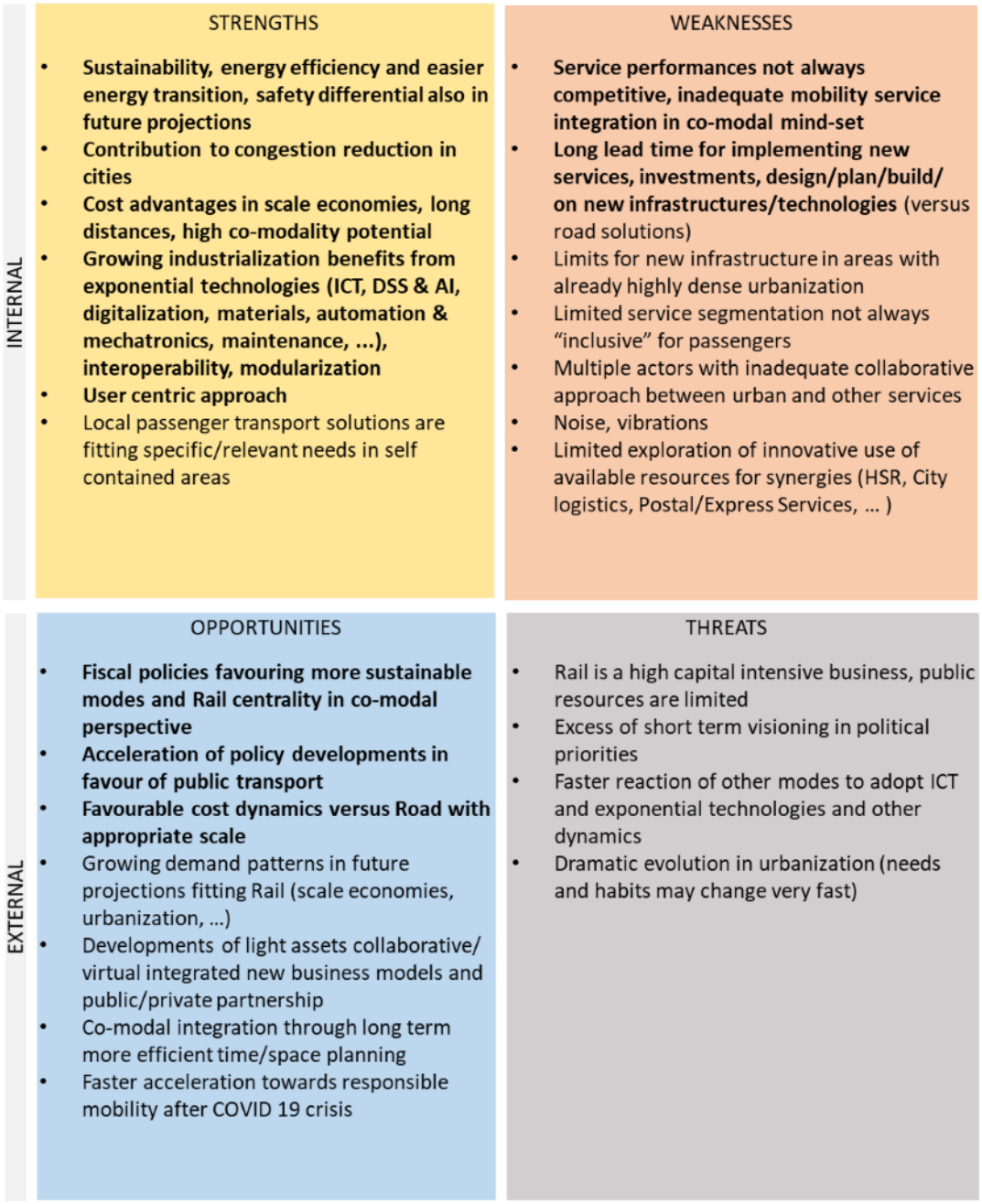


Figure 3 - *SWOT Tram & Metro – Source: New Opera (2020)*

Rail serving urban mobility with Metro and Light Rail solutions is expected to be in good shape for increasing its role. Sustainability is the major strength. In fact, while it is a relevant issue for all mobility, it is particularly relevant in urban space where there is no alternative powered solution better than rail (walking and biking excluded). Contribution to congestion reduction and

consequently air pollution in cities is important. A user centric approach is largely adopted. Cost, when scale factors are appropriate, are competitive and growing industrialization is bringing additional advantages.

