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Deliverable D 3.1- Data Studies Handbook - including:

D3.1.1 "Metro ridership and infrastructure data set collection"

D3.1.2 "Light Rail data set collection"

D3.1.3 "Freight and Logistics data set collection"

D 3.1.4 "Social, environmental, economic variables data set collection"

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1. Executive Summary

This document was prepared in accordance with the original proposal and has a structure of four pillars supporting the TER4RAIL guiding vision with rail as the backbone of Europe's future multimodal transport system for both passenger and freight.

The four pillars, managed accordingly as individual subsets, are:

- **D3.1.1 "Metro ridership and infrastructure data set collection"**
- **D3.1.2 "Light Rail data set collection"**
- **D3.1.3 "Freight and Logistics data set collection"**
- **D 3.1.4 "Social, environmental, economic variables data set collection" (with a focus on passenger data).**

The segmentation takes into account the individual specificity of related markets in terms of players representing Demand, Offer, European and National/Local Authorities.

While for freight the carriers and the players have operations that vary from global to local with a prevalence of international ones, concerning passengers most traffics and players are effectively national and even local. Local players are especially of vital importance, considering the influence of metropolis in highly significant features. Furthermore, companies managing local transport are amongst the most significant European actors in the industry.

While each individual subset identified above required a dedicated summary, there are common outcomes that support the advantages for rail and are supportive of the TER4RAIL vision "rail as the backbone of future Europe's multimodal transport system". While the traffic trends are not always in favour of rail in all market segments and/or geographies, **the overall picture shows a consistent potential for rail growth for social and economic reasons.** In this context, social and economic reasons are mentioned as a simple aggregation of several elements better segmented in the individual subsets documents. In some segments and geographies, rail appears to already exhibited progress, although the pace of progress may not always be consistent with European ambitions. However, to have champions and examples of best practice is good and this supports the ambition of the wider European target.

Some **risks exist** in given geographies, especially for passenger transport, where the rail traffic share is modest and subject of future further reduction. Rail is a business dominated by economies of scale. In areas where traffic continues to decrease, the risk of irreversible damages exists, this risk could jeopardize the European vision. In order to tackle these risks and to contribute to an enhanced and more harmonized frame, it is important to concentrate on the key priorities that support actions that demonstrate significant success.

The summaries of the individual subsets are reported in appropriate document sections, that follow.
Each subset document is self-contained and can be read independently as was envisaged in the Grant Agreement.

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D.3.1.1. Summary of the subset **"Metro ridership and infrastructure data set collection"**

As of 31 December 2018, **metro systems are available in 178 cities worldwide**. 46 of them are in Europe (25% of the total). Europe has been the world champion in metro from the mid-19th century (London opened the first line in 1863) until the 1970s-80s. Then, the Asia Pacific region took the lead, inaugurating new systems at an increasingly fast pace. In 2018, 70 cities in the Asia Pacific had at least one line (39% of the worldwide presence). In particular, in the decade 2010-19, 34 new systems have been inaugurated in this region. **Regarding population, Europe remains the world region with the most metro networks**.

The present report describes the evolution of metro in Europe focusing on the period 2013-2018 (UITP collects rail data according to a three-year cycle - Metro, LRT and regional/commuter railways) and gives a snapshot of the situation in the year 2018, based on the findings of the UITP. In parts of the document, comparisons among world regions are made, to monitor the global situation and better understand the trends in our Continent. Pushed by the tremendous developments in Asia, the global world metro systems length grew exponentially. In Europe, this growth was slower in the considered period. 10 new lines were opened (passing from 161 to 171 lines) and the total length grew by +7.35%, (2,943 km). Finland, Turkey and Hungary are the Countries experiencing the most significant growth in total length. Countries with already extensively developed systems (notably Spain, France, Germany and UK) experienced a moderate increase in total length. These four countries are the ones with the most extended systems, the highest number of stations and carriages, the most significant ridership. Europe's metro ridership grew on average by 13 % in the considered amount of time. This percentage is not far from the global growth in the same period (about 19%). The European average line length is about 17 km with an average distance between stops of 1 km. Notable differences exist across different countries and between new and old lines. London has by far the most extended metro system in Europe (ranks 4th worldwide); Paris the busiest and Budapest the most crowded (ridership/km of lines). Prague has the most used metro system in the Continent in terms of numbers of metro trips/year per inhabitant.

In terms of fleet, Spain, France, Germany and UK account for the 62% of the total European carriages, Poland (Warsaw) has the highest number (15.52) of cars per km of metro infrastructure, followed by France and the Czech Republic.

In terms of ridership, data show that the symbolic threshold of 10 billion passengers per year was reached in 2014. Spain, France, Germany and the UK accounted for 56% of the total European ridership in 2018. Despite these figures, the highest increase in ridership in the considered period was experienced by Turkey (+48%), Norway (+43%) and Finland (+42%). Czech Republic (Prague), Austria (Vienna) and Sweden (Stockholm) are the European champions in terms of metro trips per inhabitant per year. Still, strong differences are visible in cities belonging to the same Country (particularly the UK, Spain and France). The document discusses growth trends in Europe and provides a list of new projects under development. About 491 new km of metro lines are under planning, construction or operation phase in Europe, particularly in Turkey, France and Italy.

This document, in its final paragraph, investigates the status and the potential of the deployment of fully automated metros. In 2018, Asia consolidated its status as the leading world region in FAO (Fully Automated Operation) with 50% of the km fully automated. Europe remains second at 30%. After the positive conversion projects of Nuremberg (2009) and Paris (2012), 7 European cities have confirmed conversion projects in the coming decade. These conversion projects represent only 7% of the planned

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global metros growth. Still, implementing FAO in an existing line while in operation is a complex and time-consuming task. Moreover, in Europe re-signalling projects are also highly challenging since many of the lines are 40 or 50 years old, and nowadays they reached critical asset replacement needs. The total number of European cities with at least one FAO line is 15 (2018). Globally, automated metros represent 7% of the infrastructure currently in operation. The first automated line was opened in Kobe (Japan) in 1981, followed by Lille in 1983. The growth rate of FAO lines increased exponentially in the last years (particularly due to greenfield projects started in the last two decades). It is expected that, in 2022, 48% of metro infrastructure in planning and construction will be FAO (2,000 km of new lines have already been commissioned worldwide). In general, penetration of FAO systems will be growing in the next decade at a faster pace than it did so far, and full automation will progressively become the universal standard in metro, due to its higher levels of safety, reliability, energy and cost-efficiency.

Since societies are becoming more and more urbanised, and people tend to concentrate in urban areas, metros play a critical role in people's mobility. This aspect is increasingly important if the urbanisation trend is analysed under the "environmental" perspective, with an increasing number of vehicles entering in the urban areas in the future, making congestion and further intensifying pollution problem. Metros can concretely reduce the dependence on private car reaching the targets of the "EU Green Deal" moving a massive quantity of people in an efficient, safe and smooth way in extremely populated areas. Their development has been very successful over the last three decades, and, considering the planned openings, it will proceed further at a faster pace, satisfying mobility needs of citizens.

With forecasts of the global demand for urban mobility set to double by 2050, the development potential of metros is considerable. From 2019 to 2024, global metro infrastructure is expected to grow by 40%, with 25 more cities opening their first line and a further 60 new lines opening in existing networks. **11 European cities have new lines under construction and will open lines in the next years.** 20 cities have extension projects already under construction.

To ensure a proper transition towards an integrated transport system with urban rail as the backbone, it is crucial that authorities (especially local authorities that will become "transport orchestrators"), planners and operators collaborate. It is necessary to create a valuable partnership between all the involved public and private stakeholders, including the citizens themselves, who are the users and can support the authorities from the very first steps, to identify the needs and to understand the best ways to satisfy them. The above-mentioned process includes a clear and solid urban development strategy capable of building coherent transport policies, exploiting the benefits of each mode (keeping rail at the centre), ensuring the consistency of the project over a long-time horizon, regenerating urban areas fuelling housing, jobs and public equipment.

Metros require significant cyclical investments to ensure that safety, reliability and performance are maintained over time. With a high quantity of lines opened in Europe in the 70s-80s, time for primary asset replacement is coming, and it deserves as much attention as new developments.

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D.3.1.2 Summary of subset "Light Rail data set collection"

As of 31 December 2018, tram and Light rail systems (both designed as LRT in this document) are available in 402 cities of the world. Despite a significant increase in the number of new lines recently opened in the Asia Pacific region, Europe remains the world's leader in LRT, in terms of lines number, km and number of cities served (208). The present report describes the evolution of LRT in Europe since 2015 and gives a snapshot of the situation in 2018, based on the findings of the UITP LRT Statistics Report produced by UITP in 2019.

To ease the readability of the statistics, European countries have been clustered in 9 sub-regions (Nordic/Baltic, Poland, Germany, Benelux, British Isles, France, Western Mediterranean, Central Europe, South-Eastern Europe).

From the analysis, it emerged that **between 2015 and 2018, LRT infrastructure in Europe grew on average by 3.9%**, with a peak of 9% in the British Isles and 9,5% in the Nordic/Baltic region, totalling 9.296 km. The European average line length is 7.3 km, with an average distance between stops of 300-600m. Notable differences exist across different countries and between new and old lines. Berlin has the most extended LRT system in Europe; Budapest the busiest and Istanbul the most crowded.

In terms of fleet, Germany, Poland and Central Europe account for the 59% of the total European trams and LRVs, roughly half of them low-floor. Central, South-Eastern Europe and Benelux have the densest feet (2+ LRV/Km). Data on yearly mileage per vehicle show that the European average is 52.000 Km. Still, differences exist among the various countries and considerations have to be made in terms of rush/peak hours utilisation and vehicles immobilised for maintenance.

In terms of ridership, data show that the symbolic threshold of 10 billion passengers per year was reached in 2016. An increasing trend is visible between 2015 and 2018, with Germany, Central and South-Eastern Europe accounting for 61% of the total European ridership. Despite this, British Isles, Nordic/Baltic and Benelux showed the most robust increase in the number of passengers. The average European ridership growth 2015-2018 is 6.9%. The demand growth is 50% higher than the supply growth. Central Europe, Poland and Germany are the champions in terms of LRT trips per year per inhabitant, but substantial variations are visible in countries belonging to the same cluster.

In terms of both environment-friendliness and safety, the report shows that LRT results to be 7 times less pollutant and 6 times safer than private cars. Any modal shift towards LRT public transport positively affects the overall safety record of a city and its environmental footprint.

In terms of innovations, new technical solutions have been analysed. Catenary-less power supplies will continue to be chosen, but still representing a niche market, while trams on tires are unlikely to know rejuvenation or widespread utilisation. Advanced Driver Assistance Systems are likely to increase their market share in Europe. In this sense, technology is available and is expected that operators will be more and more interested in deploying this solution soon to avoid the high number of collisions in street operations.

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D.3.1.3 Summary of subset **"Freight and Logistics data set collection"**

Logistics is vital for understanding market conditions where different solutions and modes compete for satisfying market demand. Logistics favours increased potential because of continuous innovation dynamics characterised by several elements. Outsourcing penetration with the growing role of international Logistics Operators (such as 4PLs, 5PLs) and increased support by available ICT technology, stimulate the rail growing potential in industries and distribution. As such, the market capabilities of integrated rail services in logistic systems should increase. Moreover, barriers to the modal shift of traffic flows using road should reduce due to environmental considerations. Social evolutions like drivers shortage and environmental considerations are significantly contributing to this projection.

Despite the main elements of the rail ecosystem show little modifications throughout the considered time frame from 2000 up to 2019, **it is possible to imagine for rail a more significant potential improving its role in a modern co-modal freight mobility system considerably**. Currently, rail connections from the EU to the intercontinental flows account in 2017 for only 3.8% of tons of import + export. Still, the new Eastern overland traffic looks promising on the eve of the Silk Road initiatives. These are enormous driving innovations, much more significant than the "simple" growth in quantities.

Infra EU **traffic** constitutes for rail a big chance for increasing its share that currently is well below the "2011 White Book" target. Looking at transport performances in the period 2000-2017, the cumulated growth in terms of ton*km has been 3.6% while the overall transport growth has been 14.9%. Nevertheless, some indicators (inland mode in ton) in most recent years, show slightly better rail performances.

The most significant market segmentation is operated according to service production scheme:

- Intermodal units show robust constant growth and appear in the best position to continue this performance if well supported;
- Full/block trains (excluding intermodal trains) and Single Wagons Loads appear to require attention to revitalise their role. Projects with specific focus have been carried out to exploit this currently unexpressed potential;
- As the rail freight industrialisation is paramount for any development ambition, several considerations potentially contributing to future rail success are deeply investigated in the document;
- The potential of longer and heavier trains is mentioned as the first point contributing to upgrade the rail ecosystem. Trains of Marathon FP7 project (to be elaborated in the TER4RAIL case study dedicated to freight) demonstrated the operational feasibility, with 30% costs saving +5% energy saving and more than 40% capacity saving per ton transported which is massive capacity generation. These improvements lengthen the life of the existing infrastructure substantially, avoiding new investments in new tracks, which in any case have a very long time to market. The train length, after the investments currently in progress, is going be aligned to 750m in most of the EU countries while the target up to 1,500m seems possible;
- Equally tests for using High-Speed Trains for the same day delivery growing market represent a positive signal as theorised by the SPECTRUM project for HVLDG;

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- When accurately evaluating cost competitiveness, distance is the traditional and the most critical variable. Rail transport is generally considered effective on distances not lower than 300 km and extremely competitive on trips longer than 900 km. However, in all distance segments there are significant opportunities, particularly in traffics to and from seaports where scale economy already exists, as well as in mass transportation for commodities and raw materials;
- Service upgrading must be pursued. The service is the first selection criteria in comparison with the road door-to-door, which is faster, more flexible and reliable. Even when short lead-time does not represent a constraint, the service reliability is prevailing.

Other elements addressed in the report Include liberalisation, rolling stock, infrastructure, ICT technologies. All these elements represent evolutions in place with significant potential.

The **liberalisation** process, started in Europe around the year 2007, is continuing. While the incumbents are still the major players in most countries, "liberalisation" has progressed, providing the customers with alternative choices and more value-added services. This process will continue in the future, forcing the incumbents to improve their performances to avoid a decrease in their traffic flows. An essential aspect of the market development offering is the growth and the international consolidation of major incumbents. Although the incumbents are playing an essential role in these aggregations, the private operators contributed to the creation of an own international network. The consolidation process is continuing.

Rolling stock is another essential asset and wagons ownership, in particular, is a standard marketing tool for those companies owning them. As such, wagons availability is a crucial element for managing current traffic flows efficiently and for developing new ones. The rail wagons stock figures show massive reductions. When interpreting these statistics, redundancies and obsolescence have to be taken into account. While the efficient wagons constitute only part of the rolling stock, with the availability shortage as a consequence of progressive equipment specialisation, significant quantities of wagons remain unused and/or under-maintained. The wagons' fleet reduction is also linked to the fact that it becomes economically obsolete compared with new, more efficient polyvalent wagons. To encourage the purchase of new equipment or retrofitting existing ones, initiatives are in place in some European countries.

The **infrastructure network** with a focus on the Core Network is progressing its path towards the full operability in 2030. Within the Core Network, Freight Corridors according to the principle of The Regulation (EU) No. 913/2010 have been defined by linking the leading industrial and port regions in Europe. Looking at freight corridors KPIs, capacity seems still "largely" available, with the exception of specific bottlenecks, urban bypasses, port connections and technical features such as wagons profile and train length.

While it is not a "direct" player, **Information and Communication Technology** (ICT) presence is omnipresent in the rail freight industry as a critical enabler towards a higher service level and industrialisation. Most relevant aspects of its role and potential contribution to progress are:

- Setting up new solutions and business models (including governance model, data property, connections to users, transactions, control, management);
- Supporting innovative players' categories and resources;
- Integrating management processes;

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- Incorporating new Technology SW and toolkits (AI, Block-chain, IoT, PI, Tech Boxes and others).

Dealing with **constraints**, it may be useful to distinguish "hard", and "soft" barriers since their overcoming may have different investment requirements, technical limitations and time to market. Infrastructure and rolling stock are in the "hard" cluster while operations - both on the RU and the IM field - may be predominantly in the "soft" cluster. ICT may have a more significant role in the "soft" dimensions with relatively limited investments and shorter lead times. The generation gap is an issue in the rail system since the challenge is represented by the new fast disrupting technologies to be applied to a business model "old" by definition. The resistance to change is a significant issue to be tackled. A new generation of workers and managers replacing the significant number of retiring people will be more open to operational and market changes.

D.3.1.4 Summary of subset **"Social, environmental, economic variables data set collection"**

Transport is a crucial component of the European socio-economic system, having several interrelations with other resources of which is part.

The most synthetic of such correlations is between mobility and GDP. Even if transport brings some undesired consequences, mobility curbing cannot be an answer to them as mobility growth is part of the EU progress. The EU Commission declared that curbing mobility is not an option.

In terms of **share by mode** in the year 2017, car transportation is by far the most popular used mode in Europe with 70.9% traffic share and 4.901 billion pkm. Air follows with 11.2%, and bus & coach is third, with 7.4%. Rail is "only" the fourth modal choice with 6.8%. The remaining part includes tram & metro, powered two wheels and sea.

In terms of **market share dynamics** in the period 2000-2017, when comparing each mode with the overall growth of 17.3%, the modal evolutions are not similar. The most relevant market share change is in the Air mode, with a 69.1% increase. Tram & metro is following with 33.8%. In terms of growth, Railway is the third growing mode with 24.6% primarily due to High-Speed Rail.

Furthermore, looking at the last 3 years, Air mode is by far the most growing. Railway follows at a distance.

Country differences are significant and are investigated in the report in many aspects, such as: Propensity to travel by rail, Density of infrastructure and services, Degree of market opening, Perceived quality of service in terms of customer satisfaction, Fares in terms of revenues per pkm, Public service contracts, Structure of territory and urbanization, Development of HSR, Focus on motorways investments opposed to rail modernization and fast evolvement of car mobility, Availability of service of mobility integration.

These differences can be very shortly summarised with data regarding market share and its dynamics in the observed period. Therefore, the overall picture presents the aggregation of national situations with evident diverging patterns more significantly than real EU harmonized dynamics.

Most rail traffic remains within the individual countries, and even the High-Speed "revolution" shows a modest impact on international routes.

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		Traffic dynamics 2000-2017 in absolute value of pkm			
		<0	<EU avg 24.6%	>EU avg 24.6%	>2 EU avg 24.6%
Current inland market share % (2017)	<7.0%	BG, EL, HR, LV, LT, RO, SI	IT, PT	LU, FI, ES	EE, IE
	7.0-8.5 % (AVG EU 7.8%)	PL	DK	BE, CZ	
	>8.5%	HU		DE, FR. NL, AT, SK	SE, UK

Source: Newopera elaboration based on ISTAT data 2000-2017

Consequently, the overall picture about rail mode includes different clusters of countries ranging between situations where:

- marginal share and negative trends would require to stop the decline for avoiding dismantling existing resources before planning the renaissance;
- significant market share and trend higher than overall mobility might be little more than "simple continued" for further developments.

The quality of transport services has a significant impact not only on the EU economy in a macroeconomic perspective but directly on people's spending and quality of life.

In general, the quality of rail service is not perceived as adequate. Lack of competition and service segmentation often limit the quality innovation process. At the same time, the transformation of stations in nodes for interchange modality appears to be progressing slowly.

The most significant technological innovation of rail in modern times is represented by **High-Speed Rail** (HSR) which has delivered an enormous improvement in service quality and increased competitiveness with other modes such as air transport. HSR, however, is still very much a National Country business. The capability to compete with air in the fast-growing international traffic, when distances are already approachable with HSR is not exploited. In fact, the orientation of investments in cross border connections appear limited, and no operator with an international scope is targeting this market at present.

Relevant rail features impacting life quality are safety and sustainability:

- rail is by far the safer mode than any other surface transport - according to ERRAC it is 24 times safer than car land transport, 1.5 times better than coach;
- in terms of absolute values, the rail contribution to GHC emissions is relatively modest - looking specifically at CO_2 as an example representative all GHC, rail is 7 times more energy-efficient than cars, produces 2.6 times less CO_2 than passenger-km and 3.6 times than t/km. High-Speed rail service is 3.4 times less polluting than air transport;

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- noise reduction remains a point of attention – fleet renewal and widely affordable retrofitting of the current fleet are progressing.

Looking more specifically at economic aspects, the expenditure on the transport of goods and services accounts on average for about 13% of every household's budget. Transport industry accounts for about 5% of Europe's Gross Domestic Product (GDP). The segment of rail transport accounts for about 1.1% of EU's GDP.

Transport companies are amongst the biggest EU companies in terms of employment per enterprise. Despite their dimension, most companies have a large part of their employees concentrated in a single Country. This trend is the case for the majority of rail companies. Public transport is one of the largest employers at the local level; virtuous examples are Amsterdam, Barcelona, Brussels and Dublin.

After road, rail transport is the primary mode in terms of people employed. People working in the rail sector, including indirect employment, are about 2.3 ml people. Gender disparity still constitutes an issue to be solved in the rail sector to reach an acceptable gender balance. Age structure also needs attention since the report shows that the vast majority of employees in this sector are over 50.

Considering the capital intensity of rail investments and their long time to market their continuous progression is critical for increasing capacity, create new offerings and improve performances generating employment. Most investments derive from medium-long term planning as the lead-time, especially for infrastructure, is quite long. Significant actions up to 2030 are already in plans currently under implementation with continuity in funding intensity.

The transport industry is significantly contributing to **R&I investments** in the EU. Studies quoted in this document show that transportation has a higher share of the overall spending. Between 4 and 10% of the turnover of the rail sector is dedicated to R&D.

The Shift2Rail (S2R) program represents the most important instrument for developing research activities in the rail sector. Shift2Rail was established in July 2014 as a Joint Undertaking supported by the European Union's 'Horizon 2020' programme. The Shift2Rail aim is to promote the competitiveness of the European rail industry. Research is fundamental for accelerating the integration of new and advanced technologies into innovative rail solutions necessary to:

- support the completion of the Single European Railway Area (SERA);
- increase the capacity of the European rail system;
- improve the reliability and the quality of rail services, whilst reducing costs.

Other relevant initiatives can be identified in H2020 program even excluding rail specific topics but including rail contribution in a broader co-modal perspective. Examples show to focus on territory and urban mobility, logistics, a new concept such as physical internet, modular unit load, technology applications both soft and hard.

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2. Abbreviations and acronyms

Abbreviation / Acronyms	Description
ADAS	Advanced Driver-Assistance Systems
AI	Artificial Intelligence
ATO	Automated Train Operation
ATP	Automated Train Protection
BOP	Booking Optimization Platform
BU	Business Unit
CEF	Connecting Europe Facilities
CT	Combined Transport
CTO	Carrier and Terminal Operator
ERP	Enterprise Resource Planning
FAO	Fully Automated Operation
FTA	Full Train Automation
FTL	Full Truck Load
GDP	Gross Domestic Product
GHG	Green House Gases
GoA	Grade of Automation
GVA	Gross Value Added
HSR	High Speed Railways
HVLDG	High Value Low Density Goods
ICT	Information Communication Technology
IM	Infrastructure Manager(s)
IOT	Internet Of Things
ITU	Intermodal Transport Unit
JIT	Just In Time
LCC	Life Cycle Cost
LRT	Light Rail Transportation
LRV	Light Rail Vehicle
LTC	Less than Truck Load
MaaS	Mobility as a Service

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MENA	Middle East North Africa
MPI	Market Performance Indicator
NDTAC	Noise Differentiated Track Access Charges
OD	Origin-Destination
OEM	Original Equipment Manufacturer
OSS	One-Stop Shops
PKM	Passenger Kilometre
PI	Physical Internet
PSO	Public Service Contract
PT	Public Transport
PTA	Public Transport Authority
PTO	Public Transport Operator
RFID	Radio-Frequency Identification
RMMS	Rail Market Monitoring Scheme
ROW	Right-of-Way
RU	Railway Undertaking
SCS	Supply Chain Specialist
SERA	Single European Rail Area
SP	Service Provider
SW	Software
SWL	Single Wagon Load
TEN-T	Trans European Network
TEU	Twenty foot Equivalent Unit
TKM	Tonnes Kilometre
TSI	Technical Specifications for Interoperability
UTO	Unmanned Train Operation
WW	Worldwide

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3. Background, objectives and methodology

The present document constitutes the Deliverable D.3.1 of TER4RAIL project S2R IPX-02-2018, and its structure shows four subsets each addressing specialized topics, as designed in the project proposal.

Each set includes analysis of data and information regarding the current situation representing the European state-of-the-art. While analysing past relevant dynamics and recent/ongoing evolutions, the main objective includes considerations of the rail advantages for sustainable mobility.

The subsets include:

- D3.1.1 "Metro ridership and infrastructure data set collection" – The analysis is based on the Metro Statistics Report 2018. The extensive report is available, together with the full dataset, on request from UITP. Data from the report mentioned above have been enriched with elaborations based on updated UITP datasets. Population figures are based on the UN DESA World Urbanization Prospects report figures for 2018. Other data in this report are based on research from available official company sources or trusted public sources, and cross-checked whenever possible, with the help of UITP regional offices. Infrastructure predictions are based on scenarios developed from UITP's rail projects database.
- D3.1.2 "Light Rail data set collection" – The analysis covers 9 geographical clusters of countries through the period 2015-2018. LRT and trams are urban rail-guided systems operated at least partly on line-of-sight, on infrastructure shared with other users and partly on their own infrastructure (Right-of-Way type 2). Tram and LRV vehicle are urban rail vehicles designed to run on a tram/LRT network. Systems operated on guided rubber-tyred multi-articulated vehicles with right-of-Way 2 are included.
- D3.1.3 "Freight and Logistics data set collection" – The role of rail freight is outlined, and its potential is highlighted in the "market demand", perspective that uses and pays for the services. Therefore, an extensive logistics state of the art is described, representing the logistics' situation and its recent and/or ongoing evolution. The evaluations trends consider the period from the year 2000 onwards when data are available.
- D 3.1.4 "Social, environmental, economic variables data set collection" – This section shows general aspects of the rail ecosystem and in particular topics related to passenger mobility.

The adopted methodologies are different for the different subsets of the document. In fact, the markets are different as well as the knowledge basis.

For the subsets:

- D3.1.1 "Metro ridership and infrastructure data set collection"
- D3.1.2 "Light Rail data set collection"

the market structure shows several local situations with a plurality of urban and political implications explaining the history and driving the future projections.

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As a consequence, the most significant data are not "European" and not even national. UITP manages the most critical existing data and information in the form of a proprietary database compiled by UITP using official company data and other authoritative sources (national statistics office, national associations, etc.). The database covers both traffic and infrastructure and is the basis for predictions on scenarios developed from UITP's rail projects.

The data for this document was extracted from UITP database and in particular from Statistics Report 2019, which includes further details and analysis. The extensive report is available, together with the full dataset, on request from UITP.

For the other subsets:

- D3.1.3 "Freight and Logistics data set collection"
- D 3.1.4 "Social, environmental, economic variables data set collection"

the market structure shows numerous European and even Global segments together with National and Local ones, whose history and projections have been in the scope of several statistics, studies, researches, scientific articles and publications. While the EUROPEAN COMMISSION and SHIFT2RAIL project researches are considered as preferred sources and quoted as applicable, the adopted methodology takes advantage of browsing all sources. Even if they are not necessarily all aligned in terms of observed time and scope or variables definitions, they are useful for supporting the understanding of the elements to be assembled. In some cases, especially for one-time studies, the coherence among different reports is not guaranteed.

In particular, comprehensive and systematic European databases coherent with the objective of this study are not available since a significant part of the traffic remains within the individual countries. The EU interpretation of "internal market" is yet to be consolidated. Therefore, many pieces of available information and statistics represent the European Union as a sum of individual countries. Nevertheless, many efforts continue to be dedicated by the European institutions to the selection of meaningful data for achieving knowledge completeness. Due to the aggregation and the complexity of interpreting such data, the progress is not as fast as desired.

Individual snapshots originating from magazines and newspapers articles are also included, especially when providing information on emerging evolutions. For the same reasons, a certain number of items may not be fully supported by data. To find appropriate data in the rail ecosystem is, in some cases, remarkably challenging. For example, statistics about the traffic composition of full trains and wagonloads are available only for some countries, and some weaknesses are extremely difficult to be described with quantitative elements.

The data analysis considers the period from the year 2000 onwards, highlighting the most recent evolution when appropriate.

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4. Deliverable D 3.1.1 - Metro Ridership and Infrastructure Data Set

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Tardivo, Carrillo Zanuy	EURNEX	Final edition and conclusions

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4.1. Executive Summary

As of 31 December 2018, metro systems are available in 178 cities worldwide. 46 of them are in Europe (25% of the total). Europe has been the world champion in metro from the mid-19th century (when London opened the first line in 1863) until the 1970s-80s. Then, the Asia Pacific region took the lead, inaugurating new systems at an increasingly fast pace. In 2018, 70 cities in the Asia Pacific had at least one line (39% of the worldwide presence). In particular, in the decade 2010-19, 34 new systems have been inaugurated in this region. Relative to population, Europe remains the world region with the most metro networks.

The present report describes the evolution of metro in Europe, focusing on the period 2013-2018[1] and gives a snapshot of the situation in the year 2018, based on the findings of the UITP. In certain sections, the document draws comparisons among world regions, to monitor the global situation and better understand the trends in our continent. Pushed by the tremendous developments in Asia, the global world metro systems length grew exponentially. In Europe, this growth was slower in the considered period. 10 new lines were opened (passing from 161 to 171 lines) and the total length grew by +7.35%, (2,943 km). Finland, Turkey and Hungary are the countries experiencing the most significant growth in total length. Countries with already extensively developed systems (notably Spain, France, Germany and the UK) experienced a very moderate increase in total length. These four countries are the ones with the most extended systems, the highest number of stations and carriages, the most significant ridership. Europe's metro ridership grew on average by 13 % in the considered amount of time. This percentage is not far from the global growth in the same period (about 19%). The European average line length is about 17 km with an average distance between stops of 1 km. Notable differences exist across different countries and between new and old lines. London has by far the most extended metro system in Europe (ranks 4th worldwide); Paris the busiest and Budapest the most crowded (ridership/km of lines). Prague has the most used metro system in the continent, in terms of number of metro trips/year per inhabitant.

In terms of fleet, Spain, France, Germany and the UK account for the 62% of the total European carriages, but Poland (Warsaw) has the highest number (15.52) of cars per km of metro infrastructure, followed by France and the Czech Republic.

In terms of ridership, data show that the symbolic threshold of 10 billion passengers per year was reached in 2014. Spain, France, Germany and the UK accounted for 56% of the total European ridership in 2018. Despite this, the countries which experienced the highest increase in ridership in the considered period were Turkey (+48%), Norway (+43%) and Finland (+42%). The Czech Republic (Prague), Austria (Vienna) and Sweden (Stockholm) are the European champions in terms of metro trips per inhabitant per year. Still, significant differences are visible in cities belonging to the same country (particularly the UK, Spain and France). The document discusses growth trends in Europe and provides a list of new projects under development. About 491 new km of metro lines are under planning, construction or operation phase in Europe, particularly in Turkey, France and Italy.

This document, in its final paragraph, investigates the status and the potential of the deployment of fully automated metros. In 2018, Asia consolidated its status as the leading world region in FAO (Fully Automated Operation) with 50% of the km fully automated. Europe remains second with 30%. After

[1] UITP collects rail data according to a three-year cycle (Metro, LRT and regional/commuter railways)

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the positive conversion projects of Nuremberg (2009) and Paris (2012), 7 European cities have confirmed conversion projects in the coming decade. These conversion projects represent only 7% of the planned global metros growth. Still, implementing FAO in an existing line while in operation is a complex and time-consuming task. Moreover, in Europe re-signalling projects are also highly challenging since many of the lines are 40 or 50 years old and, nowadays, they reached critical asset replacement needs. The total number of European cities with at least one FAO line is 15 (2018). Globally, automated metros represent 7% of the infrastructure currently in operation. The first automated line was opened in Kobe (Japan) in 1981, followed by Lille in 1983. The growth rate of FAO lines increased exponentially in the last years, particularly due to greenfield projects started in the last two decades. It is expected that in 2022, 48% of the metro infrastructure in planning and construction will be FAO (2,000 km of new lines have already been commissioned worldwide). In general, penetration of FAO systems will be growing in the next decade at a faster pace than it did so far and full automation will progressively become the common standard in metro, due to its higher levels of safety, reliability, energy and cost-efficiency.

Since societies are becoming more and more urbanised, and people tend to concentrate in urban areas, metros play a critical role in people's mobility. This aspect is increasingly important if the urbanisation trend is analysed under the "environmental" perspective, with an increasing number of vehicles entering in the urban areas in the future, making congestion and pollution problem grow. Metros can concretely reduce the dependence on private car reaching the targets of the "EU Green Deal" moving a massive quantity of people in an efficient, safe and smooth way in extremely populated areas. Their development has been very successful over the last three decades, and, considering the planned openings, it will further proceed at a faster pace, satisfying mobility needs of citizens.

With forecasts of the global demand for urban mobility set to double by 2050, the development potential of metros is considerable. From 2019 to 2024, global metro infrastructure is expected to grow by 40%, with 25 more cities opening their first line and a further 60 new lines opening in existing networks. 11 European cities have new lines under construction and will open lines in the next years. 20 cities have extension projects already under construction.

To ensure a proper transition towards an integrated transport system with urban rail as the backbone, it is crucial that authorities (especially local ones that will become "transport orchestrators"), planners and operators collaborate. It is necessary to create a valuable partnership between all the involved public and private stakeholders, including the citizens themselves, who are the users and can support the authorities from the very first step to identify the needs and understand the best ways to satisfy their expectations. The process mentioned above includes a clear and solid urban development strategy capable of building coherent transport policies, exploiting the benefits of each mode (keeping rail at the centre), ensuring the consistency of the project over a long time horizon, regenerating urban areas by fuelling housing, jobs and public equipment.

Metros require significant cyclical investments to ensure that safety, reliability and performance are maintained over time. With a high quantity of lines opened in Europe in the 70s-80s, time for primary asset replacement is coming and deserves as much attention as new developments.

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4.2. Introduction

The data for this document were extracted from a database compiled by UITP using official company data and other authoritative sources (national statistics office, national associations, EC Eurostat Database, etc.)[2].

Metros are high capacity urban rail systems, running on an exclusive right-of-way. Metro lines included in these statistics run with trains composed of a minimum of two cars and with a total capacity of at least 100 passengers per train. Suburban railways are not included. Systems that are based on the monorail or magnetic levitation technology are included if they meet all other criteria above. Suspended systems are not included.

This document is based on the Metro Statistics Report 2018, which includes further details and analysis. The extensive report is available, together with the full dataset, on request from UITP. Data from the report mentioned above have been enriched with elaborations based on updated UITP datasets.

Population figures are based on the UN DESA World Urbanization Prospects report figures for 2018.

Other data in this report are based on research from available official company sources or trusted public sources, and cross-checked whenever possible, with the help of UITP regional offices. In a limited number of cases, figures are an estimation based on other available data. Few missing data about metro ridership (2018) are estimated using reliable methods such as the national public transport trends or figures included in national institutes of statistics, national public transport associations and public transport operators official reports.

Infrastructure predictions are based on scenarios developed from UITP's rail projects database.

In the first part of this document, an investigation of the benefits of metros has been made, using UITP elaborations based on metro worldwide statistics, highlighting, in particular, the European situation. After, there is a focus on the European Countries in which at least one metro line is in operation, using charts produced internally by UITP and based on databases updated continuously. A chapter was entirely dedicated to the FAO (fully automated operation, or UTO, GoA4), to describe the current state of the art (worldwide and especially in Europe) and the planned evolutions for the near future. A list of metro projects to be developed soon in Europe is included in Appendix 2.

Additional definitions:

Lines: Number of lines in the metro network (when 2 or more lines share the same infrastructure, it is counted only once; branch lines are considered when the branch infrastructure is proportionately relevant with regards to the length of the full line).

Line length: Length of the entire metro network infrastructure (excluding service track) at the end of the year.

Stations: Number of stations at the end of the year (interchange stations counted only once except in some cases if used by different operators).

Carriages: The unit chosen for comparing the operational fleet of metros is the carriage (sometimes

[2] UITP uses the UN system World Urbanisation Prospects (WUP)

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referred to as a car). A carriage can be detachable (thus used in different train configurations) or, increasingly with modern trains, a section within the train delimited by articulations that passengers can walk through.

Ridership: Passenger trips on metro network for the given year. Trips with transfers between lines are counted only once. When the data reported by the operating company was using a different definition or was reported on a daily rather than yearly basis, an estimate was made to present comparable figures for all the systems in the database.

Opening: Year of inauguration of the first line.

4.3. The benefits of metro

Originally designed to combat congestion in crowded cities, metro systems have confirmed their powerful attraction for politicians, the business community and even the travelling public. Metros have the proven ability to help accommodate population growth with minimum negative externalities, foster economic development and enhance citizens' quality of life. They are a fundamental tool to deliver sustainable, resilient and smart cities being the backbone of a rail-centric transport system.

The first-ever metro high-capacity electrically-guided urban rail systems with exclusive ROW (right-of-way), fully protected from disruption by third parties, was opened in 1863 in London. Metros developed mainly in the Western World, the (former) Soviet Union, parts of Asia and South America in the second half of the 20th century. With the new millennium, metro development has been massive, with 79 new cities opening lines by December 2018. Many of them are in Asia, but also in Africa and the Middle East, reflecting global urbanisation and economic development trends. Figure 1 shows the evolution of metro systems openings divided per decade from 1863 to nowadays (the chart is from the UITP World Metro Figures report, released in 2018, but it includes projects whose opening was planned for 2019). It is clearly visible the intense development metro systems had in the Asia-Pacific area, particularly in the last 10 years.

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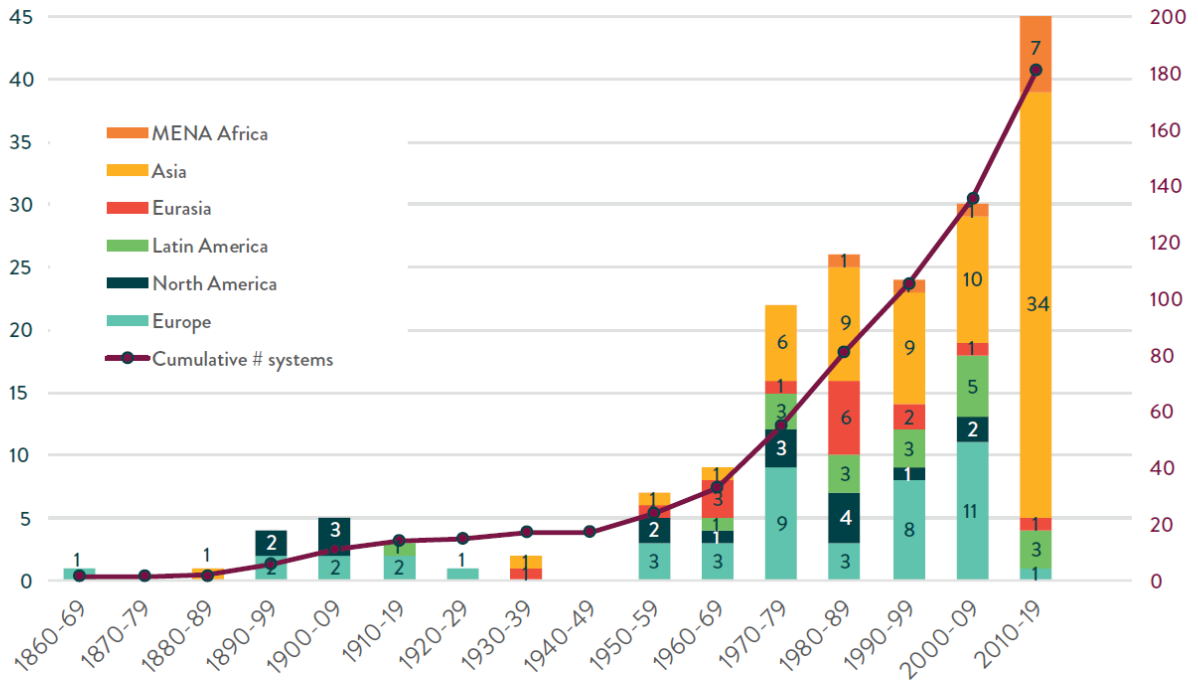

Figure 1: Metro systems openings per decade and cumulative number of systems (1860-2019) - Source: UITP Statistic Brief, World Metro Figures 2018

This growing trend is more visible when analysing figure 2, showing the detailed evolution of networks length in different global areas in the period 2013-2017. In Europe, the growth in the total length was minimal. In the Asia Pacific, in the same period, there was a 49% increase in km of the metro network.

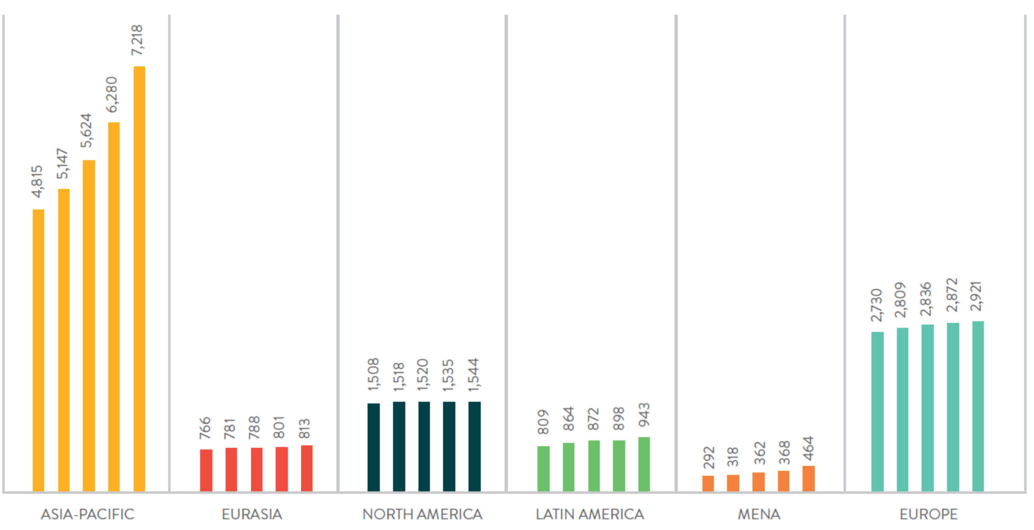

Figure 2: Global total line length evolution (km) per region (2013-2017) - Source: UITP Knowledge Brief - Metros: the backbone of mobile communities and sustainable cities (2019)

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With regards to the ridership evolution in the very last years, Figure 3 shows the constant increase in metro utilization worldwide. Despite a slight decrease in 2013, the incremental growth (pushed in particular by the Asia Pacific area and especially China) was tremendous. In 2017, the 178 metro systems accounted for a total annual ridership of 53,768 million passengers. In the last seven years, annual metro ridership grew globally by 8,716 million passengers (+19.5%).

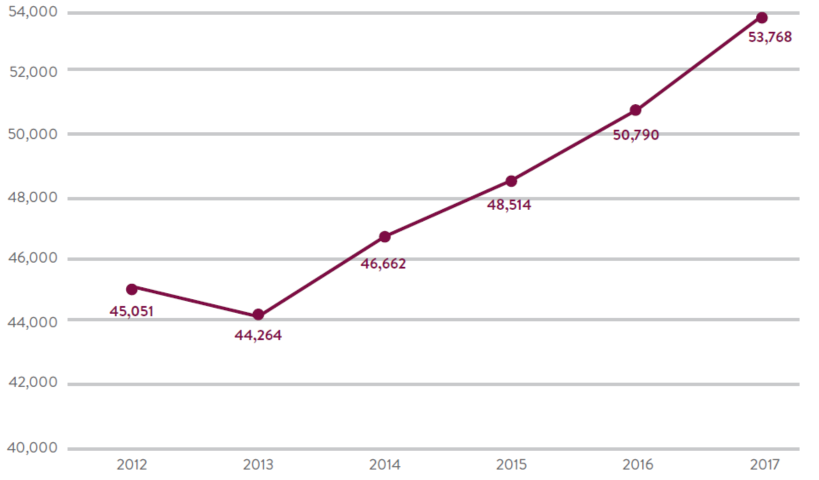

Figure 3: Global ridership evolution worldwide (million pax, 2012-17) – Source: UITP Statistic Brief, World Metro Figures 2018

Broken down by geographical macro-area, the ridership growth rate between 2012 and 2017 was the most robust in the MENA region (58%), followed by Asia (28%) and Latin America (20%). North America and Europe recorded 10% and 12% increase respectively, while Eurasia[3] lost 3% of passengers (Fig. 4).

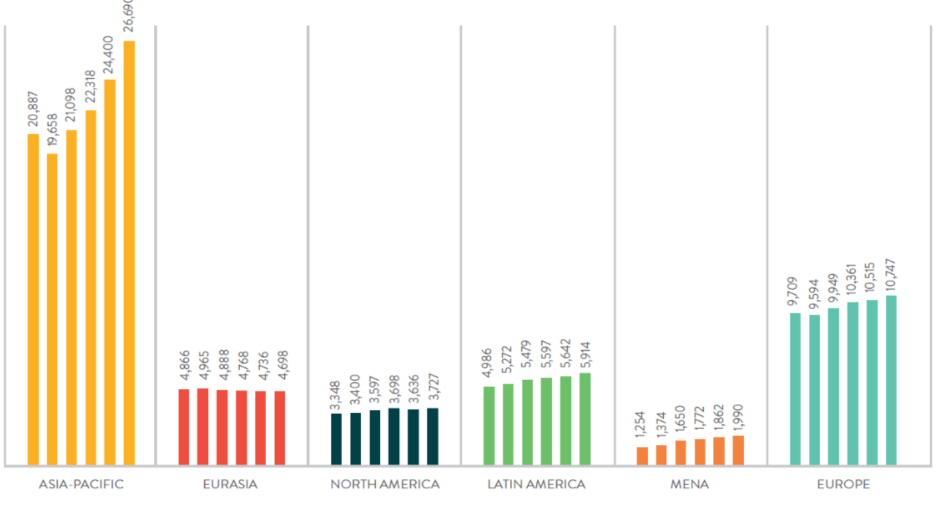

Figure 4: Worldwide ridership by region (in million pax, 2012-2017) – Source: UITP Knowledge Brief - Metros: the backbone of mobile communities and sustainable cities (2019)

[3] According to UITP regional nomenclature, Eurasia refers to the Russian Federation and the CIS region. More details on http://eurasia.uitp.org/

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The situation at the end of 2017 regarding metro systems worldwide and some interesting data are represented in the following Figure 5, which is taken from the UITP Statistic Brief, World Metro Figures published in 2018.

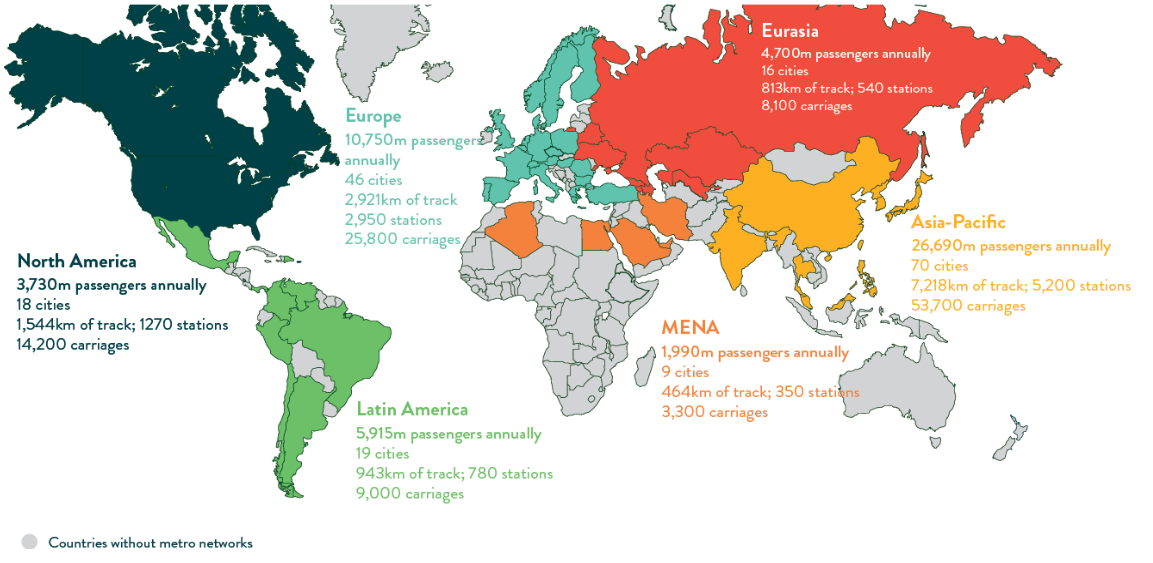

Figure 5: Metro networks worldwide – Source: UITP Statistic Brief, World Metro Figures 2018

Since societies are becoming more and more urbanised, and people tend to concentrate in urban areas, metros play a critical role in people's mobility. As already shown, in 2018, 178 cities in 56 countries had at least one metro line in operation, carrying on average a total of 168 million passengers per day. 75 new metro systems have been opened between 2000 and 2018 (+70%). As said, this massive growth is to be credited mostly to developments in a few countries in Asia. In Europe, the situation was slightly different, and the growth was much lighter. The European situation is largely presented in this document.

With forecasts of the global demand for urban mobility set to double by 2050, the development potential of metros is considerable. From 2019 to 2024, global met-ro infrastructure is expected to grow by 40%, with 25 more cities opening their first line and a fur-ther 60 new lines opening in existing networks[4]. 11 European cities have new lines under construction and will open lines in the next years. 20 cities have extension projects already under construction.

The economic and social impor-tance of metro networks is remarkable. Considering an average occupancy of 1.3 passengers per private car, metros are capable of removing the equivalent of 133 million cars from city streets every day. With their large trains and short headways, metros of-fer transport capacity in excess of 60,000 passengers per hour per direction (pphpd) and are strategically suited for the most heavily used transport corridors, thus becoming the pulsing arteries of bustling cities.

Their construction and operation mobilise vast expertise, know-how and financial means. In exchange, they deliver high economic, social and environmental value through a set of unrivalled positive

[4] UITP Knowledge Brief - Metros: the backbone of mobile communities and sustainable cities (2019)

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externalities. Daily, they make people's life easier enhancing opportunities to ac-cess jobs, education, healthcare, culture and entertainment, among others.

Metros have several advantages that are going to be investigated and summarised in this paragraph. First of all, they are fast, with commercial speed ranging typically between 30-45 km/h, even in rush-hour when cars are unable to drive over 15-20 km/h. In congested cities, the introduction of a new metro line let the citizens (particularly the commuters) save hundreds of hours every year (around 220 hours saved per year[5]).

Secondly, metros are safe. They are 50 times safer than cars in ur-ban areas. Accidents like derailment or collision are ex-tremely rare events, and so are injuries and casualties: for the last 20 years, the global average of metro accident casualties was below 7 per year[6].

Thirdly, they are a stress-saver: legible and easy to understand routes, high frequency, high reliability and travel time predicta-bility offer passengers quality time to read, interact or simply take a rest. It is one of the primary missions of the PTOs to ensure customer satisfaction delivering a qualitative and smooth service even in crowded and disrupted situations.

Metros are also the most efficient response to congestion problems, allowing to save billions of euros in congestion losses with massive impacts on the GDP every year. To mention a straightforward example, it has been calculated that London drivers lose 1.680 pounds every year for (car) congestion[7].

Additionally, excellent and reliable metro services support efficient economies, driving the economic development of cities and (metropolitan) regions.

Metros are also a massive contributor to the fight against climate change that nowadays is a global priority (and on top of the European agendas due to the "EU Green Deal"). Metros can boast today an energy efficiency performance that no other mode will ever reach, at least shortly and with the same volumes. Metros emit 40 times less CO2 per passenger than cars, and in the last decade, many metros are procuring renewable energy, targeting real zero carbon emissions[8]. In this way, met-ros act as powerful tools to concretely achieve carbon reductions meeting the Paris agreements and the ambitious EU Green Deal objectives. Additionally, metros have run exclusively on electricity for more than a century, producing no exhaust emissions in sensitive metropolitan areas. This, combined with their impact in reducing car trips, leads to an overall air quality improvement and harmful emissions reduction. A rail-based transport system with metros as the backbone, not only contributes to fulfilling the environment goals but also has beneficial and visible effects on the citizens' health.

Additionally, metros are a space (re)creator, perfectly meeting the increasing space shortage in largely and densely populated areas. Municipalities and urban planners have to fulfil growing requests for space-efficiency. With very limited space re-quirements, metros are the most space-efficient trans-port system. Besides, dense and high-rise develop-ment (retail, office, housing) above and around metro stations allows for additional space, value and conveni-ence in dense areas, contributing to increasing the quality of urban environment and life. Being space creators, metros can also foster the fulfilment of

[5] Calculation based on Metro de Santiago line 3 data (2019)

[6] UITP Knowledge Brief - Metros: the backbone of mobile communities and sustainable cities (2019)

[7] Calculation based on London metropolitan area data (2018)

[8] UITP Knowledge Brief - Metros: the backbone of mobile communities and sustainable cities (2019)

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co-modality principles in passenger transport, becoming the real backbone of integrated multimodal systems. This achievement can also be reached by having the stations as "hubs" capable of integrating virtuously different modes (including logistics facilities) that can exploit the network in underutilised non-peak hours or night hours. City logistics is an increasingly important issue after the explosion of e-commerce and the consequent parcel distribution in cities).

As digitalisation and auto-mation are shaping our lives dominating every aspect of people's daily routine, the transport sector needs to deal with this. With the progress in digitalisation, new tools and platforms, also mobility is changing, becoming "a service business". A "service business" is a business in which the end-users do not own their 'mobility assets' but conveniently choose from a portfolio of services called "MaaS" (Mobility as a Service) designed around the most sustainable transport options. MaaS can be defined as "the integration of, and access to, different transport services (such as public transport, ride-sharing, car-sharing, bike-sharing, scooter-sharing, taxi, car rental, ride-hailing and so on) in one single digital mobility offer, with active mobility and an efficient public transport system as its basis"[9]. As the backbone of the mobility system in dense urban areas, metros are the ideal structure around which other modes can be efficiently organised. Metro stations are the main hubs/nodes for convenient connectivity and perfectly fulfil the role of integration leader in the trans-port and land use policy of a given territory, gathering different types of transport services and modes, including the new mobility patterns such as e-bikes, e-scooters, e-car sharing.