Some weaknesses are a poor co-modal mind-set amongst users and planners, leading to sometimes insufficient efforts to overcome existing barriers in terms of infrastructures and businesses, limiting the integration and scope of mobility services. Coordinating actions involving multiple actors may be not easy even at local level.

The drivers of change are expected to influence the external conditions in an overall positive way for the same macro reasons of other segments even if projected in different geographies and covering different actors and stakeholders.

Specific opportunity can be considered the increasing effort in co-modal integration through long term more efficient time/space planning in coordinating mobility services in complex urban and metropolitan geographies.

Dramatic evolution in urbanization may be a threat as needs and habits may change very fast.

The growth of unregulated drive sharing and on demand 'taxi' systems such as Uber or Lyft could act as a direct threat to rail in urban areas, diluting the critical mass of passengers for public transport especially at the off peak. Autonomous cars in such a mass system may further dissuade users to share public transport, especially if pandemic fears continue in the public psyche of the 21st century.

4.3.1.3. Rail Passengers



Figure 4 - *SWOT Passengers – Source: New Opera (2020)*

Passenger business is a significant target of growth for rail. This statement is based on experiences of more virtuous countries allowing to identify a number of strengths to be further exploited and expanded with true European efforts. While most of the positive patterns are related to HSR innovation, lot of potential can be identified also in more traditional services both in commuting and local traffic, as well as in other traffic segments. In fact, the co-modal redefinition of mobility, can attract new traffic in a number of segments of business. The technology applications - are expected to improve user friendly experience, integration with other modes and cost performances. Also, sustainability, safety and security are expected to improve while still today better than other modes.

There are still in the rail industry weaknesses to be faced. The long lead time of any innovation is unavoidable because of the complexity of a huge ecosystems implying dense structure of correlations with elements of different nature. High investment requirements are part of this complexity. The difficulties of the integration process with reference to liberalization, harmonization of regulations, infrastructural charges, etc…, are part of the picture resulting in different speeds for individual countries in participating to the European progresses.

The drivers of change are expected to influence the external conditions in an overall positive way.

Main opportunities are related to cost differential, expected to grow because of better consideration of externalities and the application of penalties to more pollutant transport means. The energy transition towards eco-friendly sources and sustainability considerations represent new opportunities. Acceleration of policy developments in favour of public transport may encourage evolutions.

Major threats are the same as anticipated for Freight and Metro/Light Rail. So, continuity of the investment efforts in intensity and the implementation pace can be question marks.

4.3.1.1. Rail as overall Ecosystem

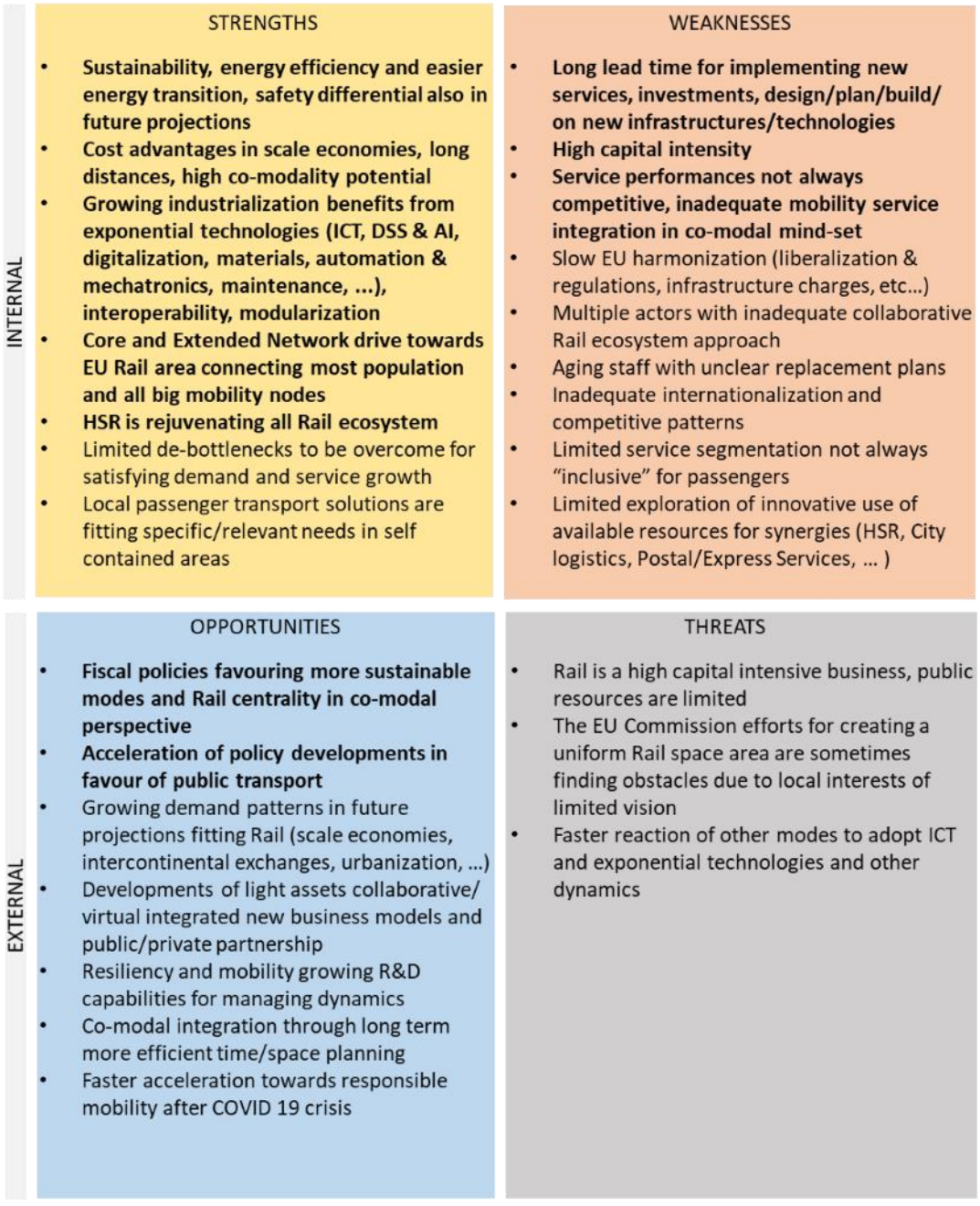


Figure 5 - *SWOT Overall Rail ecosystem – Source: New Opera (2020)*

The strengths of the overall Rail Ecosystems are the summarized consequences of its major sub systems with the additional impact of their overall synergetic relationships.

In the last decades, rail has continued to build capabilities despite limited traffic gains but creating the conditions for accelerating the growth in the near future. The successful experiences of more

virtuous countries and the demonstrated continuity of efforts allow to identify a number of strengths to be further exploited and expanded with true European efforts.

Sustainability is a major strength as well as cost competitiveness. These are going to increase rail service penetration after technology applications. Technology is expected to improve all performances including safety and security and substantially supporting seamless customer experiences. In fact, the co-modal redefinition of mobility, can attract new traffic in a number of business segments. Infrastructure has significant free capacity, to be exploited with relative limited investments (notably HW & SW together with selected infrastructure and other assets) for "quick" additional capacity.

About Freight, not only long-distance transport, traditional target for rail still shows a potential for growth, but also medium and even short distances, with the co-modal approach, can unveil new substantial demand aspects.

Metro and Light Rail solutions are expected to be in good shape for increasing their role. In particular in urban space there are no better alternative solutions (walking and biking excluded). Sustainability is a major strength.

Passenger business is a natural space for growth. While most of the positive patterns are related to HSR innovation, lot of potential can be identified also in more traditional services both in serving commuting and local traffic and in serving other traffic segments. Being the investments planned according to new co-modal thinking, they are usually beneficial to the entire rail system, including freight and metropolitan needs.