Metros are also an economic development-enabler, supporting the concentration of people and ideas that spark innovation and urban economies and reducing the plague of traffic congestion. In addition to the accessibility and connectivity benefits, socio-economic research in the past decade has identi-fied a series of "wider economic benefits" such as the agglomeration effect that provides additional jus-tification for high investment requirements. All these elements result in an enhanced cities' capacity to achieve their full potential turning into excit-ing places making ambitious, energetic and creative people together to generate growth and wealth.

Additionally, there is also a "multiplication" effect for the real estate located around stations. Numerous studies demonstrate that businesses and real estate in the immediate proximity of metros are universally identified as a "premium location". Hence, the market value of land and property in the vicinity of metros increases (+9.4% in London for properties located within 500m from a metro station, compared to properties located 1,500m away[10]), as the accessibility and connectivity attributes of metros are highly prized by real estate developers.

In parallel with the "multiplication" effect seen in the previous point, it has to be said that the construction/extension of metro lines and the increase in their service efficiency/effectiveness can be seen as an indicator of a city's modernity and progress, and can also affect its attractiveness in terms of touristic flows.

As widely described, benefits are many, but implementing metro systems is complex and pre-sents several challenges: metros are a high capital intensity business, not only when it comes to initial construction in-vestments in greenfield projects, but also for systems and rolling stock maintenance thorough their lifetime (and this is particularly true when it comes to FAO systems). A pro-active asset

[9] UITP Mobility as a Service Report. UITP, April 2019

[10] Source: Nationwide.

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management discipline is required. Moreover, to build a line is a long-term planning process, frequently taking 10-20 years between the feasibility study and the line opening. This long time to market requires political stability and contin-ued efforts to generate a high level of convergence and consensus among stakeholders. These conditions have to be met if authorities and planners want to deliver to the society virtuous examples, capable of fostering the urban growth and able to satisfy citizens' needs meeting in parallel the environmental targets set by the recent agreements.

4.4. Infrastructure

Between 2013 and 2018, the total number of lines in Europe grew by 5%, passing from 161 to 171. As shown in figure 6, Spain ranks 1st among the European Countries in terms of number of lines, followed by France, Germany and the United Kingdom. New lines were opened in Turkey (4), Spain (2), Hungary (1), Italy (1), Poland (1), the Netherlands (1).

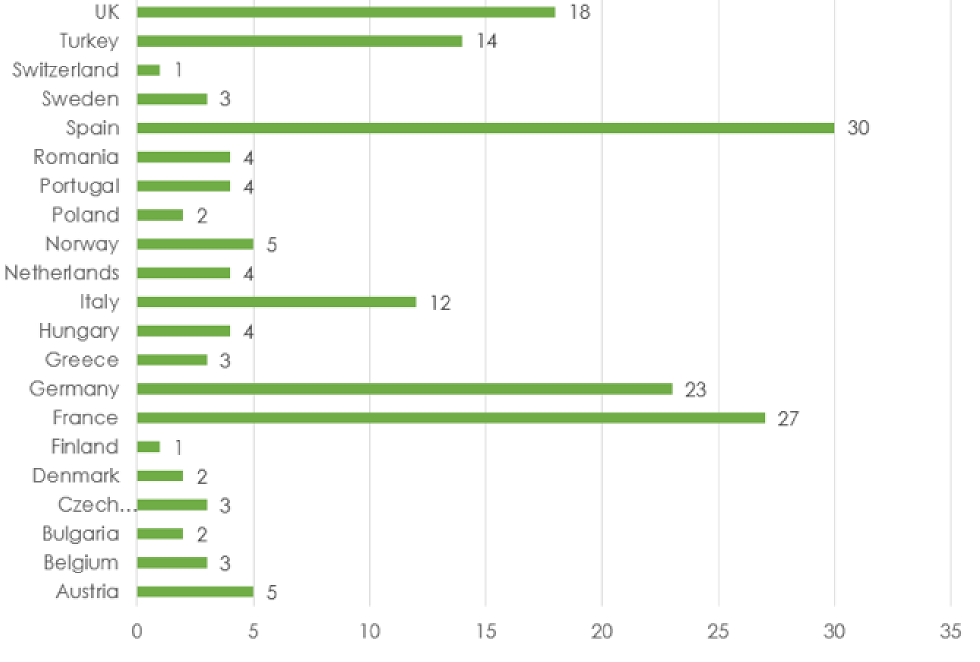

Figure 6: Number of metro lines in Europe by Country (2018) - Source: UITP elaboration

In terms of total network length, in the analysed period, the growth (in km) was 7.35%, passing from 2,742 km to 2,943 km. The strongest increases were registered in the cities of Ankara (+181%), Catania (+129%), Helsinki (+63,5%), Amsterdam (+57%) and Rome (+44,7%). Figure 7 shows the growth in the period 2013-2018 in total network length in the different EU Countries. EU average (+7,3%) has also been highlighted. Three out of four lines in Europe (75%) are underground, 16% is "at grade", 7,2% is elevated and, finally, 1,1% are "in-trench"[11].

[11] UITP Statistic Brief, World Metro Figures 2018. Estimation based on a sample of 85% worldwide stations analysed.

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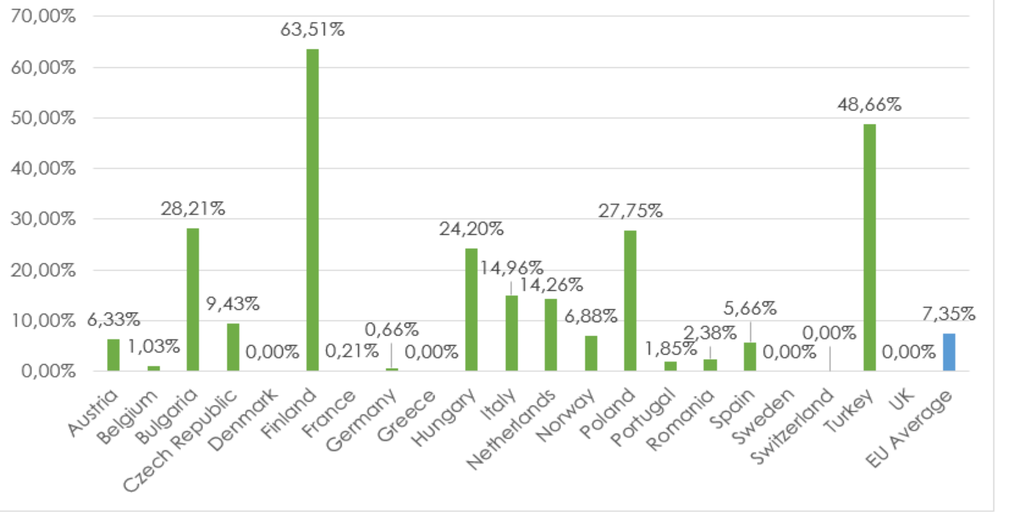

Figure 7: Evolution of metro line length (km) in Europe by Country (2013-2018) - Source: UITP elaboration

Figure 8 shows the repartition of the above mentioned 2,943 km in the various European countries. Spain not only has the highest number of lines but also ranks 1st in terms of total network length. France, Germany and the UK follow, but their position in the ranking is different from the one that emerged in Figure 6. The United Kingdom is 4th for number of lines but has the second-longest network in the Continent.

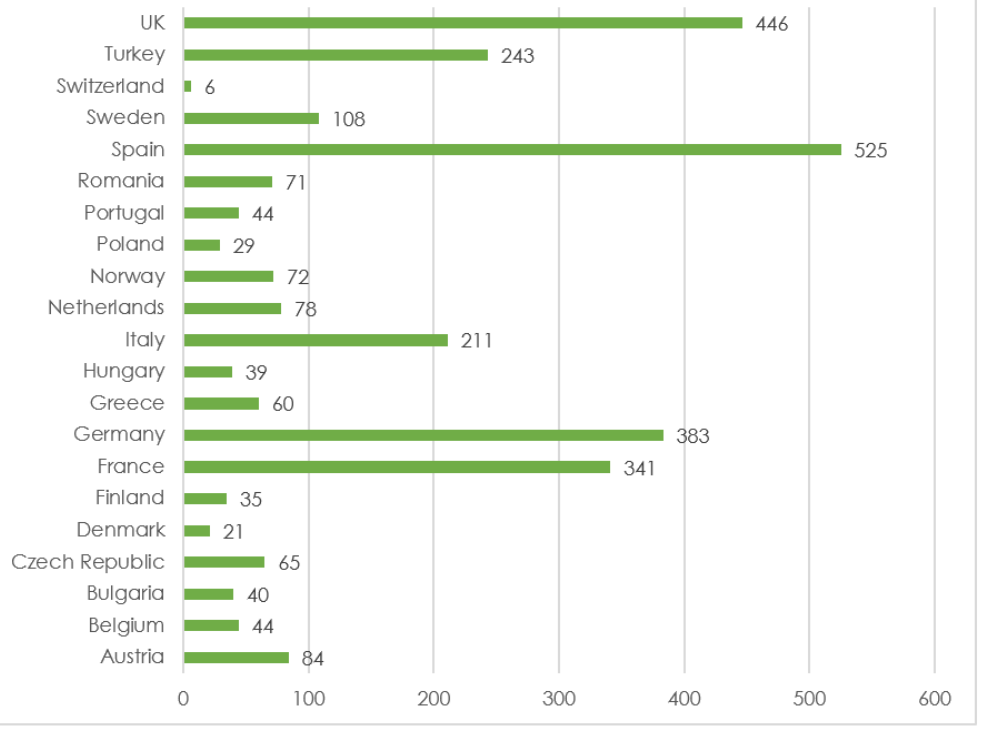

Figure 8: Metro lines length (in km) in Europe by Country (2018) - Source: UITP elaboration

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In terms of number of stations, Spain, France, Germany and the UK confirmed their leadership as European champions, but in a different order. Figure 9 shows the number of stations in various European countries. Spain ranks n.1 in terms of number of lines and km of network, but it does not have the highest number of stations (distance between stations is longer). France ranks 2nd in number of lines and 4th in km of network but is Europe's n.1 in the total number of stations. Figure 10 below helps us understand the national cases, showing the average distance between stops in 2018, calculated dividing the total length per the number of metro stations.

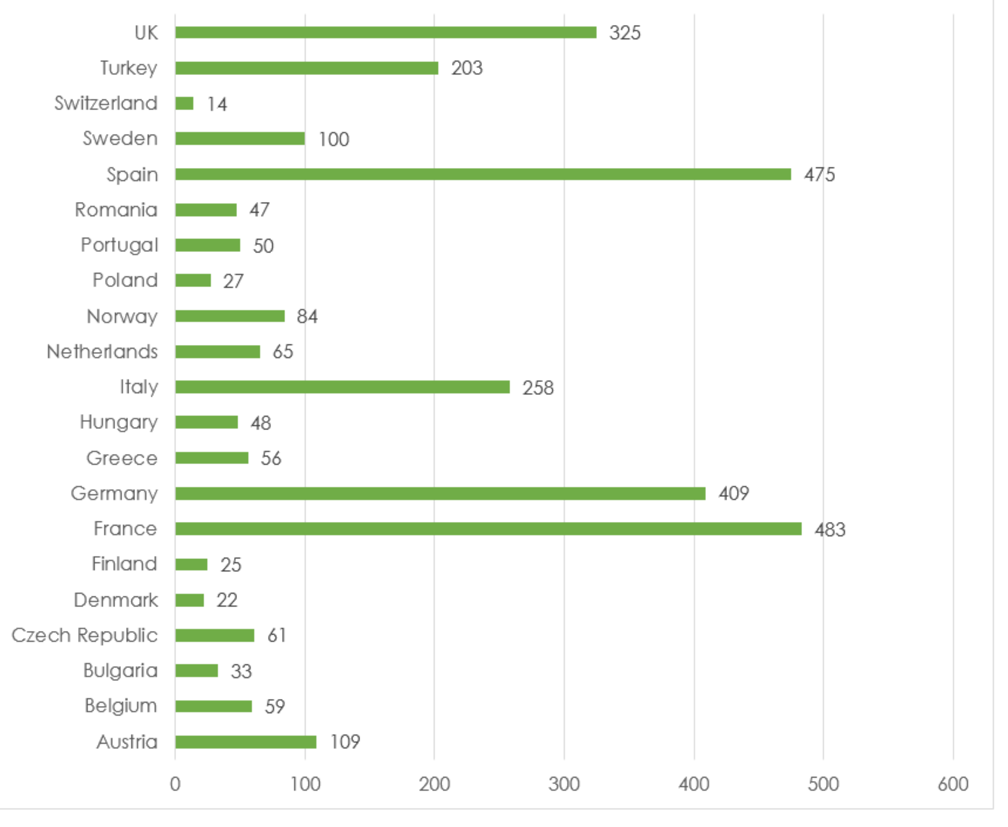

Figure 9: Number of metro stations in Europe by Country (2018) - Source: UITP elaboration

Metros in Switzerland (Lausanne), with its 430 m, have the shortest distance between stations. France ranks 2nd (710 m). The European average is 1km. Romania (1.58 km), Finland (1.38 km) and UK (1.37 km) are the Countries in which the distance between stops is longer. All the other Countries have an average distance within +/- 20% from the European average. A higher distance between the stations has positive effects on the frequency of the service since it allows an increase of the commercial speed. However, it has negative effects in terms of "time to reach the platform".

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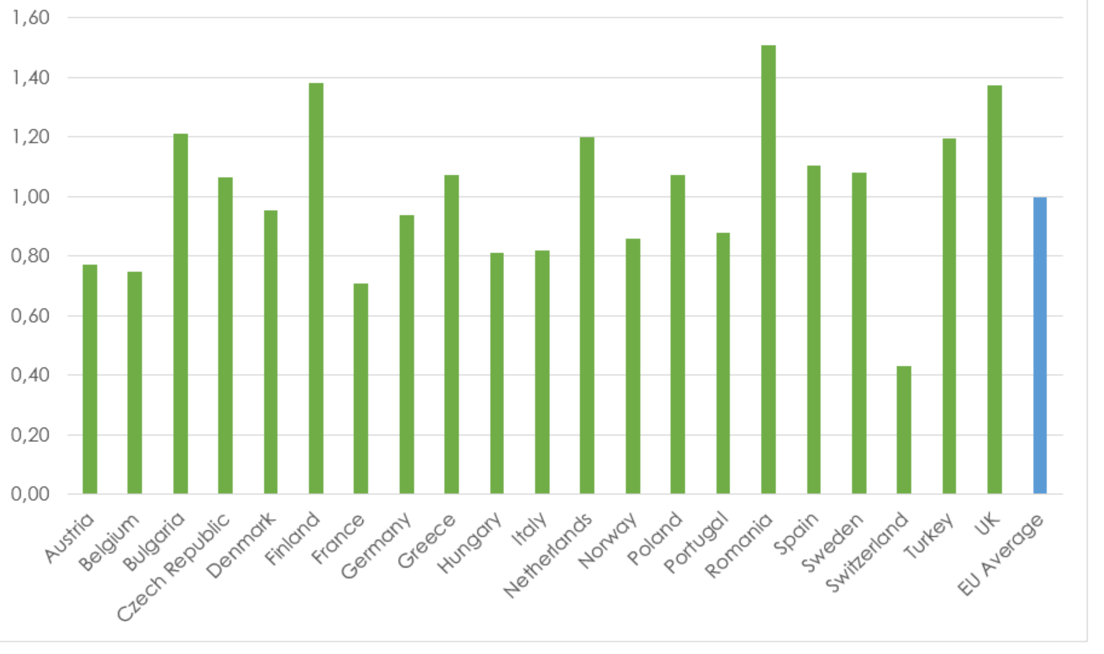

Figure 10: Average distance between metro stops (km) in Europe by Country (2018) - Source: UITP elaboration

Figure 11 shows the average line length in the considered European countries' sample. It has been obtained dividing the total network length per the number of lines. It refers to the year 2018. The European average is also highlighted. Sweden (36 km), Finland (34.5 km) and UK (24.78 km) have the longest average line length. Denmark (10.5 km), Hungary (9.75 km) and Switzerland (6 km) have the shortest lines, in average. The EU average is 17.21 km. All the other systems are in a range of +/- 20% from this average length.

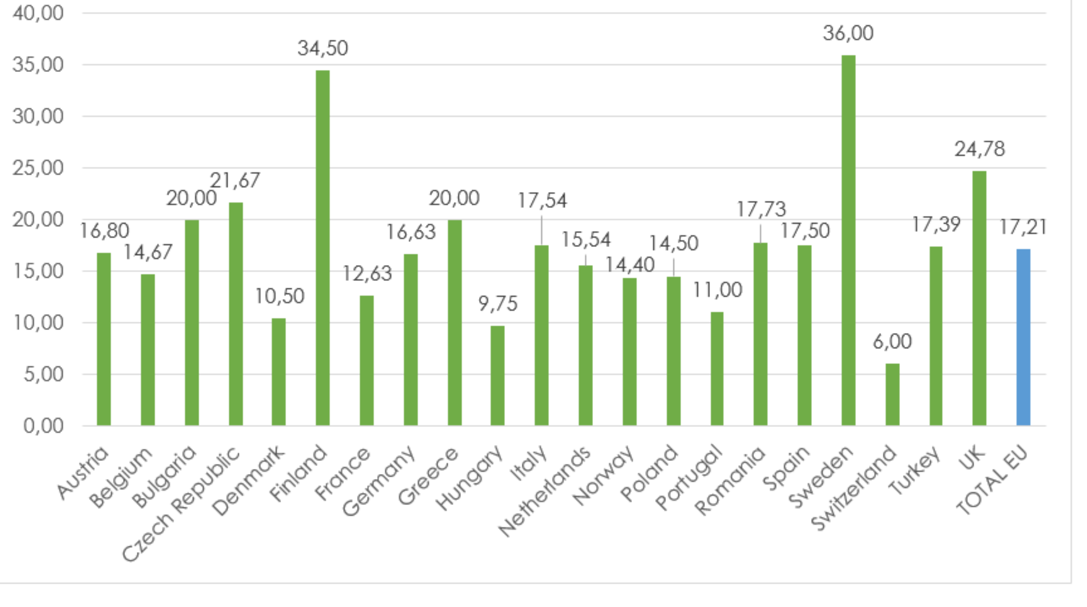

Figure 11: Average line length (km) by Country (2018) - Source: UITP elaboration

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The longest metro network in Europe is London (436 km), followed by Madrid (295 km) and Paris (205 km). London ranks 4th worldwide, after Shanghai (639 km), Beijing (590 km) and Seoul (466 km). Madrid (number 2 in Europe) ranks 9th worldwide. The top-10 European ranking is shown in Figure 12. Data are updated end of 2018.

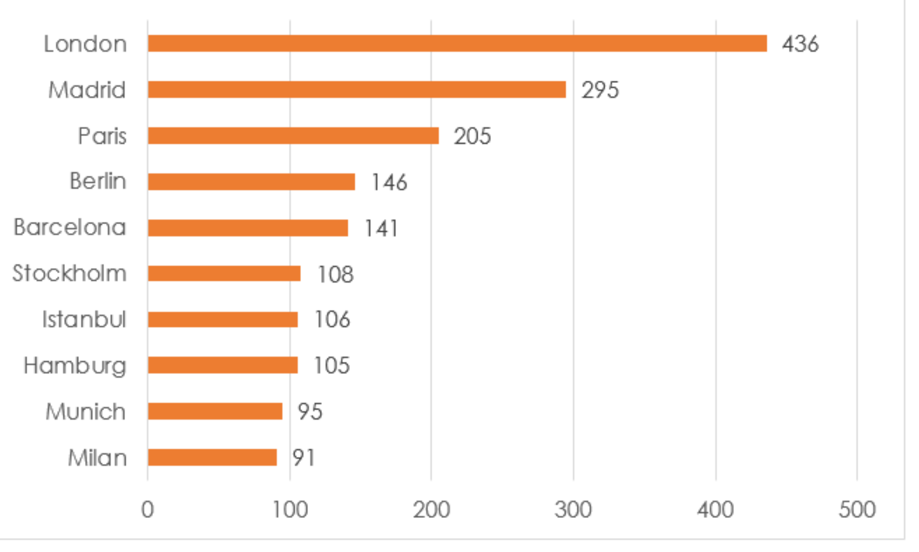

Figure 12: Top-10 longest metro systems in Europe (2018) - Source: UITP elaboration

4.5. Mobile asset

The fleet available to operate the 171 metro lines in Europe consisted in 2017 of 25,069 carriages (data for 2018 are available only for a small portion of the considered sample, but in general, due to the very limited number of new openings in 2018, no significant differences from 2017 are expected). The carriage (sometimes referred to as a car) is the unit of measure chosen for comparing the operational fleet of metros. A carriage can be detachable (thus used in different train configurations) or, increasingly with modern trains, a section within the train delimited by articulations that passengers can walk through. Confirming the trend emerged from the previous graphs regarding the infrastructure situation, UK, Spain, France and Germany are the countries in which there is the highest amount of carriages, having the longest networks in the Continent. In particular, the UK and France have roughly the same number of carriages, but France has about 100 km of network less than the UK. The current EU situation is shown in Figure 13 below. Relevant differences exist within the same Countries, depending on the size of the network. The systems with the highest number of carriages in Europe are London (4,614 - 99% of the carriages in UK), Paris (3,609 - 79% of the carriages in France), Madrid (2,341 - 65% of the carriages in Spain), Berlin (1,272 - 42% of the carriages in Germany).

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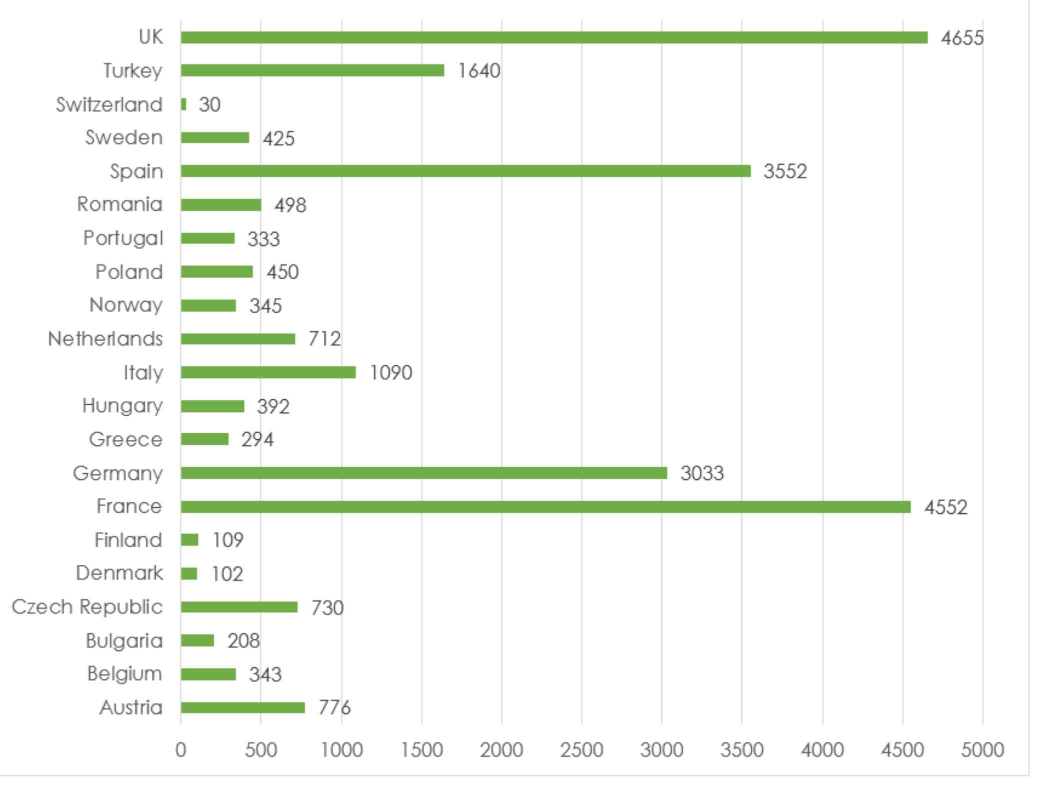

Figure 13: Number of carriages in Europe by Country (2017) - Source: UITP elaboration

Dividing the number of carriages per the length of lines, is it possible to have an idea of the number of carriages per km of metro line in Europe, and comparisons between the various national situations can be made. This is a commonly used indicator of density. Analysing Figure 14, it emerges that Poland has the highest number of cars per km of line (15.52), followed by France (13.35) and the Czech Republic (11.23). Scandinavian Countries have the smallest number of carriages per km of metro line: Denmark 4.86; Norway 4.79; Sweden 3.94; Finland 3.16. The European average is 8.55 cars per km of metro line. Almost all the other Countries' number of carriages per km of line is between +/- 20% of the EU average. Switzerland, Italy, Greece and Bulgaria are the only outliers. Once again, it can be interesting to analyse the situation within the countries since differences exist from one city to the other, depending on size, length and other parameters. In terms of density, Paris has the densest network (17.6 cars per km of line), followed by Amsterdam (17.2), Warsaw (15.52), Prague (11.23) and Milan (11.1).

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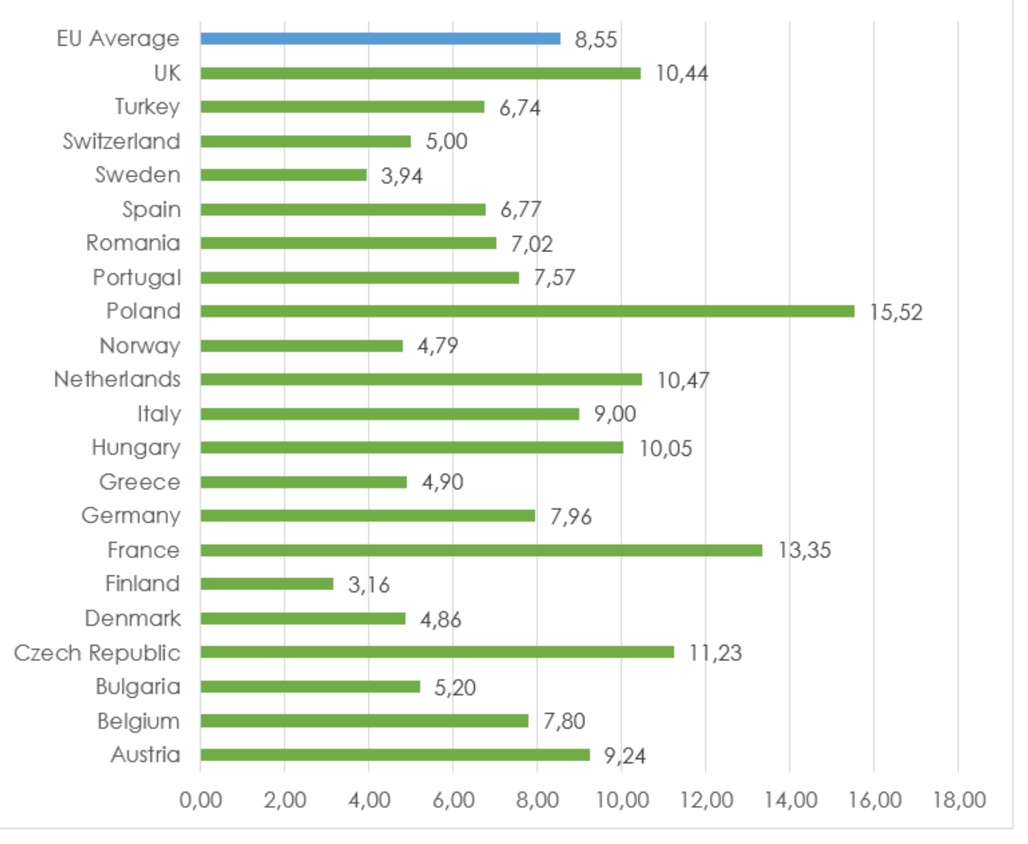

Figure 14: Number of carriages per km of metro line in Europe by Country (2017) - Source: UITP elaboration

4.6. Ridership

The current definition of "ridership" (used in this document and already mentioned in the methodological paragraph) is "passenger trips on metro network for the given year". Trips with transfers between lines are counted only once. When the data reported by the operating company was using a different definition, or was reported on a daily rather than yearly basis, an estimate was made to present comparable figures for all the systems in the database. Ridership distribution among European Countries is shown in Figure 15. Not surprisingly, France (2 bn trips), UK (1.5 bn trips), Germany (1.35 bn trips) and Spain (1.28 bn trips) are the top 4 Countries in the Continent. Details about the "city" situation will be given further in the document, when the European top-10 most used metro systems will be shown.

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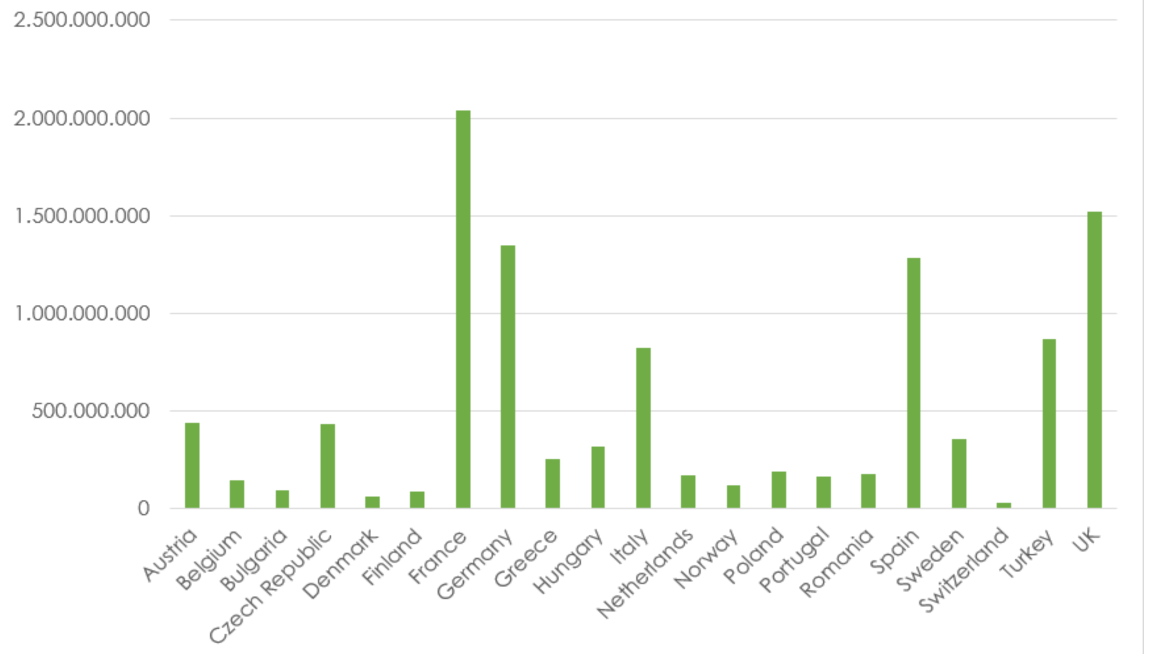

Figure 15: Metro ridership distribution in Europe by Country (2018) - Source: UITP elaboration

Metro ridership in Europe passed from 9.75 billion trips to 11 billion trips in the period 2013-2018, totalizing a 13% increase. This result is justified by the opening of new lines (particularly in the last 4 years) and by an overall improvement of the service quality. In some cases, a negative trend has been registered in some years. This was mainly due to maintenance works that forced some lines to be closed for a period or to construction works that affected the overall network service. One example is Budapest, where there was a 21% decrease in metro ridership in 2018. Analyzing the same interval of time, it is worth mentioning that the Hungarian Capital had Europe's busiest LRT system in 2018[12]. The details of the variation 2013-2018 are highlighted in the table below. It is not surprising that the biggest growth (+48.64%) was registered in Turkey. As already said, 4 new lines were opened in this period: 2 in Ankara (2014) and 2 in Istanbul (2015, 2017). A significant increase in the metro network utilization was also experienced in Norway (+43.53%), Finland (+42.29%) and Poland (+32.19%). This can be easily explained considering the extension of the Oslo line from 67 to 72 km between 2014 and 2016). Helsinki line passed from 21 to 35 km in 2017 (+38,84% growth). Warsaw metro length grew by 21,72% in the considered years.

[12] UITP Report: Tram and Light Rail landscape in Europe, 2019.

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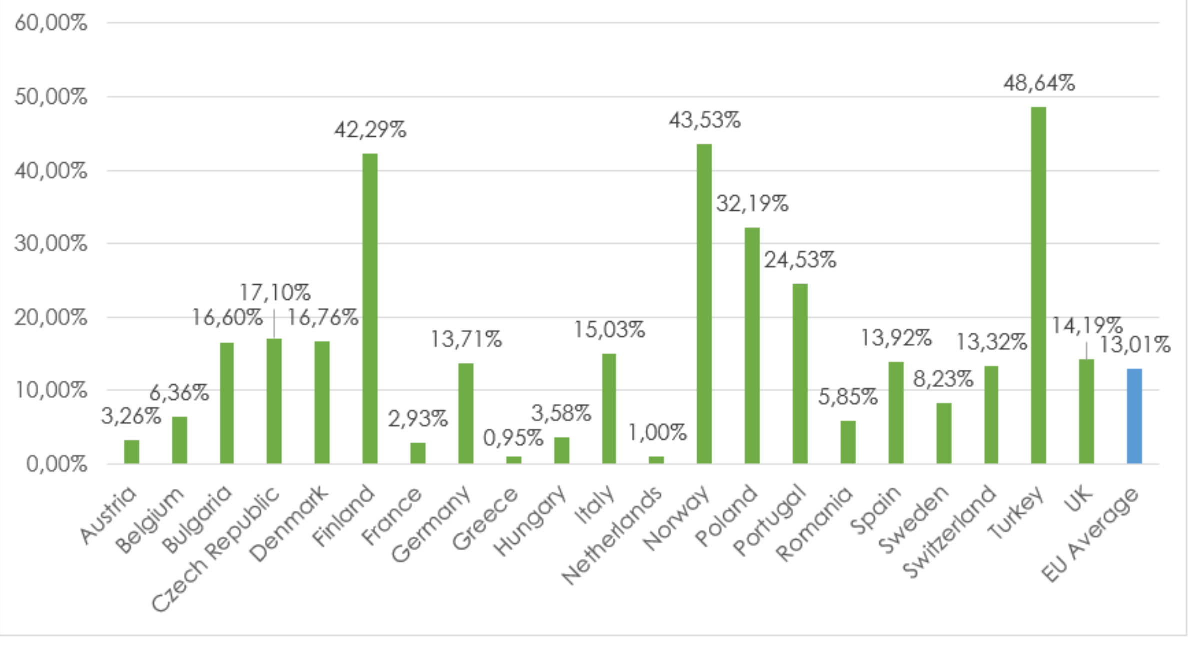

Figure 16: Metro ridership evolution in Europe by Country (2013-2018) - Source: UITP elaboration

The average number of metro trips per inhabitant per year is a useful KPI to measure the intensity of use of the available service, or (in other words) its "popularity". It is obtained dividing the ridership per the city population. The UN system World Urbanisation Prospects (WUP) are used for this purpose. The population considered is the one living in the urban areas.

What emerges from Figure 17 below, is that the Czech Republic is the Country in which metro is more "popular" (339.51 trips per year per inhabitant). The European average is 97.21 trips per year. Metro systems are also extremely popular in Austria, Sweden, Poland and Germany. The lowest levels of utilisation intensity are registered in Turkey, Denmark and Norway. Strong differences exist within the same Country. For example, in Marseille the trips/year per inhabitant are 47 and in Paris 143; in Palma de Mallorca the figure is 3.4 while in Madrid it is 103. The size of the city, the presence of viable alternatives and the touristic attractiveness are all factors affecting these figures.

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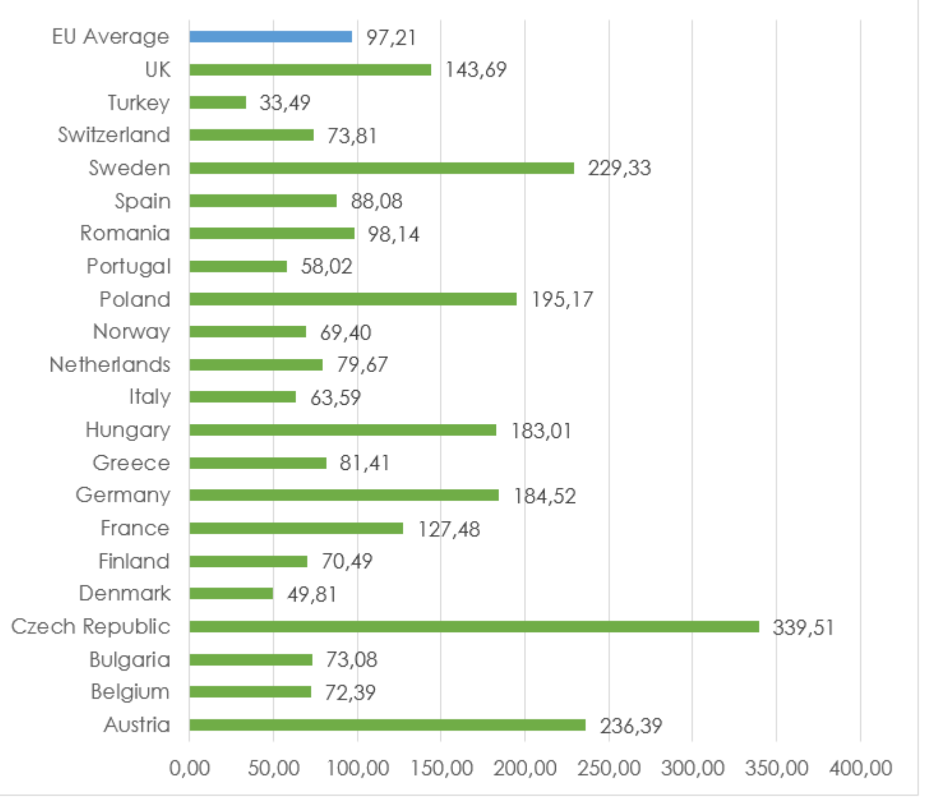

Figure 17: Number of metro trips/year per inhabitant in Europe by Country (2018) - Source: UITP elaboration

The following Figure 18 shows the number of metro trips per year per inhabitant in Europe by City in 2018. Prague is the most used system in the Continent, followed by Munich, Vienna and Stockholm.

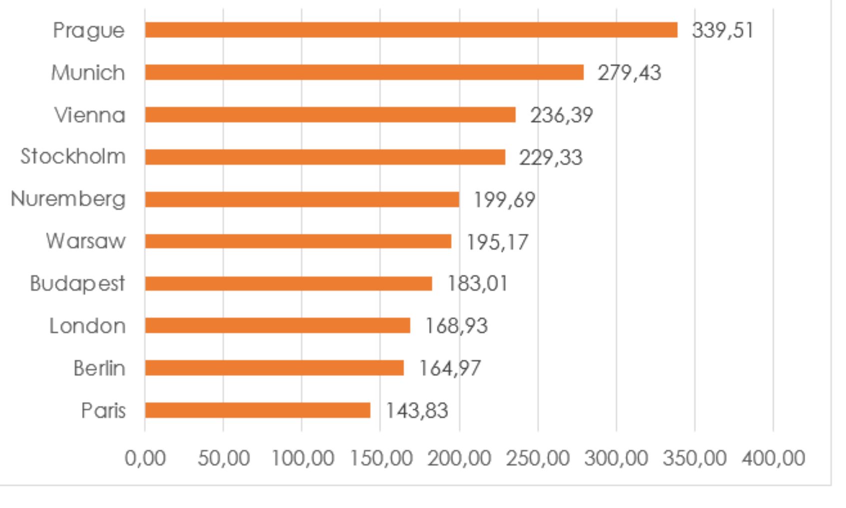

Figure 18: Number of metro trips/year per inhabitant in Europe by city (2018, top-10) - Source: UITP elaboration

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Figure 19 shows the top-10 busiest metro systems in 2018. Paris was the busiest system in 2018, with 1,560 million passengers), followed by London (1,505 million) and Istanbul (663 million). Paris and London are the oldest metro systems in Europe, opened in 1900 and 1863. Istanbul is a modern metro system whose first line was opened in 2000. Istanbul is the only metro system in this chart whose inauguration dates less than 45 years ago. The complete table summarising the cities analysed and the relative opening date is included in Appendix 1 of this document. With "opening year", the opening of the first line is considered. None of the cities included in Figure 19 is included in the world's top-10 busiest systems. Hong Kong is the 10th busiest network in the world with 1,600 million passengers per year. Paris (Europe's first) has 1,560 million.

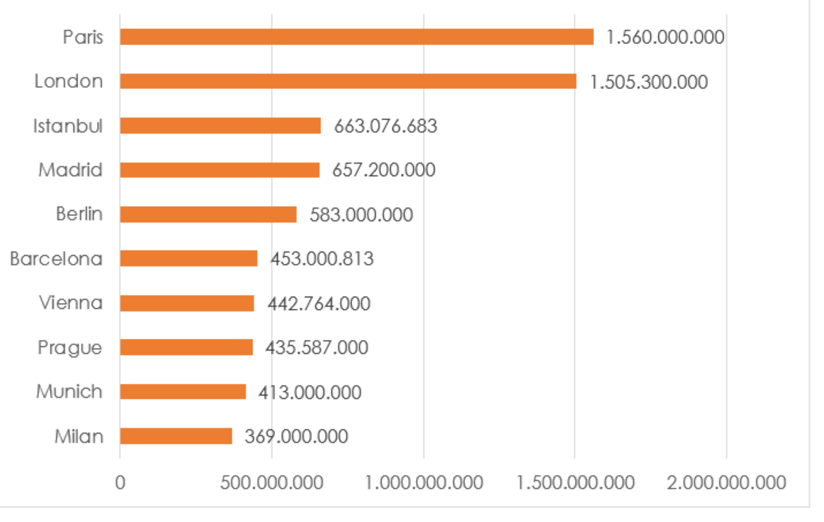

Figure 19: Top-10 busiest metro systems in Europe (pax, 2018) - Source: UITP elaboration

Figure 20 below shows the top-10 most crowded metro systems in Europe, obtained dividing the ridership per the total km of lines. Budapest (busiest LRT system in 2018) is the leader of the ranking, followed by Paris, Warsaw and Prague (which, as seen above, is also the most "popular" system in the Continent).

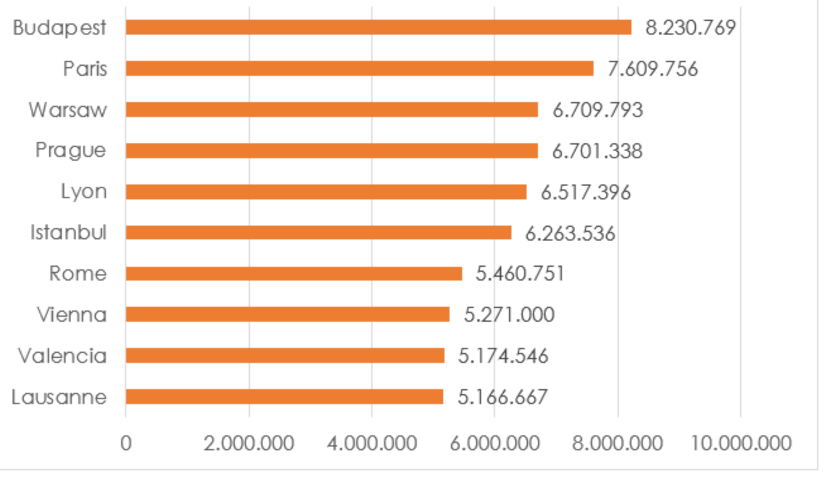

Figure 20: Top-10 most crowded metro systems in Europe (pax per km of line, 2018) - Source: UITP elaboration

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In terms of passenger-km (pkm), Figure 21 below shows the evolution of pkm (tram + metro) from 1995 to 2017 in Europe. Air was the sector experiencing the most impressive increase (+123%), followed by the combination of tram and metros. Overall growth in other modes was more "light" and in some cases negative (sea). To have a better idea of the internal split between these two modes (LRT is included in the "tram" definition), it can be said that, elaborating data from the UITP database on LRT, trams and light rail transport represented the 80,8% of total pkm in 2015, 81.8% in 2016 and 80.8% in 2017. Data from 2018 are not sufficient enough to make any estimation, but the historic trend allows us to make some considerations on this issue. An important thing that has to be considered is that these elaborations on total pkm are based on the deductions from the UITP LRT database, that collect data on LRT in Europe considering the UITP nomenclature and the definitions widely utilized by UITP in all its publications. Considered this, it is realistic to total metro pkm in Europe have been about 82.41 billion in 2015, 85.89 in 2016 and 86.45 in 2017 (a 0.6%) from 2016 to 2017.

PASSENGER TRANSPORT

billion pkm

	PASSENGER CARS	P2W	BUS & COACH	RAILWAY	TRAM & METRO	AIR	SEA	TOTAL
1995	3 904	113	515	343	74	348	31	5 327
2000	4 301	105	545	377	80	460	29	5 896
2005	4 508	121	542	384	86	530	29	6 201
2006	4 549	120	540	397	88	552	28	6 274
2007	4 597	116	551	404	90	575	28	6 360
2008	4 602	121	559	420	94	563	32	6 391
2009	4 675	118	536	412	93	524	27	6 386
2010	4 626	119	530	414	96	535	25	6 344
2011	4 593	123	531	423	97	577	22	6 366
2012	4 498	123	526	428	99	570	21	6 266
2013	4 549	122	523	434	99	580	21	6 329
2014	4 615	125	518	441	101	610	22	6 431
2015	4 712	125	528	448	102	640	22	6 576
2016	4 827	126	527	455	105	713	25	6 779
2017	4 901	123	510	470	107	777	24	6 913
'95/'17	25.5 %	9.5 %	-0.8 %	37.0 %	45.4 %	123.3 %	-21.2 %	29.8 %
/year	1.0 %	0.4 %	-0.0 %	1.4 %	1.7 %	3.7 %	-1.1 %	1.2 %
'00/'17	14.0 %	17.8 %	-6.4 %	24.6 %	33.8 %	69.1 %	-16.1 %	17.3 %
/year	0.8 %	1.0 %	-0.4 %	1.3 %	1.7 %	3.1 %	-1.0 %	0.9 %
'16/'17	1.5 %	-2.4 %	-3.1 %	3.3 %	1.7 %	8.9 %	-2.9 %	2.0 %

Figure 21: Evolution of total pkm per mode in Europe (in billions) - Source: EUROSTAT Database, 2019

4.7. Metro innovation market uptake: a focus on automated metros

One of the most critical innovations largely developed and promoted for the metro systems worldwide is the so-called FAO – Fully Automated Operation. Even though this concept was introduced decades ago and that the first UTO (Unmanned Train Operation) line was opened in Kobe (Japan) in 1981, automation in metros is still the most promising technology likely to be increasingly implemented soon.

FAO ensures higher levels of safety to the metro operations, due to the presence of barriers protecting the platform (although not all FAO lines used platform screen doors), a smoother train ride, absence of

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errors due to the drivers' repetitive tasks. It also ensures a more efficient and affordable service, due to the reduction of dwell times and the speed increase, which also have positive effects on the train service frequency (and a better/more straightforward adaptation to the demand). FAO also ensures a cleverer energy consumption (17% energy saving) and a better perception of the overall quality level, since the human presence in the stations would be increased to support the users and guarantee their safety. Finally, FAO ensures cost efficiency both on the Capex and Opex side (particularly when it comes to greenfield projects), since more capacity is served without enlarging the fleet size, lower reserves are required, drivers' cost are saved, maintenance and energy costs are lower.

An overview of the state-of-the-art regarding automated metros around the world with a particular focus on the European situation is presented in this chapter. Before starting the analysis of the current situation and future trends, it is essential to clarify some key concepts. Figure 22 helps to understand what the definition of metro automation is and the different "Grades of Automation" (GoA).

In metro systems, automation refers to the process by which responsibility for operation management of the trains is transferred from the driver to the train control system.

There are various degrees of automation (or Grades of Automation, GoA); these are defined according to which essential functions of train operation are the responsibility of staff, and which are the responsibility of the system itself. For example, a Grade of Automation 0 would correspond to on-sight operation, like a tram running on street traffic. Grade of Automation 4 (or UTO – Unattended Train Operations) would refer to a system in which vehicles are run fully automatically without any operating staff on board.

Currently, the vast majority of metro systems worldwide is GoA2. This means that setting train in motion and stopping are processed automatically. The driver opens and closes the doors and intervenes in case of disruptions. In GoA3, there is no driver, but a train attendant is in charge of door closure and operation in case of disruption. There is only one example of GoA3, and it is London.

Grade of Automation	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of disruption
GoA1	ATP* with driver	Driver	Driver	Driver	Driver
GoA2	ATP and ATO* with driver	Automatic	Automatic	Driver	Driver
GoA3	Driverless	Automatic	Automatic	Train attendant	Train attendant
GoA4	UTO	Automatic	Automatic	Automatic	Automatic

**ATP - Automatic Train Protection; ATO - Automatic Train Operation*

Figure 22: Definitions and levels of GoA – Source: UITP Statistic Brief, World Report on Metro Automation (2019)

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In March 2018, automated metros worldwide reached the 1,000 km milestone with the opening of the Pu-jiang Line in Shanghai. As of December 2018, nearly a quarter of the world's metro systems have at least one fully automated line in operation. In total, there are 64 fully automated metro lines (GoA4) in 42 cities, operating 1,026km, a 27.7% increase in km over the 2016 figures. According to confirmed planned projects by 2023, the number of automated metro km in the world is set to triple the current figure. Figure 22 shows the current situation regarding GoA4 metro systems in the world, split into three categories based on the capacity of the trains. It is visible that Europe and the Asia Pacific are champions in GoA4 development since they account (combined) for the 80% of the lines. Despite in the beginning they were deployed in low capacity lines, currently 75% of the world's automated metro infrastructure operate me-dium and high capacity trains, in a continuously growing trend.

In total, there were 64 fully automated metro lines in operation in 2018 totalizing over 1,026km and 1,026 metro stations in 42 cities across the world. Singapore is the "champion" of GoA4, with 65% of the total length of its metro fully automated.

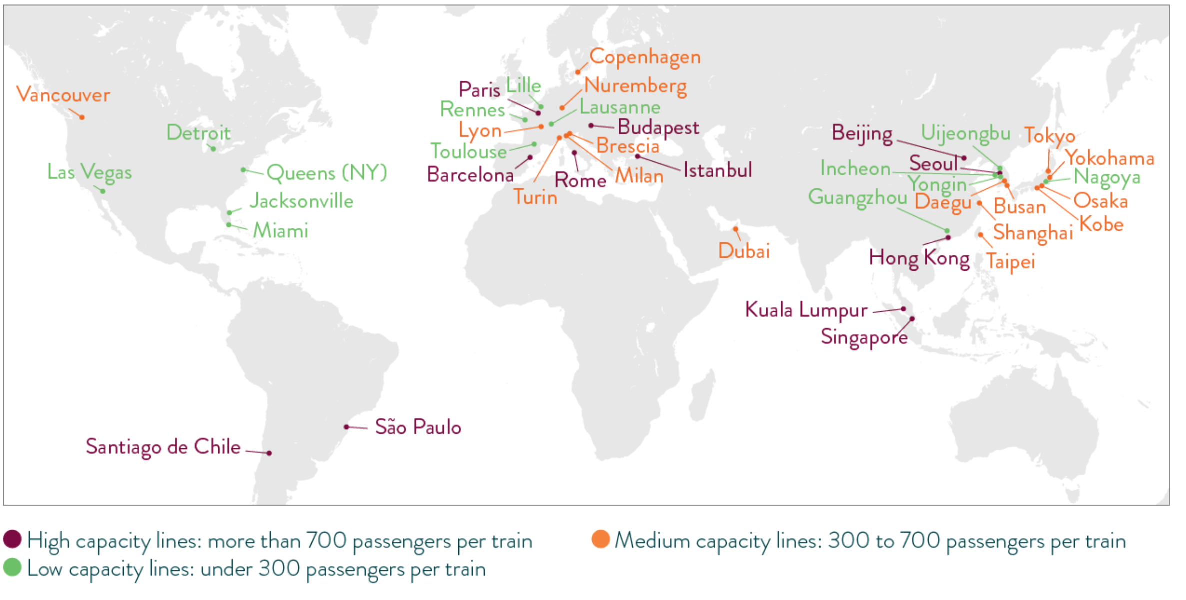

Figure 23: Cities with fully automated metro lines in operation, as of 31 December 2018 - Source: UITP Statistic Brief, World Report on Metro Automation (2019)

In 2018, Asia consolidated its status as the leading world region in metro automation with 50% of the km of fully automated metro lines in operation, thanks in particular to the opening of five new lines (in Korea, Malaysia and China) in the last two years. As shown in Figure 24 below, Europe remains second at 30%, with North America and MENA following at 11% and 8% respectively. Last in the chart, Latin America has however experienced one of the highest relative growth rates, with the opening of Line 6 in Santiago.

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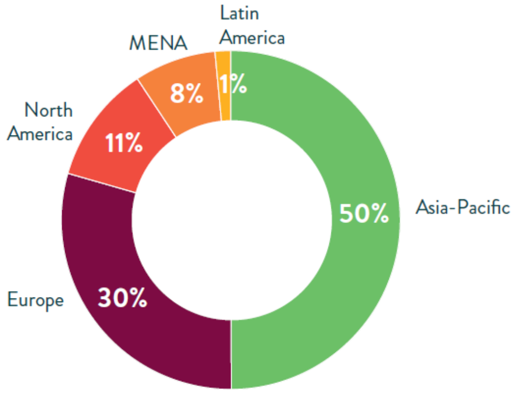

Figure 24: Automated metros per world region, measured as a % of km in operation (2018) - Source: UITP Statistic Brief, World Report on Metro Automation (2019)

Figure 25 summarizes in a better way the distribution of GoA4 systems around the globe. Focusing on Europe, it is to say that its 293km are almost equally split between the three capacity clusters (<300 pax per train; 300-700 pax per train; >700 pax per train).

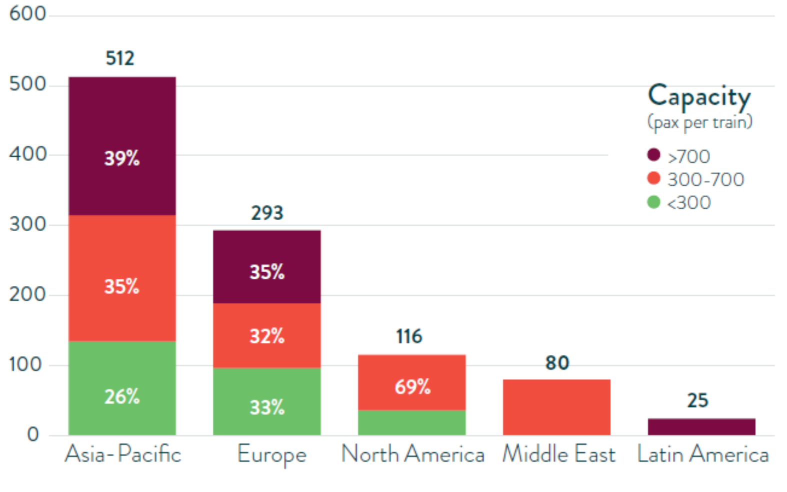

Figure 25: Automated metros per world region and per train capacity, measured as a % of km in operation (2018) - Source: UITP Statistic Brief, World Report on Metro Automation (2019)

Fully automated metro lines represent 7% of the world's metro infrastructure in operation. This comparatively small figure is the outcome of a relatively short period of exponential growth, especially when compared to the 150 years of conventional metro history. In the 38 years since the implementation of the first automated line, their growth rate has accelerated each decade with a faster pace, with 2018 marking a significant inflexion point. In the next five years, it is expected that full automation will become the mainstream design for greenfield met-ro lines, increasing from the current share of 10% of km of metro infrastructure in planning and construction to 48% by 2022. In this timeframe, a further 2,000 km will be commissioned, tripling the current figure. The total growth in GoA4 metros, measured as km in operation, is shown in figure 26. Projected growth based on the already confirmed projects is highlighted in purple. According to these forecasts, by 2028 there will be

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over 3,800 km of automated metro lines in operation, 611 of them in Europe. Most of this growth corre-sponds to the expected opening of 87 new lines (64%), or ex-tensions of existing lines (29%), with conversion projects rep-resenting only under 7% of the new infrastructure, all of them in Europe.

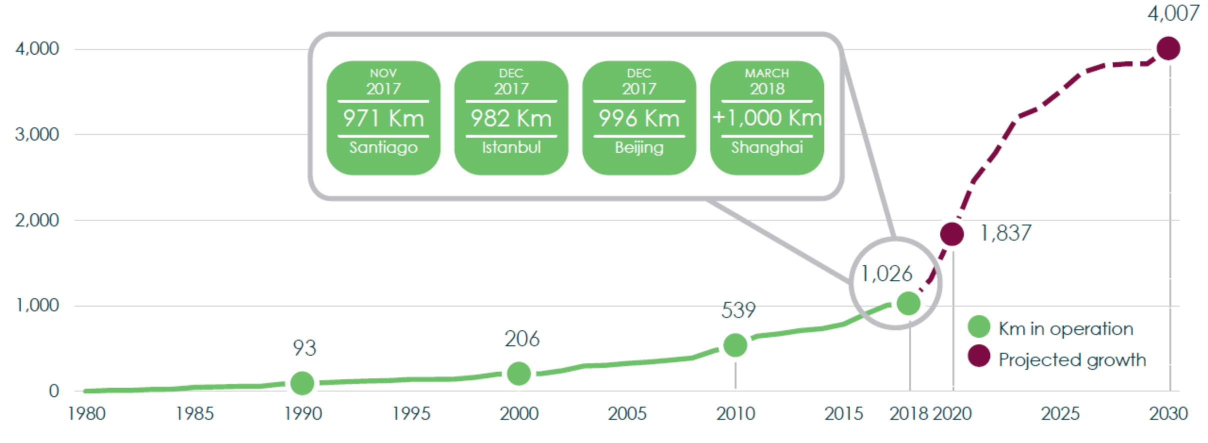

Figure 26: Total growth in automated metros, measured as km in operation - Source: UITP Statistic Brief, World Report on Metro Automation (2019)

With regards to European conversion projects from conventional to automated metros, following the successful conversion projects of Nuremberg (2009) and Paris L1 (2012), seven European cities have confirmed conversion projects in the coming decade:

- Brussels, lines 1 and 5
- Glasgow, G. Subway
- London, Docklands
- Lyon, lines A and B
- Marseille, lines 1 and 2
- Paris, line 4
- Vienna, U2/U5

All the conversion projects mentioned above represent only 7% of the projected global growth. This rel-atively low percentage may be due to the complexity of implementing full automation in an ex-isting line while in operation. This difficulty, however, is not unique to full automation: brownfield re-signalling projects are also highly challenging. Compared to Asia and, in some cases, South America, many of the European lines (over 140) have been inaugurated in the 70s and 80s, and nowadays they have reached critical asset replacement needs. Besides this, it is therefore expected that the market for conversions will grow.

Enlarging the picture to the analysis of the rest of the world, it has to be said that the largest share of the growth will be located in Asia, which will quadruple the number of km currently in operation in the next decade and represents, on its own, half of the projected growth. MENA and Europe (due to the conversion projects already mentioned and new projects planned for the next 10 years) follow at a relative distance. In 2028, Asia is expected to represent 53% of the world's km of automated metro, followed by Europe (21%) and the Middle East (15%). This forecast is clearly pictured in figure 27.

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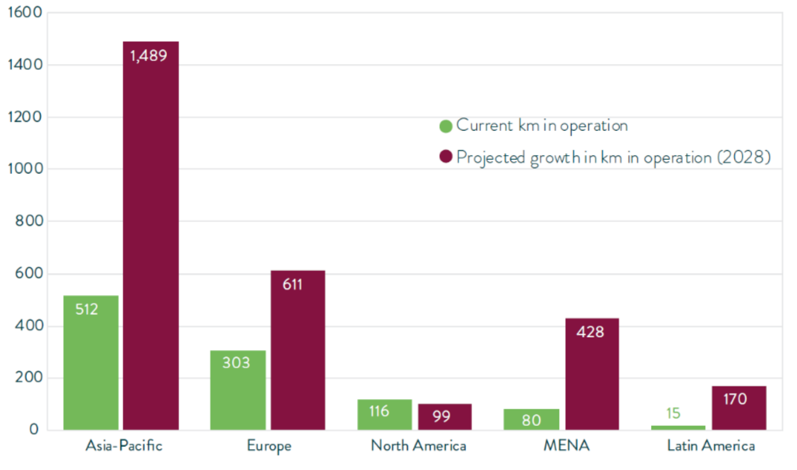

Figure 27: Current length of automated metro lines and projected growth for the next decade, per world region - Source: UITP Statistic Brief, World Report on Metro Automation (2019)

Figure 28 shows the split between conventional metros and GoA4 metros, with a projection until 2022. As clearly visible, penetration of automation will grow consistently in the future, reaching a peak of 31% in 2020, according to the currently available data.

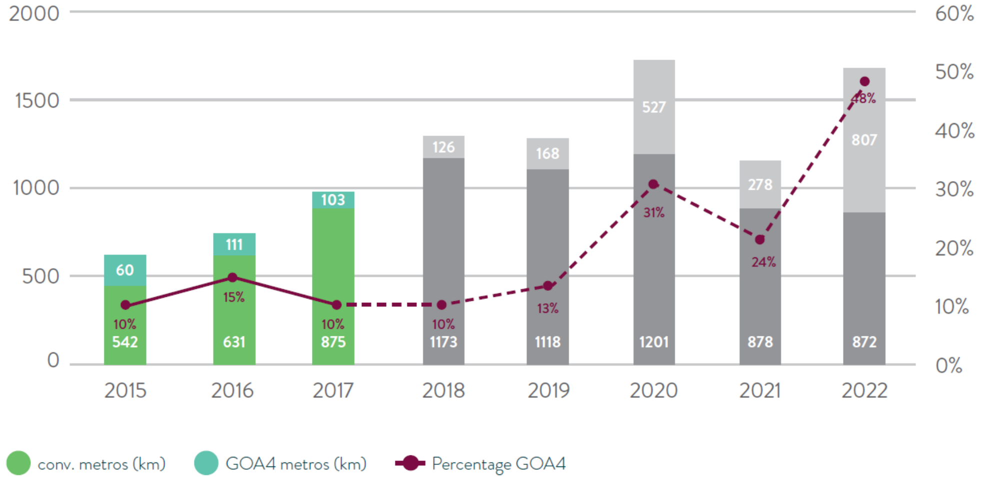

Figure 28: Conv. metros (km) vs GoA4 metros (km) + percentage penetration GoA4 (projection 2022) - Source: UITP Statistic Brief, World Report on Metro Automation (2019)

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Automation in metros is at the forefront of innovation, but it must not be seen as a purely technological project. Its development around the globe and also in Europe must be seen as a company project. Digitalization, new technologies and tools will change the mobility scenario in the next decades, developing a "smart" mobility concept and taking it to a higher level. One example can be new materials or the automatic vertical platform doors, an innovative solution to increase the safety and comfort of passengers tested in Barcelona in 2019. Automation is at the forefront of this "digital" transition, providing companies with a lever to attain strategic goals linked to a more human, customer orientated and flexible service.

In conclusion, FAO facili-tates improved performances in five key areas that are essential to any metro network: improve the mobility of-fer, enhance safety, contribute to the economic balance of the system, reduce its ecological imprint and provide improved customer service while enhancing staff satis-faction. This is something that planners, authorities and operators should never forget when delivering the mobility systems of the future. Much work has to be done in the next decades to increase the market share of FAO worldwide and in Europe notably. Still, projects in planning and construction phases and the increased acceptance by the citizens of this kind of automated solutions demonstrates that we are following the right path towards a more extensive diffusion of these technologies.

4.8. Perspectives

Metros have many positive attributes as they can concretely re-duce the dependence on private car reaching the targets of the "EU Green Deal" and moving a considerable quantity of people in an efficient, safe and smooth way in extremely densely populated areas. Their develop-ment has been very successful over the last three decades, and, considering the planned openings, it will go on. As extensively illustrated in this document, Asia Pacific (and particularly China) are the champions in this sense, but also in Europe, new projects are on their way and will be implemented in the next decade. 25% of the world's metro systems are in Europe, and data analysed in the report show that the number of lines, total length and ridership are growing in our continent. Differences exist among different countries and sometimes within the same country, mainly if we focus on the four leading players (Spain, UK, France and Germany). Despite a slower pace (if compared to the Asian one), new projects are underway in our continent. New cities are opening new lines, and conversion (to GoA4) systems are in some cases already undergoing or planned for the near future. In Europe, conversion, extension and brownfield projects (such as re-signalling) are also highly challenging since many of the lines are 40 or 50 years old and they reached critical asset replacement needs.

Metros are and will continue to be good for people, businesses and society. They deliver technical, economic, political, social and environmental benefits, helping people to create li-veable and smart cities, and to move safely, fast and efficiently in increasingly congested urban areas. They are also stress savers, economic drivers for cities (particularly in the real estate sector), space creators capable of affirming themselves as proactive multimodal hubs. As widely investigated, most advantages can be further amplified with fully automated metros (GoA4), whose development (pushed by well-known additional benefits, extensively debated in this document) is ongoing.

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To fully exploit their potential, metros need to be integrated not only with other public transport modes but even with modern and innovative modes such as ride-sharing. Speaking about this, companies offering ride-sharing services such as Uber, Lyft, Didi and Grab are increasingly enlarging their market share and their presence in the transport of people. Public transport has to see them not as a competitor but as complementary partners to develop an offer capable of meeting the rapidly changing customer expectations. According to a report published by Accenture in 2019[13], by 2023, worldwide revenue in the ride-sharing segment is expected to exceed 318 billion dollars. Privately owned digital disruptors are leveraging the sharing economy and connectedness of customers to offer new platforms that don't need significant infrastructure investment and can scale quickly. They are also highly responsive, constantly launching more compelling offers. Bike-sharing companies, e-scooter services and micro-mobility options are popping up in Europe very fast, invading the cities and the urban landscapes. They don't have to be seen as a threat but as an opportunity to finally develop multimodal transport solutions with public transport as the backbone (according to a study by the American Public Transportation Association APTA, nearly 80 per cent of commuters still see public transit as the backbone of a mobility landscape[14]). Available technologies make it possible and the capability of the public transport to respond to these disruptive technologies integrating them in seamless commuting experiences for customers will shape the future of mass transport. Understanding the new demographic and social trends is also crucial for promptly responding to customer needs, since nowadays the so-called "24/7 economy" has risen, and remote working, flexible hours are standard practices. This means that public transportation is becoming more personalised and less regular, and the appeal of standard weekly tickets or monthly passes may decrease.To ensure a proper transition towards an integrated transport system with urban rail as the backbone, it is crucial that authorities (especially local authorities that will become "transport orchestrators"), planners and operators collaborate. It is necessary to create a valuable partnership between all the involved public and private stakeholders, including the citizens themselves, who are the users and can support the authorities from the very first steps to identify the needs and to understand the best ways to satisfy them. The process mentioned above includes a clear and solid urban development strategy capable of building coherent transport policies, exploiting the benefits of each mode (keeping rail at the centre), ensuring the consistency of the project over a long time horizon, regenerating urban areas fuelling housing, jobs and public equipment. Metros require significant cyclical investments to ensure that safety, reliability and performance are maintained over time. With a high quantity of lines opened in Europe in the 70s-80s, time for primary asset replacement is coming and deserves as much attention as new developments. For this purpose, PTAs and PTOs should:

- Ensure that sufficient resources (money and expertise) are available and earmarked to keep assets in a 'state of good repair'. Different financing/funding schemes exist (depending basically on the contract types). The most common are: fare revenue,

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[13] Accenture Report: Orchestrating a mobility ecosystem. Accenture, 2019

[14] https://www.metro-magazine.com/mobility/news/732387/nearly-80-of-commuters-see-public-transit-as-backbone-of-mobility

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subsidies, non-fare revenues, earmarked charges, leasing, institutional loans, PPPs;

- Prepare metros to the digital transformation: digitalisation can bring significant efficiency gains to metro planning, design, construction, operation and maintenance, and (as described) MaaS is transforming the urban mobility landscape. This is an opportunity to reposition various stakeholders on the added-value chain;
- Proactively explore partnerships or develop Mobility as a Service initiatives reinforcing metro as the backbone of modern urban mobility, collaborating and not competing with new disruptive mobility patterns such as ride-sharing;
- Improve the people's capacity to shift from one mode to the other seamlessly and the overall accessibility of co-modal services. As described in the document, a lot has been done, and metros are in some virtuous cases, the real backbone of urban mobility. Efforts have to be made in order to better integrate metros with all the other modes, including the so-called "soft modes" and the new mobility patterns, as largely investigated. Particularly metro stations have the potential to become efficient multimodal hubs integrating various modes and, in some cases, also logistics and distribution of goods. Experiments are carried out or are under consideration on this issue;
- Analyse new delivery and O&M (Operate and Maintain) models beyond the traditional approach; the relationship with suppliers is likely to change with more partnership relations in the field of predictive maintenance;
- Understand citizens needs and deeply analyse urbanisation and social trends (ageing of the population is one of the most critical), involving all relevant stakeholders from the very beginning (planning phases). This will allow to deliver tailored services and increase customer satisfaction, shaping our cities in a long term perspective.

In order to strengthen this concept, it is important to summarize what emerged from a survey carried out within the UITP Metro Division in 2019. Members were asked to identify the key priorities for the future. From the survey, it emerged that quality in the service offered, together with digitalization and automation, asset management, financing/funding, big data, artificial intelligence, MaaS, capacity to attract talents and new skills, security/cybersecurity are the key issues to be inserted in planners, operators, authorities and all related stakeholders' agendas in the years to come.

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4.9. Conclusions

From the first line opened in London in 1863, metros experienced a worldwide growth. Between the years 2013 and 2018, the global world metro system grew exponentially both in infrastructure and ridership. The previous materials have shown that metros play and will play a fundamental role in public transport because of several reasons.

Firstly, metro proved to have several benefits: not only it easily accommodates population growth, foster economic development and enhance citizens' quality of life, but it also deliver a sustainable, efficient, resilient and safe transport mode. Furthermore, metros are massive contributors to the fight against climate change.

Daily, metros make people's life easier enhancing opportunities to ac-cess jobs, education, healthcare, culture and entertainment. Because of the digitalisation process, the efficiency and extension of the metro systems will further increase with positive effects on people's daily life.

In today's fast-paced life, metros are stress-savers: high frequency, reliability and predictability offer passengers quality time to read, interact or simply take a rest. Because they are strategically suited for the most heavily used transport corridors, metros deliver a qualitative and smooth service even in crowded and disrupted situations.

Lastly, metros are not only capable of removing the equivalent of 133 million cars from city streets every day, but they also save to every citizen around 220 hours per year, compared to taking the car. At the same time, metros provide a great way of saving money for the citizens: it has been calculated that London drivers lose 1.680 pounds every year for car congestion, which is not the case of metro users. Lastly, metros emit 40 times less CO2 per passenger than cars.

The prospects are excellent: between 2019 and 2024 the global met-ro infrastructure is expected to grow by 40%, with developments in 85 cities, 31 of which in Europe. Overall, the increasing trend of urbanisation means the role of metro in public transport will further increase and thus play a critical role in people's mobility.

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4.10. Appendix

4.10.1. List of European metro lines and opening year

City	Country	Opening year	City	Country	Opening year
Vienna	Austria	1976	Rome	Italy	1955
Brussels	Belgium	1976	Turin	Italy	2006
Sofia	Bulgaria	1998	Amsterdam	Netherlands	1977
Prague	Czech Republic	1974	Rotterdam	Netherlands	1968
Copenhagen	Denmark	2002	Oslo	Norway	1966
Helsinki	Finland	1982	Warsaw	Poland	1995
Lille	France	1983	Lisbon	Portugal	1959
Lyon	France	1978	Bucharest	Romania	1979
Marseille	France	1978	Barcelona	Spain	1924
Paris	France	1900	Bilbao	Spain	1995
Rennes	France	2002	Madrid	Spain	1919
Toulouse	France	1993	Palma	Spain	2007
Berlin	Germany	1902	Sevilla	Spain	2009
Hamburg	Germany	1912	Valencia	Spain	1987
Munich	Germany	1971	Stockholm	Sweden	1950
Nuremberg	Germany	1972	Lausanne	Switzerland	2008
Athens	Greece	2000	Adana	Turkey	2009
Budapest	Hungary	1896	Ankara	Turkey	1997
Brescia	Italy	2013	Bürsa	Turkey	2002
Catania	Italy	1996	Istanbul	Turkey	2000
Genoa	Italy	1990	Izmir	Turkey	2000
Milan	Italy	1964	Glasgow	UK	1896
Naples	Italy	1991	London	UK	1863

4.10.2. New metro infrastructure in Europe

Methodological note: in the following table, only projects whose status is "in construction", "in test phase" and "in operation" have been considered. Planned projects and projects "in design phase" have not been taken into account. The list (and the one included in D3.1.2) has been regularly updated by UITP in 2017, 2018 and 2019.

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COUNTRY	CITY	DESCRIPTION	WORK	STATUS	LENGTH (KM)	TOT. KM
Austria	Wien	U5 phase 1: Rathaus - Altes Akh (will take part of existing U2 line)	new	constr	0,5	9,4
Austria	Wien	U6: alfred adler str. - Aspergasse	extension	constr	0,9	
Bulgaria	Sofia	Line 3: (west-east): Boulevard Valdimir Vazov-Centre-Zhitnitsa Street	new	constr	8	8
Denmark	København	M3 Cityringen: Østerport - Kongens Nytorv - København H - Frederiksberg - Nørrebro	new	op	15,5	18,5
Denmark	København	M4 Harbour line North	new	constr	3	
Finland	Helsinki	Matinkylä - Kivenlahti	extension	constr	6,8	6,8
France	Paris	Line 11: Mairie des Lilas - Rosny Bois Perrier	extension	constr	5,4	77,5
France	Paris	Line 12: Front Populaire - Mairie d'Aubervilliers	extension	constr	0,7	
France	Paris	Line 14 south: extension to Orly	extension	constr	14	
France	Paris	Line 15 south : Noisy-Champs - Pont-de-Sèvres	new	constr	33	
France	Paris	line 17 Saint-Denis-Pleyel - Le Bourget RER	new	constr	9	
France	Paris	Line 4: Mairie de Montrouge - Verdun Sud - Bagneux	extension	constr	2,7	
France	Rennes	(VAL) Line 2: Mermoz - Gares - city centre - Champs-Blanc	new	test	12,7	
Germany	Berlin	U5: (temporarily U55): Brandenburger Tor - Alexanderplatz	extension	constr	2,2	7
Germany	Hamburg	U1		o	0	
Germany	München	U5 (west): Laimer Platz - Pasing	extension	constr	3,7	
Germany	Nürnberg	Line 3: Gustav-Adolf Strasse - Grossreuth	extension	constr	1,1	
Greece	Athens	Line 3: Egaleio - Haidari - A. Varvara - Korydallos - Nikea - Maniatika - Piraeus - Dim. Theatro	extension	constr	7,6	17,1
Greece	Thessaloniki	Line 1: OSE-Dimokr.-Venizel.-A. Sophia-Sintrivani-Panepist.-Papafi-Efklidi-Fleming-Analip.-Patrikiou-Voulgari-N. Elvetia	new	constr	9,5	

COUNTRY	CITY	DESCRIPTION	WORK	STATUS	LENGTH (KM)	TOT. KM
Italy	Catania	Line 1: Stesicoro - Palestro	extension	constr	2,2	51,7
Italy	Catania	Line 1: Nessima - Monte Po	extension	constr	1,7	
Italy	Catanzaro	Catanzaro station on the FS route from Lamezia Terme with Dulcino station	new	constr	5	
Italy	Genova	Brin - Canepari (later- Rivarolo) in the northwest	extension	constr	0,55	
Italy	Milano	Line 1 north ext. : Sesto - Monza-Bettola	extension	constr	1,8	
Italy	Milano	Line 4: Airport - San Cristoforo FS railway station	new	constr	14,5	
Italy	Milano	Line 4: Airport - Forlanini	new	constr		
Italy	Milano	Line 4: Forlanini - Dateo	extension	constr		
Italy	Milano	Line 4: Dateo - San Babila	extension	constr		
Italy	Milano	Line 4: San Babila - San Cristoforo FS	extension	constr		
Italy	Napoli	Line 1: di Vittorio - Capodichino Airport - - Garibaldi	extension	constr		
Italy	Napoli	Line 1: Piscinola - di Vittorio	extension	constr	3,3	
Italy	Napoli	Line 6: Mergellina - Arco Mirelli - San Pasquale - Chiaia - Municipio	extension	constr	3,077	
Italy	Roma	Line C: Phase 4: S Giovani- coloseo	extension	constr	3	
Italy	Torino	Line 1: Lingotto - Italia 61 - Bengasi	extension	constr	1,6	
Italy	Torino	Line 2 : Rebaudengo - Anselmeti	new	constr	15	
Netherlands	Rotterdam	Schniedam Centrum - Hoek van Holland	conversion	op	24	25,2
Netherlands	Rotterdam	Hoek van Holland ext	extension	constr	1,2	
Norway	Oslo	Line 2: Avløs - Kolsås	extension	constr	1,6	10
Norway	Oslo	Fornebu metro line 6: Majorstuen - Fornebu senter	new	d	8,3	

COUNTRY	CITY	DESCRIPTION	WORK	STATUS	LENGTH (KM)	TOT. KM
Poland	Warszawa	Line 2: (West) Rondo Daszyńskiego - Ksiecia Janusza	extension	constr	3,5	6,6
Poland	Warszawa	Line 2 (east) Dworzec Wileński - Trocka	extension	constr	3,1	
Romania	Bucuresti	Line 5: Drumul Taberei - Eroilor	new	constr	6,7	16,3
Romania	Bucuresti	Line 5: Drumul Eroilor - Universitate - Iancului - Pantelimon	new	constr	9,6	
Spain	Barcelona	Line 9: Campus Nord - Prat de Riba - Sarrià - Putxet - Lesseps - Guinardó - Sagrera Meridiana - Sagrera AVE	extension	constr	21,8	25,7
Spain	Barcelona	Line S1: Terrassa-Rambla - Can Roca	extension	constr	3,9	
Sweden	Stockholm	Blue line (11) North extension: Akalla - Barkaby	extension	constr	3,4	15,7
Sweden	Stockholm	Blue line (11) South extension: Kungsträdgrden - Nacka	extension	constr	7,7	
Sweden	Stockholm	Gold line(s): Odenplan - Hagastaden - Solna	new	constr	4,6	
Turkey	Ankara	M4: Atatürk Kültür Merkezi to Kızılay	extension	constr	1,4	198,5
Turkey	Kocaeli / Gezbe	line 1 : Gebze and Darıca	new	constr	15,6	
Turkey	Gaziantep	Gaziray Metro	new	constr	25	
Turkey	Istanbul	M2 YENIKAPI - INCIRLI - SEFAKOY	extension	constr	14,5	
Turkey	Istanbul	M3 BASAKSEHIR - KAYASEHIR	extension	constr	6,45	
Turkey	Istanbul	M3 IKITELLI - ATAKOY	extension	constr	13,3	
Turkey	Istanbul	M4 PENDIK-KAYNARCA	extension	constr	3,2	
Turkey	Istanbul	M8 DUDULLU - BOSTANCI METRO LINE	new	constr	14,2	
Turkey	Istanbul	Göztepe Atasehir ümraniye		constr	13	
Turkey	Istanbul	Cekmekoy - Tasdelen - yenidogan		constr	5,7	
Turkey	Istanbul	Kaynarca - tuzla		constr	7,8	
Turkey	Istanbul	M7 Kabataş and Mahmutbey	new	test	24,5	
Turkey	Istanbul	M7 MAHMUTBEY - Enseyurt	extension	constr	16,44	
Turkey	Istanbul	M11 - Airport line 1: Gayrettepe (M2) - airport T1 T2 T3	new	test	37,4	
UK	London	Piccadilly Line: Heathrow Airport Terminal 5	extension	constr	1,9	5,2
UK	London	Northern Line: Kennington - Nine Elms - Battersea	extension	constr	3,3	

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5. Deliverable D 3.1.2 - Light Rail data set collection

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Report contributors		
Name	Beneficiary Short Name	Details of contribution
Dauby, Rizzi	UITP	Draft 1
Dauby, Rizzi	UITP	Executive Summary
Castagnetti	NEWO	Revision
Dauby, Rizzi	UITP	Draft 2
Dauby, Rizzi	UITP	Draft 3 and FINAL
Tardivo, Carrillo Zanuy	EURNEX	Final edition and conclusions

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5.1. Executive Summary

As of 31 December 2018, tram and Light rail systems (both designed as LRT in this document) are available in 402 cities of the world. Despite a significant increase in the number of new lines recently opened in the Asia Pacific region, Europe remains the world's leader in LRT, in terms of number of lines, km and number of cities served (208). The present report describes the evolution of LRT in Europe since 2015[15] and gives a snapshot of the situation in 2018, based on the findings of the UITP LRT Statistics Report produced by UITP in 2019. To ease the readability of the statistics, European countries have been clustered in 9 sub-regions (Nordic/Baltic, Poland, Germany, Benelux, the British Isles, France, Western Mediterranean, Central Europe, South-Eastern Europe). From the analysis, it emerged that between 2015 and 2018, LRT infrastructure in Europe grew on average by 3.9%, with a peak of 9% in the British Isles and 9,5% in the Nordic/Baltic region, totalling 9.296 km. The European average line length is 7.3 km, with an average distance between stops of 300-600m. Notable differences exist across different countries and between new and old lines. Berlin has the longest LRT system in Europe; Budapest the busiest and Istanbul the most crowded.

In terms of fleet, Germany, Poland and Central Europe account for the 59% of the total European trams and LRVs, roughly half of them low-floor. Central, South-Eastern Europe and Benelux have the densest feet (2+ LRV/Km). Data on yearly mileage per vehicle show that the European average is 52.000 Km. Still, differences exist among the different countries and considerations have to be made in terms of rush/peak hours utilisation and vehicles immobilised for maintenance.

In terms of ridership, data show that the symbolic threshold of 10 billion passengers per year was reached in 2016. An increasing trend is visible between 2015 and 2018, with Germany, Central and South-Eastern Europe accounting for 61% of the total European ridership. Despite this, the British Isles, Nordic/Baltic and Benelux showed the most robust increase in the number of passengers. The average European ridership growth in 2015-2018 is 6.9%. The demand growth is 50% higher than the supply growth. Central Europe, Poland and Germany are the champions in terms of LRT trips per year per inhabitant, but substantial variations are visible in countries belonging to the same cluster.

In terms of both environment-friendliness and safety, the report shows that LRT results to be 7 times less pollutant and 6 times safer than private cars. Any modal shift towards LRT public transport positively affects the overall safety record of a city and its environmental footprint.

In terms of innovations, new technical solutions have been analysed. Catenary-less power supplies will continue to be chosen but still representing a niche market, while trams on tyres are unlikely to know rejuvenation or widespread utilisation. Advanced Driver Assistance Systems are likely to increase their market share in Europe. In this sense, technology is available and is expected that operators will be more and more interested in deploying this solution soon to avoid the high number of collisions in street operations.

[15] UITP collects rail data according to a three-year cycle (Metro, LRT and regional/commuter railways)

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5.2. Introduction

The data for this document was extracted from a database compiled by UITP using official company data and other authoritative sources (national statistics office, national associations, etc.).

LRT and trams are urban rail-guided systems operated at least partly on line-of-sight, on infrastructure shared with other users and partly on their own infrastructure (Right-of-Way type 2). Tram and LRV vehicle are urban rail vehicles designed to run on a tram/LRT network. Systems operated on guided rubber-tyred multi-articulated vehicles with right-of-Way 2 are included.

Infrastructure predictions are based on scenarios developed from UITP's rail project database.

This Europe LRT landscape is based on the full LRT Statistics Report 2019, which includes further details and analysis. The extensive report is available, together with the full dataset, on request from UITP.

LRT has enjoyed a sheer renaissance since the new Millennium, with no less than 108 new cities (re)opening their first line. As Figure 1 shows, Europe has traditionally been a leader in LRT development with 70 new systems, let alone new lines in existing systems and line extensions.

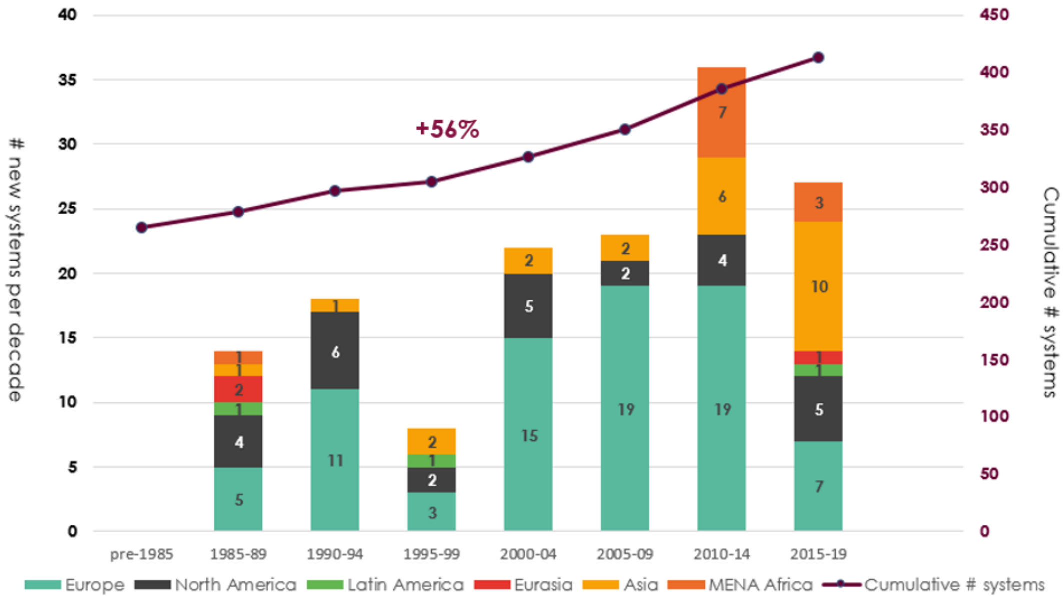

Figure 1: LRT system opening per half-decade 1985-2019 – Source: UITP LRT Statistics Report 2019

Between 2015 and 2018, 420 km of new LRT opened in Europe (Figure 2), i.e. 36 % of the total. 2017 was a watershed year as, for the first time, green-field LRT projects in Asia-Pacific outpaced Europe (Figure 3). The trend is expected to continue, as China has started massive investment in this intermediate capacity systems and Europe has to dedicate significant resources to asset maintenance and modernization (brown-field).

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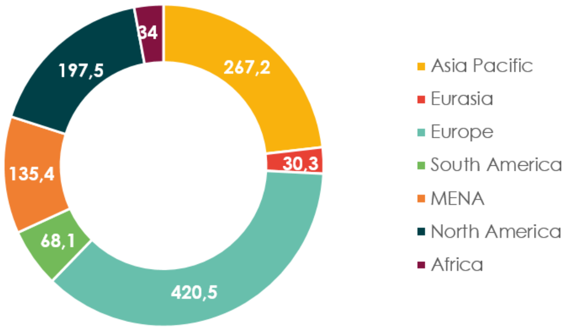

Figure 2: Figure 31New LRT infrastructure (km) 2015-2018 by year and by region – Source: UITP LRT Statistics Report 2019

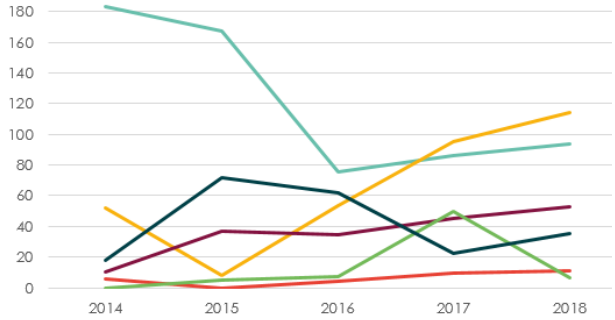

Figure 3: Evolution of LRT development (km) by year and by region – Source: UITP LRT Statistics Report 2019

For the purpose of the analysis, Europe has been divided into 9 sub-regions, offering more "legible" report and charts (9 groups instead of 30 individual countries). The approach is a subjective and imperfect attempt by the report author at clustering countries in relatively consistent groups. The colour codes used for the charts are indicated on the map below.

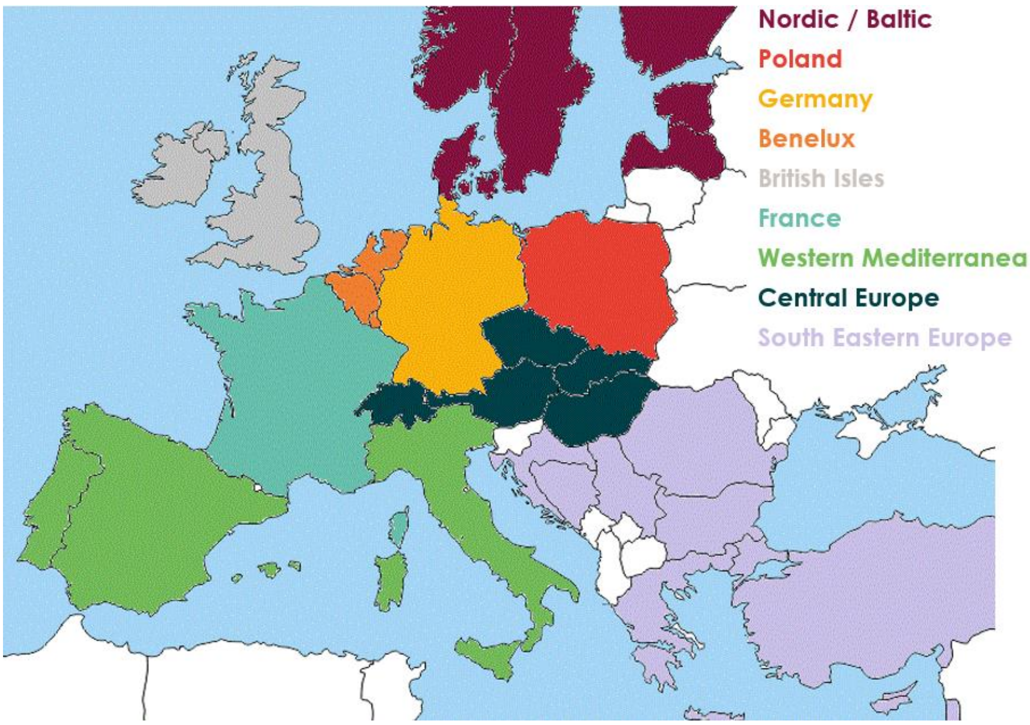

Figure 4: Map of colour codes used for clustering European "sub-regions" – Source: UITP LRT Statistics Report 2019

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5.3. Infrastructure

Between 2015 and 2018, LRT infrastructure in Europe grew by 3.9% from 8 943 km to 9 296 km. No single region exposes stagnation or decline, although growth rates vary widely between 8-9.5% (the British Isles, the Nordic region, France) and 1% (Poland, Central Europe), depending on the "legacy level" of LRT equipment, as detailed in Figure 5.

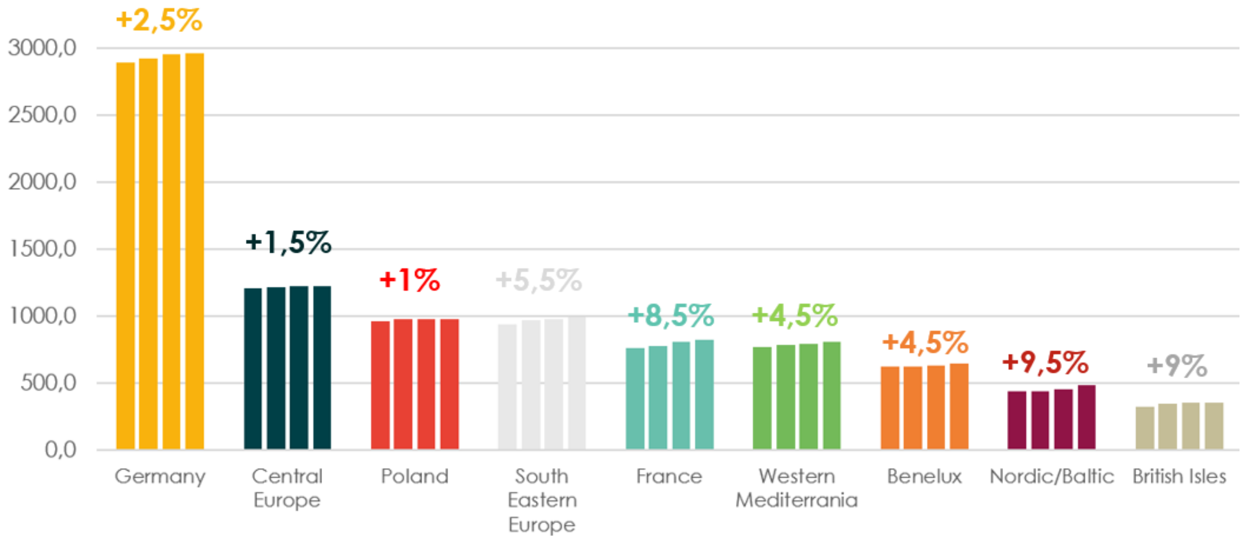

Figure 5: Evolution of line length in Europe (km) 2015-2018 – Source: UITP LRT Statistics Report 2019

As Figure 5 shows, there are notable differences between network structures (line length and distance between stops) across the countries of Europe: while the European average lies at 7.3 km, lines tend to be longer on average in countries with newer systems and limited number of lines like UK, Ireland, France, Spain and Portugal (8-16 km). In contrast, older and more complex systems(with shorter branches, or wider sections of shared infrastructure for multiple lines) feature average line length ranging between 5 and 8 km. Except for the UK, which has a sizable portion of the LRT networks using former railway infrastructure, the average distance between stops range between 300 and 600 m. The specificity of British systems will also "naturally" translate in an average journey distance higher than the average (see Figure 15). Newer systems also tend to be designed with typically fewer stops (>500 m between two stations), in a logic of increase of commercial speed performance of a modern LRT, as compared to the practice used in "older" tram systems.

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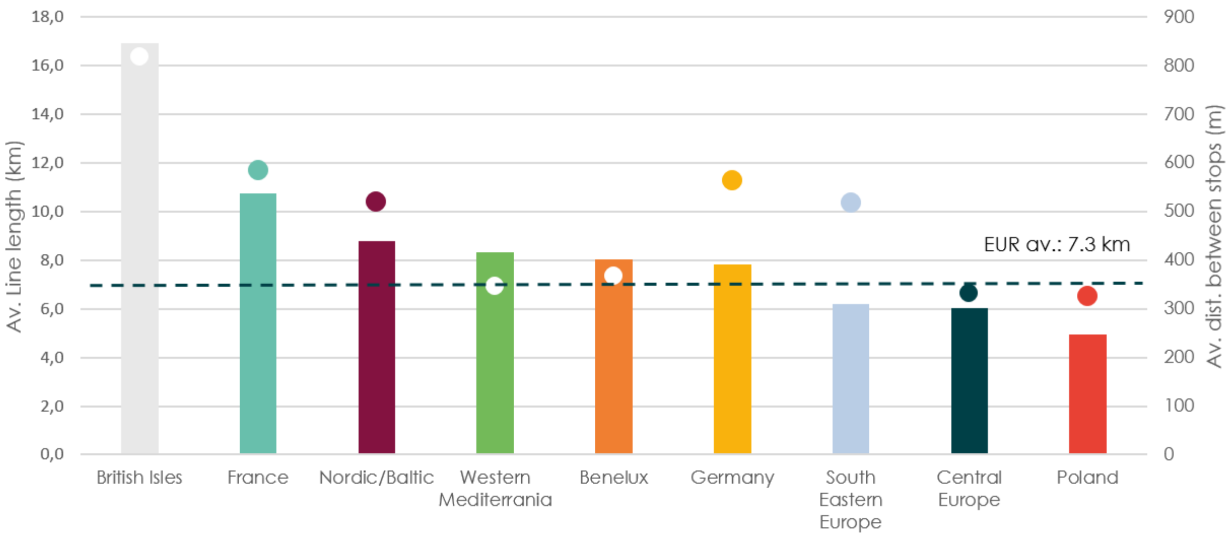

Figure 29: LRT network characteristics: bar=line length/bullet=distance between stops – Source: UITP LRT Statistics Report

The longest LRT network is Berlin (193 km), ranging number 3 worldwide after Melbourne (250) and Saint Petersburg (246). The top-10 ranking is shown in Figure 7.

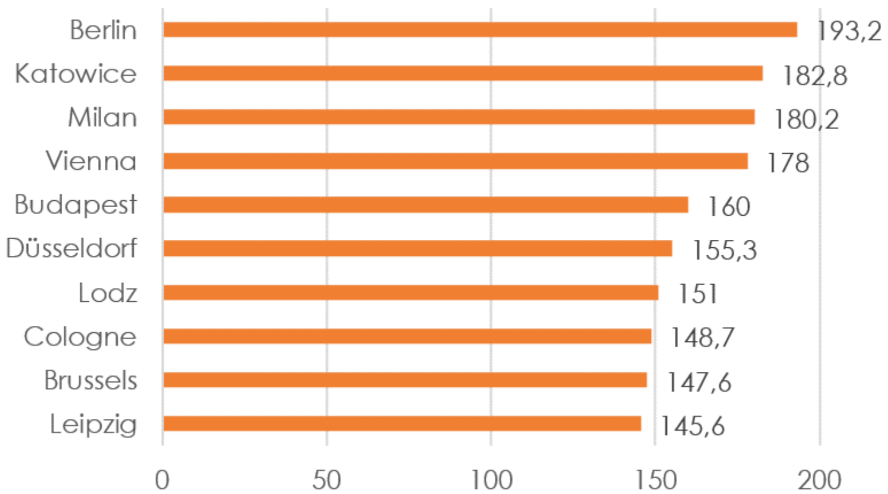

Figure 30: Top-10 longest LRT systems in Europe (km) – Source: UITP LRT Statistics Report 2019

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5.4. Mobile asset

The fleet available to operate the 1275 LRT lines in Europe consists of 20 750 trams and light rail vehicles. The fleet is distributed as shown in Figure 8.

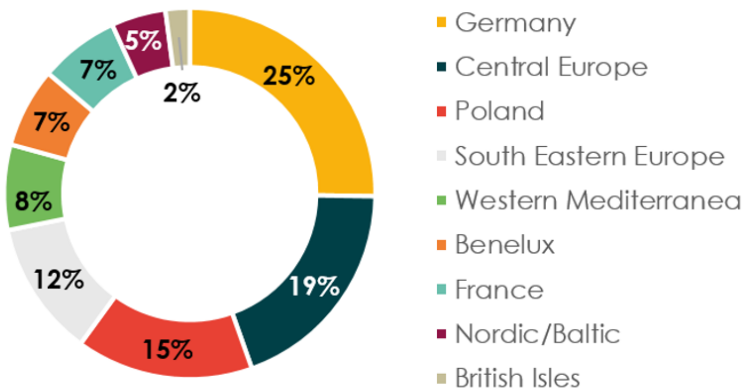

Figure 31: Distribution of mobile assets by European regions – Source: UITP LRT Statistics Report 2019

Low-floor technology has been available since the early 90ies and has widely been adopted for green-field projects and fleet renewal procurements to improve accessibility and comfort. Currently, with 10 592 units, 51% of the total installed fleet in Europe is partial or full low-floor vehicles, ranging from countries with close to 100% (France, Spain, Ireland, UK, Norway) to much lower levels, as indicated in Figure 9. The proportion of state-of-the-art low-floor LRVs depends of course on the market structure (modern LRT systems opened since the early 90ies vs. legacy systems) and the financial capabilities of operators to renew their ageing fleets.

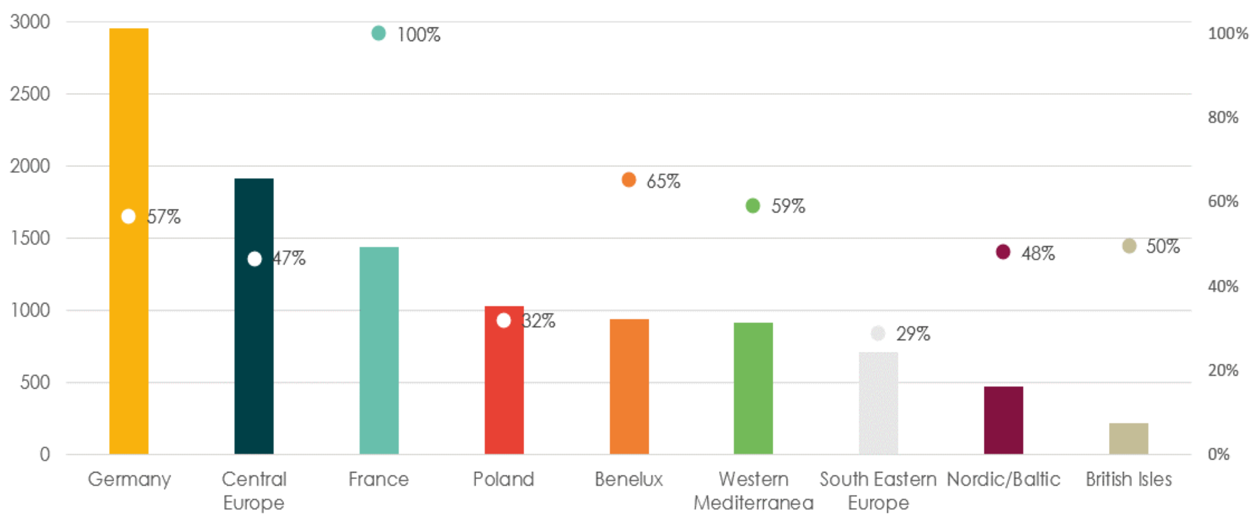

Figure 32: Low-floor vehicles by regions: number and %age of total fleet – Source: UITP LRT Statistics Report 2019

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Low-floor LRVs (possibly equipped with additional devices such as ramps or gap-fillers) are a major technical innovation. However, they are not a perfect indicator to gauge accessibility. Some specific tram stops arrangements do not allow for wheelchair accessibility despite the use of low-floor, and reversely, some high-floor vehicles offer excellent step-less access with high-floor platforms. The latter configuration is present in some large systems in Bonn, Cologne, Düsseldorf, Frankfurt, Hannover, Manchester, Newcastle, and Stuttgart. Taking into account these high-floor fleets, the European average rate of accessible LRVs climbs from 51% to 58%, with Germany reaching 81% and British Isle 98%.

However, accessibility assessment is a complex and holistic discipline. Vehicle accessibility is not enough to qualify system accessibility. A precise assessment would require a detailed analysis of the accessibility conditions of each station and each platform and is not feasible in the scope of this study.

An indicator of fleet density (# of vehicle per km of infrastructure) was defined to characterize the fleet size required to provide urban LRT services (Figure 10).

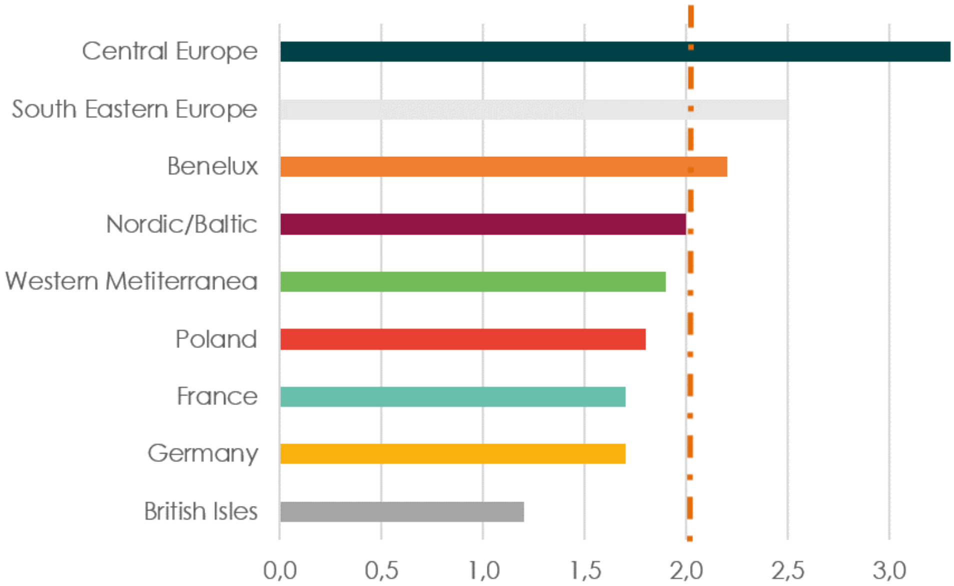

Figure 33: Number of LRVs per km of line – Source: UITP LRT Statistics Report 2019

Two vehicles per km of line is the European average. The higher value in Central Europe (3.3) and South-East Europe (2.5) is probably explained by the higher average age of the fleet in these regions and the higher level of downtime due to technical failures with potentially longer immobilization time required for repair. The lower value in France, Germany and the UK is probably due to the use of newer and longer multi-articulated vehicles.

Another common rolling stock KPI is the average yearly mileage per unit. Data about vehicle-kilometre were available, at least partly, for 23 countries out of 30. Weighted average annual mileage per vehicle in Europe is 52 000 km, ranging between 36 400 km (South-Eastern Europe) and 77 500 km (British Isles). The fleet age structure can partly explain the discrepancy depicted

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in Figure 11. Besides, this value is theoretical and based on the assumption that all vehicles are equally used.

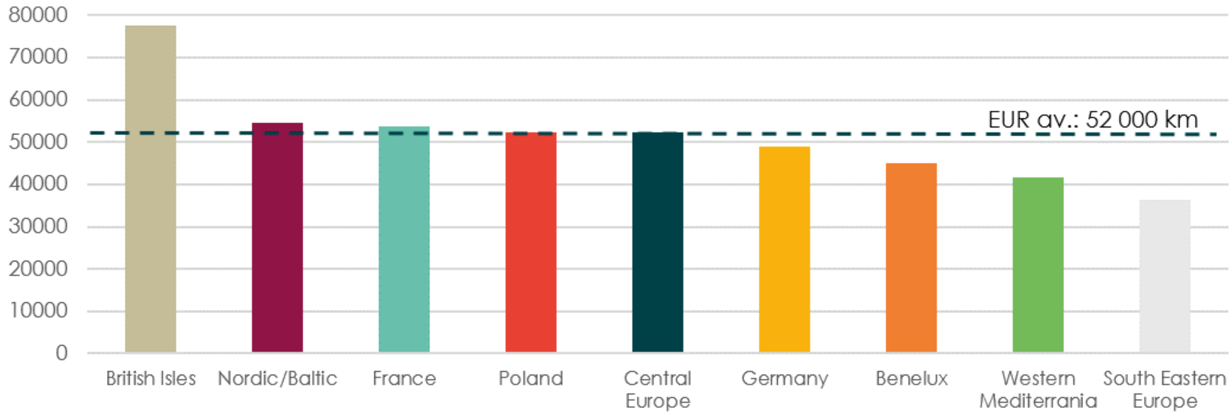

Figure 34: Average annual mileage per LRV (km) – Source: UITP LRT Statistics Report 2019

In reality, if we account for the difference between rush and off-peak hours, vehicles immobilized for maintenance and the reserve fleet (varying between 10 and 25%), the real mileage per vehicle is higher. As an example, Poland is the only country providing precise data about total fleet and maximum fleet in operation during peak hours; with 25% reserve fleet, the real annual mileage of the fleet is 71 000 km instead of 52 000 km as reported below.

The low value of South-Eastern Europe should be considered with caution, as data are only available for 3 cities, and 5 countries of the regions are entirely missing, among which the largest (Romania and Turkey).

5.5. Ridership

However interesting the evolution of assets can be, the real success of LRT is best measured through ridership. The symbolic threshold of 10 billion yearly passengers was reached in 2016.

With a total of 10 294 million passengers per year, LRT carries as many passengers as metros and regional/commuter rail in Europe, with respectively 10 750 m. and 8 900 m. in 2017. And ten time more passengers than air travel in Europe! The small railways do certainly NOT play a small role in the sustainability of European cities.

Germany and Central Europe region make up half of all patronage, the rest being distributed as shown in Figure 13 below.