There are still in the Rail industry weaknesses to face. The long lead time of any innovation is unavoidable because of the complexity of a huge ecosystems with dense structure of correlations. High investment requirements are part of this complexity. Service performances can be a weakness, unless new service policies enabled by the upgrading of operational capabilities, new processes of communicating and customer relationship management allow to turn this weakness into a strength. The difficulties of the integration process with reference to liberalization, harmonization of regulations, infrastructural charges, etc… are part of the picture resulting in many different speeds of individual countries in participating to the European progresses.

The drivers of change are expected to influence the external conditions in an overall positive way.

Main opportunities are related to cost differential, expected to grow because of better consideration of externalities and the application of penalties to more pollutant transport means.

Threats cannot be under evaluated as well. Unfortunately, investments and regulations are mainly oriented by policies and continuity of efforts. The intensity and pace of development are largely outside the control of the rail Industry. Also, the fragmentation of the Road transport industry and the social implication of relevant modal shift may be a barrier to an effective implementation of co-modal mobility of goods. EU countries in the East of Europe as first option they started to finance motorways constructions and road trucking.

Major threats are in any case related to the continuity of the investment efforts both in intensity and in the implementation pace.

One has to appreciate that the “Rail as an Opportunity to EU Society” has much greater development potential beyond the “Declared Opportunities”. In fact, the “Weaknesses” which have been existing in rail services for many years are partially self-generated inside the system itself. If one was to imagine that indeed EU Institutions together with the member States would undertake actions for achieving uniformity of intents/objectives and modular organization in all aspects such as operations and communication in order to overcome the 27 different approaches, the weaknesses would transform themselves in positive elements with enormous benefits to EU Society far beyond the declared ones. Also unexpected critical events (as COVID 19) may accelerate the transition towards smarter/responsible mobility due to increased environmental and safety/security awareness.

5. Conclusions

TER4RAIL project was structured in 5 WPs, 3 of them (WP1, WP2, WP3) thematic, being represented in the figure below:

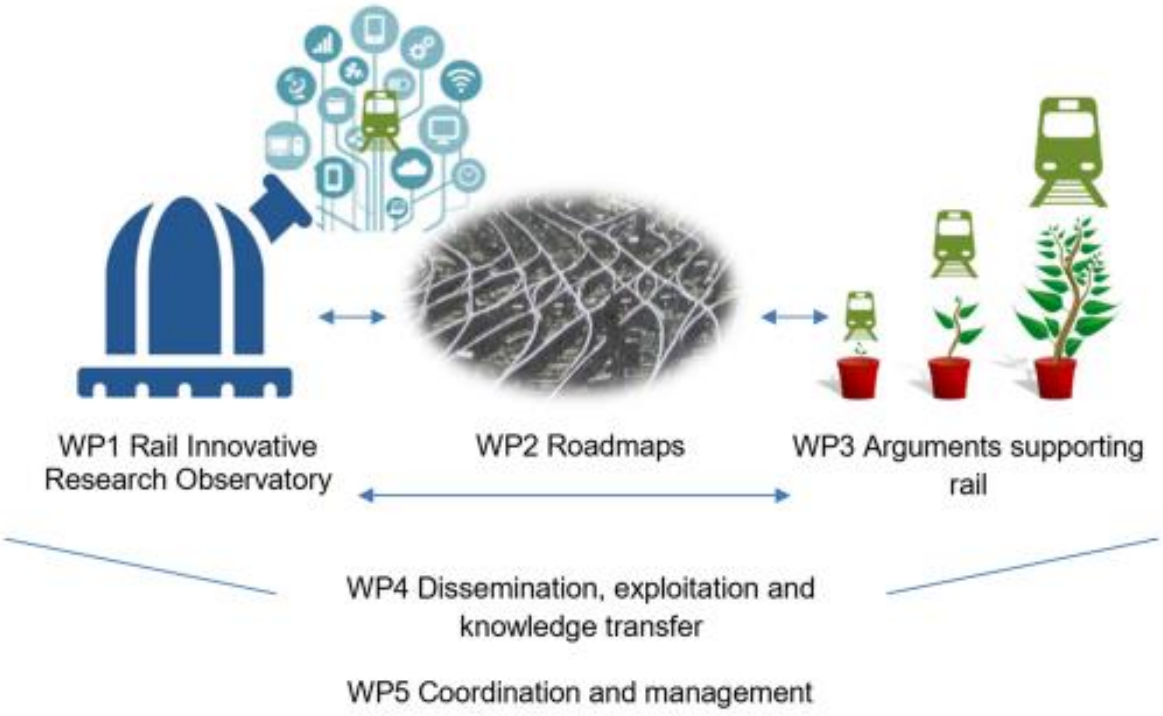


Figure 6 – *TER4RAIL WPs*

WP1 objectives were to:

- Identify, monitor, and facilitate the analysis of new **opportunities emerging from the rail sector and other sectors** for a **more successful rail research**.
- **Stimulate the transfer of knowledge** within and outside the sector.
- Structure interactions and **stimulate networking, cross-fertilisation, common collaboration and the kick-starting of new ideas**.



WP1 conclusive remarks are:

- Rail Innovative Research Observatory provides complementary knowledge of Rail R&D status, evolution and vision
- Excellent exercise to map the rail related work developed by other sectors and their relation/influence with the railway sector. It stimulates networking, contributes to the transfer of knowledge and cross-fertilisation.
- TER4RAIL only provided a baseline. There is a need of more resources to broad the exercise to more sectors and programmes. Especially relevant for Horizon Europe – Cluster 5: Climate, energy and mobility.

WP2 objectives were to analyse, compare and get feedback on the existing roadmaps for railways, see methodology below:

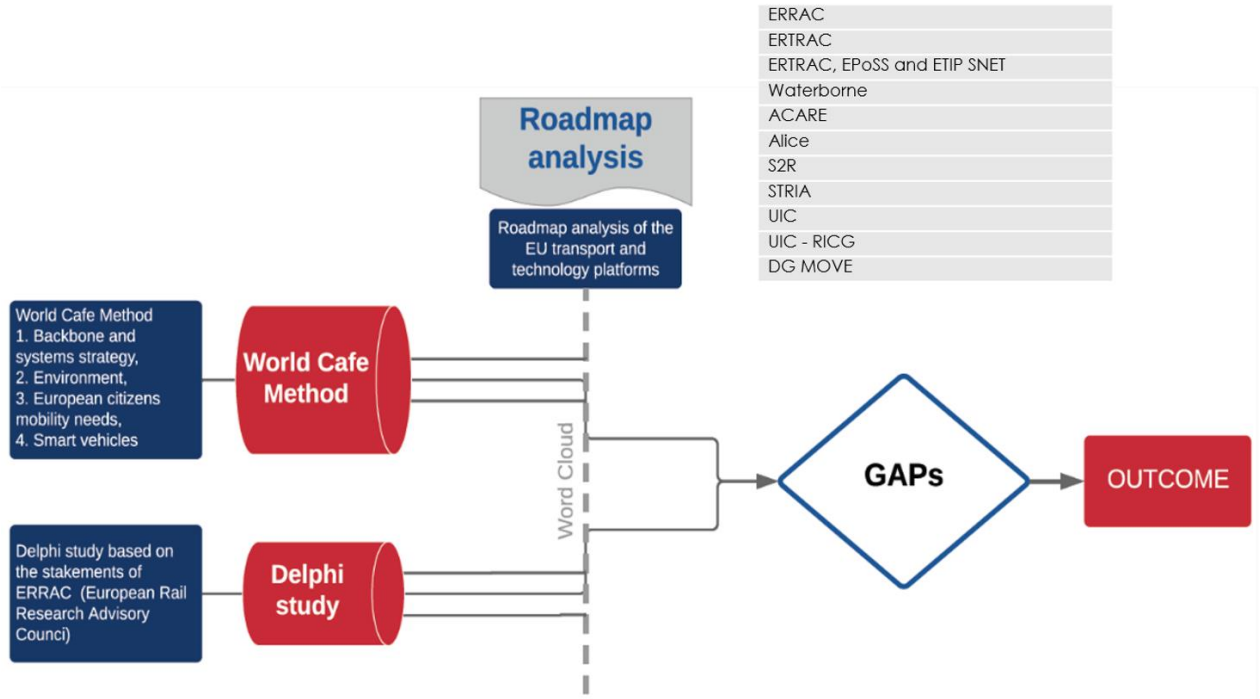


Figure 7 – *TER4RAIL WP2*

WP2 main conclusions are that the roadmaps have major shortcomings in:

- Adapting citizen's needs, user acceptation and integration of railways;
- The influence of short-term policy on transport developments over the long term;
- An absent multi-modal mind-set in all transport sectors towards the integration of railways; and
- The need for tailored and on-demand mobility in railways.

WP2 Delphi panel pointed out the following common themes to be reflected in the next railway roadmaps:

- Market orientation;
- Cost, competition and efficiency;
- Leadership, political issues, lobbying, government intervention for good or ill;
- Lack of seamlessness for many reasons;
- Inadequate speed of reaction/investments compared to Asian competitors;
- Lacking technical/technological innovations and skills;
- Language barriers;
- Different regulations barriers in EU rail space;
- Info, data availability sharing and management;
- Safety and security issues;
- Accessibility and capacity;
- A limiting of scope from universal visions to: Urban, Native, Backbone.

WP3 of TER4RAIL compilated and organized lots of data of railways performance in Europe, as example issued successful stories, (see figure 8) and finally carried a SWOT analysis (see figure 9).

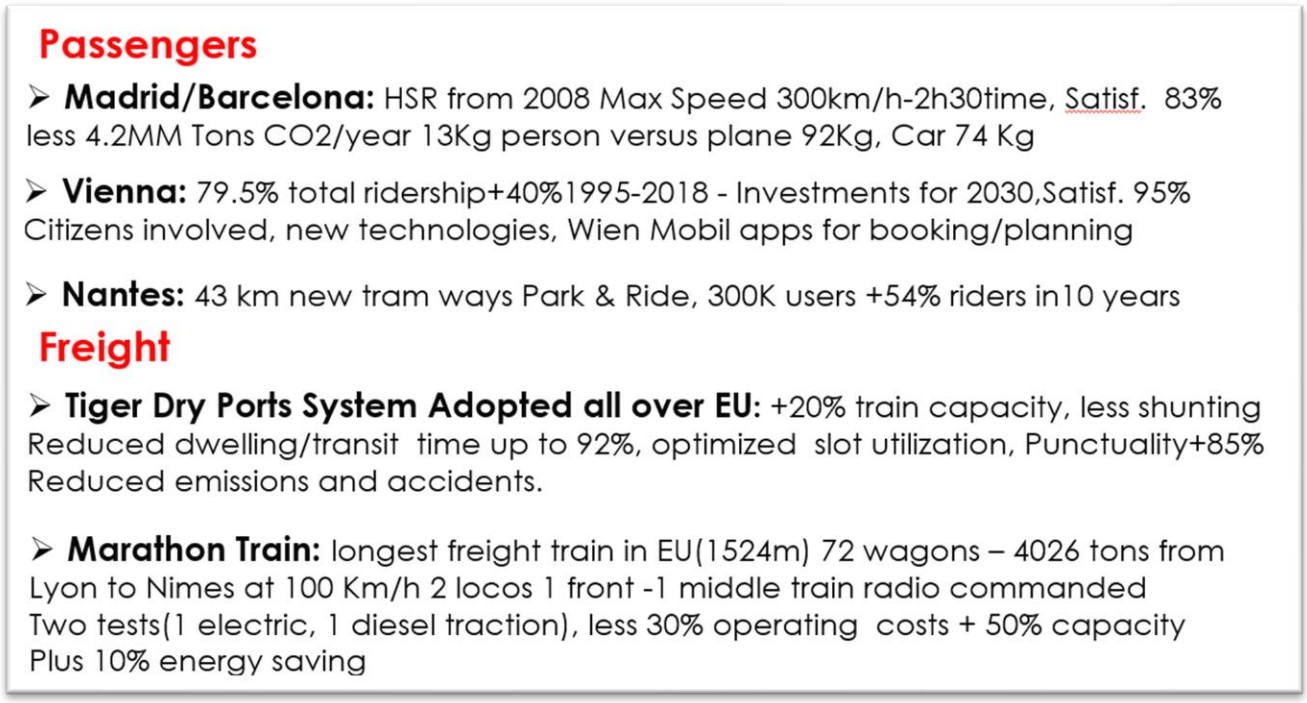


Figure 8 – *TER4RAIL WP3 Success Stories*

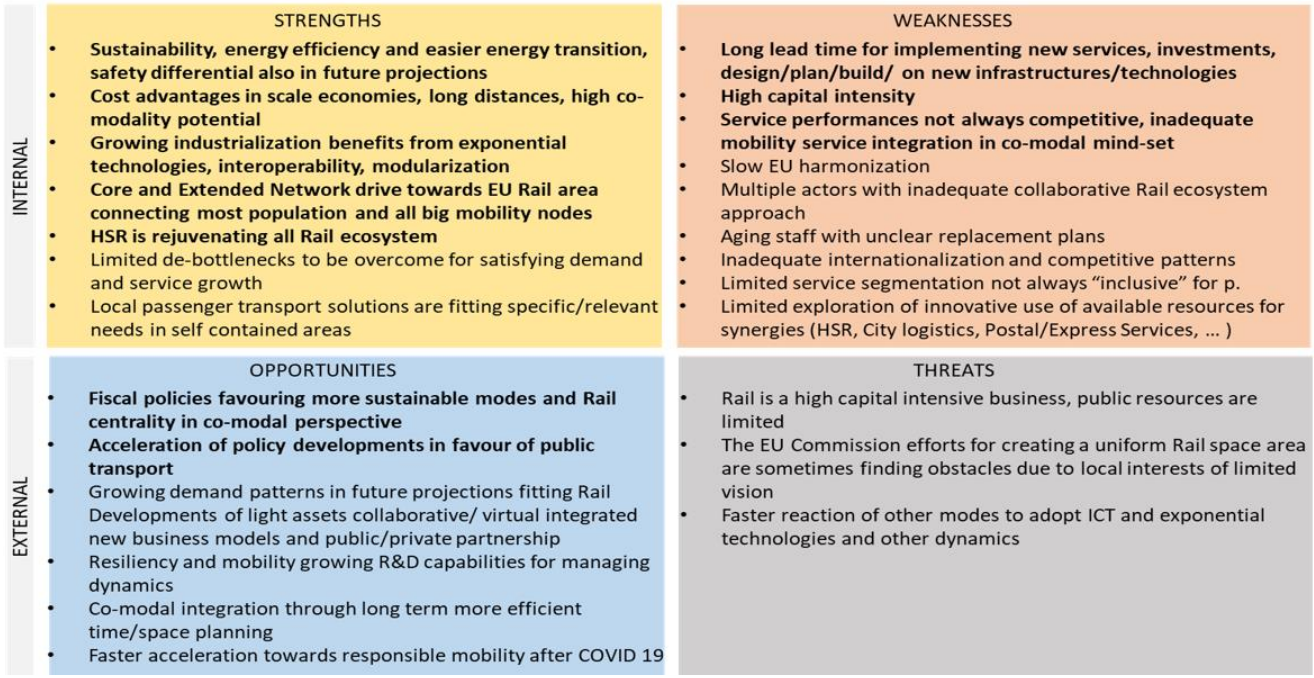


Figure 9 – *TER4RAIL WP3 railways SWOT*

The **overall conclusive remarks** of the project are summarized below:

- The Rail Innovative Research Observatory could be the basis for the synergies identified by ERRAC SRIA and contributes to a more successful multimodal rail research in HE.
- Railways should be considered in non-railway roadmaps as the key mode to be integrated with. For that, engagement at institutional and individual level in other areas should be pursued.
- Success stories of railways can be told in urban/rural, high speed and freight with large margin of growth, cost advantages in scale economies (while sustainable) together with important societal benefits.
- There are high chances to achieve having railways as the backbone of European mobility, however it needs the railway sector to actively engage with the outside.