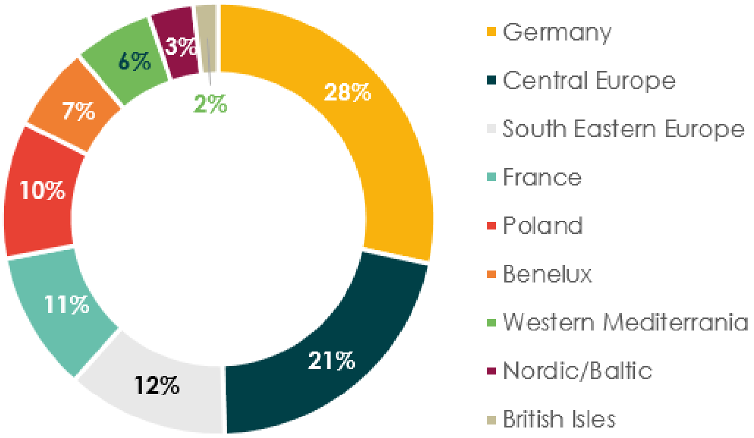

Figure 35: Ridership distribution 2017 – Source: UITP LRT Statistics Report 2019

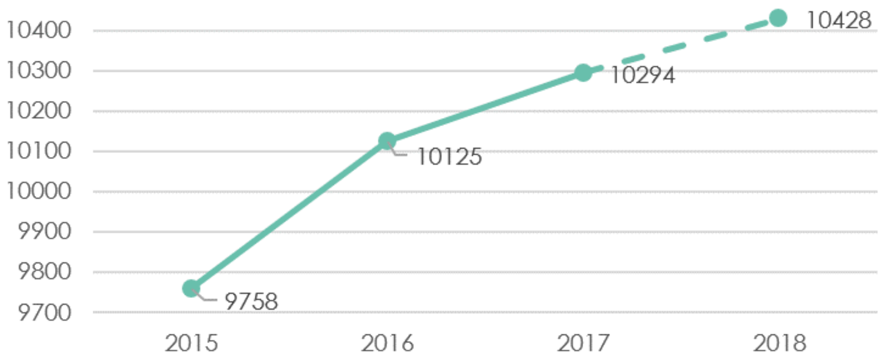

Figure 36: Ridership evolution in Europe (m.) 2015-2018 – Source: UITP Tram and LRT Statistics

Patronage data for 2018 are not yet available for all countries at this point in time. The detailed analysis by regions is, therefore, using extrapolation for France, Poland and Switzerland for 2018 (see Figure 14 below). However, 2018 data available in 19 countries suggests a growth of 1.3% between 2017 and 2018. The extrapolation of this data yields a ridership growth of 6.9 % from 9 740 million in 2015 to 10 428 million passengers between 2015 and 2018 (Figure 13 above). Demand growth is therefore 50% higher than the supply growth (km of line) over the same period of time and is a sign of a positive response from the travelling public.

Figure 14 shows different ridership evolution according to regions, ranging from vigorous 17.5 % in the British Isles (where infrastructure growth was also the strongest) to 1.5% in Poland.

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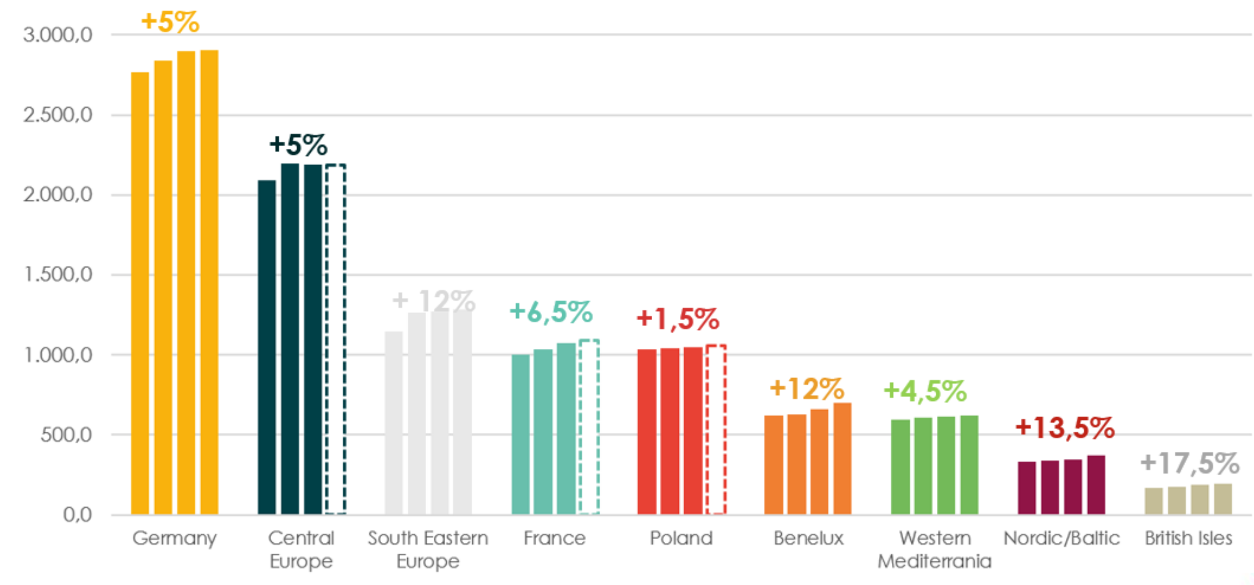

Figure 37: Ridership evolution by region (m. passengers) 2015-18 (dotted stacks=estimations) – Source: UITP LRT Statistics Report 2019

Data about passenger-kilometres is only available for 16 countries and depicted in Figur. 15 below. Weighted average distance per tram/LRT journey in Europe is 3.27 km, ranging between 1.75 km in Luxemburg (but the line is currently only 5 km long) and 4.75 km in the UK.

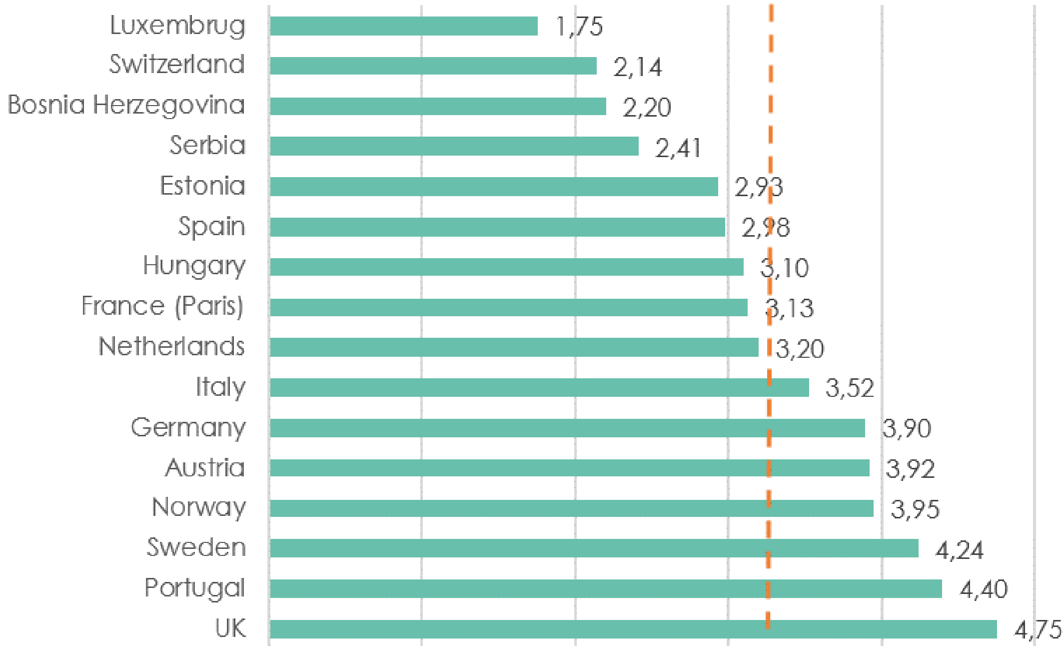

Figure 38: Average distance per trip in selected countries (km) 2017 – Source: UITP LRT Statistics Report 2019

Portugal's results are profoundly shaped by the largest system in Porto. The latter and most UK systems features large sections of former railway alignments converted to LRT service. This

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explains the higher pattern of traffic as the systems are not exclusively serving the urban areas.

The average number of LRT trips per inhabitant per year is a useful KPI to measure the intensity of use of available service, or expressed differently, the "popularity" of tram/LRT. Such an indicator is only relevant if it bases on a consistent methodology for the collection of population data in the given urban area[16]. The yearly use intensity range between 182 and 10, as shown in Figure 16.

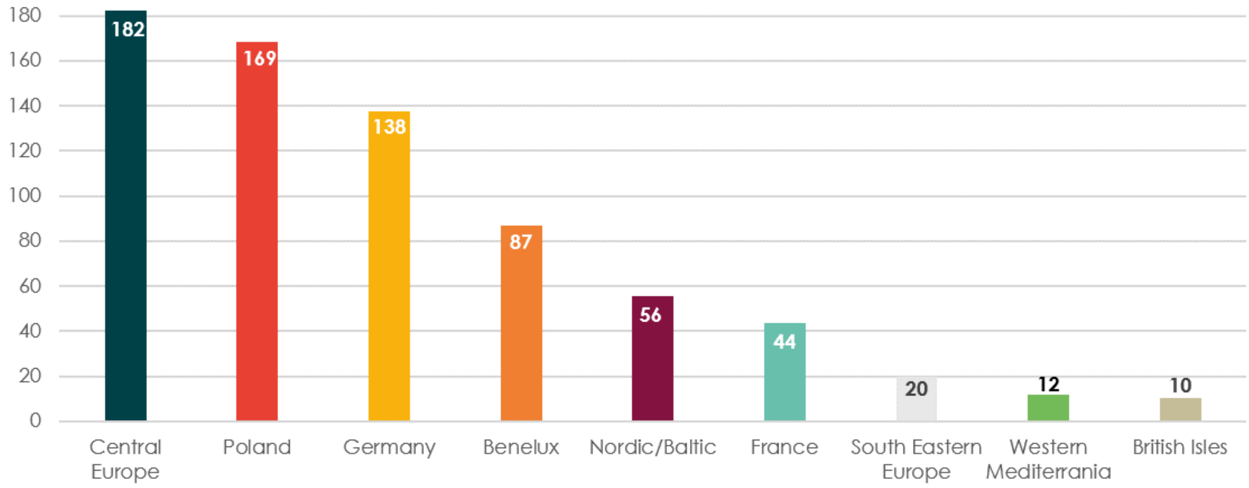

Figure 39: Number of LRT trips per year per inhabitants – Source: UITP LRT Statistics Report 2019

There are substantial variations within a region (15 for Turkey and 261 for Croatia; 9 for the UK and 32 for Ireland or 20 for Portugal and 4 for Spain), or even within a country (9 in Lille and 145 in Montpellier). These differences can be –at least partly – explained by system development and sophistication: LRT is more likely to be intensively used if it offers wide spatial coverage. Figure 17 is plotting individual network characteristics (number of lines) and use intensity for 174 cities across Europe and shows that the more lines in the network, the more it is used.

[16] UITP uses the UN system World Urbanisation Prospects (WUP)

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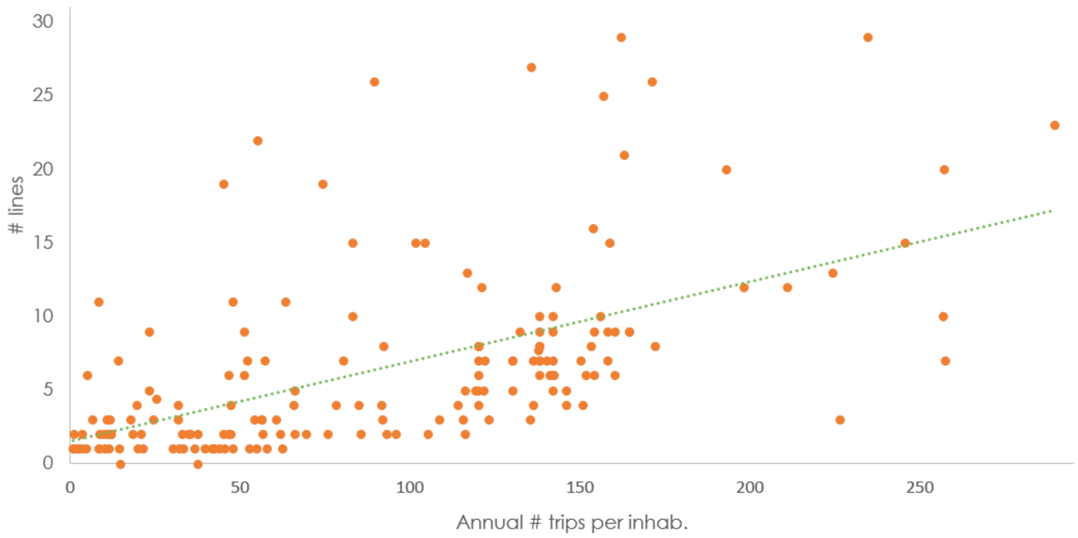

Figure 40: Distribution of annual usage per inhabitant vs. network complexity – Source: UITP LRT Statistics Report

The busiest LRT network is Budapest (411 m. passengers) which is the 5th longest system. The top-10 ranking is shown in Figure 18. All systems in this top-10 are long-established tram networks, except Paris where LRT was re-introduced just 25 years ago after it was completely dismantled in the 50ies. This rank #3 is all the more remarkable since Paris does not have an LRT network but a series of 11 un-connected lines.

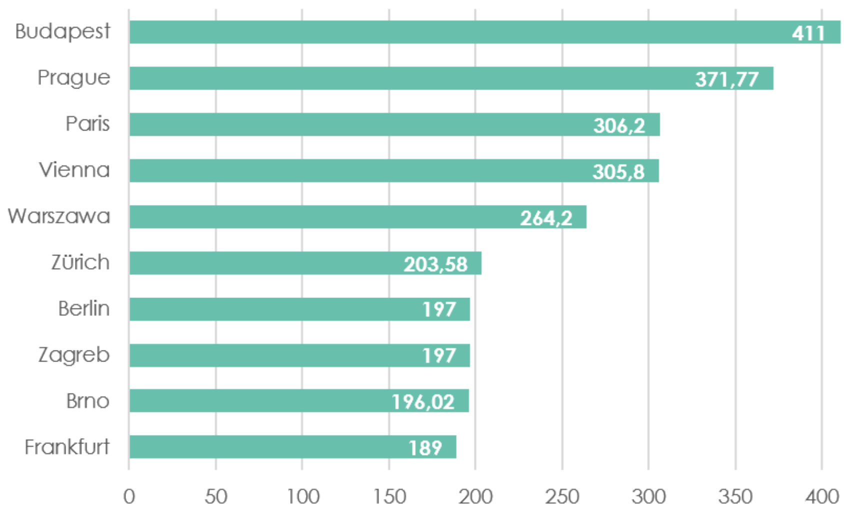

Figure 41: Top-10 busiest LRT systems in Europe (m. passengers) 2017 – Source: UITP LRT Statistics Report 2019

The most crowded LRT network is Istanbul (4.4 m passenger p.a. per km of line). The top-10 ranking is shown in Figure 19.

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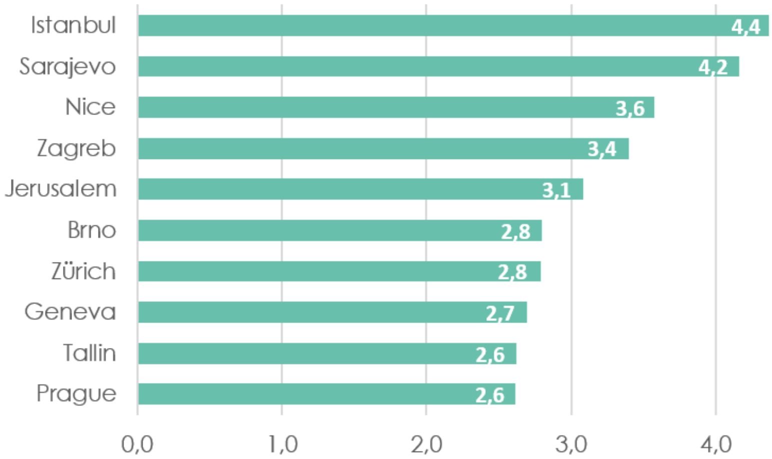

Figure 42: Top-10 most crowded LRT systems in Europe (m. passengers per km of line) 2017 - Source: UITP LRT Statistics Report 2019

5.6. Environment

As per the ERRAC 2050 Vision, released in 2018, rail transport is recognised as the most environmentally friendly form of mass transport. Its low levels of atmospheric emissions compared to automotive and air transport, widespread use of electric traction, low energy consumption, relatively small land use of its infrastructure, ability to smoothly and quickly access town and city centres, together with its effectiveness in comfortably and quickly moving large volumes of people and goods over long distances make it the most sustainable mode. With regards to the average energy consumption, urban rail, with its 0.12 kWh per passenger-km is 7 times more energy-efficient than private cars in cities[17]. Rail's carbon footprint is significantly smaller than those of the other transport modes. LRT produces no emissions at street level in sensitive areas and therefore contributes significantly to localised air quality improvement. Carbon-free train operation and zero nitrogen oxides (NOx) and particulate matter (PM10) emissions achievable objectives. Noise and vibrations caused by the railways are, in different cities, no longer an issue.

For public transport to become citizens' preferred mode of choice, it has to become the decision-makers' mode of choice. Integrated urban policies must be implemented to optimise the benefits of public transport as well as supporting mobility management to steer demand.

A set of sector initiatives to reduce energy consumption, included by UITP in its "Energy efficiency: contribution of urban rail systems" leaflet are hereby summarised. Although the study was released in 2014, the set of recommendations remains actual.

<u>In buildings such as depots, workshops and stations:</u>

• Optimising ventilation, heating and cooling

[17] UITP - Energy efficiency: contribution of urban rail systems leaflet - 2014

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• Replacing old lighting equipment and lighting control

• Improving energy efficiency of equipment such as escalators, power transformers

• Designing eco-friendly buildings

In vehicles:

• Using eco-friendly driving rail and bus vehicles

• Uncoupling metro cars during off-peak hours

• Recovering braking energy

In energy production systems:

• Geothermal energy for heating/cooling system of buildings

• Wind energy with the installation of turbines at stations

• Solar energy on the roofs of tram/bus depots

As mentioned, rail is already the greenest form of mass transport. Despite technical research and innovation activities led, particularly in the latest years, to significant improvements, constant efforts in this sense are required to reach the target of a zero-carbon footprint. In terms of energy in the railway sector, the continuous R&I effort is twofold: to reduce energy consumption and to maximise the share of renewably-sourced energy.

Alternative propulsion concepts, such as fuel cells, have been already introduced in the market. Discontinuous electrification at stations and on branch lines dramatically reduce the capital costs of extending electrification. Automated Train Operation (ATO) improves energy efficiency. Optimised on-board and line-side energy storage and charging technologies (e.g. dynamic wireless power transfer) allow the railway to redistribute energy throughout the whole transport system, including at urban level, according to supply and demand. A fully-integrated system approach to an intelligent energy supply maximises renewable energy generation and the use of smart grids, including those outside the railway system, through links with the broader energy supply sector. The use of lightweight materials for rolling stock reduces maintenance costs and energy consumption. Suppliers and manufacturers have incorporated the principles of zero-carbon footprint and sustainable development into the whole life cycle. Zero waste cycles start to be implemented. Regenerative braking is more energy efficient and reduces both costs and environmental harm.

A constant monitoring of the energy consumption and CO2/PM10/NOX emissions is required to every company directly involved in the public transport services offering, to identify the primary sources of GHG emissions and prioritise effective action plans. Indicators have to be set to track the energy consumption in traction, stations, workshops, depots, office buildings.

With regards to climate change and its consequences, a report produced by UITP in 2016 collected the results of a survey made with a sample of companies involved in public transport activities (mainly rail operators). From this report, it emerges that most of the respondents are aware of the potential risks associated with climate change, measures to avoid adverse effects on rail infrastructure and quick restoration of the system after damage. Some companies have

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already put in place concrete measures, and some are planning to implement measures to avoid climate effects (e.g. rain, flooding, extreme hot weather, snow, freeze, wind among others). The crucial step in implementation is to prioritise the tasks according to potential risks and impact severity on the overall system. Better communication between different stakeholders helps authorities doing a better risk assessment and planning how to be prepared in case of adverse situation.

5.7. Safety

In terms of safety, a UITP study produced in 2009 and updated in 2016 analyses the accident statistics in a sample of 14 European cities, to illustrate the LRT level of safety compared to other means of transport (particularly private car), providing a robust statistical analysis to the assumption "LRT is safer than private transport".

Generally, trams move in public street space and are "operated by sight", just like all other road users. In traditional systems trams share the same pathway as general road traffic; newly built LRT systems operate on partly separated infrastructure, still within public street space but largely segregated from private transport pathways. Laws, signage and signalling equipment regulate the right of way.

From UITP analysis, accidents which are caused by the LRT system itself remain restricted to a number of single individual events. Despite many accompanying arrangements, accidents with third parties cannot be entirely avoided due to deliberate violation of traffic rules and/or a lack of awareness. Local authorities and LRT operators have to analyse accidents and propose safety measures according to the local conditions. All traffic planning measures related to alignment and rolling stock must be undertaken, with the aim to reduce the number of accidents and their severity. Local conditions and features always need to be taken into account. All operators systematically collect accident statistics.

These figures include data about the nature of accidents and their severity, which are summarised in Figures 20 and 21.

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2014	LRT accidents with									
	Cars		Two-wheelers		Bikes		Pedestrians		Inside falls	
	Total	Accident rate [per million train km]	Total	Accident rate [per million train km]	Total	Accident rate [per million train km]	Total	Accident rate [per million train km]	Total	Accident rate [per million train km]
Barcelona	37	15,0	5	2,0	2	0,8	9	3,7	63	25,6
Berlin	345	18,2	3	0,2	28	1,5	56	2,9	140	7,4
Bochum	140	18,9	0	0,0	0	0,0	2	0,3	4	0,5
Dublin	37	9,5	0	0,0	1	0,3	1	0,3	51	13,1
Düsseldorf	537	45,9	2	0,2	9	0,8	26	2,2	82	7,0
Frankfurt	360	24,4	1	0,1	10	0,7	20	1,4	78	5,3
Köln	295	17,2	3	0,2	12	0,7	49	2,8	137	8,0
Leipzig	306	24,1	4	0,3	26	2,0	11	0,9	11	0,9
Montpellier	85	15,6	7	1,3	5	0,9	12	2,2	76	14,0
Porto	25	3,5	0	0,0	0	0,0	16	2,2	36	5,0
Rotterdam	133	19,0	12	1,7	16	2,3	5	0,7	65	9,3
Stuttgart	105	6,9	1	0,1	2	0,1	17	1,1	121	8,0
Teneriffa	22	14,0	0	0,0	0	0,0	5	3,2	16	10,2
Wien	1048	34,5	18	0,6	22	0,7	96	3,2	113	3,7

Classification of LRT accidents within sampled cities, 2014

Figure 43: Occurrence of accidents involving LRT with other modes including passengers falling inside the vehicle – Source: UITP Knowledge brief "Light Rail Transit – a safe means of transport", 2016

2014	Severity							
	Casualties		Total wounded		Heavily wounded		Lightly wounded	
	Total	Per million train km	Total	Per million train km	Total	Per million train km	Total	Per million train km
Barcelona	0	0,0	138	56,1	3	1,2	135	54,9
Berlin	3	0,2	252	13,3	29	1,5	223	11,7
Bochum	1	0,1	34	4,6	11	1,5	23	3,1
Dublin	1	0,3	10	2,6	1	0,3	9	2,3
Düsseldorf	3	0,3	149	12,8	8	0,7	137	11,7
Frankfurt	-	-	-	-	-	-	-	-
Köln	6	0,3	359	20,9	18	1,0	341	19,8
Leipzig	1	0,1	66	5,2	11	0,9	55	4,3
Montpellier	0	0,0	108	19,9	2	0,4	106	19,5
Porto	0	0,0	16	2,2	1	0,1	15	2,1
Rotterdam	0	0,0	73	10,4	8	1,1	65	9,3
Stuttgart	1	0,1	166	10,9	9	0,6	157	10,3
Teneriffa	0	0,0	64	40,8	-	-	64	40,8
Wien	-	-	-	-	-	-	-	-

Grade of severity of LRT accidents within sampled cities, 2014

Figure 44: Severity of accidents involving LRV – Source: UITP Knowledge brief "Light Rail Transit – a safe means of transport", 2016

Figure 22 shows the accident rate, an average of the sampled cities LRT versus private car, in terms of frequency of accidents per persons-km. As a result of the analysis, the LRT accident rate is 6 times smaller than the car one. The traffic misbehaviour of third parties causes the majority

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of such accidents. This also shows that the operation of LRT in a city contributes to the reduction of the number of traffic accidents. Consequently, any modal shift towards more LRT public transport (either through the extension of lines or through the creation of new lines) has a positive impact on the overall safety record of a city. Moreover, when a new line or system starts revenue service, a decrease in private traffic is observed, as a result of the attractiveness of the new LRT service. This has a positive impact on overall traffic safety.

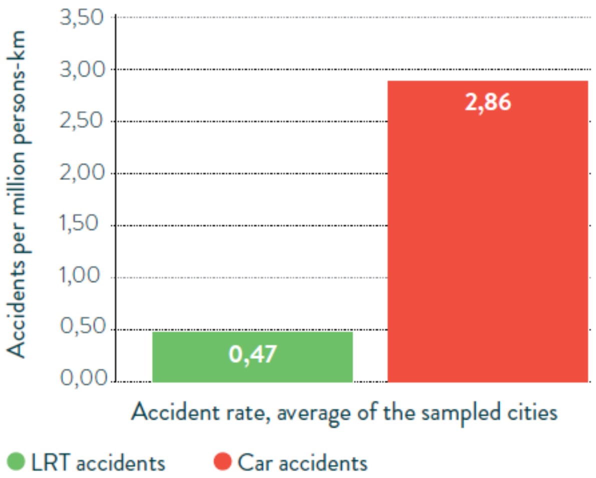

Figure 45: Accident rate LRT – car (per million persons km) comparison, average of 15 sampled cities, 2014 – Source: UITP Knowledge brief "Light Rail Transit – a safe means of transport", 2016

5.8. LRT Innovation market uptake in Europe

Several innovations have largely been developed and promoted for the LRT market in the past two decades. This update of the LRT statistics offers an opportunity to review the market uptake of these innovations.

5.8.1. Catenary-less power supply

Since mid-90ies, suppliers have developed and demonstrated technical solutions allowing to remove overhead power supply wires. Several proprietary solutions are available on the market (listed below). These solutions will continue to be chosen, especially if suppliers agree to "de-proprietaritise" their technologies. However, it will remain a niche market.

Technologies	km	fleet
Alstom APS (6 cities) Bordeaux, Reims, Angers, Orléans, Toulouse, Tours	~20	202
Alstom batteries (1 city) Nice	0.8	28
CAF ACR (4 cities) Sevilla, Zaragoza, Luxemburg, Granada,	13,7	75

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Skoda (1 city) Konya	1,8	12
TOTAL	**~36**	**317**
Expected growth (greenfield only)	**Moderate**	

5.8.2. Trams on tyres

Several models of "trams on tyres" have been developed in the late 90ies. One model developed by French company Lohr (now part of the Alstom Portfolio under the name NTL-Translohr) "survived" its teething problems. These vehicles, available in a range of length ranging from 25 to 46m, are operated in 5 cities in France and Italy. The total installed fleet consists of 130 units. There does not seem to be either strong appetite from cities, nor a great marketing willingness from the supplier to find new customers, and it can reasonably be assumed that there will not be a 2nd generation of such products. The "trackless tram" currently tested in Zhuzhou (China) is drawing some media attention but so far failing to make a compelling case. It is anyway more a guided bus than a trackless tram.

Cities with rubber-tyrred trams	Km	fleet
Clermond-Ferrand (1 line)	15.7	26
Paris (2 line)	20.6	43
Venice (1 line)	6.3	20
Padova (1 line)	10.3	16
Nancy (Bombardier TVR system)	11.4	25
TOTAL	64.3	130
Expected growth (greenfield only)	Unlikely	

5.8.3. Advanced Driver-Assistance Systems (ADAS)

Anti-collision warning device using automotive sensor technologies have been adapted to tram operation and tested since 2014-2015. They can be implemented as part of the original design of LRVs, or retrofitted in the existing fleet. So far, only Frankfurt operator has deployed ADAS on a larger scale (75 LRVs). Due to the high number of collision in street operation, it is expected than more operators will be interested in deploying this innovation which does not require specific infrastructure adaptation and can be deployed for brown-field as easily as for green-field projects. This assumption was confirmed by a survey in UITP Light Rail Committee conducted in 2018. Operators in Ulm, The Hague, Munich and more cities have ordered ADAS in their most recent LRV procurement. 2022 edition of UITP LRT statistics will provide a better view.

Further sophistication of ADAS technologies combined with ATO-like functionalities paves the way for autonomous or even driverless operation. The concrete benefits and relevant use cases are yet to be refined, and technologies are not yet fully mature. However, the pace of progress could be fast, and the 2022 edition of UITP LRT statistics will provide a better view of these prospects.

5.9. Perspective

With continued pressure to reduce congestion, to tackle air quality in cities, to reduce greenhouse gas emissions contributing to climate change, and to decrease the levels of noise and vibrations, LRT will continue to obtain decision-makers and travelling public support in Europe. LRT has been proved to be clean, silent and space-efficient. The analysis of the incidents'/casualties' rate demonstrates its high safety records compared to other modes and particularly to road vehicles.

However, much attention and resource will flow into the maintenance, modernization and replacement of assets like fleet, tracks, stations etc. to keep ageing systems attractive and fit for operational purpose. For this reason, the growth of green-field projects in Europe will continue to slow down as illustrated by Fig. 23. The surge in 2019 is attributable to a large tram-train conversion project in Denmark. Without it, 2019 green-field prognosis is in line with the declining trend line. A comprehensive list of all the LRT project currently under completion in Europe is included in Appendix 1 of this document.

Significant challenges are going to be tackled in the next future. First of all, the environmental one. New materials, new propulsion concepts alternative to fossil fuels, more efficient energy storage systems, improved infrastructure (including charging facilities and smart grids) are key aspects to be exploited. Secondly, digital transformation, artificial intelligence, automation and autonomous mobility are promising technologies with the potential to transform the rail sector. Finally, a multimodal and integrated transport system needs higher levels of accessibility and social inclusiveness and a better understanding of people's needs and behaviours. In this sense, stations (which are facing an ongoing rejuvenation process) are likely to play a central role in the rail-centric mobility of the future, emerging as multimodal hubs gathering "traditional" and innovative (shared) mobility options.

The ability to tackle these challenges in the right way will shape the way all actors involved in people's mobility in urban and suburban areas will improve their service offering, better interacting with users, increasing efficiency and effectiveness of the solutions and addressing sustainability/environmental challenges in order to deliver resilient, versatile and flexible services.

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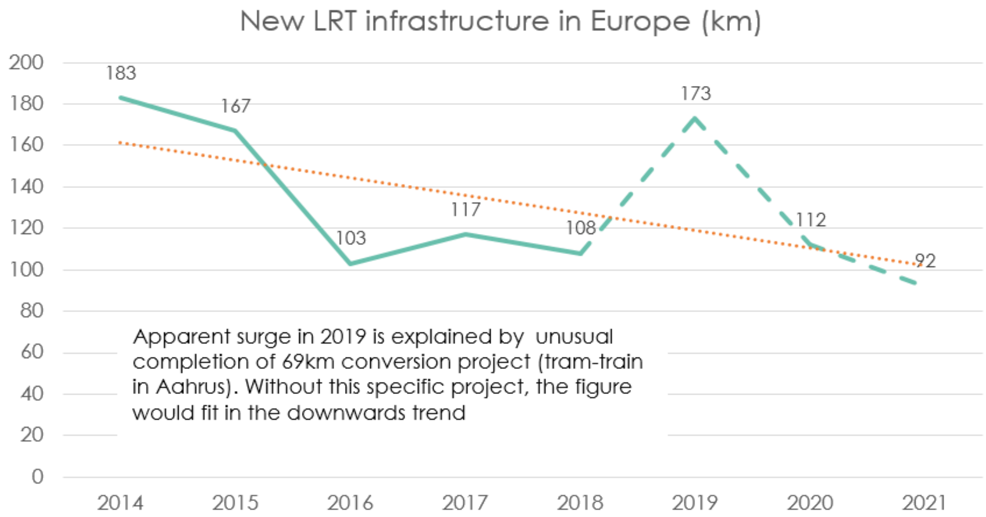

Figure 46: Forecast for new LRT infrastructure in Europe (km) – Source: UITP LRT Statistics Report 2019

5.10. Conclusions

Tram and Light Rail systems, or LRT, play a significant role in public transportation throughout the world. From 2000 onwards, 108 cities worldwide have opened their first line, 70 of which are in Europe. Furthermore, our continent remains the world leader in this transport mode, with 208 cities benefiting from LRT effects compared to a total of 402 cities worldwide. Within Europe, Berlin has the most extended LRT system, Budapest the busiest and Istanbul the most crowded.

20.750 trams and light rail vehicles operate on the 1.275 European lines, delivering sustainable, efficient and safe transportation for 10.294 million passengers per year.

These figures show that LRT plays and will play a fundamental role in public transport, as it allows to reduce congestion, tackle air quality in cities, reduce greenhouse gas emissions contributing to climate change, and to decrease the levels of noise and vibrations. With regards to the average energy consumption, LRT is seven times more energy-efficient than private cars. LRT produces no emissions at street level in sensitive areas and therefore contributes significantly to localised air quality improvement. Its low levels of atmospheric emissions compared to automotive and air transport, widespread use of electric traction, low energy consumption, relatively small land use of its infrastructure, make LRT amongst the most sustainable transport modes.

LRT enjoys significant support from travelling public throughout Europe as it proved to be clean, silent and space efficient. Its ability to smoothly and quickly access town and city centres, together with its effectiveness in swiftly and comfortably moving large volumes of people and goods over long distances make LRT one of the most efficient modes of transportation.

Furthermore, LRT is six times safer than car transportation, and it is also effective in reducing the number of traffic accidents: when a new line or system starts service, cities observe a decrease in private traffic. This decrease in private traffic reveals the higher attractiveness of LRT services

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compared to other private transport modes, such as cars.

As these figures show, small railways do certainly not play a small role in the sustainability of European cities but rather are a key player in public transportation.

5.11. Appendix

5.11.1. New LRT infrastructure in Europe

PLACE	COUNTRY	DESCRIPTION	TYPE	PHASE	LENGTH (KM)	TOTAL (COUNTRY)
Innsbruck	Austria	Line 2 (East ext) : Stadt - Olympisches Dorf	extension	op	4,3	
Innsbruck	Austria	Line 5: Schützenstrasse - Rum	extension	constr	1,2	7,7
Innsbruck	Austria	Line 5: Technik West - Völs	extension	constr	2,2	
Brussels	Belgium	Route 9: arbre ballon - Roi Baudouin	extension	constr		0
Aarhus	Denmark	Grenaa - Aahrus	conversion	op	69	
Aarhus	Denmark	Lisbjerg on Line 2 - Lystrup on Grenaa line	conversion	op	5	74
Odense	Denmark	Phase 1: Tarup - DSB station - Hjallese	new	constr	14,7	
Tampere	Finland	LRT phase 1 A Lentävänniemi - Hervanta LRTB Pyyniktori - University hospital	new	constr	15	15
Angers	France	Line 2: Belle beille - patton - Montaigne - Monplaisir	new	constr	10,1	
Avignon	France	Line B: St Roch - St-Chamand	new	test	5,4	
Bordeaux	France	Line C ext Sud: Vacla Havel - Pyrénées	extension	op	1,4	
Bordeaux	France	Line D: Quinconces - Medoc	new	constr	1,5	
Bordeaux	France	Line D: Le Bouscat - Brugge - Eysines	extension	constr	8,5	
Caen	France	Line 1 (replace TVR) Hérouville - Ifs Jean Vilar	conversion	op	16,8	
Grenoble	France	Line A extenion to pont de Claix	extension	constr	0,9	92,5
Lyon	France	T6: Debourg - Gerland (rocade)	new	constr	7	
Nice	France	Line 3: Arenas - aeroport - St isidore	new	constr	3,7	
Paris	France	T4: branch to Clichy-Montfermeil	extension	constr	6,5	
Paris	France	T9: Porte de Choisy - Orly ville	new	constr	10,3	
Paris	France	T13: Tangentielle Ouest (ph1) : St Germain - Saint Cyr l'Ecole	new	constr	18,8	
Saint Etienne	France	Line 3: Château Creux - La terrasse	new	constr		
Strasbourg	France	Line E Robertsau	extension	op	1,6	
Berlin	Germany	Mahlsdorf Süd - S-Bahnhof Mahlsdorf	extension	constr	2,9	
Bochum	Germany	Route 310: Langendreer Bhf - Witten	extension	constr	3	
Chemnitz	Germany	Stollberg to Oelsnitz (Stage 5)	extension	constr	3,5	
Freiburg	Germany	Werder - Rotteckring	extension	op	2,2	19,3
Freiburg	Germany	L4 : Universität Freiburg - Neue Messe	extension	constr	1	
Karlsruhe	Germany	T-shaped, north - south and east - west tram subway under Kaiserstrasse and Karl-Frie	conversion	constr	3,6	
Stuttgart	Germany	U6: Fasanenhof-Ost - Airport	extension	constr	3,1	

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6. Deliverable D 3.1.3 - Freight and Logistics data set collection

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Tardivo, Carrillo Zanuy	EURNEX	Final edition and conclusions

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6.1. Executive Summary

The purpose of this report is to represent the European rail situation and the relevant dynamics regarding freight and logistics.

Logistics is vital for understanding market conditions where different solutions and modes compete for satisfying market demand. Logistics favours increased potential because of continuous innovation dynamics characterised by several elements. Outsourcing penetration with the growing role of international Logistics Operators (such as 4PLs, 5PLs) and increased support by available ICT technology, stimulate the rail growing potential in industries and distribution. As such, the market capabilities of integrated rail services in logistic systems should increase. Moreover, barriers to the modal shift of traffic flows using road should reduce due to environmental considerations. Social evolutions like drivers shortage and environmental considerations are significantly contributing to this projection.

Despite the main elements of the rail ecosystem show little modifications throughout the considered time frame from 2000 up to 2019 it is possible to imagine for rail a more significant potential improving its role in a modern co-modal freight mobility system considerably. In 2017, rail connections from the EU to the intercontinental flows accounted for only 3.8% of total import and export tons. Still, the new Eastern overland traffic looks promising on the eve of the Silk Road initiatives. These are enormous driving innovations, much more significant than the "simple" growth in quantities.

Infra EU traffic constitutes for rail a significant chance for increasing its share, which currently is well below the "2011 White Book" target. Looking at transport performances in the period 2000-2017, the cumulated growth in terms of ton*km has been 3.6%, while the overall transport growth has been 14.9%. Nevertheless, some indicators (inland mode in ton) in most recent years, show slightly better rail performances.

The most significant market segmentation is operated according to service production scheme:

- Intermodal units show robust constant growth and appear in the best position to continue this performance if well supported;
- Full/block trains (excluding intermodal trains) and Single Wagons Loads appear to require attention to revitalise their role. Projects with specific focus have been carried out to exploit this currently unexpressed potential.

As the rail freight industrialisation is paramount for any development ambition, several considerations potentially contributing to future rail success are deeply investigated in the document:

- The potential of longer and heavier trains is mentioned as the first point contributing to upgrade the rail ecosystem. Trains of Marathon FP7 project (to be elaborated in the TER4RAIL case study dedicated to freight) demonstrated the operational feasibility, with 30% costs saving, 5% energy saving and more than 40% capacity saving per ton

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transported which is a massive capacity generation. These improvements lengthen the life of the existing infrastructure substantially, avoiding new investments in new tracks, which in any case have a very long time to market. The train length, after the investments currently in progress, is going be aligned to 750m in most of the EU countries, while the target up to 1.500m seems possible.

- Equally tests for using High-Speed Trains for the same-day-delivery growing market represent a positive signal as theorised by the SPECTRUM project for HVLDG.
- When accurately evaluating cost competitiveness, distance is the traditional and the most critical variable. Rail transport is generally considered effective on distances not lower than 300 km and extremely competitive on trips longer than 900 km. However, in all distance segments there are significant opportunities, particularly in traffics to and from seaports where scale economy already exists, as well as in mass transportation for commodities and raw materials.
- Service upgrading must be pursued. The service is the first selection criteria in the comparison with the road door-to-door, which is faster, more flexible and reliable. Even when short lead-time does not represent a constraint, the service reliability is prevailing.

Other elements addressed in the report Include liberalisation, rolling stock, infrastructure, ICT technologies. All these elements represent evolutions in place with significant potential.

The liberalisation process, which started in Europe around the year 2007, is continuing. While the incumbents are still the major players in most countries, "liberalisation" has progressed, providing the customers with alternative choices and more value-added services. This process will continue in the future, forcing the incumbents to improve their performances to avoid a decrease in their traffic flows. An essential aspect of the market development offering is the growth and the international consolidation of major incumbents. Although the incumbents are playing an essential role in these aggregations, private operators contributed to the creation of an own international network. The consolidation process is continuing.

Rolling stock is another important asset and wagons ownership, in particular, is a standard marketing tool for those companies owning them. As such, wagons availability is a crucial element for managing current traffic flows efficiently and for developing new ones. The rail wagons stock figures show massive reductions. When interpreting these statistics, redundancies and obsolescence have to be taken into account. While the efficient wagons constitute only part of the rolling stock, with the availability shortage as a consequence of progressive equipment specialisation, significant quantities of wagons remain unused and/or under-maintained. The wagons' fleet reduction is also linked to the fact that it becomes economically obsolete compared with new, more efficient polyvalent wagons. To encourage the purchase of new equipment or retrofitting existing ones, initiatives are in place in some European countries.

The infrastructure network, with focus on the Core Network, is progressing its path towards the full operability in 2030. Within the Core Network, Freight Corridors according to the principle of The Regulation (EU) No. 913/2010 have been defined by linking the main industrial and port

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regions in Europe. Looking at freight corridors KPIs, capacity seems still "largely" available, with the exception of specific bottlenecks, urban bypasses, port connections and technical features such as wagons profile and train length.

While it is not a "direct" player, Information and Communication Technology (ICT) presence is omnipresent in the rail freight industry as a critical enabler towards a higher service level and industrialisation. The most relevant aspects of its role and potential contribution to progress are:

- Setting up new solutions and business models (including governance model, data property, connections to users, transactions, control, management);
- Supporting innovative players' categories and resources;
- Integrating management processes;
- Incorporating new Technology SW and toolkits (AI, Block-chain, IoT, PI, Tech Boxes and others).

Dealing with constraints, it may be useful to distinguish "hard", and "soft" barriers since their overcoming may have different investment requirements, technical limitations and time to market. Infrastructure and rolling stock are in the "hard" cluster while operations - both on the RU and the IM field - may be predominantly in the "soft" cluster. ICT may have a more significant role in the "soft" dimensions with relatively limited investments and shorter lead times. The generation gap is an issue in the rail system since the challenge is represented by the new fast disrupting technologies to be applied to a business model "old" by definition. The resistance to change is a considerable issue to be tackled. A new generation of workers and managers, replacing the significant number of retiring people, will be more open to operational and market changes.

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6.2. Introduction

The adopted methodology takes advantage of browsing several sources such as statistics, studies, researches, scientific articles and publications. Even if they are not necessarily all aligned in terms of observed time and scope or variables definitions, they are useful for supporting the understanding of the elements to be assembled. In some cases, especially for one-time studies, the coherence among different reports is not guaranteed. In these situations, the most generally accepted results are reported with the addition of specific notes.

The comprehensive and systematic databases representing the freight and logistics environment coherent with the objective of this study are not available since a big part of the traffic remains within the individual countries and statistics usually separates domestic (within the country) and international data flows. The EU interpretation of "internal market" is yet to be consolidated. Therefore, many pieces of available information and statistics represent the European Union as a sum of individual countries. The examples are elaborated in the following pages. Nevertheless, many efforts continue to be dedicated by the European institutions to the selection of meaningful data for achieving knowledge completeness. Due to the aggregation and the complexity of interpreting such data, the progress is not as fast as desired.

Individual snapshots originating from magazines and newspapers articles are also included, especially when providing information on emerging evolutions. For the same reasons, a certain number of items may not be fully supported by data. To find appropriate data in the rail ecosystem is, in some cases, remarkably challenging. For example, statistics about the traffic composition of full trains and wagonloads are available only for some countries, and some weaknesses are extremely difficult to be described with quantitative elements.

In this report, the sources, when known and available together with the year of publication and/or year of figures, are shown.

The evaluations trends consider the period from the year 2000 onwards when data are available. The time series are reported so the reader can add his/her own considerations.

The emerging rail freight picture, data-driven, follows multiple perspectives interpreting dynamics and supporting logical projections when looking at the future.

Significant areas of analysis are:

- service production scheme, including intermodal trains, with full trains and wagonloads
- service demand categories qualified by distance and product
- issues and opportunities related to industrialization processes
- territory situations by country, core/extended network and nodal infrastructures
- technology progression especially in ICT and wagons

The EUROPEAN COMMISSION and SHIFT2RAIL project researches are considered as preferred sources and quoted as applicable.

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6.3. Logistics and relevance of transport on logistics costs

6.3.1. Logistics concept definition and limit

The companies apply different definitions of logistics costs. For instance, some companies do not account interest and depreciation on inventories as logistics costs. Others include the distribution costs of their suppliers or the purchasing costs. Some differences depend on the outsourcing or insourcing model. Besides, duties or other costs are sometimes included. The transport costs in particular, also depending on the incoterms delivery conditions, can be partially included in the overall cost of the product or sales costs.

Logistics as an industrial discipline was born in the second half of the last century. Efforts in defining its components were developed by the end of the last century up to the beginning of the current one. Periodical studies and surveys for monitoring logistics cost incidence on companies' turnover, private consultants' interventions, focus dedicated to national and international Supply Chains together with other researches contributed to this evolution process. Because of the different definitions adopted in all the various researches produced over the years, these trends can be understood observing different editions of the same source, such as, for instance AT Kearney and Cap Gemini among the most valuable.

The cost dynamics of AT Kearney series of surveys in Europe shows, since the beginning of the current century's first decade, a progressive increase in transport costs after a significant reduction during the previous years. In addition, the other logistics costs, according to this source, show an increase in the same period, with the only exception of administrative activities.

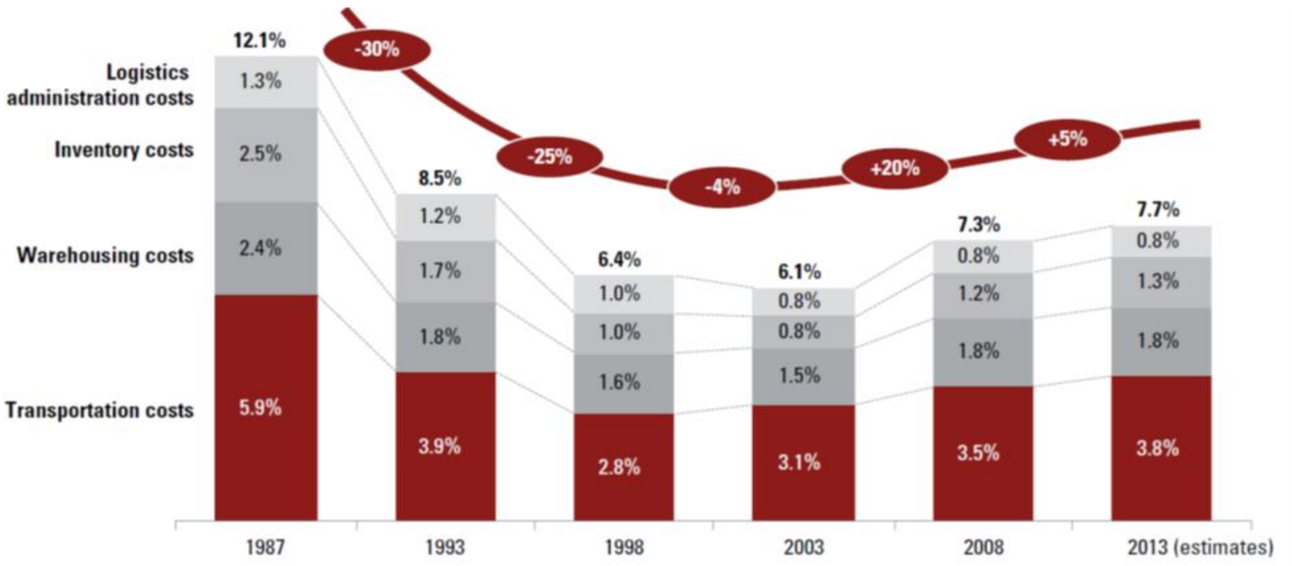

Figure 1: Logistics cost as % of sales of European Companies – Source: Supply chain excellence amidst the global economic crisis, A.T. Kearney, 2009

The progressive specific qualification as logistics cost of elements which before were mixed in the product cost (such as inbound transport included in material manufacturing or

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financial/administrative cost such as the interest for inventory included in financial expenses) explains part of this apparent growth. Other comments follow the dynamics that are the result of combined elements.

Therefore, after recognizing that there is not a general definition useful for all situations, the prevailing principle is that every corporation identifies its own logistics costs and its own KPI's to control them.

Several factors continue to play a significant role in the Supply chain evolution having different impacts on the prevailing models in the industry.

Looking at the last 1-2 decades, relevant examples can be the following:

- different cost trends of resources segmented in labour, energy, space, money, encouraging different trade-offs decisions;
- applied technologies in process automation enabling upgrading both in terms of planning and execution;
- general growth of service requirements including the increased competition on service performances due to continuous supply chain complexities and sophistication;
- restructuring of value chain impacting on manufacturing decision such as offshoring or nearshoring and distribution networks such as primary/factory warehouses and secondary/proximity/distribution warehouses;
- postponement of manufacturing with customized final product qualification in the distribution phase such as assembling and packaging or plug adaptation of electric/electronic appliances, promotional assembly/ campaign for consumer goods;
- trade evolutions for both sourcing and selling concerning geography expansion;
- channels evolutions concerning e-commerce up to omnichannel principles.

The next picture shows the dynamics of unit cost of resources for logistics activities in Italy, after the 2008/09 crisis, just as an example of their order of magnitude. Of course, such dynamics is Country-specific since figures of other countries might be different: fuel and energy had similar pattern in other EU countries; labour costs of employees and not employees had specific increases in Italy due to new regulations aiming at overcoming past gaps; space varied on local market conditions; money had relatively lower differences. According to such dynamics, the mix of resources in Italy has been modified implying: higher automation after the technological progress and the lower cost of money; shift of people from not employees (external) to employees due to new regulations impacting on cost while reducing social risk (strikes).

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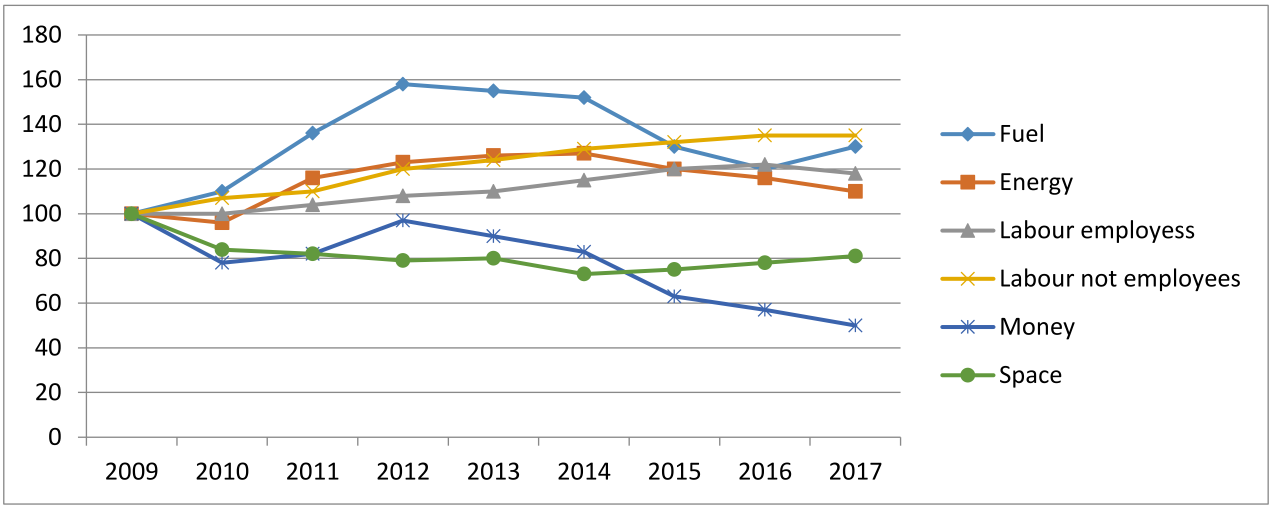

Figure 2: Cost of resources for logistics activities - Source: NewOpera re-elaboration on data from Osservatorio Contract Logistics – Politecnico Milano, November 2018

6.3.2. Logistics cost and transportation cost

The evolutions mentioned above had impacts on overall logistics cost increase and significantly on transportation.

Examples of transportation cost increase:

- In the last decades of the last century up to the initial decade of the current one, the Just In Time (JIT) philosophy had the objective of minimizing inventories. Inventory remains in production pipeline as upstream as possible, and goods move directly to users just when required with faster deliveries, in quantity needed with almost "no" constraints of minimum order quantity which is a basic parameter of unit load and transport cost.
- More recently, e-commerce increased the fragmentation of flows from both sources and destinations. In particular, the explosion of last-mile requirements implied volume shift to express couriers' deliveries as an extension of the transportation network, specialized for managing small shipments in large quantities at high speed. As a result, the need for ancillary services and returned products implying appointments, communications, installations, additional handling and transport contribute to increasing the cost incidence.

While the market peculiarities shown above justified the cost increase, the efficiency improvements - "doing better the operation" - contributed in the opposite direction to reduce costs. Overall in the picture of logistics costs, transportation remains the first item in terms of incidence on sales and is likely to remain the most frequent growing part of the overall logistics cost projection.

Despite the effort to monitor logistics cost as a general indicator of the efficiency, the industrial

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sectors showed weaknesses in adapting this KPI to several significant transformations. Numerous industries are pursuing the specialization of their manufacturing footprint on a European basis as well as implementing delocalization and outsourcing of manufacturing phases. These evolutions, while changing the industrial footprint, modify the structure of both the sourcing and the distribution flows. Trade-offs of cost components are not only between "logistics" but also between elements of the entire value chain. For these reasons, often, in the effort of keeping in a single frame the entire systemic evolution, instead of "logistics", the scope becomes the "supply chain" or the "operations" within the overall "value chain". In many instances in the decision-making, the production component is predominant having the prime objective of reducing the fixed costs of labour and investments, leaving the analysis of the entire supply chain costs to a successive evaluation. This tends to explain the reasons why some companies (according to their structure and sector of competence) have started to re-shore against excessive complexities in managing extended supply chains, quality products issues, mounting transportation costs and a long time to replenish market needs.

Therefore, there is not simple monitoring of such complex transformations, not in a wide logistics perspective and not even in a more specific transportation view. For this reason, there is not a real transparent perception of the transport cost of a given industry supply chain from sources to consumers. Also reverse logistics components must be included even if only for specific product categories such as automotive, fashion, electric and electronic appliances where they can be separately identified.

Downstream and upstream transport [18]

The picture below shows one of the few examples of evaluating transport costs of exemplary product categories in their entire flow. The analysis segments the cost in "downstream", including the cost of the finished product manufacturer and the retailer in the traditional channels, and "upstream", including the cost from sources and the one of the components' manufacturer. The downstream is by far the biggest for several reasons.

The upstream transport includes in prevalence:

- bulk transport in large scale and sometimes with specialized solutions such as up to pipeline for oil and chemicals
- unitized transport and handling for semi-finished and finished products leveraging unit load solutions such as containers and pallets using competitive cost modes such as sea, rail, air, road in an industrial scale.

For these modes continuous improvement process are ongoing, also supported by EU research (practical examples are e-procurement and subsequent initiatives expanding and implementing these principles, scale factor for sea transport or automation of unit load loading and handling).

The downstream is operated almost exclusively in the exemplary product categories with road

[18] **Upstream** production refers to the activities required to create a finished product. The **downstream** stage includes elements such as distribution, wholesaling and retailing.

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transport including

- full truck load - FTL especially within companies' distribution networks (for instance between plants and warehouses or OEM components for the automotive industry) and to major customers' facilities (for instance distribution centres for consumers products, groceries, beverages, domestic appliances, consumers electronics);
- less than truck load – LTL especially for final distribution segments including the different models as groupage, milk run, etc.; in such cases in prevalence small trucks are needed with much higher costs;
- city logistics and urban distribution, which is a sector in significant evolution due to internet business to consumers.

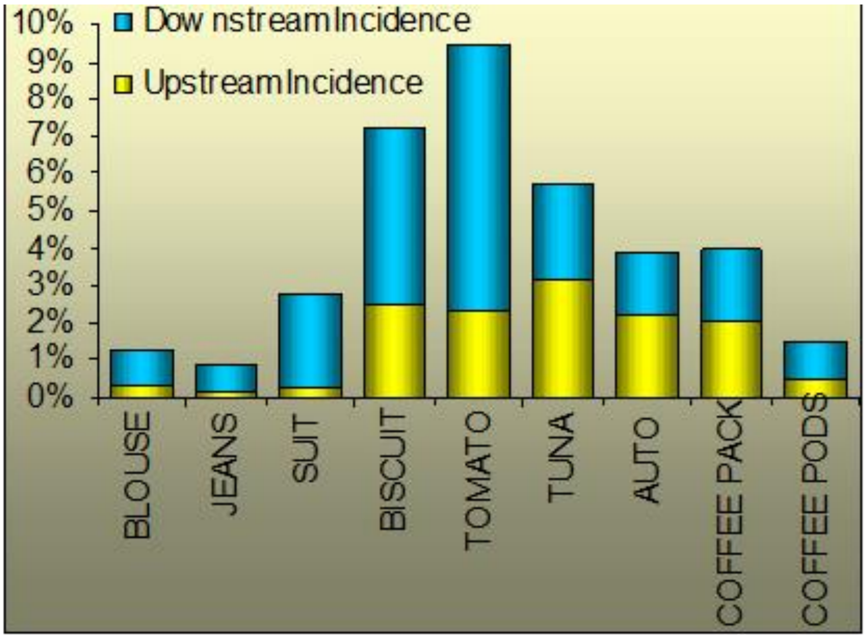

Figure 3: Incidence of transport upstream and downstream cost on the final prices of exemplary goods – Source: ECOTRA energy use and Cost in freight Transport chains – by TRT, 2006

The downstream is intrinsically more expensive. As mentioned, the road is the largely prevalent mode with some limited share of the air.

6.3.3. The service dimension

Like logistics also the service itself has not only "one" definition. Different sets of KPIs are in existence.

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World Bank reports are good references for understanding service and the evolution of the observed elements. The quality of logistics performance of the World Bank shows Country differences even if most of the market presents qualified "Offer" facing qualified "Demand". Most of the players, from both sides representing Demand and Offer, even if belonging to global groups, still act with the country approach. Nevertheless, strategies and operational setting tend progressively to be harmonized at least for country clusters. This evolution is not a fast one.

2018	overall LPI rank	overall LPI score	Customs	Infrastructure	International shipments	Logistics quality and competence	Tracking and tracing	Timeliness
Country	rank	score	score	score	score	score	score	score
Germany	1	4,20	4,09	4,37	3,86	4,31	4,24	4,39
Sweden	2	4,05	4,05	4,24	3,92	3,98	3,88	4,28
Belgium	3	4,04	3,66	3,98	3,99	4,13	4,05	4,41
Austria	4	4,03	3,71	4,18	3,88	4,08	4,09	4,25
Netherlands	6	4,02	3,92	4,21	3,68	4,09	4,02	4,25
Denmark	8	3,99	3,92	3,96	3,53	4,01	4,18	4,41
United Kingdom	9	3,99	3,77	4,03	3,67	4,05	4,11	4,33
France	16	3,84	3,59	4,00	3,55	3,84	4,00	4,15
Spain	17	3,83	3,62	3,84	3,83	3,80	3,83	4,06
Italy	19	3,74	3,47	3,85	3,51	3,66	3,85	4,13
Norway	21	3,70	3,52	3,69	3,43	3,69	3,94	3,94
Czech Republic	22	3,68	3,29	3,46	3,75	3,72	3,70	4,13
Portugal	23	3,64	3,17	3,25	3,83	3,71	3,72	4,13
Luxembourg	24	3,63	3,53	3,63	3,37	3,76	3,61	3,90
Poland	28	3,54	3,25	3,21	3,68	3,58	3,51	3,95
Ireland	29	3,51	3,36	3,29	3,42	3,60	3,62	3,76
Hungary	31	3,42	3,35	3,27	3,22	3,21	3,67	3,79
Slovenia	35	3,31	3,42	3,26	3,19	3,05	3,27	3,70
Estonia	36	3,31	3,32	3,10	3,26	3,15	3,21	3,80
Greece	42	3,20	2,84	3,17	3,30	3,06	3,18	3,66
Cyprus	45	3,15	3,05	2,89	3,15	3,00	3,15	3,62
Romania	48	3,12	2,58	2,91	3,18	3,07	3,26	3,68
Croatia	49	3,10	2,98	3,01	2,93	3,10	3,01	3,59
Bulgaria	52	3,03	2,94	2,76	3,23	2,88	3,02	3,31
Slovak Republic	53	3,03	2,79	3,00	3,10	3,14	2,99	3,14
Lithuania	54	3,02	2,85	2,73	2,79	2,96	3,12	3,65
Malta	69	2,81	2,70	2,90	2,70	2,80	2,80	3,01
Latvia	70	2,81	2,80	2,98	2,74	2,69	2,79	2,88

Figure 4: Logistics performance index 2018 – selection of only EU countries - Source: World Bank, 2018[19]

6.3.4. The logistics cost and the GDP

For the complex reasons discussed above and due to the business fragmentation, the evaluations of logistics cost in macroeconomic perspective shows weaknesses and lack of reliable data. Therefore, the need to overcome this weakness justifies the effort of smart evaluations and tentative projections based on the available existing quantifications. This is unavoidable.

19 https://lpi.worldbank.org/international/scorecard/radar/254/C/DEU/2018/R/EAP/2018/R/ECA/2018/R/LAC/2018/R/MNA/2018/R/SAS/2018/R/SSA/2018?featured=17

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Therefore, taking into account the above observations, a summary can be found in the following EU Commission statement: "Transport plays an important role in today's economy and society and has a large impact on growth and employment. The transport industry directly employs around 10 million people and accounts for about 5% of gross domestic product (GDP). Effective transport systems are fundamental for the European companies' ability to compete in the world economy. Logistics, such as transport and storage, account for 10–15% of the cost of a finished product for European companies"[20].

The incidence of logistics cost on GDP is estimated by EU sources around 7%[21] or up to 10%[22] .

While this topic is not properly under observation, "it is recommended that coherent and consistent monitoring of the logistics sector's performance is introduced. This would allow both companies and policymakers to follow the logistic sector's performance and monitor its behaviour. This is important when it comes to considering new policy options and actions"[23].

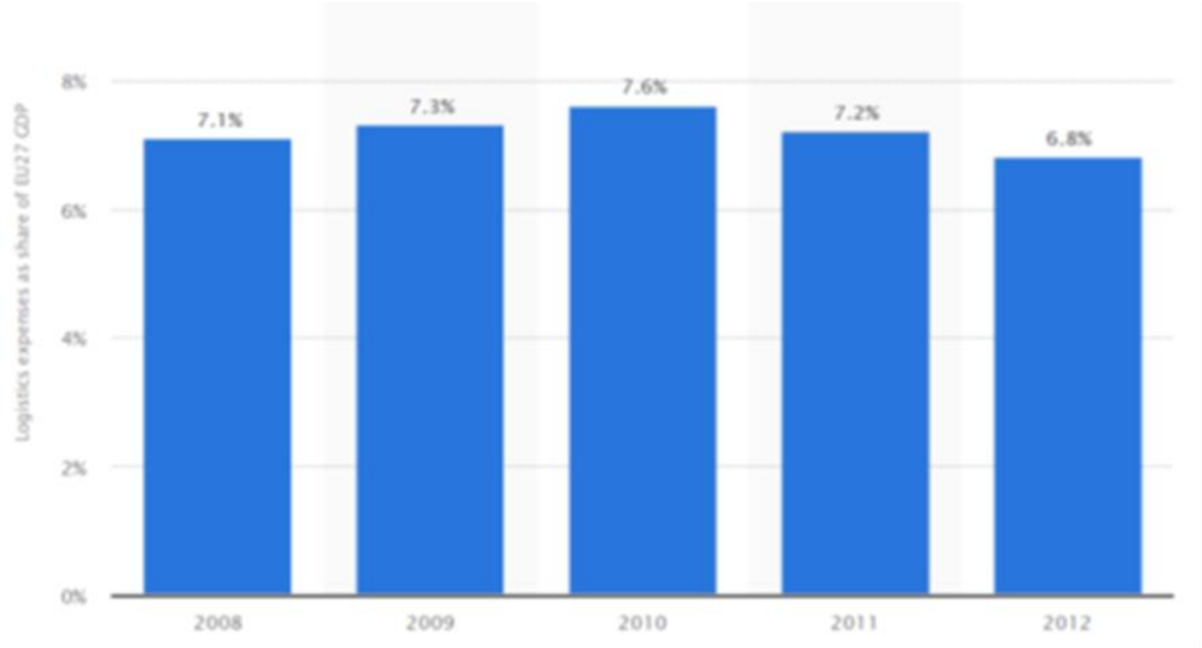

Figure 5: Total annual expenses of the EU27 countries in the logistics sector 2008-2012, as a percentage share of the EU27's GDP – Source: https://www.statista.com/statistics/429626/logistics-expenses-in-the-eu27/

To support the above evaluations, it is useful to mention that logistics cost on GDP in the US is estimated in the year 2016 at 7.5%[24]. In general, transport incidence on overall US logistics costs

[20] https://ec.europa.eu/jrc/en/research-topic/transport-sector-economic-analysis

[21] https://www.statista.com/statistics/429626/logistics-expenses-in-the-eu27/

[22] Savy M, Logistics as a political issue - 2016 - Transport Reviews, p. 413-417, https://doi.org/10.1080/01441647.2016.1182793

[23] Fact-finding studies in support of the development of an EU strategy for freight transport logistics – 2015

[24] State of Logistics Report - Accelerating into Uncertainty by A.T. Kearney in partnership with Council of Supply

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is estimated higher than in Europe.

Several emerging topics considered critical issues for today and even more for the immediate future are not in screens of logistics monitoring.

Some of the most important emerging topics are:

- Eco-friendly/sustainability - Efforts for controlling the energy consumption, the limitation of waste and the recovery of packing, the reduction of gas emissions and noise are in place, and most advanced companies already publish sustainability reports;
- Safety/security, including protection from cyber-attacks – also due to regulations measures are in place. For instance, individual steps of transport arrangements need to follow detailed instructions;
- Labour conditions – It is generally known that drivers' shortage is a problem in a number of Countries and that labour conditions in handling and warehousing operations are not always considered attractive;
- Operating standards – The lowering of operating standards is sometimes occurring when outsourcing is implemented only for cost reduction and not for improving efficiency and service effectiveness. In such cases, the presence of international specialised organisation could be a deterrent.

These issues are not part of the World Bank KPIs and not of any EU systematic monitoring.

While these topics are obviously well known, and efforts are being made for improving their knowledge, the integration of their impact in a systemic logistics approach seems not in place.

6.4. Outsourcing in transition to new models

6.4.1. Logistics outsourcing penetration and evolutions

A relevant aspect of logistics is that about half of it is managed in an outsourced model. In fact, about half of the companies' budget for logistics in Europe is paid to Logistics Operators. This trend started about 20 years ago with major producers shifting progressively a number of in-house operations to logistics service providers connected to them by direct ICT technologies making the outsources their virtual operating arm. This started a race towards more advanced forms of logistics services outsourcing in the quest to outsmart the competition. In addition to the Third Party Logistics 3PL in the market place started to become customary the 4PL with increased process involvement and, more recently, the 5PL with increased ICT role. Further sophistications of this scheme are not excluded, being a variation of the original outsourcing model with various specialization and specifications dictated by the industry requirements. Partnership agreements and open book transparent negotiations are examples.

Chain Management Professionals CSCMP and Penske Logistics – 2017-18

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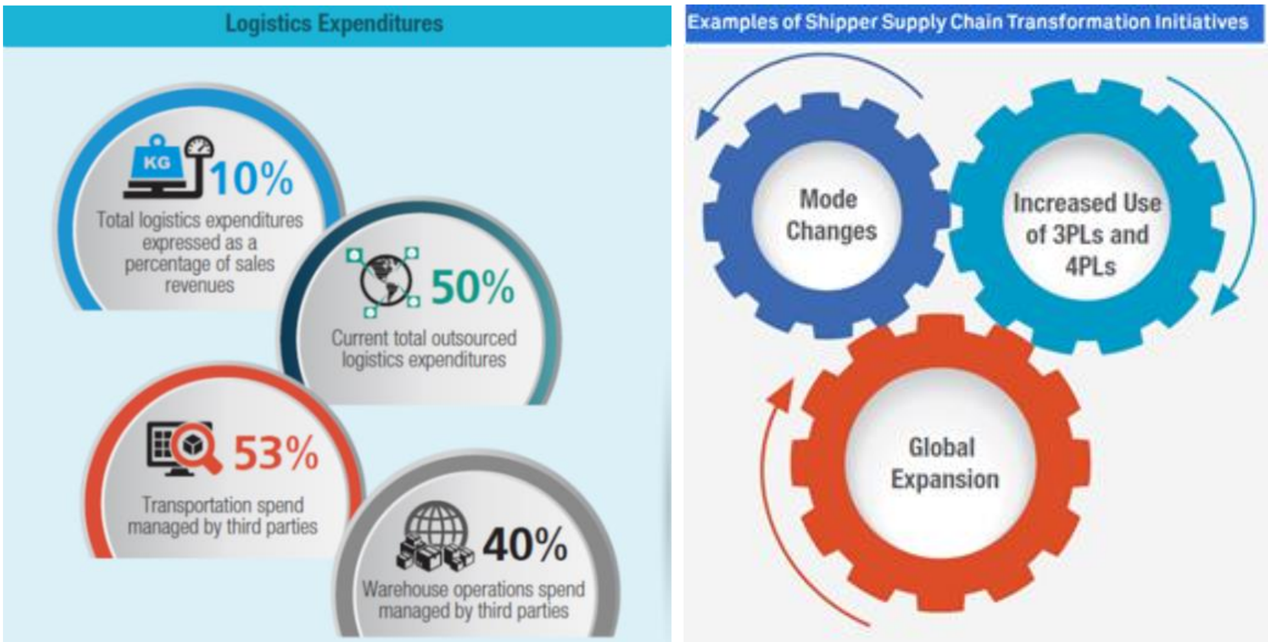

Figure 6: Logistics outsourcing – Source: 2017 Third-Party Logistics Study - The State of Logistics Outsourcing, CAPGEMINI Results and Findings of the 21st Annual Global Study

The penetration of outsourcing depends on the scope definition and by activity, geography and company size:

- By activity
    - Operations more process-related, like order processing and other administrative tasks, are in most cases carried out internally. Some warehousing is done with the insourcing model;
    - Transportation is usually outsourced but with significant differences. While local services are mostly insourced, long-distance services are mostly outsourced. International services in sea/air/rail modes are outsourced exception made for those corporations having their own dedicated business unit.
- By geography
    - Countries such as the United Kingdom and Germany, where big companies represent the industrial structure of the "Demand" and also the industrial structure of the "Offer" shows relative lower fragmentation, have a higher share of logistics outsourcing;
    - Countries such as Italy and Spain with the "Demand" represented by relatively smaller companies and the "Offer" highly fragmented, the outsourcing is at a less sophisticated phase, and logistics outsourcing has a relative lower share.
- By company size
    - Small companies tend to have process-related activities less segmented and also

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for this reason often manage them in house. Also, short-distance transport is in the main directly managed with own resources. Smaller companies not having an economy of scale volumes manage these processes as part of production or sales;

- Medium and big companies tend to be more structured and unless they have their own logistics business units, the outsourcing is more utilized.

Other differences may be due to the product life or production cycle

In e-commerce companies, the outsourcing penetration in order fulfilment is relatively lower especially in the early stages, while the transportation of parcels is "always" outsourced.

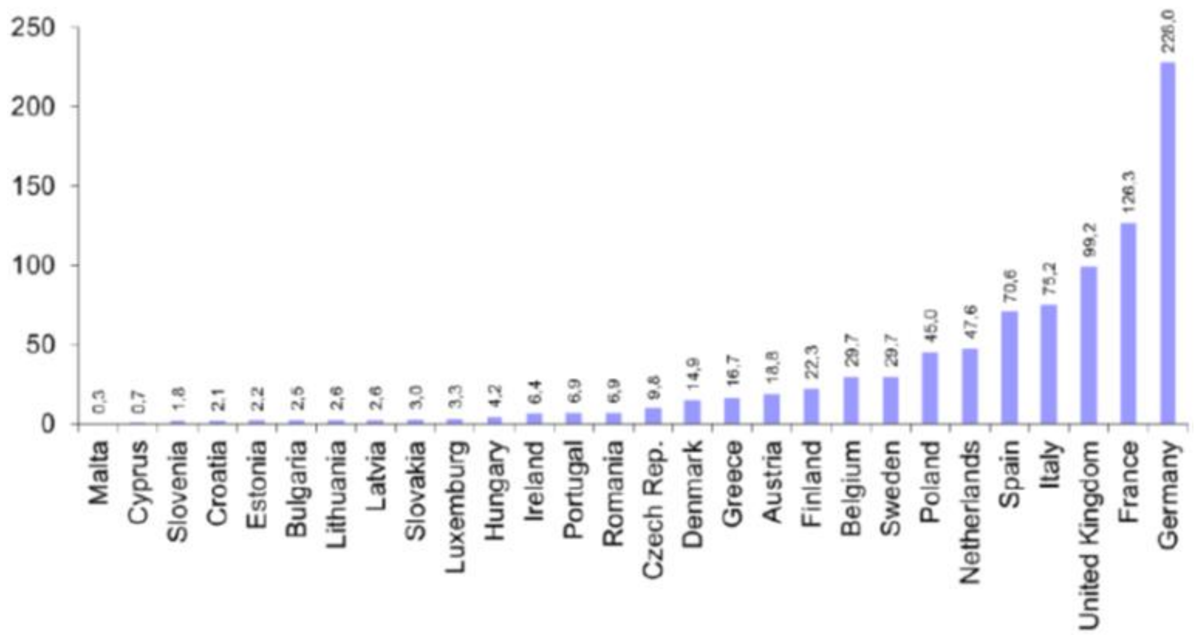

Figure 7: Logistics market size - data 2012 - Source: Fraunhofer SCS, 2015[25]

According to prevailing estimates, outsourcing in Europe shows "continue" growth.

In its normal evolution, outsourcing is slowly evolving:

- from the outsourcing of individual activities to several logistics operators
- to the outsourcing of clusters of activities to a few logistics operators.

In Italy, where a large observatory coordinated by Politecnico di Milano University publishes yearly market data, these two components are separately monitored. The first one is classified "commodity outsourcing", the second one "strategic outsourcing". The second one is

[25] https://ec.europa.eu/transport/sites/transport/files/themes/strategies/studies/doc/2015-01-freight-logistics-lot1-logistics-sector.pdf

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progressing faster with the growing role of the major players tending to reduce fragmentation of logistics operators.

Figure 8: Logistics market in Italy – Demand and Offer with evidence of outsourcing share – Source: Osservatorio Contract Logistics Politecnico Milano, 2018

There are no studies showing for multinational companies their preference for the same transport and logistics outsourcing organisation capable of providing services on a multinational basis. This could be important for corporations when they are exploring the entrance into new markets. The existing presence of business expertise in consolidated areas could facilitate commercial penetration and the establishment of successful business models.

International worldwide organisations specialised in outsourcing services are existing in sectors other than transport and logistics such as engineering, chemicals, automotive to mention few.

Because of the developments of outsourcing organisational models, the role of integration and decision-making for transportation is partially shifting from outsourcee to outsourcer. In parallel, as anticipated in the example of the well-monitored Italian market, the fragmentation of logistics operators is progressively reducing, and the market share of most qualified logistics operators is growing accordingly.

M&A, driven by leading operators, contributes to accelerating such evolution, reducing fragmentation and allowing the consolidation of several big European/global companies. This trend facilitates the growth of professionalisation and performances of the logistics service

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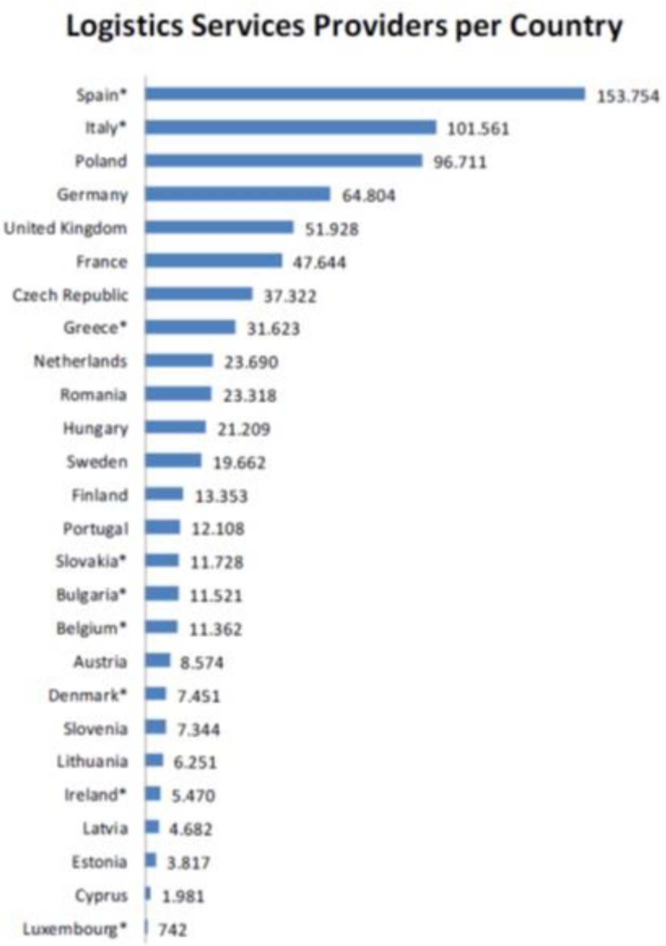
industry. The growth of professionalisation can be in the future a lever contributing to a more balanced co-modality. Nevertheless, the fragmentation of the logistics industry still shows important country differences.



	GDP in mln 2011	population in mln 2011	GDP per LSP in mln	population per LSP
Spain	1.046.327	46,8	6,8	304
Italy	1.579.946	61,0	15,6	601
Poland	370.851	38,4	3,8	397
Germany	2.609.900	81,5	40,3	1.257
United Kingdom	1.731.809	62,7	33,4	1.207
France	2.001.398	65,1	42,0	1.366
Czech Republic	155.486	10,2	4,2	273
Greece	208.532	10,8	6,6	340
Netherlands	599.047	16,7	25,3	703
Romania	131.478	21,9	5,6	939
Hungary	98.921	10,0	4,7	471
Sweden	385.451	9,1	19,6	462
Finland	188.744	5,3	14,1	394
Portugal	171.126	10,8	14,1	889
Slovakia	68.974	5,5	5,9	467
Bulgaria	38.505	7,1	3,3	615
Belgium	369.259	10,4	32,5	918
Austria	299.240	8,2	34,9	959
Denmark	240.487	5,5	32,3	742
Slovenia	36.150	2,0	4,9	272
Lithuania	30.959	3,5	5,0	566
Ireland	162.600	4,7	29,7	854
Latvia	20.211	2,2	4,3	470
Estonia	16.216	1,3	4,2	335
Cyprus	17.878	1,1	9,0	565
Luxembourg	41.730	0,5	56,2	674
Sum all	12.621.224	502		
Average			16,2	644

Figure **9: Number of logistics service providers per EU Member State in 2011 - Source: Eurostat, 2014 (all values for 2011; Malta/Croatia missing); population from Institut der deutschen Wirtschaft Köln26**

6.4.2. Potential new roles in digital model

Digitization is reshaping several industries and is going to change the logistics business.

The following picture summarizes contents of the study from the "2016 logistics study on digital business models" from Roland Berger Strategy Consultants[27].

[26] https://ec.europa.eu/transport/sites/transport/files/themes/s

[27] https://www.rolandberger.com/de/Publications/2016-logistics-study-on-digital-business-models-

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According to the mentioned study, there will be four types of surviving players in the logistics industry:

- Booking and Optimization Platforms (BOP) - they will take over today's standard forwarding business acting as intermediaries between customer and CTO.
- Carriers and Terminal Operators (CTO);
- Supply Chain Specialists (SCS) - they will manage complex logistics tasks that require specific industry knowledge or that cannot be standardized;
- Service Providers (SP) – they provide data, transactional, clearing, software and other services, which are enablers towards the digital evolution.

According to this scenario, the traditional forwarding business may lose most of the current volumes as shippers would directly approach carriers via a BOP for standard services. As a consequence, forwarders may become "asset oriented" and turn into a CTO or to become "service oriented" and turn into an SCS and/or an SP.

The study elaborates two other aspects to be mentioned:

- technology capabilities enhancements in various players, including shippers, will facilitate intermediate solutions with operational and strategic alliances between them, and
- collaboration capabilities will be enhanced in every direction as the digital evolution enables collaborative business models.

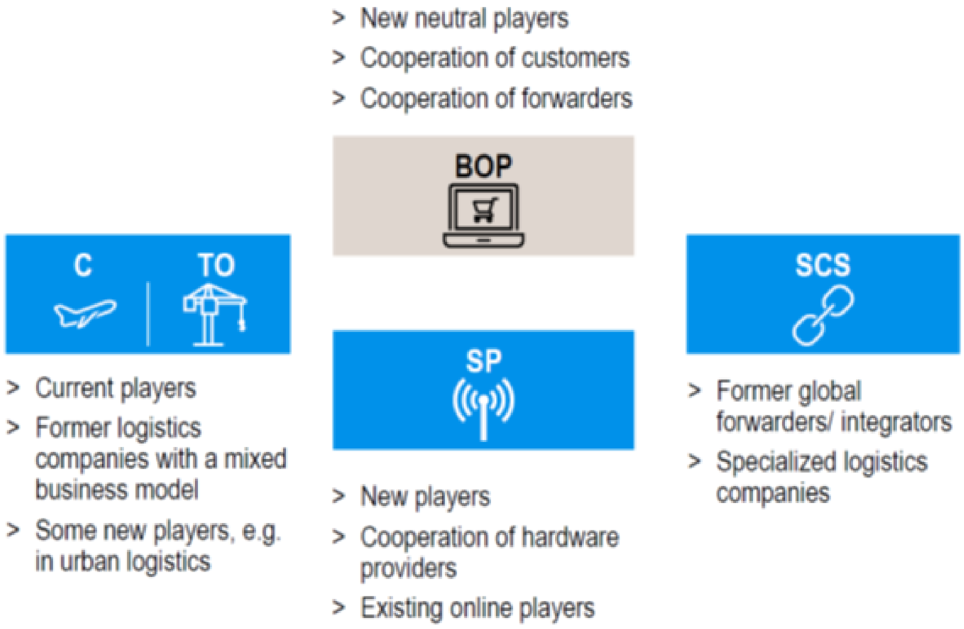

Figure 10: Logistics study on digital business models – Source: Roland Berger Strategy Consultants, October 2016

(Switzerland).html

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6.5. Role of rail in co-modal freight transport

6.5.1. Freight transport EU-other countries and rail in international traffic

Looking at the transport between the EU and the rest of the world (data 2017), the most significant share in tons is sea freight 75.7%. Pipelines follow at 11.6%. Airfreight, which is less important in terms of tons, is more relevant in terms of spending, accounting for 25.5%.

WEIGHT (MILLION TONNES)						
	EXPORT		IMPORT		EXPORT + IMPORT	
Sea	561.3	80.4%	1286.7	73.8%	1848.0	75.7%
Road	89.5	12.8%	72.6	4.2%	72.6	3.0%
Rail	19.2	2.8%	73.2	4.2%	92.4	3.8%
Inland waterway	7.0	1.0%	13.2	0.8%	20.1	0.8%
Pipeline	4.6	0.7%	277.9	15.9%	282.5	11.6%
Air	15.6	2.2%	4.8	0.3%	20.4	0.8%
Self propulsion	0.5	0.1%	2.0	0.1%	2.5	0.1%
Post	0.0	0.0%	0.0	0.0%	0.0	0.0%
Unknown	0.6	0.1%	12.7	0.7%	13.4	0.5%
TOTAL	698.4	100.0%	1743.1	100.0%	2441.5	100.0%

Figure 11: External trade by mode of transport – Source: Publications Office of the European Union - STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

Rail freight transport performance by type of transport (national, international loading/unloading and transit) in total tonne-kilometres performed is shown in Figure 12.

"The share of international transport in various countries is strongly linked to their geographical position within Europe. For the EU-28 as a whole, the share of international loadings could be estimated at almost 16 % in 2017, international unloading at 22 %, transit at 12 % and national at 50 %.

The Member States registering the highest share of international transport are located in key corridors within the European market. In the Baltic States of Latvia and Estonia, situated at the border between the EU and Russia, international unloading accounted for 86 % and 62 % of the total transport performance in 2017, respectively. The Netherlands, strategically situated in the heart of the European market, registered a share of international loadings of 61 % in total ton/Km performed. The key import port of Rotterdam, with large sea/rail transfers of goods dispatched within the European Union, strongly influence these figures. By contrast, countries with specific geographical characteristics (at the periphery of the European Union or islands) recorded a low share of international transport by rail. Small shares are observed for the United Kingdom (3 %) and Denmark (11 %). For such countries, the preferred mode for international freight transport remains maritime transport, goods being delivered at the nearest port to the point of their destination and then being forwarded in the country mainly by road, but also by rail (accounted as national transport)"[28].

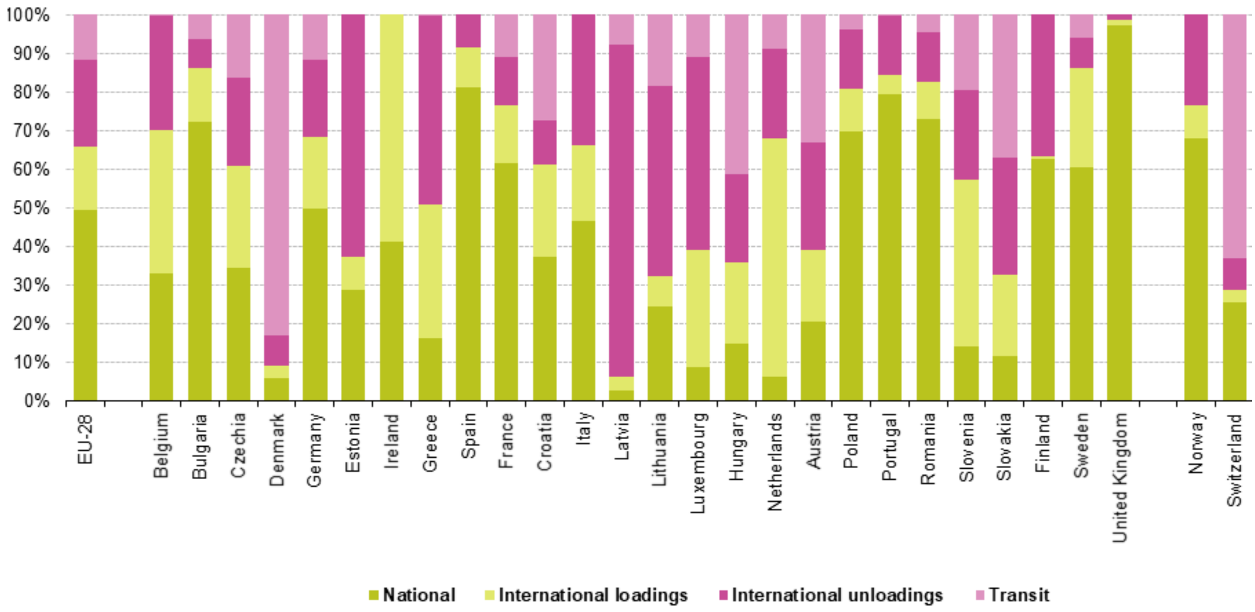

Figure 12: Rail freight transport by type of transport for main undertakings, 2017 (% on total tonne-kilometres). - Source: Eurostat

In the past years, some limited fluctuations can be observed; however, it is challenging to identify significant changes.

Looking at the future, progressive adjustments in the coming years will modify this picture due to new rail connections and pipelines with eastern countries.

In particular, rail services to and from China/Asia are already eroding the share of traditional sea-containerised traffic. Mainland China represents a substantial potential market for the Silk and Road rail connection. Due both to the long road distances from the interior to the Chinese sea-ports and the road haulage in costs and timing, the direct rail services to Europe become attractive given also the much faster transit time. In fact, the total transit time Origin-Destination (OD) from China to Europe is 14 to 19 days. By sea, it takes 23 to 43 days depending on destinations. The transport of goods by rail from Europe to the Western and Central part of China (to megacities such as Chongquing and Chengdu) are competitive also in terms of costs.

[28] https://ec.europa.eu/eurostat/statistics-explained/index.php/Railway_freight_transport_statistics#Geographical_location_plays_a_key_role_in_the_share_of_international_transport

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The table below reflects a calculation exercise made by the University of Antwerp in 2017[29], that analysed the transport cost of a TEU from different Chinese locations to Munich, utilising three different routes:

- maritime via Hamburg (current route)
- maritime via Trieste/Koper (new maritime route)
- rail connection (land-based route)

The table shows that from Chengdu and Chongquing to Munich, the use of rail is competitive. This is due to the fact that the two cities (respectively 14 and 30 million inhabitants) are far from the coast. For other cities, that are closer to the sea, the sea connection via Trieste/Koper is more convenient than the current maritime connection via Hamburg.

	Cost		
	Current route	**New Maritime Route**	**Land based route**
Origin	[EUR/TEU]	[EUR/TEU]	[EUR/TEU]
Chengdu	3,288	2,917	2,318
Chongqing	2,500	2,150	2,000
Wuhan	1,905	1,535	2,245
Guiyang	2,923	2,488	6,906
Hong Kong	1,559	1,180	7,615
Shanghai	1,676	1,306	7,419
Hangzhou	1,625	1,254	2,920

Figure 13: Transport cost of a TEU from different Chinese locations to Munich – Source: T. Vanelslander, "One Belt One Road: user opportunities through chain cost calculations", Antwerp University, Department of Transport and Regional Economics, 2017

The picture below shows the evolution of rail freight (in TEUs) in 2011, 2016 and 2017 from EU to China. Even if rail is still far from reaching the numbers of deep-sea, a considerable increase can be observed. The aim is to reach 1 million TEUs by 2025[30].

[29] T. Vanelslander, "One Belt One Road: user opportunities through chain cost calculations", Antwerp University, Department of Transport and Regional Economics, 2017

[30] "Key Corridors, Main terminals and train features in the Silk Road Railway Network" Conference, FERRMED, November 2017

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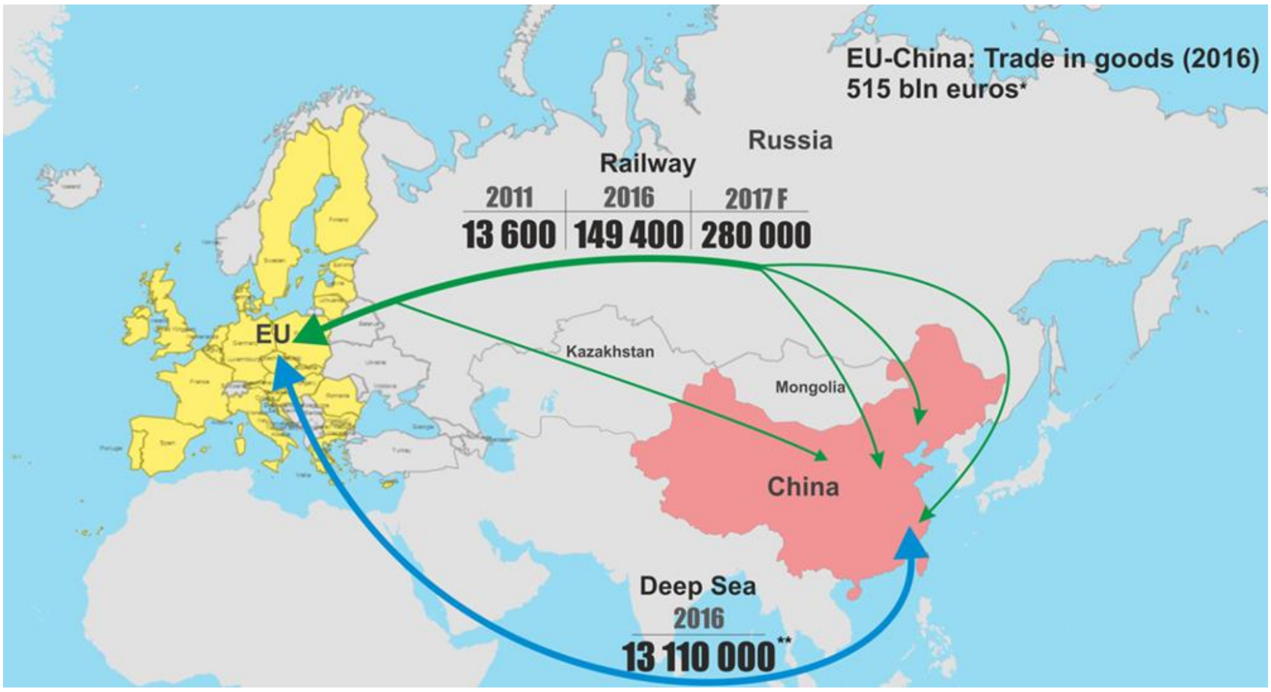

Figure 14: EU-China trade in goods (rail-deep sea) in 2016 (in TEUs) – Source: FERRMED, November 2017, re-elaboration on Eurostat 2017 database

In addition, rail services to and from China/Asia are already eroding the share of traditional air services targeting cargoes with an intermediate level of urgency. The same applies to the sea/air combinations involving Singapore and the Arabian Gulf Countries.

6.5.2. Modal split of EU freight transport

Transport growth is an integral part of EU economic growth. As such, freight transport measured as t/km, after the temporary slowdown for the crisis around 2009, continues its increase.

In 2017 total goods transport activities in the EU-28 are estimated to amount to 3.731 billion t/km. This figure includes intra-EU air and sea transport but not transport activities between the EU and the rest of the world.

Looking at transport performance in the period after the year 2000 the growth has been of 0.8% per year while, without the shock after the year 2009, the average growth would have been much higher.

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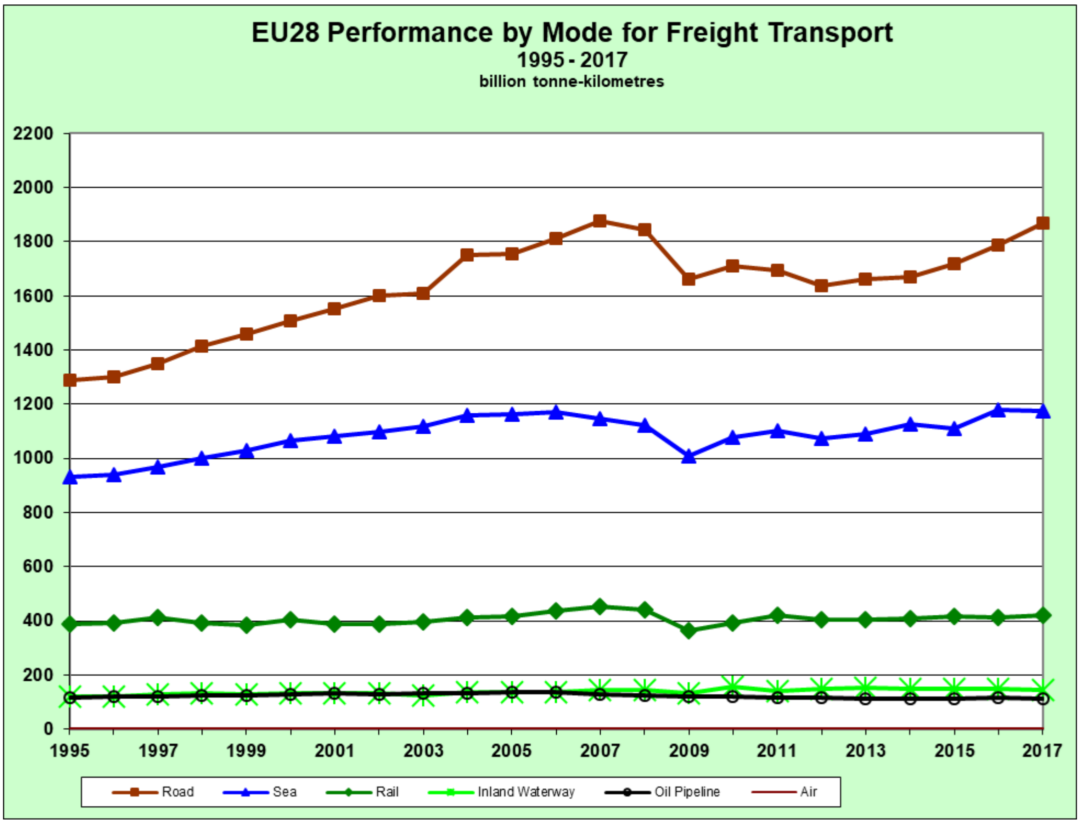

Figure 15: EU performance by mode of transport: - Source: Publications Office of the European Union - STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

billion tkm

	ROAD	RAIL	INLAND WATERWAYS	PIPELINES	SEA (*)	AIR	TOTAL
1995	1 289	388	122	115	930	2	2 846
2000	1 509	406	134	127	1 067	2	3 245
2005	1 755	416	139	138	1 161	2	3 611
2010	1 710	394	156	121	1 079	2	3 462
2011	1 699	422	142	118	1 104	2	3 488
2012	1 645	407	150	115	1 075	2	3 394
2013	1 671	407	153	112	1 089	2	3 434
2014	1 677	411	151	111	1 128	3	3 480
2015	1 720	415	147	114	1 110	3	3 510
2016	1 786	412	147	115	1 181	3	3 644
2017	1 870	421	147	114	1 176	3	3 731

Figure 16: EU performance by mode of transport in billion tkm: - Source: Publications Office of the European Union - STATISTICAL POCKET BOOK 2019 (data 2017)- EU TRANSPORT in figures

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(%)	ROAD	RAIL	INLAND WATERWAYS	PIPELINES	SEA (*)	AIR
1995	45.3	13.6	4.3	4.0	32.7	0.1
2000	46.5	12.5	4.1	3.9	32.9	0.1
2005	48.6	11.5	3.8	3.8	32.2	0.1
2010	49.4	11.4	4.5	3.5	31.2	0.1
2011	48.7	12.1	4.1	3.4	31.7	0.1
2012	48.5	12.0	4.4	3.4	31.7	0.1
2013	48.7	11.8	4.4	3.3	31.7	0.1
2014	48.2	11.8	4.3	3.2	32.4	0.1
2015	49.0	11.8	4.2	3.3	31.6	0.1
2016	49.0	11.3	4.0	3.2	32.4	0.1
2017	50.1	11.3	3.9	3.1	31.5	0.1

Figure 17: EU performance by mode of transport in % - Source: Publications Office of the European Union - STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

Focusing on the modal split, the only evident growth, of about 3%, is with road transport that reaches about 50% of the total.

According to TI-Transport Intelligence, in 2017 there was "an impressive growth in the road freight sector. The growth rate of 4.5% was its greatest in real terms since 2009. More, the momentum continued into 2018 with a growth rate of 5.8% expected for the full year and volumes set to increase by 3.5%. Looking ahead, the recent rate of growth is unlikely to be replicated and TI forecasts a real compound annual growth rate of 2.7% between 2017 and 2022"[31].

In the period after the year 2000, all other modes showed a slight decrease in their share, with the exceptions of pipelines and air. The overall picture of non-road modes shows limited fluctuation around stable values. This is especially the case of rail remaining slightly above 400 billion t/km in all observed years losing about 1.2% of the total traffic share, declining from 12.5% to 11.3%.

Looking at inland mode in ton, in most recent years, rail share performance looks slightly better even with some fluctuations. These fluctuations may also depend on the traffic structure that has changed and evolved during the years.

	2010		2013		2016	
	tonnes	%	tonnes	%	tonnes	%
Road	15 062	88.2%	13 786	86.7%	14 238	87.2%
Rail	1 477	8.7%	1 573	9.9%	1 537	9.4%
IWW	532	3.1%	543	3.4%	554	3.4%
Total	17 072	100.0%	15 903	100.0%	16 329	100.0%

Figure 18: Freight transport in the EU-28 by inland mode (million tonnes) - Source: Research for TRAN Committee – Modal shift in European transport: a way forward

[31] TI-Transport Intelligence - November 27th, 2018

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6.6. Existing services and projections in EU rail traffic

6.6.1. Existing rail services

The existing rail services can be segmented according to service production scheme in:

- Full train/block train (intermodal train not included)
- Single wagons
- Intermodal units

Mixed trains can exist as well, but they are unusual in European countries (Switzerland and to a smaller extent some routes as in France may be considered exceptions).

The evaluation of the respective market share of these services is difficult due to limited statistics representing the market according to the proposed segmentation.

The market share, according to the above segmentation is not adequately monitored as Eurostat data shows only data for countries covering about 40% of the total rail traffic[32].

According to the estimates extracted for this study accessing different sources and especially

- UIC (Report on combined transport 2018, published in January 2019);
- CER (Rail Freight Status Report, published in April 2013);
- European Commission (Study on Single Wagonload Traffic in Europe – challenges, prospects and policy options, published in July 2015)

the 2016 shares and past dynamics are shown in the following pictures.

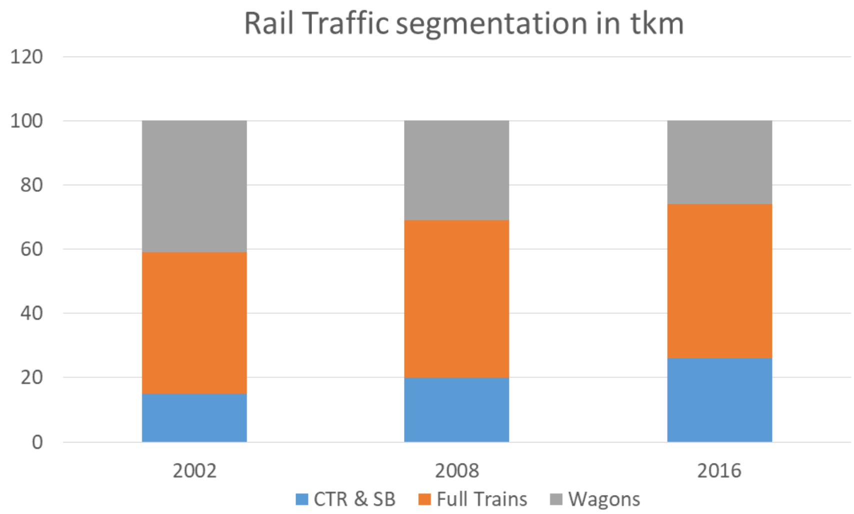

Figure 19: Share of rail traffic in tkm by rail services – Source: New Opera re-elaboration on Viwas/SPP Projects

[32] http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

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Railways							
	Million ton-kilometre (TKM)				% on Million ton-kilometre (TKM)		
2016	Total	Full trains	Full w agons	CTR & SB	Full trains	Full w agons	CTR & SB
EU-28	411.755	197.877	106.505	107.373	48%	26%	26%
BE	7.280	3.182	1.936	2.162	44%	27%	30%
BG	3.434	1.596	1596	242	46%	46%	7%
CZ	15.619	6.893	6.084	2.642	44%	39%	17%
DK	2.575	641	641	1.294	25%	25%	50%
DE	116.164	26.368	43.039	46.757	23%	37%	40%
EE	2.340	2.245	47	48	96%	2%	2%
IE	101	41	2	58	41%	2%	57%
EL	254	139	5	110	55%	2%	43%
ES	10.549	5.411	211	4.927	51%	2%	47%
FR	32.569	18.866	6.188	7.515	58%	19%	23%
HR	2.160	1.080	1080	0	50%	50%	0%
IT	22.712	6.221	3.021	13.470	27%	13%	59%
CY							
LV	15.873	15.371	317	185	97%	2%	1%
LT	13.790	13.260	276	254	96%	2%	2%
LU	201	101	101	0	50%	50%	0%
HU	10.528	4.475	4475	1.578	43%	43%	15%
MT							
NL	6.641	2.096	2096	2.449	32%	32%	37%
AT	21.361	9.322	8.117	3.922	44%	38%	18%
PL	50.650	39.905	6.456	4.289	79%	13%	8%
PT	2.774	1.584	55	1.135	57%	2%	41%
RO	13.535	10.358	2.572	605	77%	19%	4%
SI	4.360	1.771	1.340	1.249	41%	31%	29%
SK	8.370	5.740	1.922	708	69%	23%	8%
FI	9.456	7.217	2096	143	76%	22%	2%
SE	21.406	3.944	12.492	4.970	18%	58%	23%
UK	17.053	10.051	341	6.661	59%	2%	39%

Figure 20: Share of rail traffic in tkm by rail services – Source: NewOpera elaboration on EUROSTAT 2016 data and different sources including estimates based on parameters when data are not available

Full train/blocked train

A Full train/block train consists of several wagonloads transported together for one customer with no change in train composition from a single point of loading to a single point of unloading.

Full train/block trains are usually travelling between industrial OD, often moving commodities requiring dedicated fleet terminal infrastructure or private sidings.

Examples can be:

- Tank wagons trains
- IMCO class trains

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- Motor car trains
- Steel trains
- Coal trains
- Cereals trains
- Industrial trains (paper, mineral water, domestic appliances, consumers, etc.)

These services are usually stable unless the customers' networks, the volumes, the technologies or other important elements of the business system have discontinuities.

Single wagon

A Single Wagon Load (SWL) consists of the exclusive use of a wagon throughout its journey whether the full wagon loading capacity is utilized or not. Often wagons are moved by groups going together from the same origin to the same destination. So this segment includes any shipment by rail with a size not allowing to assemble a full train from its origin to the final destination or at least from terminal to terminal

Single wagon services appear to be particularly used for the transportation of specific freight commodity as chemical products, paper and pulp, forestry products and automotive. Also because of cost structure most of the single wagon traffic is concentrated on international routes (assuming "international" as a proxy for "long-distance").

The market presence of such services is not similar in the different countries because of different national strategies and different geographical distribution of the industries using such transports. There are some countries where it still covers an important segment of rail freight transport (e.g. Sweden, Austria, and Germany) and other where such a service is becoming marginal up to be terminated (as EE, LV, LT, ES, PT, IE, GR according to CER-Rail Freight Status Report published on April 2013)

In terms of supply, the deregulation process demonstrated not to be really supporting a wider European offer as "new entrants" often lack the capability or the scale to drive the development in new geographical markets. A collaborative approach such as the X-rail alliance may contribute to protect and revitalize these services, expanding the network from core countries along freight corridors again.

The market share Europe wide is generally considered declining even if structured data representing this market segments are not properly monitored. Nevertheless, different studies demonstrate there is space for "revamping" this service (for instance, the FP7 Viwas and C4R projects).

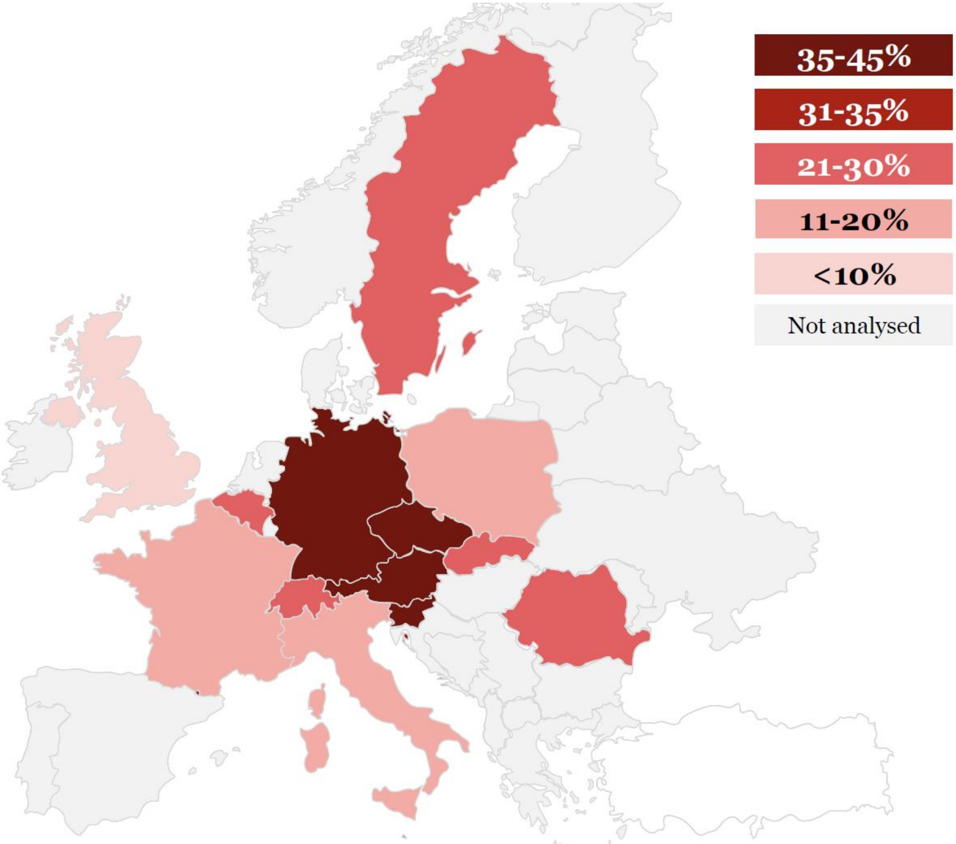

Figure 21: Share of rail traffic in tkm moved by SWL (data from Stakeholders consultation + Slovenia & Slovakia from Eurostat) – Source: Study of SWL traffic in Europe (challenges, prospects and policy options), European Commission DG MOVE, July 2015

Intermodal units

Intermodal transport is a multimodal transport where freight is hauled in ITU - Intermodal Transport Units (containers, swap bodies etc.), without any handling of the goods themselves when changing modes.

While the rail market share in Europe did not record significant variations in the last decade, remaining stable (around 17-18%) the intermodal freight segment, on the contrary, had outstanding performances in the same period. As shown by the following chart, the evolution of the intermodal rail freight registered a 50% growth in terms of tonnes and 32% in terms of tonnes-km, compared to the year 2005, utilized as baseline.

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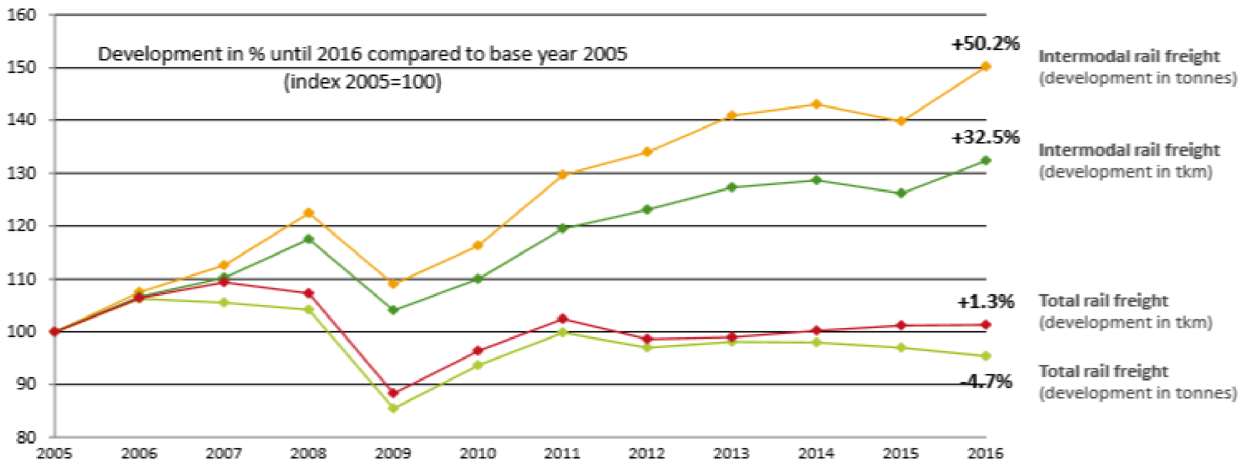

Figure 22: Development of total rail freight performance versus rail transport of goods in intermodal transport units in Europe (Index 2005 = 100) - Source: UIC & BSL, "Report on combined transport in Europe", 2018

Both in terms of domestic and international Combined Transport (CT), according to UIRR analysis, the intermodal share (numbers of TEUs) was affected by the 2009 economic crisis but showed a constant growth, and from 2011 it overcame the 2007 pre-crisis level. In both cases, in the period 2009-2017, the increase in the number of intermodal TEUs is constant.

Looking at the segmentation, the accompanied part remains a "niche" with limited reduction after the 2009 crisis while a significant part of the traffic volume and the recovery is with the unaccompanied part.

The EU share of intermodal rail freight is very different by Country with Germany, Italy and the United Kingdom representing the top 3 European markets for combined transport.

The map here below represents the intermodal share in total rail freight tkm in Europe. Sweden, Italy, UK, Spain, Portugal, Netherlands, Switzerland, Greece, Turkey are the countries in which intermodal transport is highly diffused (>30%).

The next map represents a more precise picture of the single member States situation.

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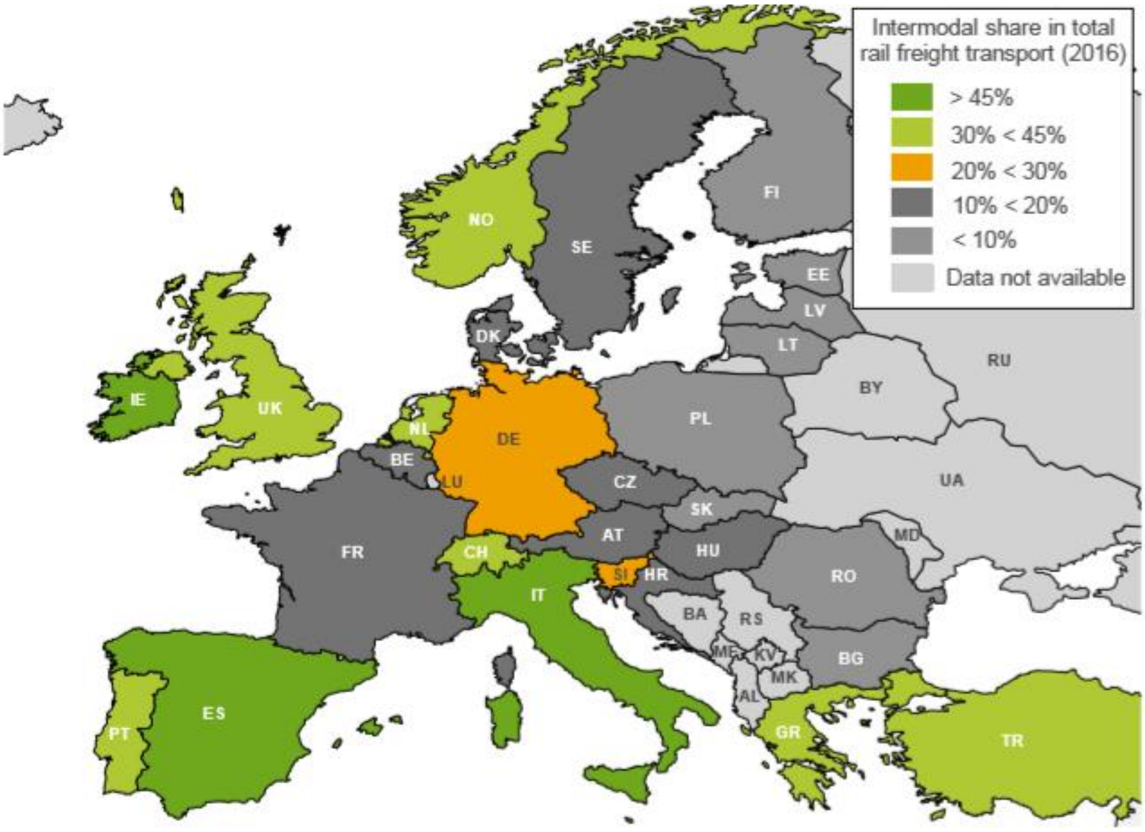

Figure 23: Map of intermodal share in Europe by country (% in total rail freight tkm) in 2016 - Source: UIC & BSL, "Report on combined transport in Europe", 2018

With regards to the average distance segments (rail and road legs) of combined transport in Europe, the following figures show that the highest utilization of rail is on distances <300 km (domestic) and <600 km (international).

With regards to the road leg, the highest utilization is on distances <100 km (domestic) and <150 km (international)[33].

[33] It has to be noted that the road data has to be handled carefully as the sample is smaller than the rail one as CT provider and rail companies often have no detailed knowledge of the actual road length. This is also the case of the % of volumes concerning less than truck load (LTL) and full truck load (FTL) shipments in European CT. According to the survey participants, the percentage of LTL in the CT composition was 6%, compared to 94% of the FTL shipments. The study is based on a survey carried out among the relevant market players in CT in Europe. Data have been matched with UIRR databases.

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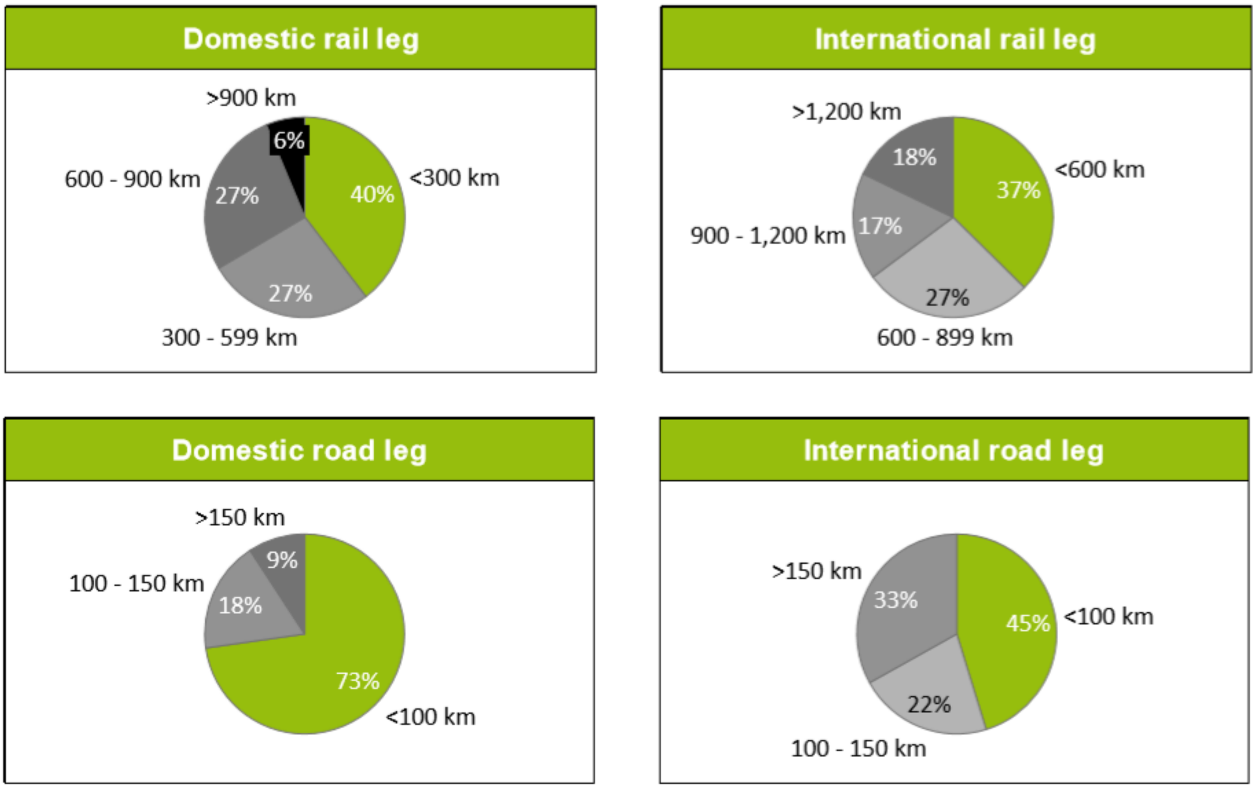

Figure 24: Average distance segments of CT in Europe (rail and road leg) - Source: UIC & BSL, "Report on combined transport in Europe", 2018

Since combined transport and seaport activity are firmly related, it is essential to give some information on the most important European ports, since the development of maritime traffic can have significant impacts on the rail and intermodal traffic. Genoa, Barcelona and Piraeus registered the highest increase in terms of TEUs from 2015 to 2017. Despite the growth in South Europe, the most significant European seaports remained: Rotterdam, Antwerp and Hamburg.

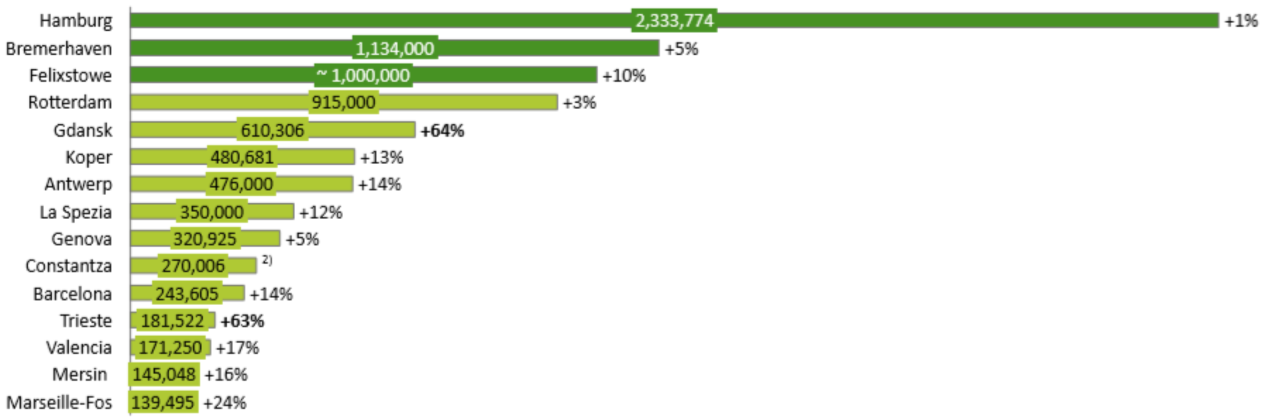

Figure 25: Top 15 EU ports in terms of container carried by rail (in TEU, 2017) and % of change 2015-2017 - Source: UIC & BSL, "Report on combined transport in Europe", 2018

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The above graph delivers a significant consideration which could be used either by rail operators or by other seaports for using more the rail mode for increasing their competitive penetration. In fact, strictly from a maritime standpoint, Hamburg is the less favoured port compared to the others of the North Range. This is due to the fact that to reach it are necessary extra days steaming including in/out of the Elbe estuary which add extra costs to the TEUs' slot for the containers handled there. The Port of Hamburg, aware of this maritime disadvantage, with a forward-looking long term policy, implemented a capillary rail connections network to all other parts of Europe towards East, West and South including Italy, Spain and connecting as far as Portugal increasing its competitive reach and penetration effectively. The Port of Hamburg adopted the "dry port" approach, dislocating thousands of boxes in an industrial scale and using every day several trains to/from pre-defined dry ports in Europe. By doing so, the port achieves the result of bringing the ships near to the final customers (FP6 TIGER and TIGER DEMO projects proved the validity of the "dry port" concept). Similarly, the Port of Trieste, which started only recently this competitive reach by rail connections towards North and East, managed to increase its rail-bound throughput by 63% in two years, although starting from relatively small numbers. This progression continued in 2018. In the S2R OPTIYARD project, simulation of optimized yard movements and in-terminal operations are performed in Trieste. The same positive situation seems to apply to Gdansk. These graphs demonstrate that the efficient use of rail can be instrumental in traffic growth, delivering both service efficiency and cost competitiveness.

The development of intermodal transport on a large scale can constitute an essential step towards more sustainable and greener transport, since it can reduce the quantity of polluting vehicles from the European motorways, transferring them on the rail tracks and leaving to the road only the "first and last mile" connections. BSL contacted 35 European ministries and transport authorities in order to know the combined transport funding measures in Europe. The results from this enquiry are represented in the following picture.

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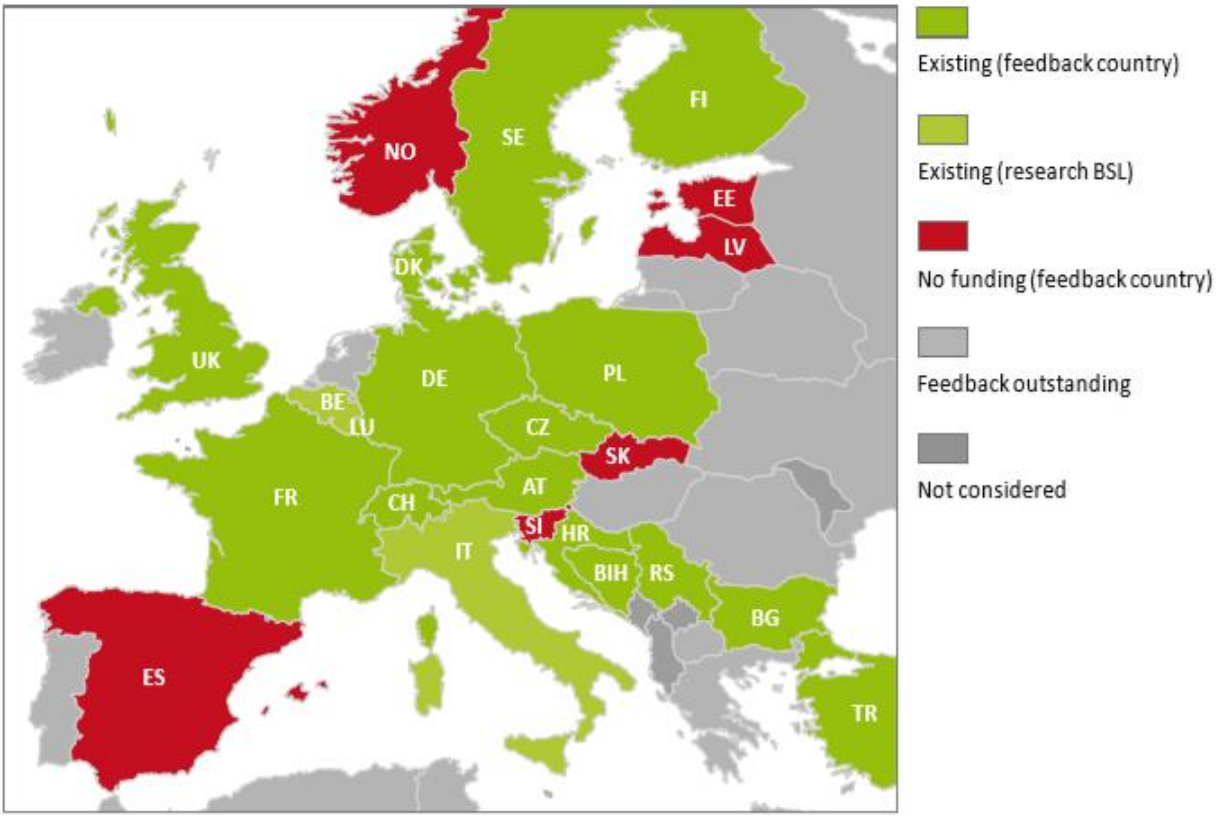

Figure 26: Countries with current National CT funding measures - Source: UIC & BSL, "Report on combined transport in Europe", 2018

6.6.2. Future traffic projections

Looking at future inland traffic forecast, significant growth is expected even if not all the studies match EU targets in terms of volume and modal shares.

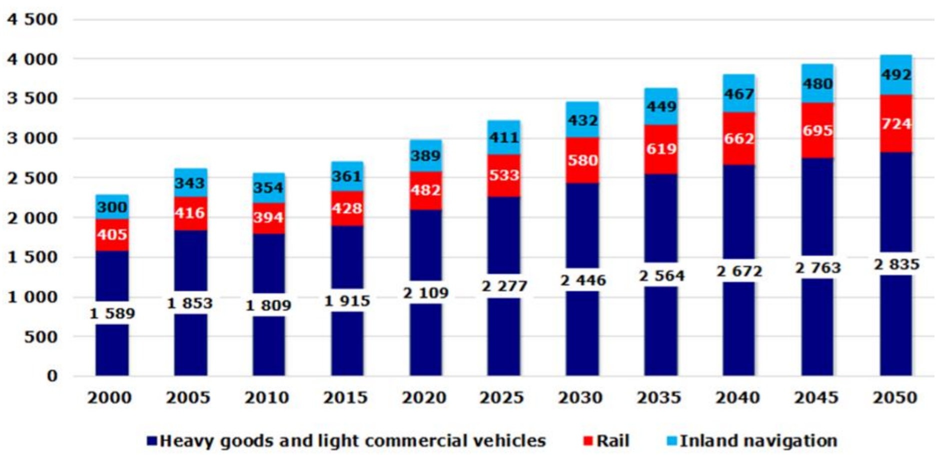

Figure 27: Projected freight transport demand – EU 28 reference scenario (billion t-km) - Source: Research for TRAN Committee – Modal shift in European transport: a way forward

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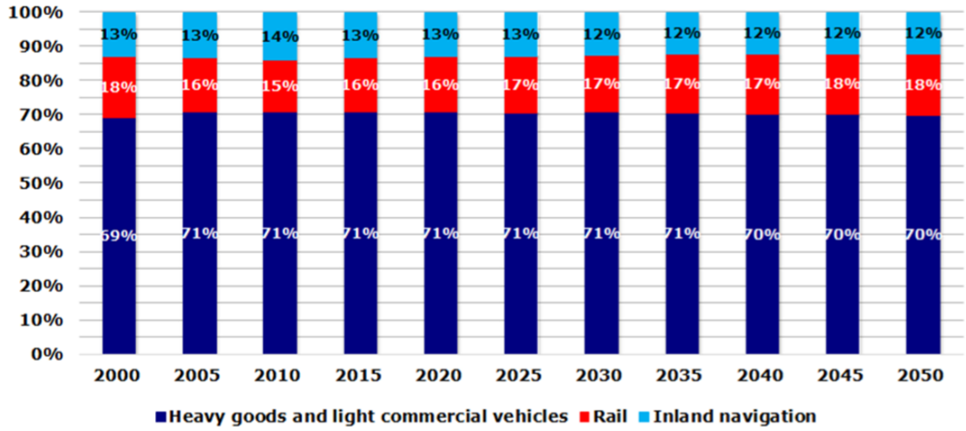

Figure 28: Projected freight transport demand – EU 28 reference scenario (%) - Source: Research for TRAN Committee – Modal shift in European transport: a way forward

Looking at rail traffic by segments, all components are expected to contribute to the growth:

- Full train growth will be linked to commodities such as steel, coal, oil, fuels and chemicals, cereals, metal scraps, urban waste etc. that in vast majority take advantage of this traffic solution.
- Single/group of wagons traffic, which has reduced considerably in some countries still represents a sizeable traffic slide. There is a market for this particular segment, such as for forestry products, paper, mineral water, construction materials and the chemical industry. Specific service solutions to suit customers' requirements and technology innovations on wagons can improve the performance of the single/group of wagons business significantly.
- Intermodal solutions that can really compete with road in large market segments represent most of the growth opportunities.

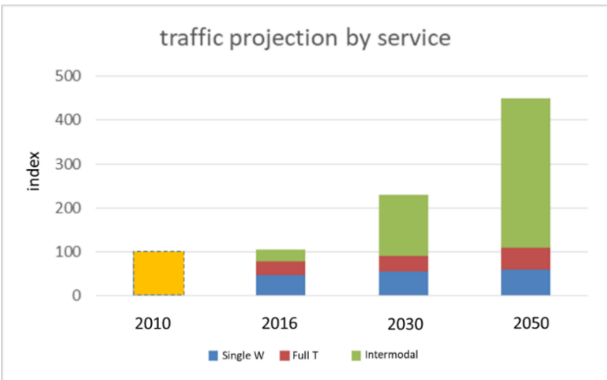

Figure 29: Rail traffic forecast in tkm by service (index 2010 = 100) – Source NewOpera projection 2030 and 2050 from SPIDER PLUS Project 2015

While in general all medium-long term rail forecasts agree about the light increase of rail traffic

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share, the success may be significantly higher/lower depending on several factors. Wanting to be positive, this means that there may be room for a more significant role of rail if a comprehensive set of actions are introduced to rejuvenate both the service components and the business model. This explains why the traffic forecast developed by the SPIDER PLUS project are much higher than those indicated for the TRAN Committee. FP7 SPIDER PLUS project assumed a more significant role of rail and in particular intermodality in the coming decades due to several measures to be adopted so that Modal Shift to rail becomes effective and not theoretical.

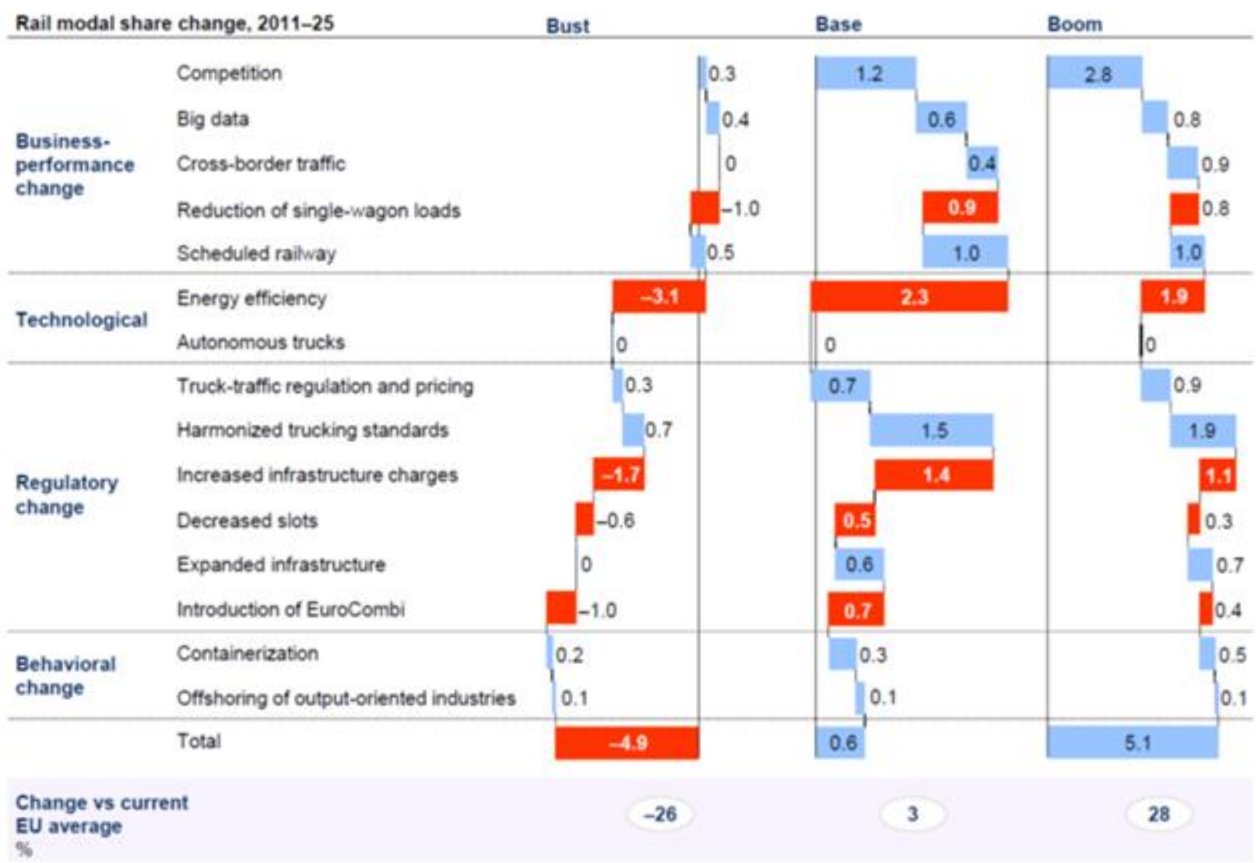

Figure 30: Forecast of rail modal share depending on conditions - Source: McKinsey & Company - Getting freight back on track, August 2014

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6.7. Towards Rail freight industrialization

While describing the status of rail freight, including some country differences, it is useful to anticipate some comments regarding issues which are preventing the modal shift.

Industrialization is the key word that summarizes the way to overcoming several gaps to be filled to achieve growth and profitability. In fact, the lack of growth and profitability, as appears in the analysis of the financial performance of rail freight transport companies, is the result of poor industrialization. The following graph provides an EU analysis for the period 2008-2012 and the example of Germany with data 2014-16.

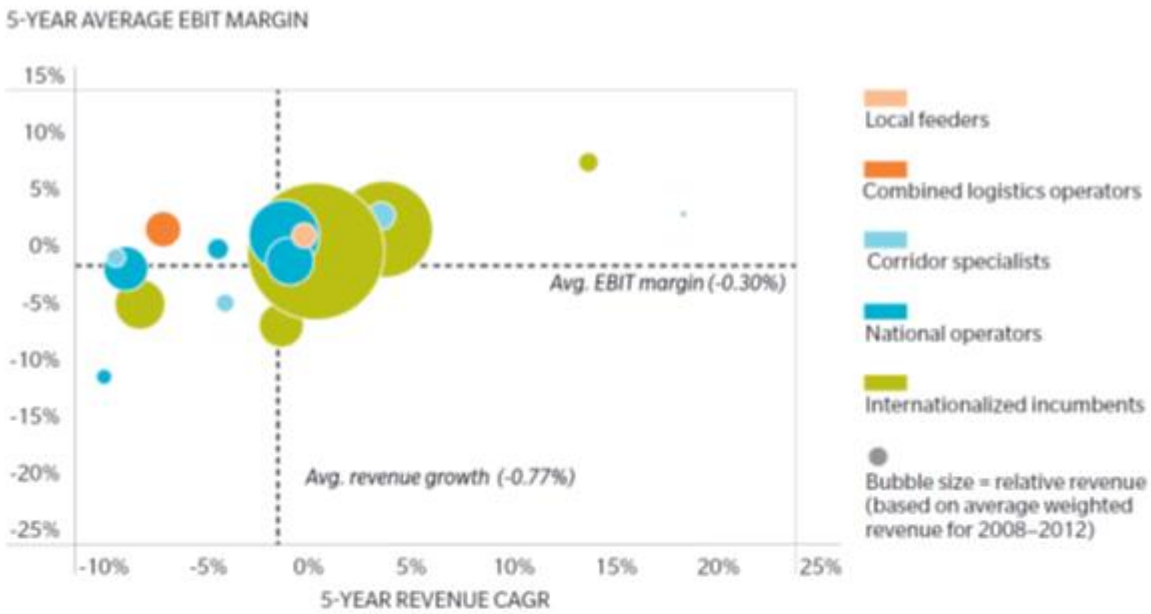

Figure 31: Financial Comparison of European Rail Freight Transport Companies (2008-2012) – Source - Oliver Wyman, Securing the future of European Freight Railway Operators, 2016

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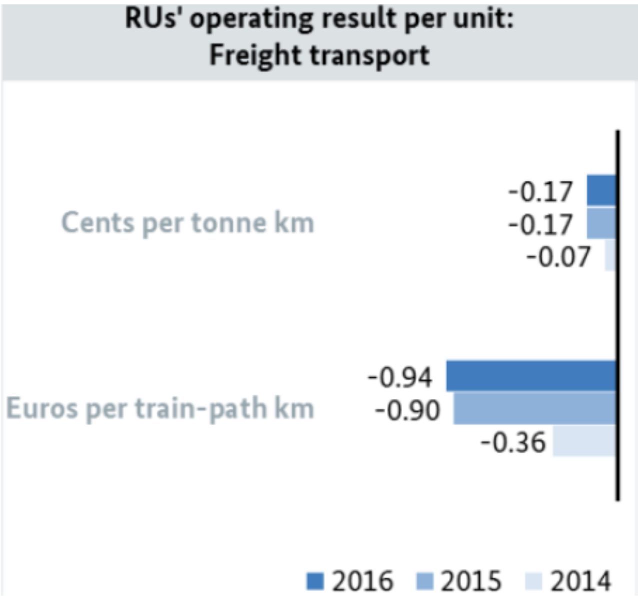

Figure 32: RU's operating result per unit (freight transport) - Source - BUNDESNETZAGENTUR Market Analysis Railway, December 2017

The description of these gaps resulting from a precise diagnosis and what to do to overcome them is not an easy exercise since multiple factors play their role also with interdependencies challenging to extricate. Nevertheless, in the following paragraphs, some key elements are highlighted.

6.7.1. Longer, heavier trains and capacity generation

Despite stable figures in terms of t/km, the traffic in train-km seems to show a limited increase supporting the hypothesis of a negative efficiency trend of train utilization. The capability to travel longer and heavier trains needs to be monitored as a critical driver of new efficiency for the overall rail freight sector. Longer and heavier trains can reduce the incidence of infrastructure charges, operational costs per unit transported as well as labour and energy costs in absolute terms while enhancing the infrastructure capacity.

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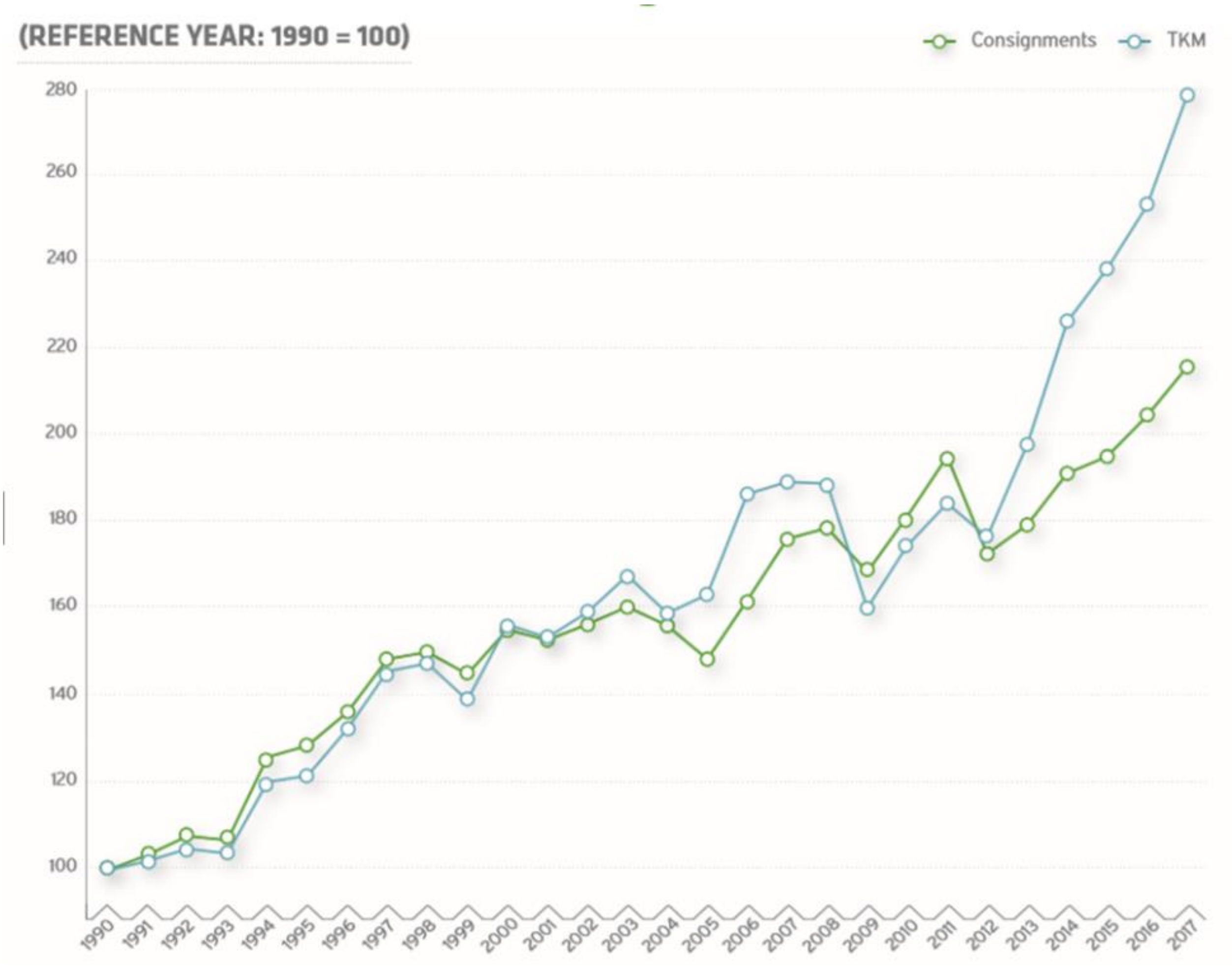

Figure 33: UIRR Combined Transport growth index - Source: UIRR Annual Report 2017-2018

The potential of longer and heavier trains is mentioned as the first point for contributing to upgrade the rail ecosystem. Trains of Marathon FP7 project (that will be successively widely treated in the TER4RAIL case study dedicated to freight – Longer and heavier trains and EU Marathon project) demonstrated the operational feasibility to develop on a large scale longer, commercially faster and heavier trains. During this project, two intermodal trains of 750m each have been coupled together with a loco in the middle of the consist, radio commanded by the front one. The Marathon train runs without problems from Lyon to Nimes in France, at a nominal speed of 100km/h. This resulted in a 30% capacity saving and 5% energy saving delivering an overall cost saving of up to 30%. Cost savings are essential, but capacity savings are even more so since they represent an alternative way to generate "immediate" capacity on existing lines. This is true especially when traditional alternatives to create capacity imply incredible long lead time to market and budget constraints for executing the necessary investments, together with other environmental and financial considerations. The results of the FP7 Marathon project have been successively exploited within the S2R Dynafreight and M2O Marathon2Operations projects.

The following map shows the differences in the current allowed train length in the various EU

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Countries.

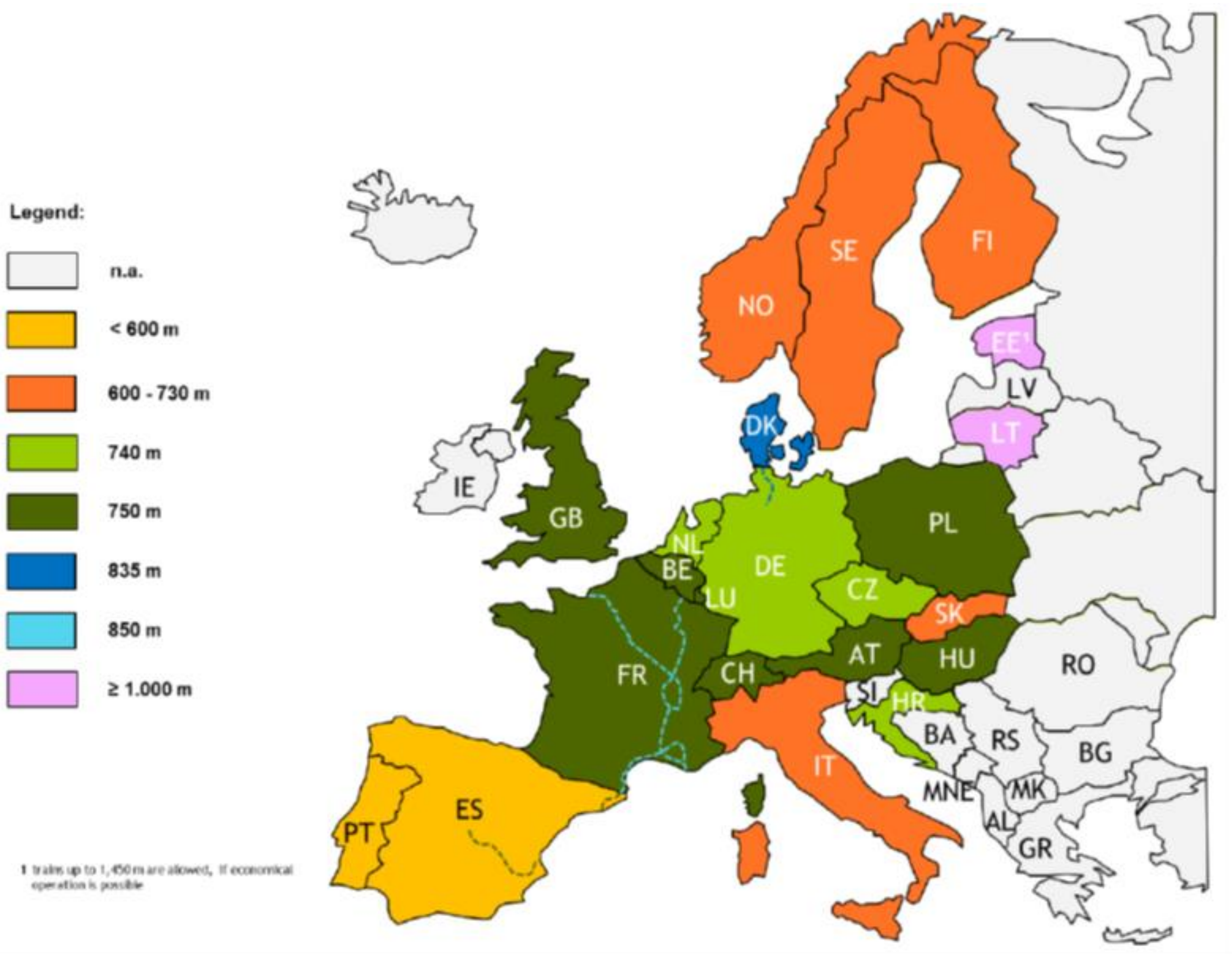

Figure 34: Max. train length per country – Source: CER Longer trains - Facts & Experiences in Europe - Results of the CER working group on longer and heavier trains, 4th edition, 2018

More significant evolutions are on the agenda while addressing new targets for this KPI rail efficiency. It is significant to note that some steps are already in progress in the right direction. For instance, in Italy, wagons profile for high cube (PC80) is allowed in the full Adriatic line since 2019. Also the train length, after the investments currently in progress, is going be aligned to 750m as in most of the EU countries.

Major constraints to have much longer trains up to 1.500m seems not to be significant. Additional insights about longer and heavier trains will be provided in the dedicated case study (TER4RAIL Deliverable 3.2).

The efficient use of capacity is a crucial lever for achieving industrialization of rail services. Other elements are mentioned in the following sections and especially when tackling cost and service. Other aspects can be mentioned, such as capabilities of integrated vertical offering, coordinated horizontal offering to cluster of users with similar or complementary requirements, service concentration in traffic attraction zones leveraging ICT both in operations and in marketing, with

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logistics engineering support.

6.7.2. Service and cost for achieving modal shift

Freight industrialisation can be more generally analysed based on cost and service performance. Even if decision-making still suffers from limited service modernisation, these elements represent a barrier towards achieving modal shift.

The following considerations focus on potential shifting from road to rail for full unit loads.

Service

The service is the first selection criteria, and the comparison is with the door-to-door road performance between origin and destination, which is the faster flexible and most reliable way. Even when short lead-time does not represent a constraint, the service reliability is prevailing. When considering service in a comparative perspective versus road it is important to keep in mind that the rail segment is only a portion of the origin/destination journey. That explains why punctuality is so important and why the parameter of 30' for delay has been put as a reference. Lack of punctuality may imply cost inefficiencies.

When looking at service performances in freight corridors, they still look disappointing and, in some cases, not yet monitored. Here rail service has an enormous area of improvement.

The service reliability can improve with enhanced planning and controlling processes based on integrated management tools adopting collaboration principles between different parties such as logistics operators. In addition, shippers can improve their planning systems, utilizing, if necessary, limited inventory buffers for contingencies. Service lead-time can improve because the traffic increase would modify the train frequencies. The total transit time can be compressed squeezing non-operational intervals whose sum may be significant for the overall performance.

Better service marketing, consistently aligning the operations, would present new opportunities. For instance, transit time can be improved when crossing areas where night driving is limited, such as in Switzerland or banned weekend for road operators. The exemption for first and last mile road operation for combined cargo has to be considered as an opportunity still to be exploited. In addition, reliability could become an advantage, when congestion or weather conditions affects the time reliability of road transport. This is the case of given nodes like ports located in metropolitan areas. Also, the information management capabilities have service marketing content. They are part of the sellable service with potential similar to what already exploited in other segments of the 3PL industry.

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Punctuality KPIs by cooridor	at origin - delay within 30'		at destination - delay within 30'	
	2017	2018	2017	2018
RFC 1 Rhine-Alpine	68%	65%	56%	55%
RFC 2 North Sea-Mediterranean	80%	78%	73%	70%
RFC 3 Scandinavian-Mediterranean	69%	70%	58%	59%
RFC 4 Atlantic	75%	NA	75%	NA
RFC 5 Baltic-Adriatic	50%	44%	35%	31%
RFC 6 Mediterranean	56%	56%	43%	45%
RFC 7 Orient/East-Med	48%	44%	35%	36%
RFC 8 North Sea-Baltic	60%	55%	51%	48%
RFC 9 Czech-Slovak/Rhine-Danube	NA	47%	NA	29%
RFC 10 Alpine-Western Balkan	NA	NA	NA	NA
RFC 11 Amber	NA	NA	NA	NA

Figure 35: Example of KPIs of Freight network for service measured as punctuality – Source: NewOpera elaboration based on corridor data[34]

In general, service can benefit from more consistent/extended application of the EU directive reserving capacity to rail freight (Regulation EU 913/2010[35]) at least in rail freight market-oriented corridors. The general orientation is still to privilege passengers when conflicts emerge, especially in urban areas. Such regulation has the objectives of striking the right balance between freight and passenger traffic along the Rail Freight Corridors, giving adequate capacity and even priority for freight in line with market needs, ensuring that punctuality targets are met for freight trains. The fulfilment of this objective requires several actions still under development. Examples include co-operation on critical aspects such as allocation of path, deployment of interoperable systems, ETA calculation, and infrastructure development with the integration of terminals into the corridor management and the development of by-passes in city nodes.

The service profile also includes management of information, both for planning and execution, as timelines and complete information accessibility allow the supply chain management process,

[34] http://www.rne.eu/rail-freight-corridors/

[35] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010R0913

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the industrial lead-time and the reaction to exceptions. These topics have implications on the investments and the automation of administrative activities for managing the process integration. Within the outsourcing model, part of the integration is often in the hands of logistics operators in charge of warehouse management activities. Such companies usually also manage road transportation and are in better conditions for integrating road traffic in their ICT systems. In fact, either they can have road transport operations in their scope of activities, or such activities may be in the scope of other BUs of the same group.

Service features largely depend on collaboration between different players, including institutions and infrastructure services. Solutions as single Window/single access point and One-Stop-Shop (OSS) for administrative procedures in all transport modes are available even though the efforts have not been fully effective.

<u>Cost</u>

When evaluating cost alternatives, distance is the traditional and still the most crucial discriminant. Looking at distances, rail transport is generally considered effective on distances no lower than 300 km and extremely competitive on trips longer than 900 km. UIRR statistics can help the analysis of these parameters. The UIRR data show that only 1% of the traffic in tkm is below 300 km, 12% between 300 and 600 km, 53% above 900 km.

COMBINED TRANSPORT	2000	2010	2011	2012 (1)	2013 (2)	2014 (3)	2015 (3)	2016 (4)	2017 (5)
Number of consignments	1,967,072	3,030,865	3,075,808	2,529,264	2,645,950	2,819,606	2,876,585	3,024,860	3,190,571
swap bodies and containers	1,334,377	2,281,746	2,330,918	2,067,488	2,134,004	2,302,831	2,348,762	2,419,586	2,606,217
(craneable) semi-trailers	172,275	300,867	318,567	333,597	375,432	362,654	382,250	470,535	446,279
complete trucks (RoLa)	460,420	448,252	426,323	128,179*	136,514	154,121	145,573	134,739	138,075
Total billion tkm	35.18	42.37	42.58	39.08	40.74	52.17	54.98	58.96	64.09
< 300km	2%	5%	7%	3%	2%	2%	1%	1%	1%
300km - 600km	28%	16%	12%	12%	21%	17%	14%	12%	11%
600km - 900km	43%	42%	44%	47%	39%	36%	36%	34%	31%
> 900km	27%	37%	37%	38%	38%	45%	49%	53%	57%

(1) Data without Ökombi - Hungarokombi (RoLa operators) | (2) From 2013 figures including traffic of new members TEL and FELB
(3) From 2015 figures including RCO CZ | (4) From 2016 with RCO HU | (5) From 2017 figures including Amber Rail, Baltic Rail and Lugo

Figure 36: UIRR Combined Transport growth index - Source: UIRR Annual Report 2017-2018

The segmentation of traffic by distance is the traditional and still the most utilised for identifying traffic potentially switchable to rail, which can be better coordinated in a co-modal perspective. This segmentation is based on parametric cost chain comparison considering the door-to-door cost of the different alternatives.

The following considerations maintain this basic segmentation and elaborate on that. When comparing alternatives, it is useful to keep in mind the road traffic segmented for equal distances. In 2015, in Europe, 44% of road traffic measured in tkm was within 300 km, 38% between 300 and 900 km, 18% above 900 km.

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	Less than 150 km		From 150 to 299 km		From 300 to 999 km		Over 1 000 km	
	2015	Change 2011-2015 (%)	2015	Change 2011-2015 (%)	2015	Change 2011-2015 (%)	2015	Change 2011-2015 (%)
EU-28 (1)	416 191	0.2	362 046	1.6	675 349	0.6	312 593	4.6
Belgium	9 787	-7.2	10 453	21.0	15 174	-8.6	1 492	-11.5
Bulgaria	3 227	18.8	3 137	32.4	9 541	58.1	16 453	62.8
Czech Republic	12 632	54.3	8 778	24.4	21 833	-5.0	14 085	-15.0
Denmark	5 043	-4.5	4 293	1.7	5 096	-1.2	1 069	-26.8
Germany (2)	89 932	5.9	71 989	-0.2	127 502	-10.0	11 348	-30.3
Estonia	912	-2.1	716	-7.5	1 765	16.6	2 853	6.4
Ireland	4 026	5.6	3 398	-0.5	1 529	-17.0	756	-10.4
Greece	5 904	-15.4	2 985	-10.8	6 734	-2.9	4 150	31.0
Spain	33 637	-8.4	26 277	2.4	92 320	1.7	57 153	6.4
France	47 656	-13.9	35 279	-15.9	66 641	-19.2	4 013	-32.4
Croatia	1 827	-11.3	1 758	12.8	4 240	20.7	2 612	45.6
Italy	30 021	-23.1	31 491	-21.0	46 846	-13.1	8 459	-15.1
Cyprus	534	-41.2	17	-10.5	1	-75.0	12	20.0
Latvia	2 028	19.7	1 211	-0.1	2 793	54.1	8 443	15.5
Lithuania	1 427	39.1	1 883	60.4	6 471	65.5	16 683	8.5
Luxembourg	1 300	-14.3	1 691	-10.9	3 792	-19.3	312	-55.9
Hungary	5 657	4.1	5 321	1.6	13 536	21.9	13 711	9.1
Malta	:	:	:	:	:	:	:	:
Netherlands	24 690	34.5	19 190	9.8	20 644	-32.2	5 537	-25.3
Austria	9 090	10.2	5 541	-6.1	7 836	-23.4	2 123	-38.9
Poland	34 187	3.5	35 781	29.4	108 672	40.9	82 069	17.5
Portugal	4 811	-22.9	4 367	-2.7	9 058	6.7	13 543	-21.4
Romania	4 802	11.8	3 837	36.8	12 977	82.0	17 402	43.6
Slovenia	1 708	-1.4	1 514	10.3	7 764	23.3	6 886	-1.4
Slovakia	3 349	13.2	3 354	22.3	13 303	42.3	13 499	-4.2
Finland	7 474	-14.4	5 886	-18.7	9 607	1.4	1 523	7.3
Sweden	12 900	40.0	9 799	23.6	14 861	2.6	3 358	37.8
United Kingdom	57 630	4.2	62 100	6.7	44 813	3.6	2 599	-23.7
Norway	7 343	7.1	4 513	37.0	9 360	23.9	1 920	29.6
Switzerland	7 859	1.2	2 581	-1.4	1 732	-27.1	:	-

(1) Provisional data.
(2) 2014 data instead of 2015.

Figure 37: Road freight transport by distance class, 2015 – Source Energy, transport and environment indicators, 2017[36]

[36] http://www.europarl.europa.eu/RegData/etudes/STUD/2015/540350/IPOL_STU(2015)540350_EN.pdf

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6.7.3. The distance grid

The following comments focus on the previous set of distances, but they may apply to all distances even if with different level of importance:

The distance below 300 km, where the vast majority of the overall transport of each country is concentrated (44% EU road average), has limited rail accessibility applying the traditional thought. The current share of rail is minimal (1% of UIRR traffic). If one introduces additional elements, these allow the identification of specific but not marginal opportunities.

A key example is the connection with ports, mainly but not only, for container traffic, of which Rotterdam and Hamburg are champions. In particular, Rotterdam with the Betuwe line entirely dedicated to freight contributed to the rail management of 760.000 Cts in 2016 in the port connections for all distances (initial operation in 2007 and full capacity in 2015). Hamburg is handling over 250 trains per day to all European destinations short, medium and long/very long distances. Trieste is another recent success story for new rail connections allowing the port to score new records in its throughput due to an extensive rail network towards the North, the East as well as the domestic market.

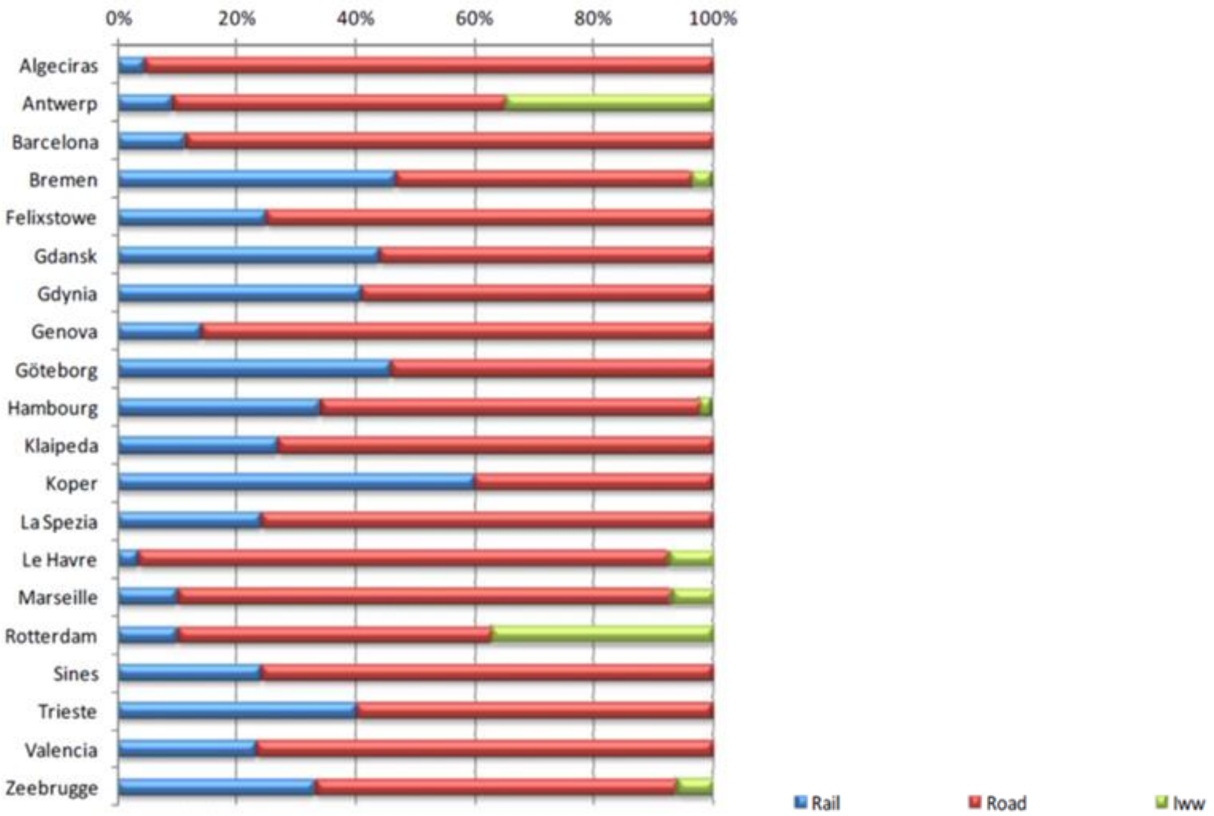

Figure 38: Modal share of freight transport to and from EU ports for CTR – 2015 – Source: European Parliament Study based on data 2013[37]

[37] http://www.europarl.europa.eu/RegData/etudes/STUD/2015/540350/IPOL_STU(2015)540350_EN.pdf

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Metropolitan urbanisation surrounds almost all big ports, and effective port connections cannot rely on road for several reasons. For instance, loading/unloading of big vessels up to and over 20.000 TEUs requires appropriate transport capacity, congestion may impose additional charges and restrictions, night circulation may become limited, security regulations may imply process steps.

Ports are a specific opportunity as the cargoes are already in an intermodal situation. The EU Tiger and Tiger Demo Projects demonstrated such opportunities.

Because of the inability of the rail industry in catching this market, the shipping lines are entering through M&A and alliances with logistics and 3PLs companies into these activities from/to ports and additional value-added services. Examples can be the takeover by CMA-CGM of CEVA (2019) and the start-up by MSC of Medlog Italia (2018 with operations since 2019).

These examples are part of a more general approach towards vertical integration lead by some shipping companies. Some of them demonstrated interest also in M&A with freight forwarding companies such as the acquisition of Atlantic Speditions and Searunner Shipping by MCS in March 2019. This is a way to answer broader collaboration needs through direct ownership while in parallel experiences of alliances and/or virtual collaboration are progressing too.

Other examples centred on metropolitan requirements may be waste movement and city logistics solutions linked with intermodal terminals where experiments are in place with outcomes to be consolidated.

When looking at nodes, improvements in the operational efficiency may reveal opportunities. Economies of scale can play a significant role in any cost element. Specific efficiencies can be found at terminals with extensive management methodologies consolidated in industrial plants covering the entire operations including maintenance. When looking at short-distance traffic, the loading-unloading and handling in at terminals are the key cost elements accounting for a substantial part of the total cost. The operations inside the terminal surface constitute additional constraints. Optiyard project aims at delivering a simulation of optimised operations and movements inside the terminals of two selected sites (Trieste and Ceska Trebova). For longer distances, rail traffic effectiveness allows better absorption of these costs.

Because of the short distance, the modal shift achieved by implementing these actions would bring little contribution in terms of t/km. Still, it would bring more than proportional benefits in terms of congestion and pollution due to the urban territories where this modal shift is realised. From the industry perspective, the transfer of these traffic flows to rail would, in any case, contribute to the economies of scale, to the traffic attraction zones clusters, and above all to the rail traffic industrialisation.

The distance between 300 and 900 km shows several potential cases for rail (46% of current UIRR and 38% of road traffic). Within this distance, probably the most interesting opportunities should come from service and cost performance improvements. In addition, the reduction of fragmentation of the trucking industry will reduce the traditional reluctance to collaborate with rail in a co-modal perspective. A better understanding of traffic flows may indicate new opportunities. An example is the empty runs which are relevant for road and may unveil opportunities for rail. This segment represents the ideal target for rail traffic industrialisation.

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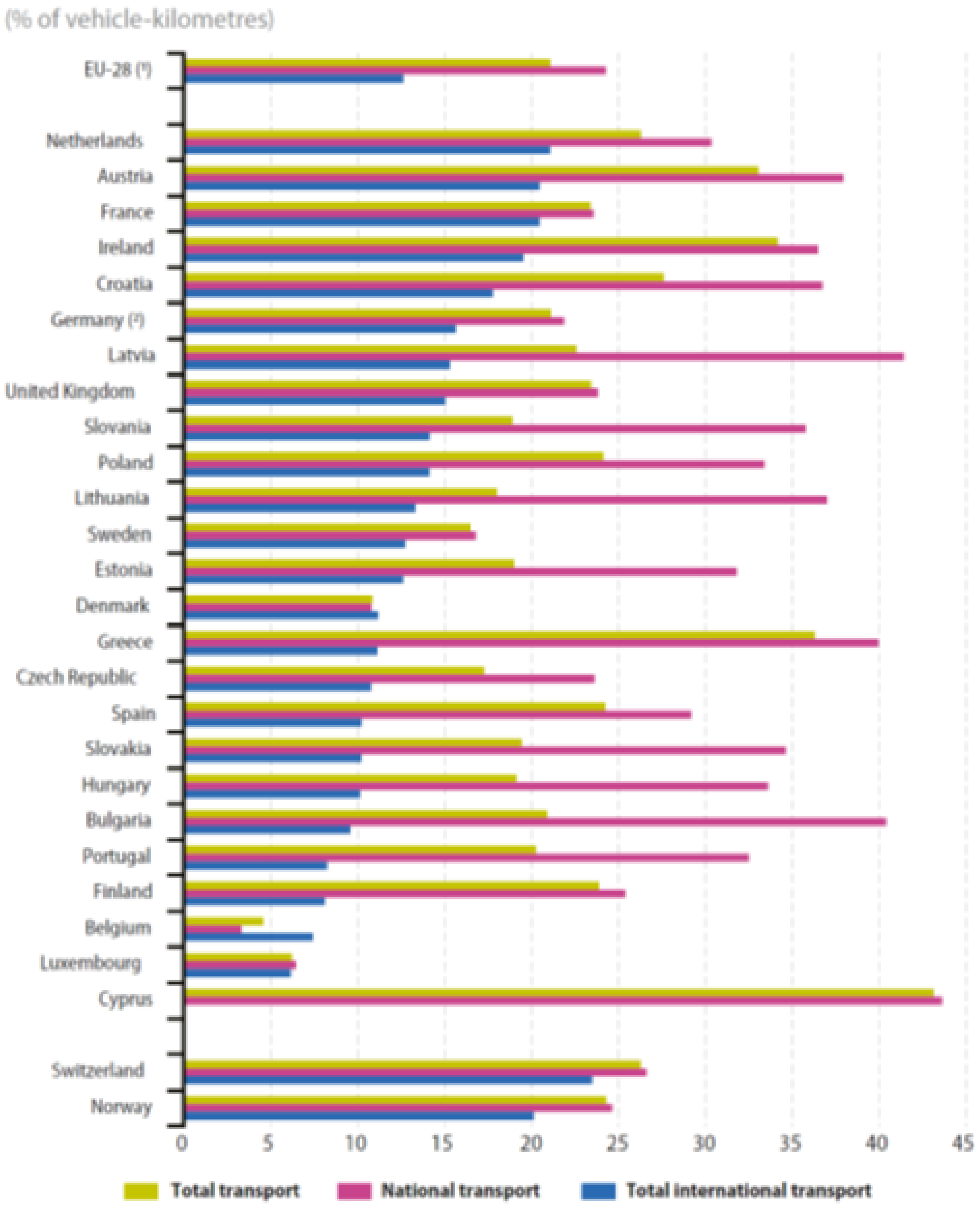

Figure 39: Road freight transport by distance class, 2015 – Source Energy, transport and environment indicators, 2017

<u>The distance above 900 km</u> can benefit from all the elements already mentioned of unit costs reducing progressively with the distance increase. In contrast, the road system increases its unit costs being more connected with the human needs of the drivers (18% of current UIRR and 53%

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of road traffic). The traffic nodes in the "core" network may be the geographic priority to be taken into account to understand the real attractiveness of rail for the traffic, which is currently routed by road. In fact, the most natural choice should be rail due to its lower costs. The shortage of truck drivers in several countries will imply new cost trade-offs impacting in rebalancing capacity in favour of rail. The truck drivers' shortage and the labour cost increase in Central Europe caused the transfer of long-distance traffic, in most recent years, to Eastern trucking companies. According to new research from Transport Intelligence published in November 2018, road transport firms are going towards a driver shortage crisis of 150,000 unfilled jobs in Europe of which 52,000 in the UK, 45,000 in Germany with additional 28,000 each year, 20,000 in France, 5,000 in Sweden, 2,500 in Denmark and 3,000 in Norway.

Labour harmonisation within the European internal market may create reasons for reshaping current long-distance transport habits, including higher use not only of rail but also of sea and inland waterways solutions. A way to investigate this topic is the road traffic shift monitored between Countries by looking at the statistics of road traffic "by haulage and by vehicles registered in the reporting Country".

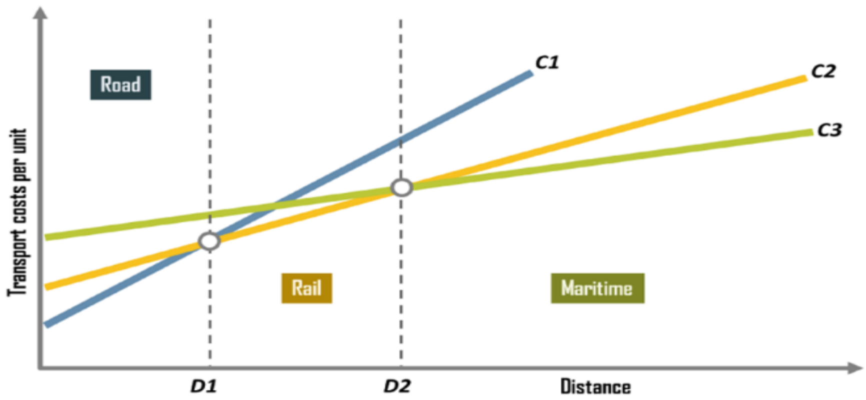

Figure 40: Simplified Cost Comparison between different Modes - Source: NewOpera elaboration on various sources

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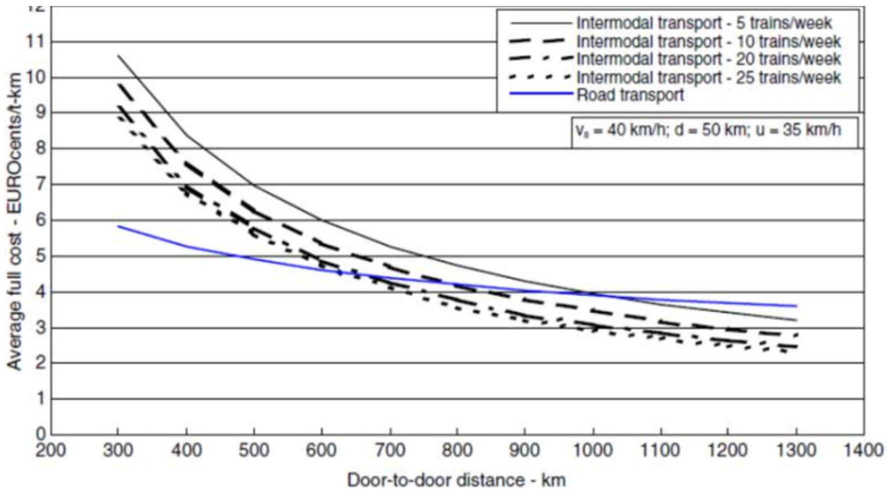

Figure 41: Dependence of average full Costs of Intermodal transport on train frequency and "Door-to-Door" Distances - Source: Modelling the full costs of an intermodal and road freight transport network, Milan Janic in SPIDER PLUS Project, 2015

HAULAGE BY VEHICLES REGISTERED IN THE REPORTING COUNTRY

	billion tkm							%
	1995	2000	2005	2010	2015	2016	2017	CHANGE '16/'17
EU-28	1 288.7	1 509.5	1 794.6	1 756.4	1 766.2	1 835.3	1 920.9	4.7
BE	45.6	51.0	43.8	35.0	36.1	35.2	34.2	-2.8
BG	5.2	6.4	14.4	19.4	32.3	35.4	35.2	-0.7
CZ	31.3	37.3	43.4	51.8	58.7	50.3	44.3	-12.0
DK	22.4	24.0	23.3	15.0	15.5	16.1	15.5	-3.7
DE	237.8	280.7	310.1	313.1	314.8	315.8	313.1	-0.8
EE	1.5	3.9	5.8	5.6	6.3	6.7	6.2	-7.8
IE	5.5	12.3	17.9	10.9	9.9	11.6	11.8	1.9
EL	24.0	29.0	23.8	29.8	19.8	24.6	28.4	15.5
ES	101.6	148.7	233.2	210.1	209.4	217.0	231.1	6.5
FR	178.2	204.0	205.3	182.2	153.6	155.8	167.7	7.6
HR		2.9	9.3	8.8	10.4	11.3	11.8	4.4
IT	174.4	184.7	211.8	175.8	116.8	112.6	119.7	6.3
CY	1.2	1.3	1.4	1.1	0.6	0.7	0.8	17.5
LV	1.8	4.8	8.4	10.6	14.7	14.2	15.0	5.2
LT	5.2	7.8	15.9	19.4	26.5	31.0	39.1	26.2
LU	5.5	7.6	8.8	8.7	8.9	9.3	9.4	1.0
HU	13.8	19.1	25.2	33.7	38.4	40.0	39.7	-0.8
MT	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0
NL	67.1	79.6	84.2	76.8	68.9	68.0	67.5	-0.6
AT	26.5	35.1	37.0	28.7	25.5	26.1	26.0	-0.6
PL	51.2	75.0	111.8	202.3	260.7	290.7	335.2	15.3
PT	32.0	26.8	42.6	35.4	31.8	34.9	34.2	-2.0
RO	19.7	14.3	51.5	25.9	39.0	48.2	54.7	13.6
SI	3.3	5.3	11.0	15.9	17.9	18.7	20.8	11.3
SK	15.9	14.3	22.6	27.6	33.5	36.1	35.4	-2.0
FI	24.5	32.0	31.9	29.5	24.5	26.8	28.0	4.2
SE	31.6	35.6	38.6	36.3	41.5	42.7	41.9	-1.9
UK	161.5	165.6	161.3	146.7	150.1	155.0	153.9	-0.7

HAULAGE PERFORMED WITHIN THE TERRITORY OF EACH COUNTRY BY ANY VEHICLE

	billion tkm					%
	2005	2010	2015	2016	2017	CHANGE '16/'17
EU-28	1 755.5	1 709.8	1 720.1	1 786.5	1 870.1	4.7
BE	46.8	45.6	50.7	52.6	52.4	-0.3
BG	11.0	8.9	11.2	11.2	12.0	7.4
CZ	32.3	32.0	42.5	43.4	43.1	-0.8
DK	16.8	17.2	18.8	20.6	20.3	-1.2
DE	370.8	404.9	427.5	447.7	463.3	3.5
EE	2.7	2.2	2.8	3.1	2.9	-6.5
IE	15.6	9.7	9.2	10.6	10.6	-0.3
EL	21.9	27.6	17.6	18.7	19.7	5.5
ES	210.7	184.4	177.9	186.7	198.0	6.0
FR	294.5	275.1	249.4	258.1	278.2	7.8
HR	10.5	7.9	8.2	8.7	9.5	8.2
IT	204.0	183.6	133.5	132.0	142.1	7.6
CY	1.4	1.1	0.5	0.7	0.8	17.3
LV	3.7	3.7	4.8	4.9	5.3	8.7
LT	4.4	5.0	7.3	7.4	7.7	3.6
LU	1.9	2.1	2.6	2.8	3.0	4.9
HU	22.2	21.3	22.1	24.5	25.8	5.4
MT						
NL	49.7	49.2	50.8	54.7	54.2	-1.0
AT	32.4	37.9	41.0	43.4	45.8	5.5
PL	86.8	116.2	147.3	154.2	174.0	12.8
PT	23.9	18.9	16.3	16.4	16.7	2.2
RO	32.5	15.6	16.5	18.0	19.4	7.6
SI	7.3	7.3	7.7	8.7	9.3	7.1
SK	10.5	11.8	13.9	15.0	16.4	9.3
FI	28.8	26.5	22.8	25.7	27.5	6.8
SE	45.1	42.4	49.3	51.3	50.4	-1.6
UK	167.3	151.5	165.9	185.6	161.8	-12.8

Figure 42: Road transport. National/International haulage performance, with variation 2016-2017 – Source: Publications Office of the European Union - STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

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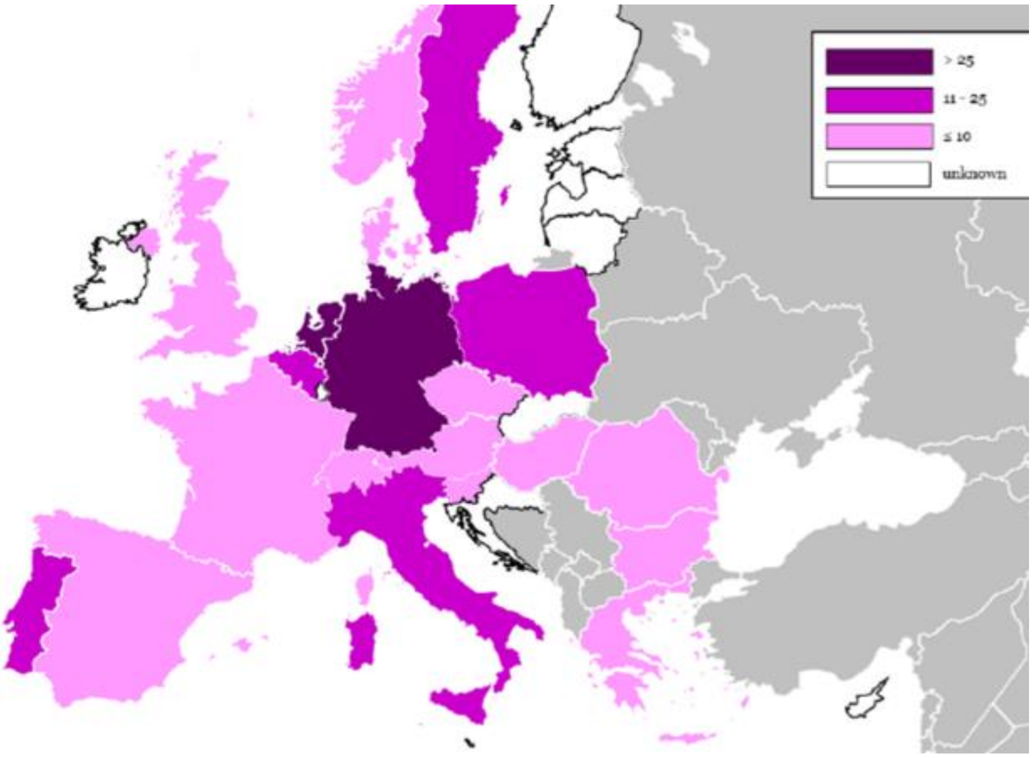

Figure 43: Rail-ports and Rail-Road terminals occurrence in Europe – Source: Research for TRAN Committee – Modal shift in European transport: a way forward

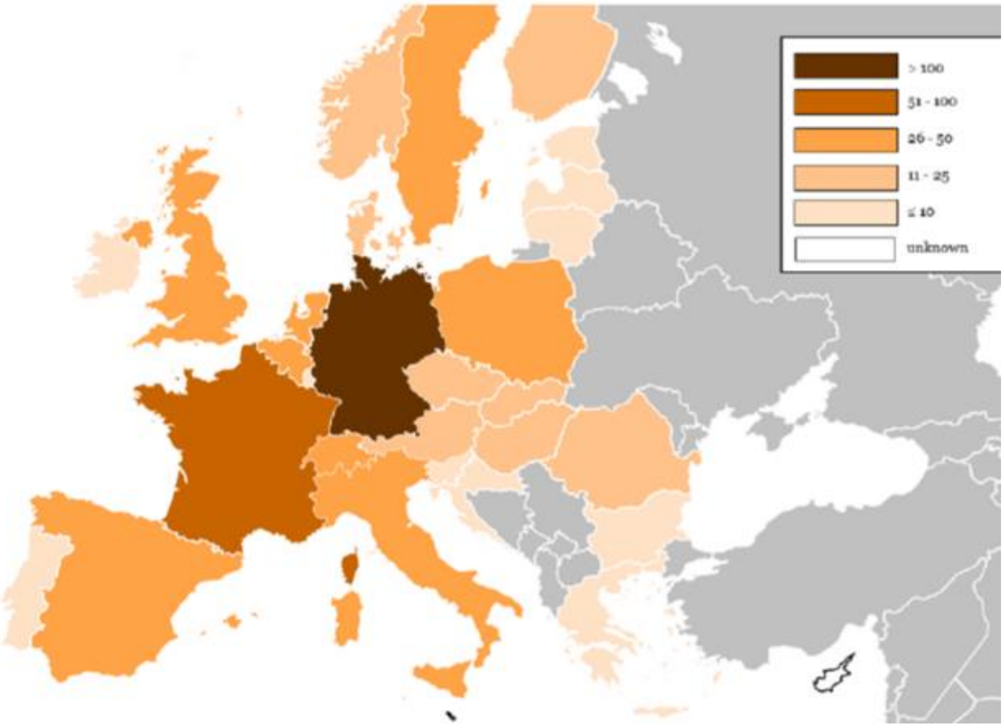

Figure 44: Intermodal terminals with rail access occurrence in Europe - Source: Research for TRAN Committee – Modal shift in European transport: a way forward

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When examining cost in the above section, they are considered in the users' perspective. So the costs equate to the price paid by users. Pricing policies have a material impact. In particular, taxes and charging policies of rail infrastructure charges contribute to affecting rail competitiveness versus road.

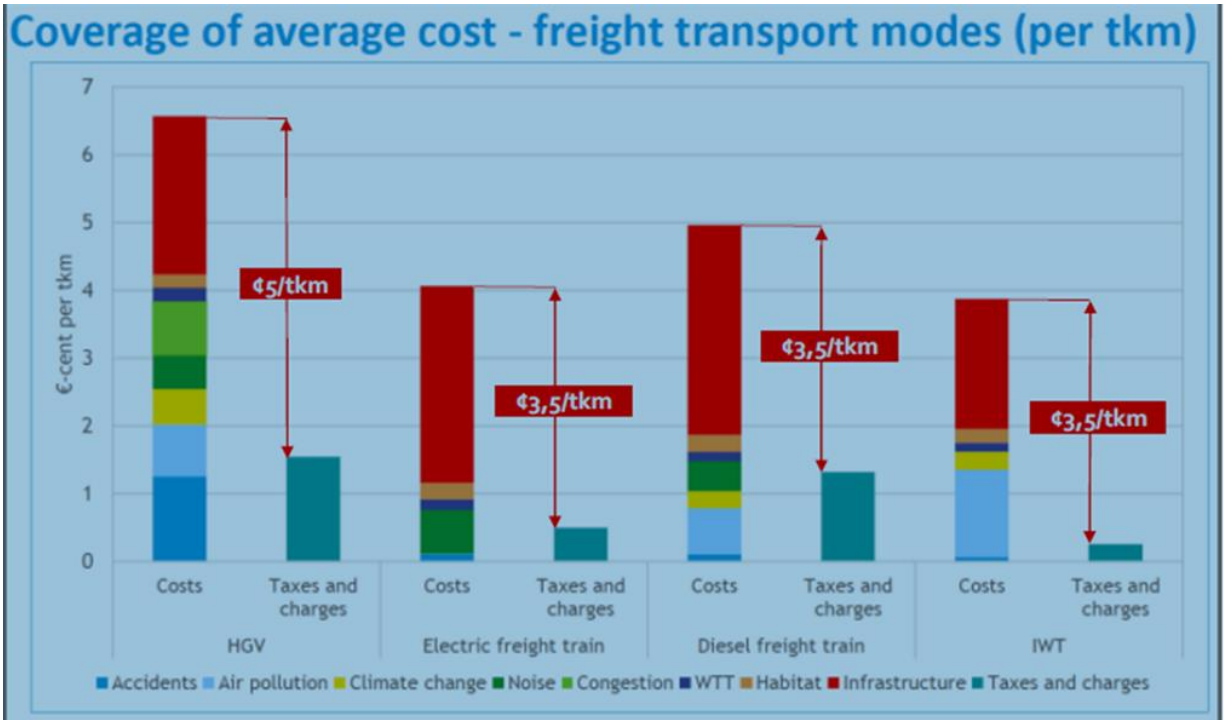

Figure 45: Coverage of average cost (freight transport modes) – Source: UIRR position paper, January 2019

Within the EU, prices show significant differences, mirroring the different charges allocated to the use of the infrastructure when splitting the passenger and freight businesses sharing the same tracks. When analysing the price offer, one should take into account several elements like incentives to traffic such as bonuses in several European countries in favour of intermodality[38] or other innovation projects such as "Marco Polo" in the past or incentives which were criticised for distorting competition[39]. The analysis of these elements is not within the scope of this research. On this point, it may be useful to look at the next pictures, even if the data refers to the year 2012.

[38] https://uic.org/IMG/pdf/2018_report_on_combined_transport_in_europe.pdf

[39] https://ec.europa.eu/transport/marcopolo/about/index_en.htm

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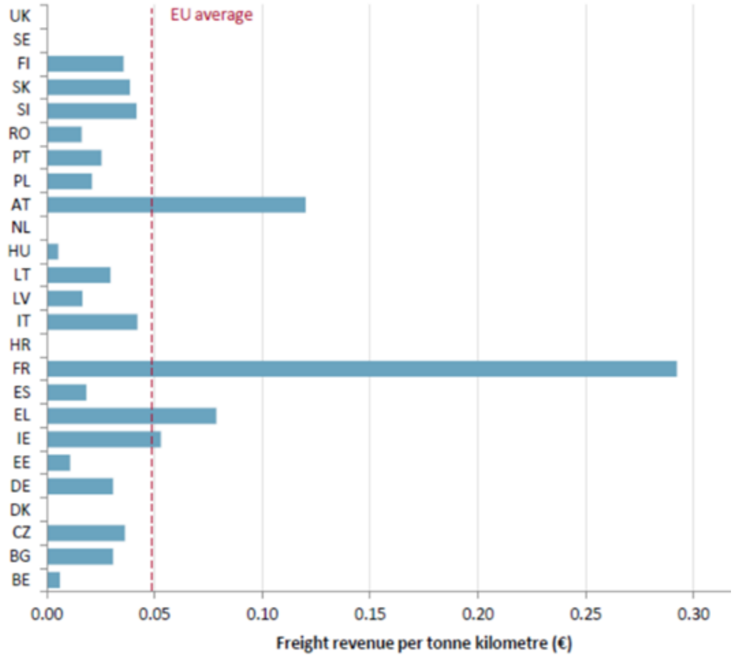

Figure 46: Freight revenue per tonne kilometre (2012) - Source https://ec.europa.eu/transport/sites/transport/files/modes/rail/studies/doc/2015-09-study-on-the-cost-and-contribution-of-the-rail-sector.pdf

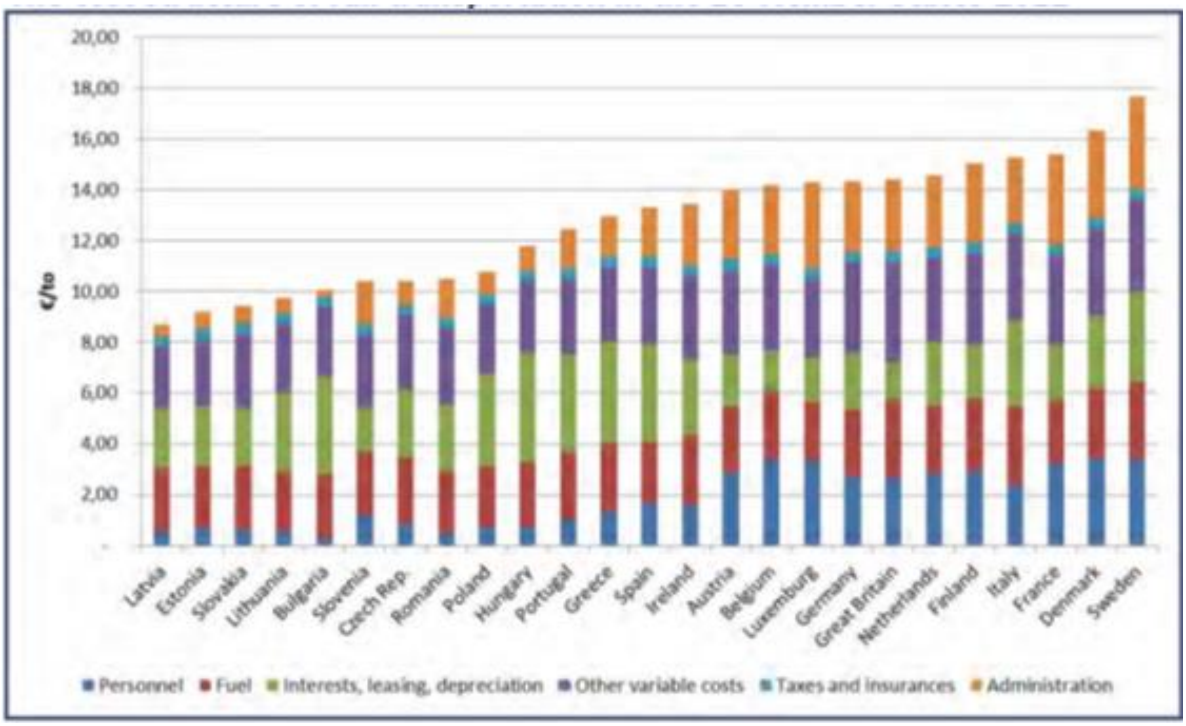

Figure 47: The cost structure of rail transport in the EU Member States (data 2012) – Source: Fraunhofer SCS, Fact-finding studies in support of the development of an EU strategy for freight transport logistics, 2015

6.7.4. The product grid

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Looking at statistics by product groups and by country between the years 2010 and 2017 (some estimates are marked in red when data are missing), with focus on 5 main product families out of the 21 segments classified by Eurostat, it is interesting to observe different evolutions.

UNIT	Million tonne-kilometre (TKM)											
NST07	Total transported goods		Coal and lignite; crude petroleum and natural gas		Metal ores and other mining and quarrying products; peat; uranium and thorium		Coke and refined petroleum products		Basic metals; fabricated metal products, except machinery and equipment		Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	
			data 3		data 4		data 8		data 11		data 20	
GEO/TIME	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017
European Union - 28	390.660	417.973	47.403	42.547	46.489	52.517	50.630	43.073	39.503	42.209	73.813	90.790
Belgium	7.282	7.282	364	364	348	348	475	475	1.662	1.662	2.727	2.727
Bulgaria	2.982	3.130	0	134	374	890	964	462	529	225	220	19
Czechia	13.770	15.843	4.876	3.199	966	888	1.225	1.498	1.407	1.364	1.974	1.920
Denmark	2.237	2.653	0	0	19	14	0	0	250	442	1.364	1.187
Germany	107.317	112.232	5.453	6.634	11.096	11.605	11.675	9.820	13.083	13.262	34.608	39.148
Estonia	6.638	2.325	1.051	587	59	22	4.785	748	83	48	0	0
Ireland	92	100	0	0	31	24	0	0	0	0	0	0
Greece	614	358	1	0	0	0	30	26	112	53	1	0
Spain	7.765	10.248	111	631	282	137	491	193	1.361	1.766	2.912	3.494
France	29.965	33.442	893	752	2.104	1.636	2.013	2.494	4.329	4.455	4.508	9.449
Croatia	2.618	2.618	57	220	304	304	334	319	281	135	194	194
Italy	22.800	22.700	96	96	822	644	415	415	2.448	3.859	7.194	9.069
Cyprus	:		:	:	:	:	:	:	:	:	:	:
Latvia	17.179	15.014	5.123	6.097	770	388	6.371	4.587	849	613	103	39
Lithuania	13.431	15.414	1.365	1.452	1.056	1.328	4.368	3.488	512	925	0	0
Luxembourg	600	200	:	:	:	:	:	:	:	:	:	:
Hungary	7.635	13.356	665	757	1.367	3.083	601	855	589	870	880	450
Malta	:	:	:	:	:	:	:	:	:	:	:	:
Netherlands	6.467	6.467	1.094	1.094	1.128	1.128	125	125	470	470	1.873	2.444
Austria	17.886	22.256	681	932	1.633	1.920	1.449	1.521	1.291	1.959	4.649	8.208
Poland	46.355	53.554	15.765	15.006	11.656	14.449	7.410	8.743	1.866	2.446	1.425	4.194
Portugal	2.313	2.751	0	0	432	173	304	606	107	198	543	1.132
Romania	11.587	13.782	2.390	1.613	483	326	4.480	4.465	618	930	662	649
Slovenia	3.283	4.447	222	385	639	704	360	374	268	392	819	1.365
Slovakia	8.054	8.477	902	640	3.304	3.378	873	654	1.025	906	193	179
Finland	9.750	10.319	136	64	1.563	2.736	544	309	891	957	0	0
Sweden	23.464	21.838	86	83	4.772	5.111	371	345	4.030	3.317	5.744	4.403
United Kingdom	18.576	17.167	6.072	1.807	1.281	1.281	967	551	1.442	955	1.220	520

Figure 48: EU rail traffic per product category - Source: NewOpera elaboration on Eurostat data

In particular:

- The groups "Coal and lignite", "crude petroleum and natural gas" (data 3), "Coke and refined petroleum products" (data 8) show an overall decline with significant negative impact in the UK while some other countries are showing more stable patterns;
- The groups "Metal ores and other mining and quarrying products, peat, uranium and thorium" (data 4), "Basic metals, fabricated metal products, except machinery and equipment" (data 11) show an overall growth with a significant contribution to the growth of countries such as Poland and Hungary;

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- The group "Unidentifiable goods: goods which for whatever reason are not identified and therefore cannot be assigned to groups 01-16" (data 20) in which most of the containerized flow is classified, represents the main group and shows the most significant growth.

Elaborating on product segmentation, it is easy to say that requirements are not the same for the various industries and some aspects need to be taken into account in interpreting rail performances and potentials.

For instance, bulk and non-bulk, light and heavy, are significant product aspects bringing cost implications. The type of handling required, together with the rolling stock specialisation, can be vital in deciding the modal alternatives.

Other aspects can be related to the players' profile, such as the company size, the industry concentration the different supply chain level and the attitude to medium-long term planning. All these aspects require customised business offerings developed with logistics engineering approach up to OSS. The Rail system has not shown a proper adaptation to the changing business environment and the modernisation of these new management tools.

One example of developing such product-oriented approaches can be found in the SPECTRUM project whose focus is on High-Value Low-Density Goods (HVLDG). Current pilot experiences of using high-speed trains can be considered part of this approach. Pilots are in place since 2018 for moving value goods and parcels between Naples and Bologna using high-speed trains converted in cargo trains capable of accommodating special containers fitting the gauge of these trains. In this way, the rail system becomes itself available for accessing the lucrative "same-day delivery market" typical of the internet channel, which is growing exponentially.

Looking at all categories at 2050 time horizon, according to Spiderplus project data summarised in the picture below, most categories show opportunities. Similar evaluations of opportunities to be pursued with product-oriented approach but with more aggregate examples, are shown in the IEA study published in January 2019 – "The Future of Rail, Opportunities for energy and the environment".

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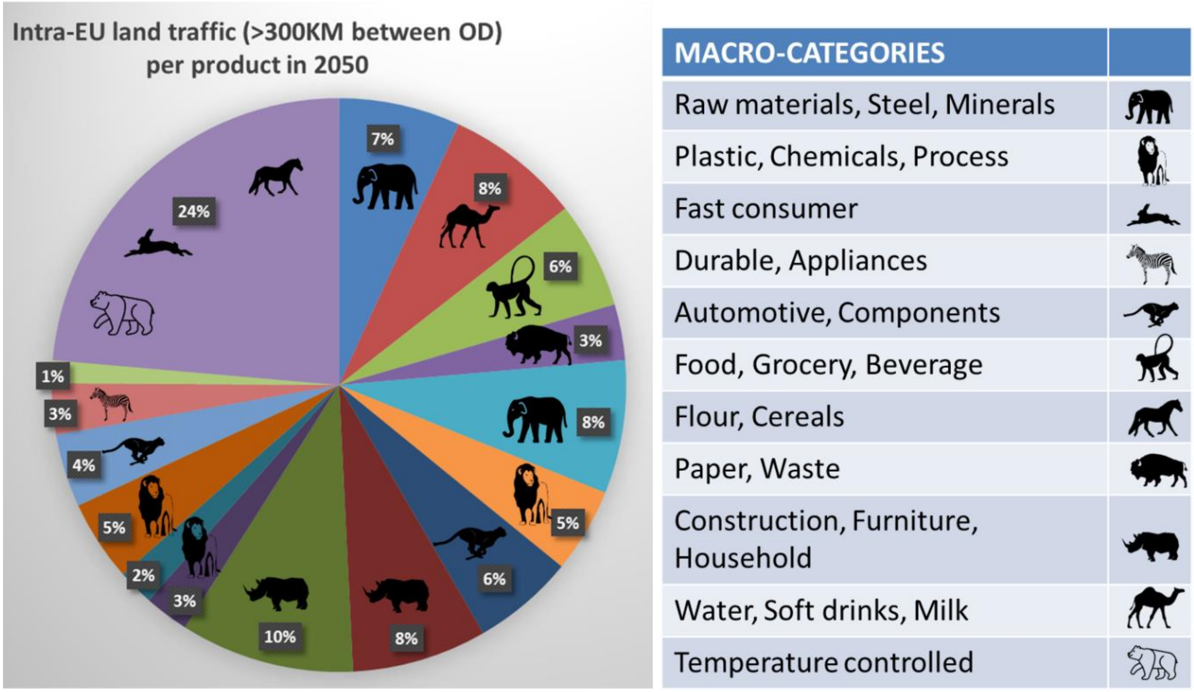

Figure 49: intra EU traffic projections per product category in 2050 – Source: BF for New Opera - Road Map 2030/2050, Towards the implementation of the comprehensive network: derived infrastructure development, December 2014

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MACRO-CATEGORIES	SYMBOL	RAIL MKT SHARE	SIZE OF MKT	GROWING POTENTIAL	CUSTOMERS GROUP
Raw Materials, Steel, Forest, Minerals-Refractory		High	Very Large	% to growth	Heavy Ind.+LSP
Plastic, Chemicals, Process Ind., Piping, Recycle		Medium	Very Large	High	Shippers+LSP
Fast Consumer, Toilet		Very Small	Very Large	Very High	LSP+Multimodal
Durable, Appliances		Medium	Very Large	High	Shippers+LSP
Automotive + Components		Very Small	Very Large	Very High	LSP+Outsourcers
Grocery, Wine & Spirit, Food		Small	Very Large	Very High	LSP+Multimodal
Flour + Cereals		High	Large	% to growth	Shippers + LSP
Paper + Waste		Medium	Very Large	High	Shippers + LSP
Construction, Furniture, Toys, Household		Very Small	Very Large	Very High	Shippers + LSP
Water + Soft Drinks + Milk		Medium	Very Large	High	Shippers + LSP
Temp. Controlled		Negligible	Large	Very High	Shippers + LSP
Ports Traffic industrialized		Medium	Very Large	High	Shippers + LSP

Figure 50: Macro categories for rail freight industrialization – Source: SPIDER PLUS Project, 2015

6.7.5. Liberalization and internationalization

The policy promoting open access for making rail freight more competitive is in place since January 2007 (Directive 2004/51/EC). The implementation process has been showing different speed and impact in different countries. Invisible barriers are still existing due to national member states' rules. In the 4th railway package, ERA is entitled with the power to overcome a certain number of barriers. The process might take some time, but it is still on its way[40].

The picture below from a 2016 study, shows the dynamics of rail freight transport volume in tkm in a sample of Countries including the UK, Sweden, Germany and France. "Although the GDP in those four Countries increased by similar rates, it shows that the rail freight transport volume has decreased in France, where the liberalisation of the freight rail market is relatively slow (it was delayed until 2006). On the other hand, the rail freight transport volume in the UK, Sweden and Germany, all of which liberalised the freight rail market through open access, has successfully increased their rail freight volume. Although it is difficult to define the reasons for the contrasting results in these four countries[41], some of the experts interviewed noted that

[40] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0796

[41] The UK market share had decreased drastically at the end of BR period dropping to 5%. From that shallow point and after some dramatic rail accidents and very substantial infrastructure investment, the market share has

improvement of rail freight traffic was obtained through a new railway transport market created by the new freight operators and their competitive pressure on the incumbents"[42].

The liberalisation process is continuing to deliver results in terms of market exploitation. An essential indicator of the real degree of market opening is the share of all but the principal undertaking. While the incumbents are still the major players in most countries, "liberalisation" has progressed and continue to do so in the future, providing the customers with alternative service choices that were not available before the liberalisation. This has been a significant success forcing the incumbents to improve their performances failing, which they would have lost their traffic flows totally.

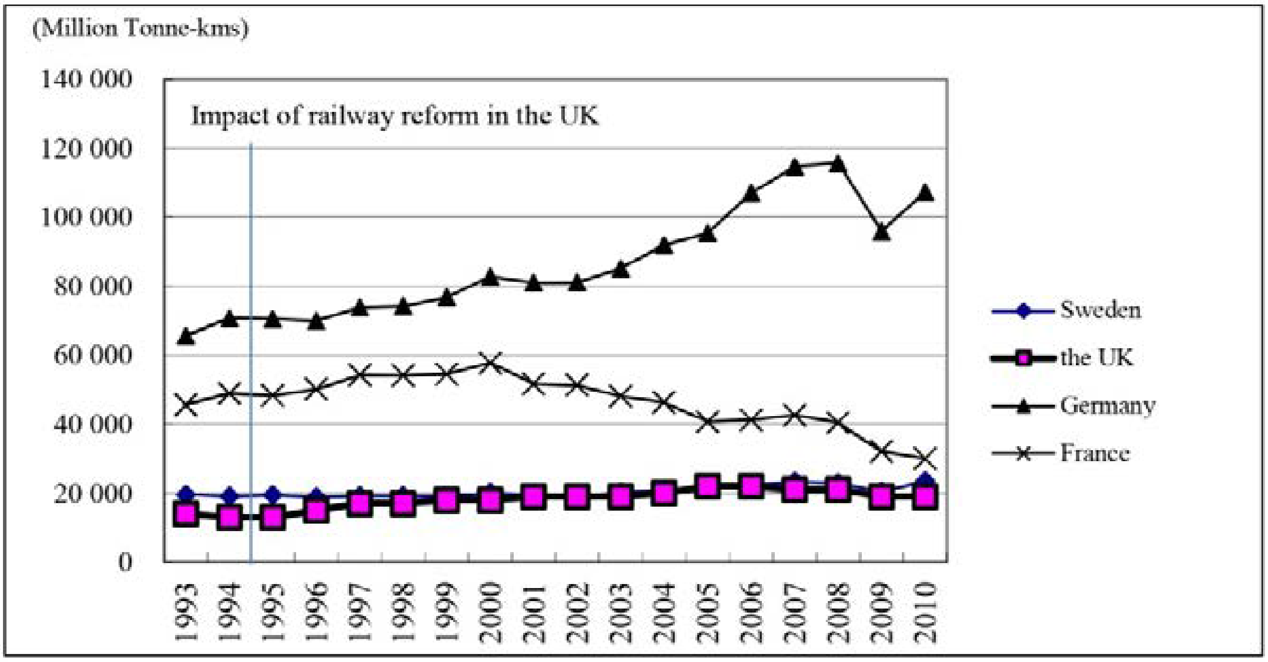

Figure 51: Transition of freight transport volume in 4 countries in EU - Comparison of three models for introducing competition in rail freight transport - Source: Fumio Kurosaki, Manoj Singh, 6th Transport Research Arena Warsaw, April 18-21, 2016

increased very well with a remarkable factor. The road network in the UK is very congested/complicated to use outside the main Motorway network.

[42] https://www.researchgate.net/publication/304530193_Comparison_of_Three_Models_for_Introducing_Competition_in_Rail_Freight_Transport/fulltext/57dafec808ae72d72ea36dfa/304530193_Comparison_of_Three_Models_for_Introducing_Competition_in_Rail_Freight_Transport.pdf?origin=publication_detail

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SHARE OF ALL BUT THE PRINCIPAL UNDERTAKINGS

%

	2006	2008	2010	2012	2013	2014	2015	2016	2017
BE	0.03	6.10	11.82	13.39	18.54	24.30	25.10	48.60	27.10
BG	3.18	14.32	21.60	36.50	44.70	48.80	51.40	54.50	58.60
CZ			13.16	20.62	23.67	30.10	33.50	34.90	36.80
DK			25.00	27.00	25.00	24.00	29.00	26.10	17.70
DE	16.40	22.00	25.00	28.60	32.60	34.10	40.90	45.50	47.50
EE	30.60	49.00	45.00	30.00	35.00	30.50	29.00	20.10	23.70
IE	0.00	0.00	0.00	0.00	*0.00*	*0.00*		*0.00*	*0.00*
EL	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
ES	4.90	5.00	8.08	16.83	19.05	20.50	26.00	29.50	30.80
FR	0.60	10.00	20.00	32.00	36.00	37.00	25.60	41.00	43.00
HR	0.00	0.00	0.00	0.00	0.00	0.52	2.00	14.70	23.90
IT	11.50		24.10	16.80	7.60	41.00	41.20	55.10	55.40
CY	-	-	-	-	-	-	-	-	-
LV	10.60	9.57	23.30	22.60	23.30	21.50	31.10	25.50	33.60
LT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU	0.00		0.00	0.00		0.00	0.00	0.00	0.00
HU	9.00	14.40	19.47	31.80	34.80	37.60	39.60	42.10	47.50
MT	-	-	-	-	-	-	-	-	-
NL	14.00	25.00	40.00	36.00	41.40	41.00		45.00	56.50
AT	10.00	14.00	14.60	17.60	19.30	21.40	23.60	26.10	24.50
PL	16.90	23.97	35.82	32.93	34.53	36.30	38.10	48.60	42.90
PT	0.00		9.00	11.00	13.40	11.30	11.80	15.40	14.20
RO	26.70	40.99	54.70	53.68	57.60	42.80	60.20	62.90	63.40
SI	0.00	0.00	0.00	9.50	9.19	9.90	12.10	13.00	13.30
SK	2.90	2.00	2.03	11.76	13.47	10.00	17.60	19.90	22.10
FI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.40
SE	32.50		40.00		56.00	*55.00*	48.00	46.00	46.00
UK		44.20	51.40	53.60	54.50	54.70	52.60	55.00	57.60

Figure 52: EU rail transport performance – Source: Publications Office of the European Union – STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

An essential aspect of the development of the market offering is the growth and the consolidation of international aggregation with major incumbents. Although the incumbents are playing an essential role in these aggregations, the private operators' object of such aggregation contributed to the creation of an international network. This evolution started with the liberalization process and had its first significant steps in the last decade, as shown in the picture below.

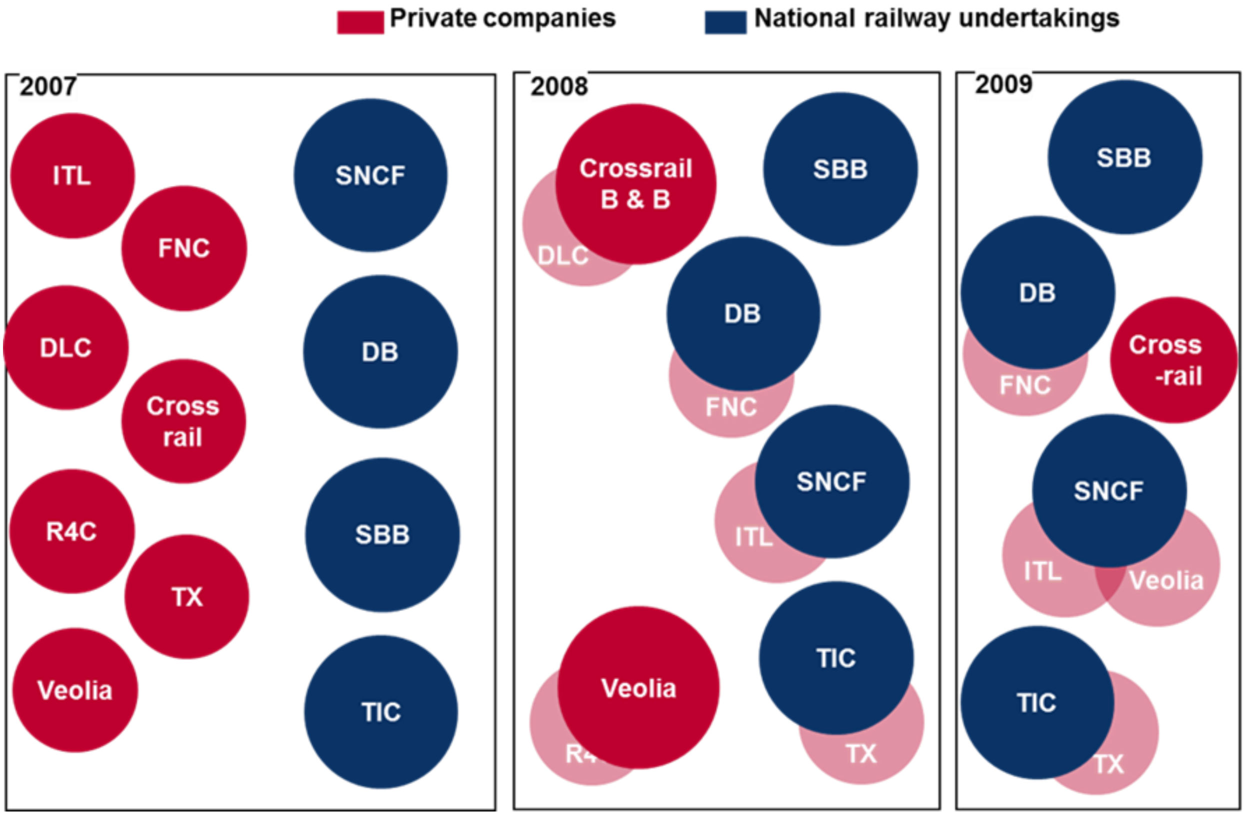

Figure 53: Rail Freight Consolidation Trend - Source: F&L 2011 meeting, Port of Antwerp presentation

The aggregation process is continuing.

In addition to the above, recent M&A operations are hereby listed:

- The acquisition by Hupac Group (Hupac) of ERS Railways BV (ERS) the Hamburg-based railway company in the second quarter of 2018[43];
- The acquisition by Mercitalia Rail (Polo Mercitalia) from the Polish PKP of 50% POL-Rail so reaching full control. POL-Rail is a company specialized in freight transport between Italy and Central-Eastern Europe December 2018[44];
- The acquisition by MSC Rail - a subsidiary of MSC Mediterranean Shipping Company SA of CP Carga - Logística e Transportes Ferroviários de Mercadorias SA in January 2016[45];
- The acquisition of the Belgian intermodal transport operator Railtraxx by Captrain

[43] http://www.hupac.com/EN/Hupac-will-acquire-ERS-Railways-to-strengthen-its-position-in-maritime-hinterland-logistics-5d387600

[44] http://www.mercitaliarail.it/cms/v/index.jsp?vgnextoid=8d2759d426589610VgnVCM1000008916f90aRCRD&vgnextchannel=737ce13f377db510VgnVCM1000008916f90aRCRD

[45] https://www.msc.com/lca/press/press-releases/2016-january/msc-rail-completes-the-acquisition-of-cp-carga

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Belgium (an SNCF Logistics company) in April 2019[46];

- The acquisition by the Swiss BLS Cargo of Cross Rail from Rhenus Logistics in March 2019[47] but retroactive since the beginning of 2019 whose primary purpose is to ensure the connection with Antwerp and Zeebrügge ports;

Another example of such international development can be the growing of Rail Cargo Group, whose network and traffic is represented in the picture below (2017).

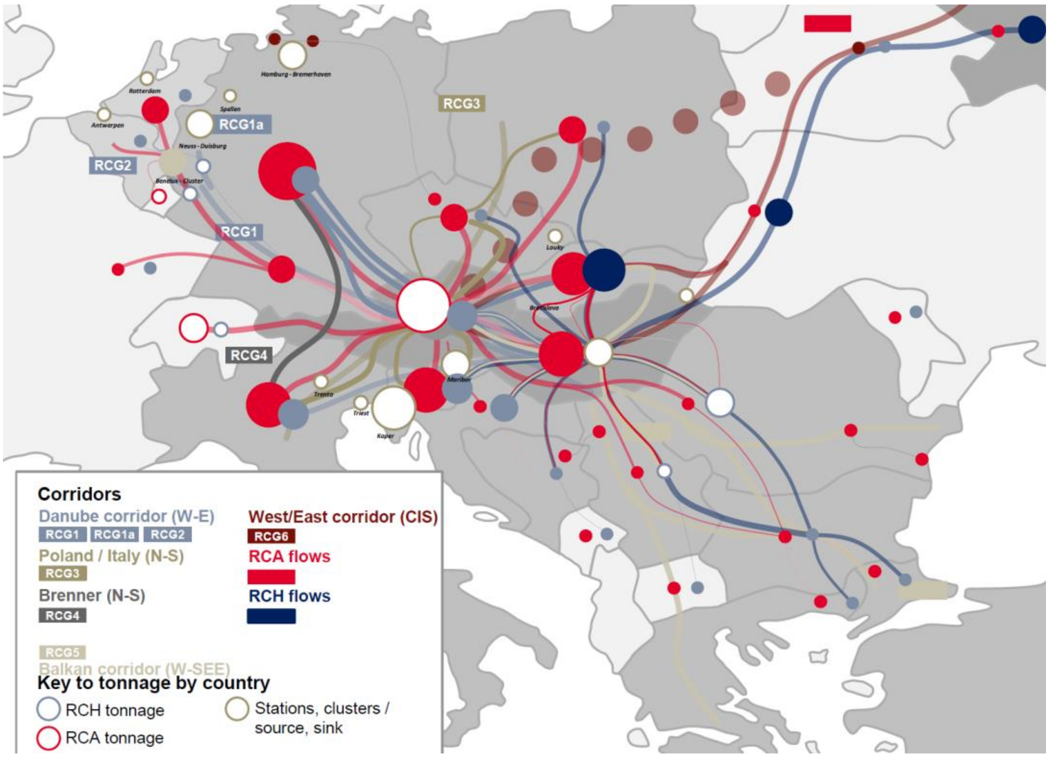

Figure 54: Rail Cargo traffic and network - Source: Rail Cargo Corporate presentation, June 2017[48]

Despite this process of internationalisation and network modernisation, the market perception from the demand side is still not entirely satisfactory. This stands to put in evidence the ground yet to be covered and how obsolete the rail system was towards answering the growing and more sophisticated demand of a fast-evolving marketplace.

6.7.6. Wagons – fleet status and requirements

Rolling stock is a valuable asset and wagons ownership, in particular, is a standard marketing tool for those companies owning them. In fact, wagons availability is a crucial element for managing

[46] Trasporto Europa, April 03, 2019

[47] https://www.regul.be/en/bls-cargo-takes-over-crossrail/

[48] http://www.xrail.eu/documents/13422/0/Corporate+Presentation+Rail+Cargo+Group+EN_20170601.pdf/cdc93f23-8d4a-4311-8697-f23e8952cbbb

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current traffic flows efficiently and for developing new ones. The rail wagons fleet is a point to be considered for setting ambitious targets for rail traffic since the wagons' availability is not abundant and lead-time for expanding the capacity through news rolling stock may not be short.

The rail wagons stock figures show massive reductions. When interpreting these statistics, redundancies and obsolescence have to be taken into account. Wagons can potentially continue to travel for several decades if declared in line with the stringent rules imposed by certified workshops that are in charge of the wagons' technical maintenance and with the TSIs. While the efficient wagons constitute only part of the rolling stock, with the availability shortage as a consequence of progressive equipment specialization, significant quantities of wagons remain unused and/or under-maintained. This is also a consequence of the progressive decrease in the SWL market share since SWL utilizes mainly very standard wagons. The wagons' fleet reduction is also linked to the fact that it becomes economically obsolete confronted to new, more efficient polyvalent wagons.

STOCK OF VEHICLES

	1990	2000	2005	2010 (*)	2015 (*)	2016 (*)	2017 (*)
EU-28							
BE	30 332	18 790	17 375	11 612	*11 612*	*11 612*	*11 612*
BG	42 459	29 720	16 511	11 751	4 572	4 586	4 510
CZ		58 524	44 545	27 416	25 863	25 322	23 560
DK	4 632	2 236					
DE	366 724	189 558	158 247	108 840	88 066	86 468	82 864
EE		5 857	18 971	17 575	21 501	21 586	21 835
IE	1 830	1 856	926	502	254	254	254
EL	10 967	3 453	3 491	3 158	3 522	3 522	3 522
ES	37 687	26 452	23 842	14 337	11 353	11 346	11 292
FR	148 100	94 789	95 738	25 314	14 052	12 347	12 347
HR	13 720	9 986	7 330	6 674	5 519	5 513	5 420
IT	99 728	70 115	45 730	30 331	20 270	19 079	*19 079*
CY	-	-	-	-	-	-	-
LV	11 085	9 146	8 871	9 033	9 807	8 896	8 769
LT	*12 860*	13 155	13 192	9 238	8 574	8 333	8 131
LU	2 719	2 626	3 222	4 147	3 006	3 043	3 117
HU		23 528	19 130	11 357	8 916	9 145	8 898
MT	-	-	-	-	-	-	-
NL	6 697	4 700					
AT	34 330	23 970	22 655	21 015	19 294	18 817	18 619
PL	275 582	130 116	103 234	89 270	86 364	87 598	87 696
PT	4 579	4 162	3 495	3 194	3 283	3 283	3 202
RO	166 086	117 982	65 175	72 605	36 858	35 553	34 175
SI	8 692	6 258	4 465	3 211	3 049	2 992	2 779
SK		26 975	25 515	15 260	15 533	15 786	15 509
FI	15 200	12 630	11 216	10 464	8 854	8 876	8 821
SE	27 470	17 596	16 637	15 166			
UK	34 403						

Figure 55: Goods wagons fleet – Source: STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

Looking at technology, wagons are not equipped with power connectors, useful both for improving the braking performances and for refrigeration purposes. It is to say that some innovations, currently under development in different EU co-funded projects like INNOWAG, are

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quite costly if the wagons are not equipped with autonomous energy supply systems. Noise reduction and automatic coupling would imply retrofitting of the existing fleet, for which affordable solutions are available. Predictive maintenance could reduce the wagons' maintenance cost significantly improving at the same time, the wagons efficiency performance and productivity. Also upgrading of the operational process to reduce cycle time may bring efficiency.

New technology boxes both for cargo monitoring and wagons running conditions are available and also in use for track and trace. This is a pre-requisite for improving the service performance to the ultimate users making rail aligned with the road modality as regards information standards. S2R INNOWAG project is studying innovative solutions for freight wagons in terms of lightweight materials, innovative design, sensors for monitoring cargo and other parameters.

To encourage the purchase of new equipment, initiatives are being put in place in some European countries. For instance, in Italy, the government since 2019 provides funds for scrapping wagons more than 20 years old. Other examples of funds' availability focus on retrofitting. Germany (from 2012 to 2020), the Netherlands, Switzerland (who is a non-EU Member State) and recently Austria (2019) have introduced the Noise Differentiated Track Access Charges (NDTAC) scheme. These countries have defined a national legislative framework providing financing and incentives to promote the retrofitting of the existing wagons fleet. Other funding initiatives are in place in Belgium and Poland[49]. The fact that Governments are starting to consider the retrofitting issues seriously is extremely positive, but harmonisation is required at European level.

On January 31, 2019, TSI noise was adopted, and noise limits will be applicable to existing freight wagons. From December 8, 2024, only quieter freight wagons shall be operated in quieter routes; therefore, wagon owners and keepers must retrofit their freight wagons for them to be allowed on quieter routes from 2024. The whole rail sector has to be prepared for this significant change, and the next five years will be crucial. Policymakers should provide the right funding instruments to wagon owners and keepers in a homogenised way all across Europe. NTADC systems may have an accelerating impact on the efficiency of retrofitting programmes if supported by harmonised funding schemes across Europe. An adequate funding of retrofitting measures is also fundamental to avoid a modal shift to road. The internalisation of external costs is required. Taking into account that the intermodal segments are and will be the growing ones, specific attention is necessary for facilitating the improvement of this traffic. Flexible solutions are represented by wagons with technologies allowing multiple uses so that new equipment is made available to the single/group of wagonload traffic. This flexibility allows the shifting of these wagons to intermodal traffic should the demand require to do so. In this sense, some solutions have been identified within the FP7 Viwas project, with stackable platforms and lightweight designed wagons.

[49] https://uic.org/IMG/pdf/2018_report_on_combined_transport_in_europe.pdf

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Selected current challenges for CT wagon fleet market in Europe	
▪ Increasing wagon prices and maintenance costs (low noise requirement) ▪ Difficulties and increasing costs in organising transports to/from workshops ▪ Congestion and reduced space in certain intermodal terminals due to the increased volume in trailer traffic ▪ Still not one European body for approvals of wagons ▪ The quality and speed of the technical development and cost efficency of our intermodal partners (road) "leads the way" ▪ Rebuild, scrap or replace inefficient or obsolete wagons to cover the needs for efficient handling (loading / unloading) transportation on rail for longer and heavier ILUs	▪ Technical challenges: Harmonisation of codification in combined transport & corrective factor, calculation methods for compatibility checks (wagon + load against line) not harmonised ▪ Operational challenge: Define and harmonise roles and functions of the various actors for codifying the ILUs, lines and wagons in combined transport ▪ Environmental challenge: noise and retrofitting ▪ Competition challenge: ☐ almost no differentiation between wagon types ☐ limited numbers of suppliers/manufacturers

Figure 56: Selected current challenges for CT wagon fleet market in Europe – Source: BSL for UIC - 2018 combined transport in Europe, January 2019

Also on the wagons keepers field, the market dynamics have played their role through M&A such as the acquisition by Railcar leasing company VTG of Nacco Group[50] in October 2018. Similarly, the acquisition by Wascosa AG of about 4,400 freight wagons from NACCO/CIT[51] in August 2018. Acquisitions effected in previous years were already consolidated, such as AAE being acquired by VTG.

6.7.7. Wagons – ongoing progress in technology

New technologies are set to play an essential role in the rejuvenation of the rolling stock park as well as the services provided to the ultimate users. Several efforts are in progress, including studies, pilots with ongoing implementations and ongoing projects. Here some examples are reported.

In the S2R project INNOWAG the innovative concepts for maximising the efficiency of wagons are founded on three main pillars:

- lightweight design and material
- cargo condition monitoring
- predictive maintenance.

The INNOWAG project concentrates on sensors and intelligent modules applicable to railcars that are capable of transmitting data on the wagons' geographical location in real-time, as well as monitoring the condition of goods on board. This information can be then integrated into

[50] https://www.railfreight.com/business/2018/10/11/vtg-completes-acquisition-of-nacco-group/?gdpr=accept

[51] https://www.wascosa.ch/media/news/?post=wascosa-acquires-about-4400-freight-wagons-from-naccocit

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customers' logistics chains enabling at the same time predictive maintenance models. "This work is intended to act as a benchmark and case study for demonstrating the application of predictive maintenance to freight wagons and the potential benefits it could bring, (in terms of efficiency, reliability, security and also cost-efficiency). INNOWAG also researches the structural design of novel lightweight materials, like high strength steels and composites, with optimised profiles. Lighter structures with lower tare weight enable higher payloads despite the axle-load limits, hence increased capacity and better energy efficiency (per ton paying). A better tonnes/cargo unit ratio would lead to more competitive costs against other transport modes. Slimmer and intelligent wagons allowing higher payloads that at the same time keep track of the transported goods in real-time, simultaneously monitoring the condition of the railcar itself and advising whether a particular maintenance is needed, represent a concrete possibility for the near future"[52].

To satisfy the new market needs, in Germany the program Innovativer Güterwagen supported by German Minister of Transport with 18 million euros is in progress since2016. In February 2019 DB e VTG presented 4 new wagons prototypes enabling higher efficiency, flexibility and more automated trains. A similar test has been done in France in 2017 by SNCF[53]. A central feature is the "digital brake" reducing train composition time and allowing predictive maintenance and automatic coupling, the prototypes include:

- automotive flexible wagons for cars of different height (including SUV);
- steel flexible wagons for containers;
- tank wagons with reduced length and weight but of the same capacity;
- special wagons 80 feet long for containers with low noise characteristics and reduced energy consumption due to their adaptable profile in curves and reduced attrition.

The "Innovative Rail Freight Wagon 2030" represents a collection of proposals for coordinated implementation of innovative rail freight wagons up to 2030, including the combination of two strategies: the construction of new wagons and the retrofitting of existing ones.

Started in 2014, it is managed by Technical Innovation Circle for Rail Freight transportation, consisting of representatives of wagon manufacturers, suppliers, customers and shippers, wagon owners, railway undertakings and scientific researchers.

The outcoming program is named "5 L" encompassing five growth factors for the successful introduction of the innovative freight wagon:

- Low noise - significant reduction of noise emissions compared to the current levels of rail passenger vehicles;
- Lightweight - higher payload, less net mass;
- Long-running - reduction of down and unproductive times, increased average annual

[52] Castagnetti, F., "Rejuvenating Europe's rail freight sector", *Baltic Transport Journal*, issue 3-4, 2017

[53] https://www.sncf.com/fr/logistique-transport/activites-ferroviaires/fret-sncf/train-fret-digital

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mileages, higher reliability;

- Logistics-capable - possibility of their integration into supply chains, service quality better than/equal to road and air transport;
- LCC-oriented (life cycle costing): integration of LCC-oriented components, with procurement costs rapidly amortised over the product lifetime.

The available components and modules need to be combined because of the synergetic effect in facing the different current issues with a focus on the entire EU plus Switzerland simultaneously.

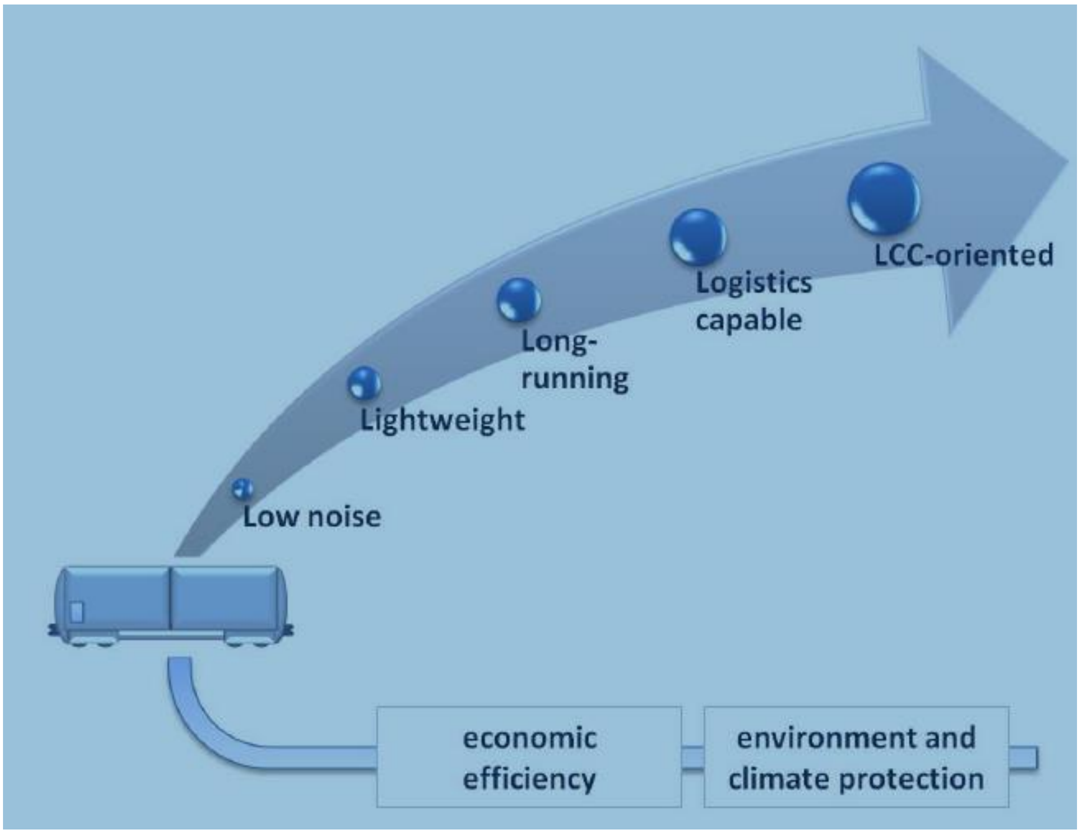

Figure 57: Growth factors for rail freight transport – Source: White paper Innovative Rail Freight Wagon 2030, September 2012

6.7.8. Other countries differences

While the EU overall data do not show an increasing role of rail, the countries' segmentation provides a significant number of differences, of which some components have been anticipated already in this research.

Other significant differences are related to geography. Examples can be the Alps crossing, the Channel tunnel, the ports and the inland waterways. Also, the type of economic activities may be necessary as there is a correlation between the type of industry and rail use intensity. It goes without saying that these structural differences, as a lever in the industrialization process, would require higher tailoring of offerings to cultivate modal shift opportunities.

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Modal split of freight transport	% in total inland freight tonne-km							
Railways								
geo\time	2005		2010	2015		2016		index 16/05
EU (28 countries	17,9	(e)	17,4	18,3	(e)	17,4	(e)	97,2
Belgium	12,6	(e)	12	11,8	(e)	11,6	(e)	92,1
Bulgaria	23,5	(e)	17	17,9		17,1		72,8
Czechia	31,5		30,1	26,4		26,4		83,8
Denmark	10,5		11,5	12,2		11,1		105,7
Germany	18		18,7	19,5		18,8		104,4
Estonia	79,9		75,4	52,4		42,9		53,7
Ireland	1,9		0,9	1		0,9		47,4
Greece	2,7		2,2	1,6		1,3		48,1
Spain	5,2		4,6	5,8		5,3		101,9
France	11,8		9,5	11,7		10,9		92,4
Croatia	20	(e)	22,8	19,4		17,3	(e)	86,5
Italy	10		9,2	13,5		14,5		145,0
Cyprus	:	(z)	:	:	(z)	:	(z)	
Latvia	84,1		82,1	79,8		76,6		91,1
Lithuania	74,1		72,8	65,9		65		87,7
Luxembourg	15		11,6	6,9		6,2		41,3
Hungary	27,2		27,1	29,5		28,5		104,8
Malta	:	(z)	:	:	(z)	:	(z)	
Netherlands	6		5,8	6,2		6		100,0
Austria	35,7		33	32,2		31,5		88,2
Poland	36,4		29,5	25,6		24,7		67,9
Portugal	9,2		10,9	14,1		14,5		157,6
Romania	26,3	(e)	29,3	31,6		30,3		115,2
Slovenia	30,8		31,8	35		33,3		108,1
Slovakia	47,1		38,5	36,6		34,5		73,2
Finland	25,2		26,8	27		26,8		106,3
Sweden	32,5		35,6	29,6		29,4		90,5
United Kingdom	11,3		10,9	10,4		8,4		74,3
:=not available e=estimated z=not applicable								

Figure 58: EU rail traffic share by country and by year (in tkm) – Source: elaboration of Eurostat figures

Looking at medium-long term dynamics, the most significant example of growth of rail traffic is in Germany, where a substantial increase of volume and market share (see for Germany - Market Analysis - Railway 2017 – BUNDESNETZAGENTUR) has occurred. Data from the German statistical agency Destatis, show an additional increase of 1.1 billion t/km in 2017, despite the Rastatt problems. In Germany, several initiatives (as incentives to modal shift with 350 million in the period 2018-2023 to pay up to 45% of infrastructure charges) supporting rail have been put in

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place in recent years with continuity, and they seem to continue to generate improvements. Infrastructure saturation is a crucial aspect detected by some areas, for instance, in the case of the Genoa-Rotterdam corridor. These cases require some actions in correcting the bottlenecks. The adoption of the "Freight Master Plan" Federal Ministry of Transport and Digital Infrastructure (as in the document published in June 2017), will enable further achievements both for the direct actions to be implemented according to a defined timetable and for the clear direction setting for the entire market.

France is the most negative case, with a significant decline in rail volumes. New initiatives, especially for reducing transit times (such as the connection between Toulon and Calais for Ro-Ro from North Africa to the UK, the Calais-Barcelona intermodal connection and the Calais-Torino rolling motorway connection) are in their initial stage beginning in 2019. It is too early to make considerations on the effects of these measures.

For countries such as Italy and Spain, where high-speed investments and management efforts have brought developments on the passenger side, it is hoped that the next efforts may target rail freight transport. The business plan 2019-23 of the Italian incumbent rail freight operator shows investments aiming at increasing the business volume by 50% within 2023. In Italy, a new Company Mercitalia incorporated under one management several activities in rail freight providing a unique strategic direction. This move appears to have improved the previous situation.

Concerning other countries, one can see those showing a decrease in rail transport. This may be due to the lower costs of truck drivers shifting traffic to road. Another reason is encompassed in the accessing countries economic development. In fact, it invariably happens that the priority of these accessing countries is to develop the motorway system to link it to the rest of Europe. The next step is to use the available drivers' abundance and the trucking companies emerging thereof to transform in hard currency the transport services produced at lower costs. This is a pattern which has been a common denominator for many emerging European economies that have seen in the initial stage an exponential growth of road transport compensated by a similar decline in rail transport. This phenomenon may affect the modal mix statistics of individual countries.

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6.8. Rail freight infrastructure towards 2030-2050

6.8.1. Core Network and Extended Network

The Rail infrastructure network consists of two layers:

- The *core network*. It prioritizes the most important links and nodes of the TEN-T to be fully operational in 2030. The strategic core network was defined by linking important nodes, multi-modal routes, as well as taking into account major traffic flows.
- The *comprehensive network*. To be completed by 2050 will ensure full coverage of the EU territories providing accessibility to all regions by feeding into the core network. The comprehensive network will allow the great majority of European citizens and businesses to be no more than 30 minutes away in travel time from the feeder network. Both layers include all transport modes: road, rail, air, inland waterways and maritime transport, as well as intermodal platforms.

The core network includes:

- 83 main European ports with rail and road links;
- 37 key airports with rail connections into major cities;
- 15,000 km of railway line upgraded to high speed;
- 35 cross border projects to reduce bottlenecks.

Transport Corridors are the main traffic axes of the rail infrastructure network. The corridors approach managing both the infrastructure development and the traffic facilitates the implementation of the coordinated development of the infrastructure within the core network. Covering at least 3 modes, 3 Member States and 2 cross border sections, the implementing corridors have been identified as a major instrument for guaranteeing co-ordination, cooperation and transparency.

The Corridors have several targets to accomplish:

- To form the backbone of EU's integration process both in territorial and functional terms such as West-East; North-South and in economic and political terms involving shared market and governance structures;
- To contribute to the sustainable growth of the EU infrastructure and help to create employment;
- To foster internal and cross-border competitiveness making the EU industry more efficient and customer-responsive;
- To contribute to the finalizing of the single European market;
- To maintain or even enhance the mobility of labour and capitals in Europe by enhancing the flow of people and goods.

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The "Corridor approach" is the way to coordinate countries fostering the planned actions collecting the full benefits for cross-border interoperability. The co-ordination implies several actions in terms of financial, technical and organizational efforts to overcome barriers due to the multinational ownership of the corridor.

6.8.2. Freight corridors

Within the Core Network Freight corridors according to the principle of The Regulation (EU) No. 913/2010 have been defined by linking the main industrial and port regions in Europe.

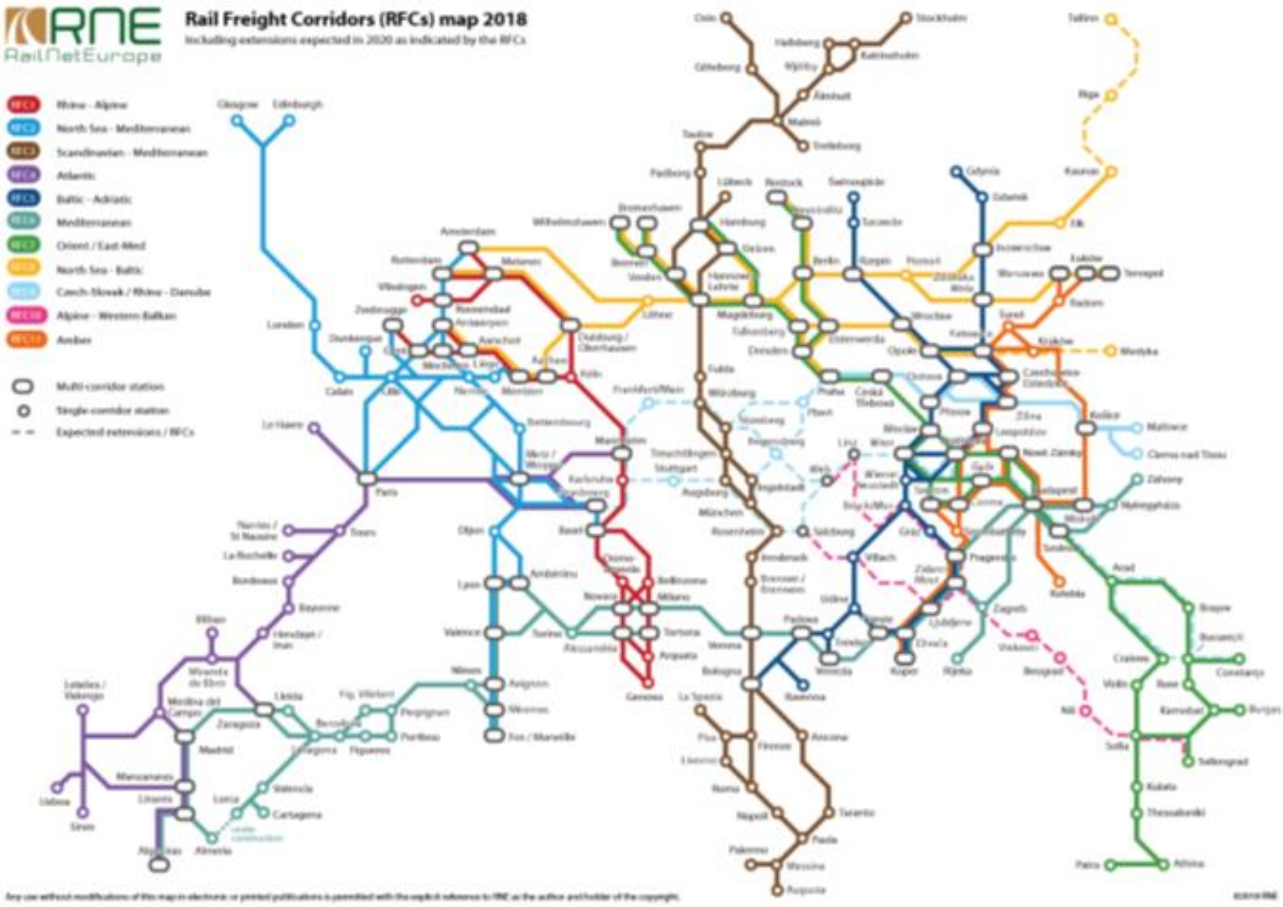

Figure 59: TEN-T Corridors and Rail Freight Corridors – Source: http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html, http://www.rne.eu/rneinhalt/uploads/RFC-MAP-2017.pdf

While corridors management is progressing, occurrences reveal the need for accelerating coordination with a wider scope. "The seven-week interruption of the Rhine Valley freight route caused by the DB Netz incident in Rastatt has made 2017 a black year for European rail freight, both operationally and financially. The lack of contingency plans and incompatible underperforming re-routing options, together with the lack of multilingual drivers (requested by TSIs) caused significant damage to the whole value chain of rail freight transportation as well as

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to the industries that have entrusted their volumes to the ecologically sustainable rail system"[54].

The freight trains competitiveness needs to be increased compared to trucks and in line with growing market needs. The Approach is primarily 'business-oriented' given that the axes are identified based on existing and potential trade flows and market needs.

Looking at freight corridors KPIs, capacity seems still "largely" available. At the same time, service quality is still hardly comparable with road, especially when considering that the monitored performance is not door to door but limited to corridor transit or Terminal/Terminal.

Punctuality KPIs by cooridor	volume of offered capacity (million km)		volume of required capacity (million km)		volume of offered capacity - reserve capacity (million km)		number of conflicts	
	2018	2019	2018	2019	2018	2019	2018	2019
RFC 1 Rhine-Alpine	17,6	17,2	7,4	7,9	2,9	2,9	40	75
RFC 2 North Sea-Mediterranean	21,3	24,7	13,5	13,9	4,9	NA	10	-
RFC 3 Scandinavian-Mediterranean	16,8	16,6	6,4	7,4	2,3	NA	28	39
RFC 4 Atlantic	9,9	11,4	4,5	4,6	2,1	NA	-	-
RFC 5 Baltic-Adriatic	8,9	7,1	0,9	0,7	3,6	NA	1	-
RFC 6 Mediterranean	14,2	14,3	4,3	6,3	6,4	NA	4	9
RFC 7 Orient/East-Med	11,3	14,2	3,6	6,1	3,3	NA	4	7
RFC 8 North Sea-Baltic	15,8	16,2	2,3	1,0	4,0	NA	5	1
RFC 9 Czech-Slovak/Rhine-Danube	4,8	4,9	3,4	3,6	1,8	1,9	-	-
RFC 10 Alpine-Western Balkan	4,8	4,9	3,4	3,6	NA	NA	-	-
RFC 11 Amber	NA	4,1	NA	0,9	NA	NA	NA	-

Figure 60: Example of KPIs of Freight network for capacity – Source: elaboration based on corridor data[55]

The Extended (or Comprehensive) network includes the infrastructure not part of the Core network. The Extended network is necessary for assuring capillarity. The Rail infrastructure is a unique infrastructure to be available for both passengers and freight. Only part of the network is currently utilized and potentially utilizable for freight. A large part of the extended network is not even electrified but, in any case, not really utilized for goods. Corridors (Core + Comprehensive networks) request upgraded ERTMS system while many last-mile connections request local Command control system. This creates problems since ERTMS implementation is not deployed largely enough. For new freight locos, ERTMS constitutes an unbearable retrofitting cost.

[54] Learnings from Rastatt: Infrastructure Managers must strengthen their support for international services – 2017 – source ERFA/NEE/UIRR

[55] http://www.rne.eu/rail-freight-corridors/

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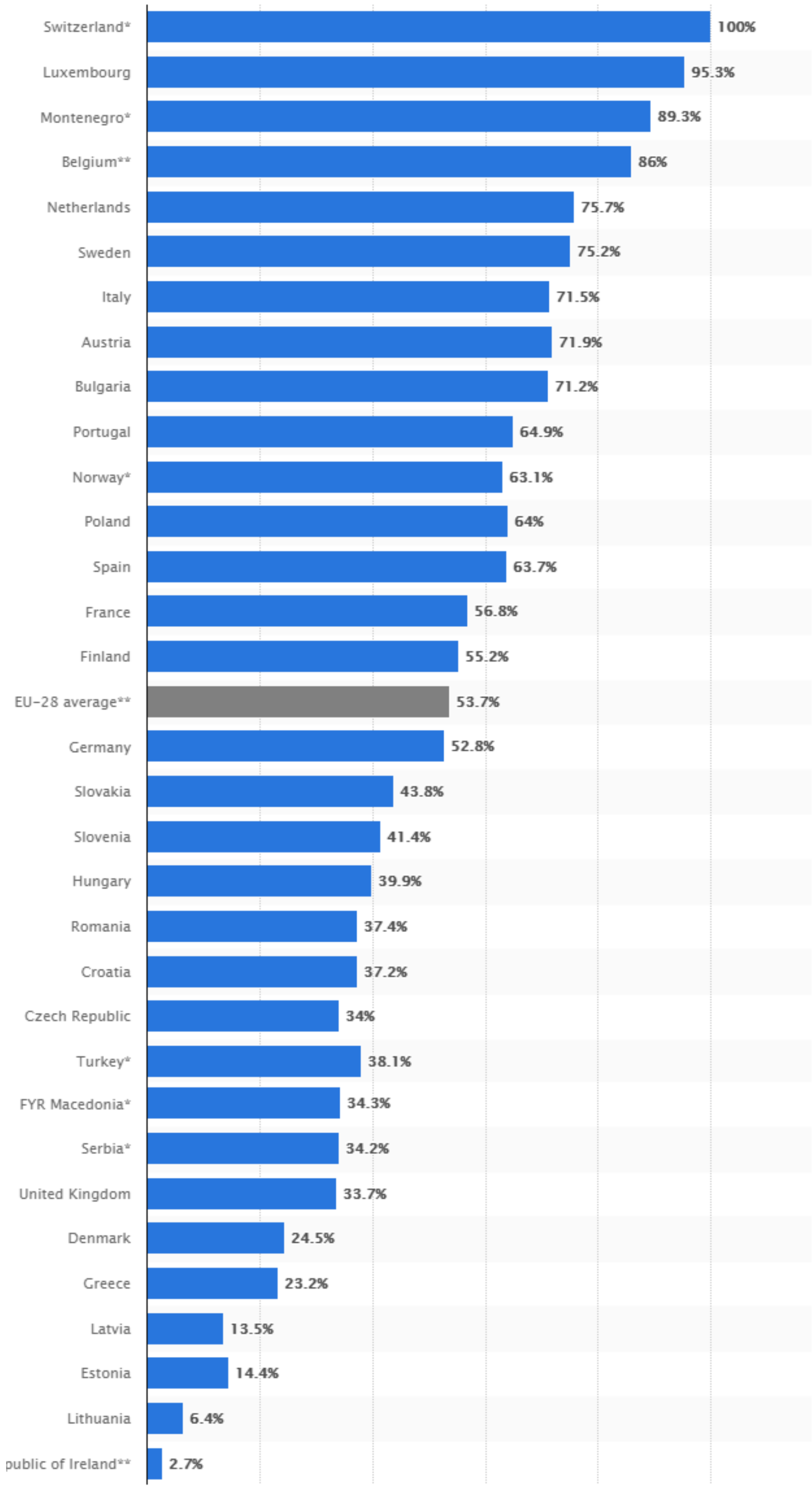

Figure 61: Percentage of the railway lines in use in Europe in 2016 which were electrified, by country (2016) – Source: Statista

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	1995	2000	2005	2010	2015	2016	2017	km OF WHICH: ELECTRIFIED 2017	%
EU-28	229 436	222 708	216 708	220 022	217 605	217 081	217 236	117 348	54.0
BE	3 368	3 471	3 544	3 582	3 607	3 607	3 605	3 102	86.0
BG	4 294	4 320	4 154	4 097	4 019	4 029	4 030	2 870	71.2
CZ	9 430	9 444	9 614	9 468	9 466	9 463	9 408	3 218	34.2
DK	2 863	2 787	2 646	2 606	2 552	2 539	2 487	632	25.4
DE	41 718	36 588	34 221	37 679	38 828	38 990	39 219	20 736	52.9
EE	1 021	968	968	919	918	918	1 033	132	12.8
IE	1 954	1 919	1 919	1 894	1 894	1 894	1 894	*108*	5.7
EL	2 474	2 385	2 576	2 552	2 239	2 240	2 240	532	23.8
ES	14 308	14 347	15 015	15 837	16 056	15 922	15 904	10 123	63.7
FR	31 940	31 397	30 871	30 335	28 808	28 364	28 120	16 052	57.1
HR	2 296	2 726	2 726	2 722	2 604	2 605	2 605	970	37.2
IT	16 003	16 187	16 545	17 022	17 041	17 096	17 105	12 217	71.4
CY	-	-	-	-	-	-	-	-	-
LV	2 413	2 331	2 270	1 897	1 859	1 860	1 860	251	13.5
LT	2 002	1 905	1 771	1 767	1 877	1 911	1 911	152	8.0
LU	275	274	275	275	275	275	275	262	95.3
HU	7 714	8 005	7 950	7 893	7 894	7 749	7 752	3 138	40.5
MT	-	-	-	-	-	-	-	-	-
NL	2 739	2 802	2 810	3 013	3 031	3 058	3 055	2 310	75.6
AT	5 672	5 665	5 691	5 039	4 937	4 917	4 953	3 557	71.8
PL	23 986	22 560	19 507	19 702	18 510	18 429	18 513	11 771	63.6
PT	2 850	2 814	2 844	2 842	2 545	2 553	2 546	1 639	64.4
RO	11 376	11 015	10 948	10 777	10 770	10 766	10 766	4 030	37.4
SI	1 201	1 201	1 228	1 228	1 209	1 209	1 209	610	50.5
SK	3 665	3 662	3 658	3 622	3 626	3 626	3 626	1 588	43.8
FI	5 880	5 854	5 732	5 919	5 923	5 926	5 926	3 284	55.4
SE	10 925	11 037	11 017	11 160	10 908	10 882	10 874	8 189	75.3
UK	17 069	17 044	16 208	16 175	16 209	16 253	16 320	5 875	36.0

Figure 62: EU railways network lines in use – Source: STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

The HSR development, while created primarily for passengers, is nonetheless allowing additional capacity to freight on existing lines for freight, particularly in the night-time.

New High-speed lines are under development (see also the specific chapter in the deliverable 3.1.4 "Social, environmental, economic variables data set collection").

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LENGTH OF LINES

km (at end of year)

	BE	DE	ES	FR	IT	NL	AT	PL	UK	EU
1985	-	-	-	425	174	-	-	-	-	599
1990	-	90	-	717	194	-	-	-	-	1 001
1995	-	447	471	1 290	238	-	-	-	-	2 446
2000	72	636	471	1 290	238	-	-	-	-	2 707
2005	137	1 183	919	1 549	238	-	-	-	74	4 100
2010	209	1 272	1 866	1 912	856	90	-	-	113	6 318
2015	209	1 475	2 413	2 058	856	90	50	224	113	7 488
2016	209	1 475	2 413	2 180	896	90	50	224	113	7 650
2017	209	1 658	2 852	2 814	896	90	268	224	113	9 124
2018	209	1 571	2 852	2 734	896	90	263	224	113	8 952

HIGH-SPEED LINES CURRENTLY UNDER CONSTRUCTION

	LINE	LENGTH km	START OF OPERATION
DK	Copenhagen - Ringsted	60	2019
DE	Wendlingen - Ulm	60	2022
DE	Stuttgart - Wendlingen	25	2024
DE	Karlsruhe - Rastatt (Basel)	17	2024
DE	(Karlsruhe) Buggingen - Katzenbergtunnel (Basel)	32	2025
DE	(Karlsruhe) Katzenbergtunnel - Basel	13	2025
ES	Monforte del Cid - Murcia	62	2019
ES	Vitoria - Bilbao - San Sebastian	175	2022
ES	León - Asturias Variante de Pajares	50	2020
ES	Bobadilla - Granada	109	2019
ES	Plasencia - Caceres / Badajoz	193	2020
ES	Venta de Banos - Burgos	91	2019
ES	Zamora - Orense	224	2020
IT	Genoa - Milan (Tortona)	53	2022
AT	Wien Stadlau - Staatsgrenze (AT/SK)	38	2022
AT	Wien Inzersdorf Ort - Wr. Neustadt (Pottendorfer Linie)	47	2023
AT	Graz - Klagenfurt (Koralmbahn)	122	2025
AT	Gloggnitz - Mürzzuschlag (Semmering-Basistunnel)	28	2026
AT	Volders - Baumkirchen / Innsbruck - Staatsgrenze AT/IT (Brenenr-Bassis-Tunnel)	46	2027
SE	Arlöv - Lund	11	2024
UK	London - Birmingham	230	2026

Figure 63: EU railways high-speed network – Source: STATISTICAL POCKET BOOK 2019 (data 2017) - EU TRANSPORT in figures

As described above the rail network capillarity, in general, does not represent a capacity limit with the exception of specific bottlenecks, urban bypasses, port connections and technical

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features such as wagons profile and train length. The mapping of such features from comprehensive and easily accessible statistics would be vital for supporting traffic more efficiently and for prioritizing actions. Even if structured data are not available, these topics are in the scope of corridors management and actions are in place for taking the necessary correcting measure.

While it is challenging to estimate investment needs failing segmented evaluations of requirements, according to Spiderplus Project about 5.000km would be sufficient for implementing new vital connections, correcting bottlenecks and bypasses together with other actions focusing on 2050 time horizon.

6.8.3. Nodal infrastructure

Looking at nodal infrastructures, a number of observations can be listed:

- Most of the sidings in stations/yards are not in use any longer even if some project would rely on these facilities with technical solutions still not consolidated by success (examples: Metrocargo and Cargomover);
- Concerning the existing professional infrastructure such as logistics centres and intermodal terminals and freight villages, their capillarity appears in general satisfactory. The analysis of traffic attraction zones, evaluating current potential and future perspectives, would allow more detailed evaluations and proper Nodes hierarchy for the economy of scale and proximity to industrial clusters or traffic attraction zones. In some cases, limits to expansion justify additional locations in close areas for satisfying dry ports requirements. As imaginable, the features of the existing facilities are not always flexible enough for future upgrading to longer trains and for mechatronics. This is even more so in major traffic attraction zones where the amount of traffic would more easily justify investments. The improvement of their accessibility avoiding urban centres may be appropriate.
- The evaluation of the Nodes' hierarchy along the corridors need to be considered since the corridor productivity is directly connected to the Nodes capacity to the point that these nodes become an integral part of the rail corridor infrastructure. There is a consolidated saying "Any corridor productivity is limited by its weakest point".
- Research undertaken by the SPIDER PLUS project for evaluating the traffic flow impact on the nodes at 2030 and 2050 revealed that changes will take place in the existing hierarchy of leading rail terminals in terms of handled volumes in favour of others strategically placed on the TEN T corridors.
- The private sidings, whose volumes are very high, may present opportunities and their rejuvenation could prevent their oblivion (process currently in place in some industrial sites).
- The seaports are a specific target for rail infrastructure, including dry port solutions.
- Specific monitoring is required for managing capacity. Terminals characteristics become important for EU overland connections with external networks, especially when/where

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transhipment is required.

- Another opportunity for developing rail connected terminals at relatively low costs is represented by the re-conversion of old industrial sites already well positioned towards the TEN T corridors or unused marshalling yards, which by definition have an extended rail network available for re-utilisation. See Tiger and Tiger Demo Projects.

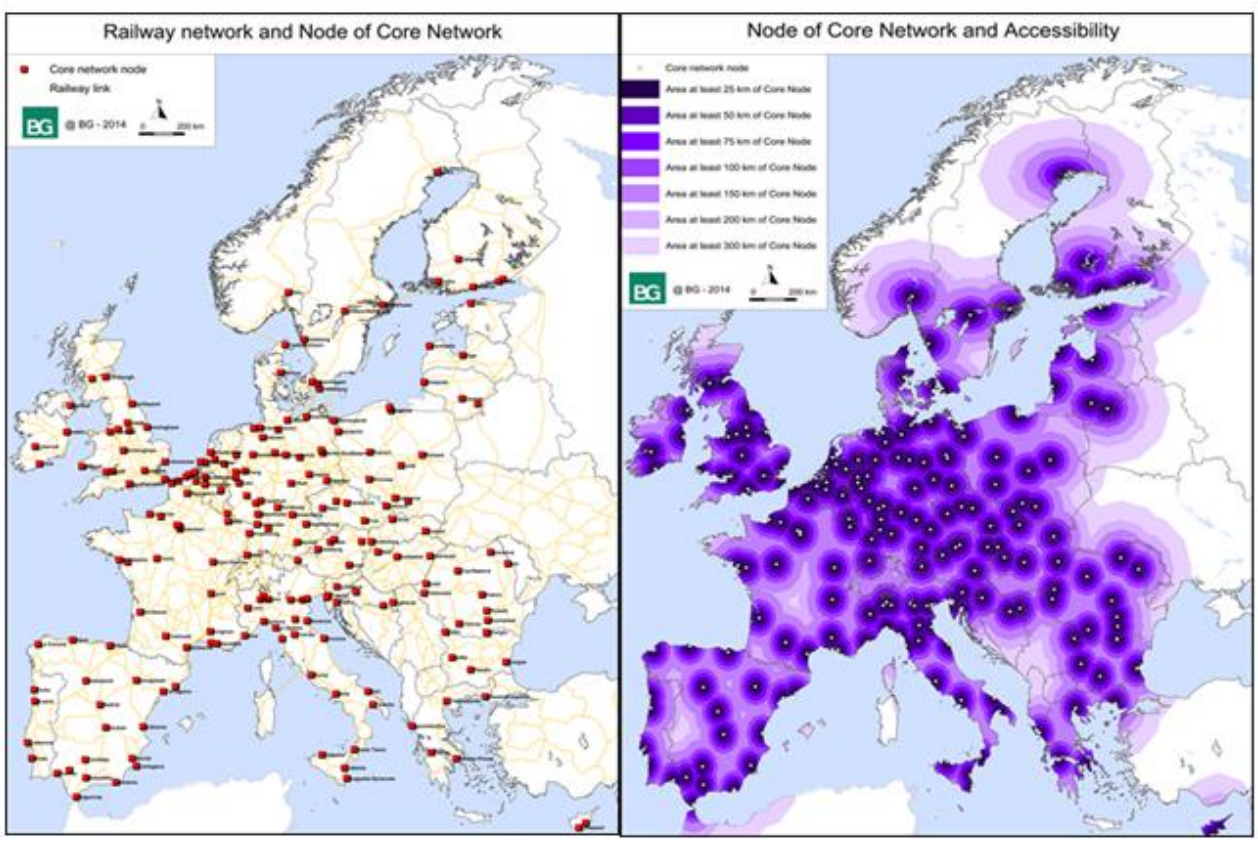

Figure 64: Railway network and node – Source: NewOpera & BG Road Map 2030/2050 - Towards the implementation of the comprehensive network: derived infrastructure development, 2014

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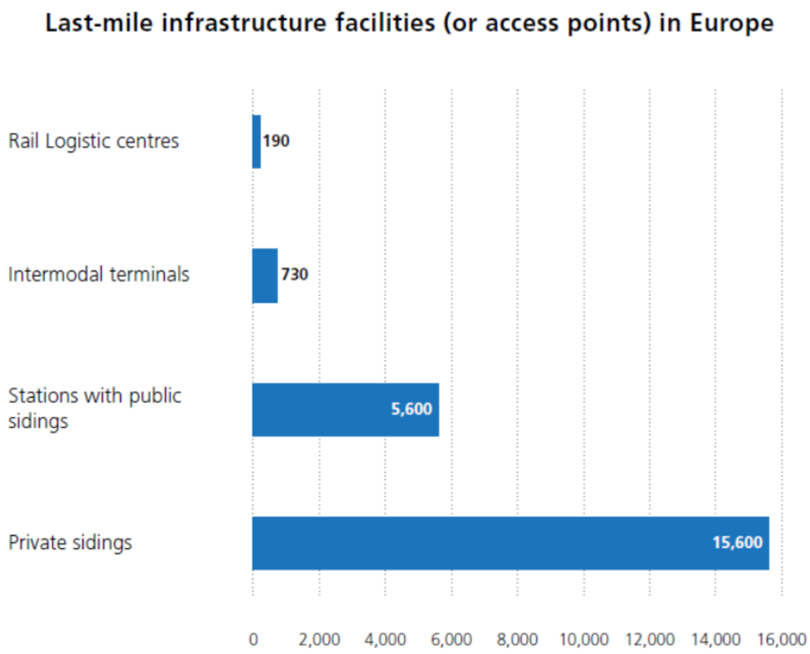

Figure 65: Last mile infrastructure facilities in Europe – Source: UIP[56]

6.9. Information and Communication Technology

6.9.1. Key enabler toward a higher level of industrialization

While it is not a "direct" player, Information and Communication Technology (ICT) presence is everywhere in the rail freight industry as a key enabler toward a higher service level and industrialization. For this reason, the above paragraphs anticipated the most relevant aspects of its role and potential contribution to progress.

Nevertheless, without entering in technical contents, but considering only the user perspective, it is useful to group here some considerations trying to apply classification criteria.

6.9.2. Possible classifications

According to the different perspectives, each item can be classified with multiple views. In addition, the convergence of technologies implies permeable borders between the "different" items.

Examples of classification can be:

[56] https://www.uiprail.org/index.php/publi/annual-report/461-uip-67th-annual-report-2016

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- Setting up new solutions and business models (including governance model, data property, connections to users, transactions, control, management)
    - Integrated offerings (door-to-door, one-stop shop, corridor services, etc…)
    - Integration of services (neutral and/or dedicated platforms, asset and non-asset based)
    - Specialized offerings (by product, by service segment, crowdsourcing and crowd shipping, cybersecurity, communications to stakeholders, data provider, transactional and clearing services, certification)
    - Dynamic pricing (time and routing based, contributing to specific investments, other parameters)
    - Environmental guidance (linked to pollution, noise, geography, circular economy models)
    - Design of infrastructures and services (network and hubs design, market research, flows simulations, empty return minimization, modularization)
    - Return logistics
- Category of players/resources:
    - Infrastructure (building, managing and maintaining lines, terminals)
    - Rolling stock (building, managing and maintaining locomotives, wagons)
    - Rail undertaking (selling and using traffic capacity) and other stakeholders
    - Agencies and industry associations (ERA, S2R, ERAC, UIRR, CER, UIC, UNIFE, ERFA)
- Management processes:
    - Planning (departmental and master planning, vertical and horizontal integration/collaboration)
    - Executing (revenue management, security, workflow, data visibility, dematerialization, single window, smart contracts, security and data protection)
    - Controlling (cost and service KPIs, innovation and new value added, pollution safety and security, new metrics, tracking & tracing)
    - Training (turn over, new roles, inclusion)
- Technology SW and toolkits:
    - Analytics & artificial intelligence, blockchain, internet of things, physical internet, 5G, RFID, WiFi, augmented reality, connected sensors, smart glasses, tech boxes, handheld devices, drones, machine learning, robotics and mechatronics, drones, autonomous vehicles
    - Collaborative platforms, cloud services, etc…
    - SW (ERP, supply chain planning and optimization SW, Apps)

Most of the listed items are already well known in the rail ecosystem. Knowledge is never a limit, but new applications need a scenario of sufficient stability before entering in evaluating new novel tools and disruptive technologies.

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6.9.3. Constraints

Investments are a constraint for rail as for any industry. Rail even more so for the investments' magnitude required and for being an "Asset based" business.

Dealing with constraints, it may be useful to distinguish "hard", and "soft" barriers as their overcoming may have different investment requirements, technical limitations and time to market. Infrastructure and rolling stock are in the "hard" cluster while operations - both on the RU and the IM field - may be predominantly in the "soft" cluster (with exceptions related, for instance, to signalling issues and for operations requiring a substantial behavioural change). ICT may have larger role in the "soft" dimensions with relatively limited investments and shorter lead times.

However, the main issues are represented by the complexities. Such complexities require deep engineering analysis and long lead time to market before harvesting results. Often these considerations are hindering the entrance into the implementation phase.

In all industries, there are "innovators" aiming at gaining competitive advantages taking reasonable risks and "followers" aiming at entering in new opportunities only for avoiding the risks of too big gaps. One must consider that not all innovations are a potential game-changer. Therefore, both enthusiasm and concern have to be interpreted accordingly. Nevertheless, in the rail ecosystem, complexity and lead times are not encouraging the arising of large innovator groups.

Several EU funded research projects have been addressing such topics, and the issues are still with the capability to manage data intelligently and to interconnect the technological standards of different generations. The generation gap is an issue in the rail system since the challenge is represented by the new fast disrupting technologies to be applied to a business model which is old by definition. The resistance to change is considerable. Strong workers organisations into Unions and strong influence exercised by Governments and Politicians are elements constraining changes to lead changes.

6.9.4. Blockchain, a "flagship" ongoing case

Despite having mentioned the above structural difficulties, the ongoing pilot experience lead by IBM and Maersk in applying the blockchain technologies to the containerized sea traffic is showing how with real willingness and collaborative approach two leading players can steer the transformation of the freight industry. In fact, this is an example of the pivotal role played by innovative technology for stimulating the revolution of the complete transport industry. The sea and air sectors have always been the most innovative, and they prove to be in the lead also this time, even if constraints are still objects of debate.

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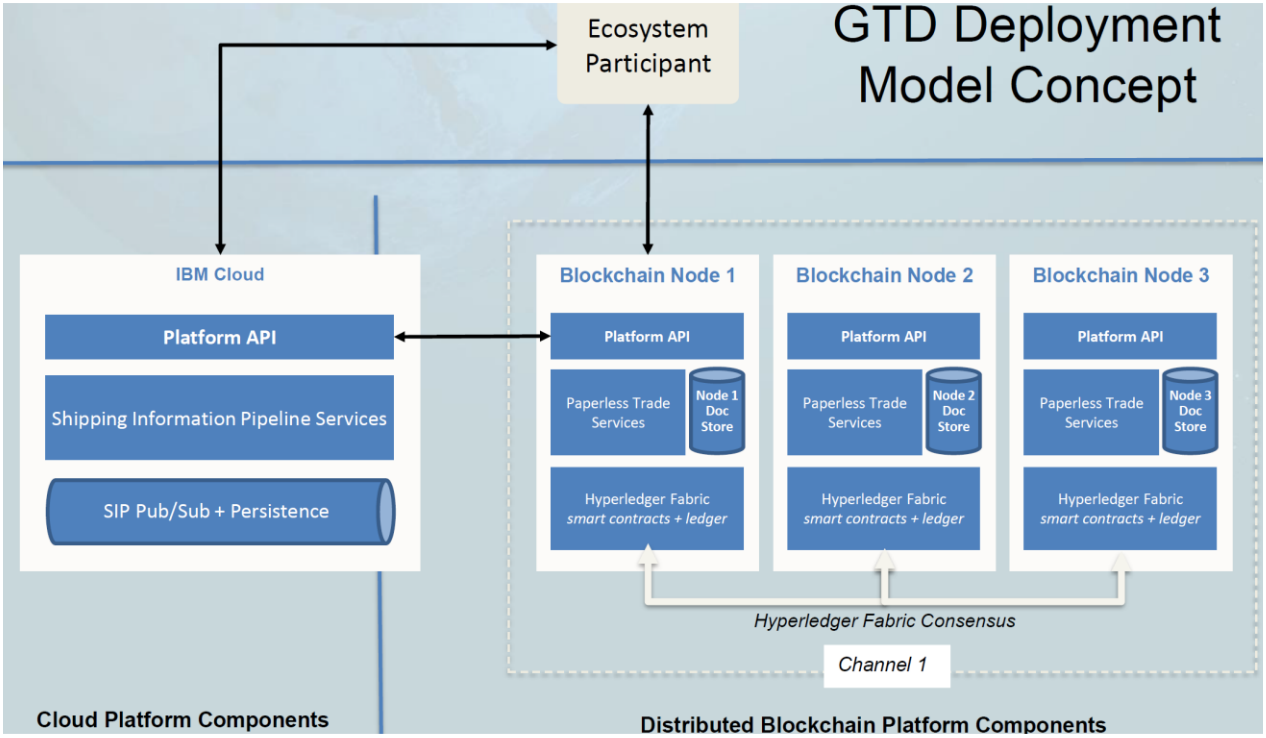

Figure 66: Global Trade Digitalization (GTD) managing blockchain – Source: Project CORE under development by IBM and Maersk, 2018

Projects are already in the pipeline also within H2020 umbrella (for instance H2020 call MG-2.9-2019: Inco Flagship: Integrated multimodal, low-emission freight transport systems and logistics), for extending the type of IBM and Maersk initiative to the land segments and in particular to the rail transport segments.

The blockchain may be a pivotal innovation opportunity since it can:

- Address several "pain points" of the transport and logistics industry both in specialized logistics and in a transport integration projection;
- Be "affordable". It is estimated as being a relatively low-cost technology due to the fact that it does not require to replace existing systems since it introduces new layers of data which remain fixed.

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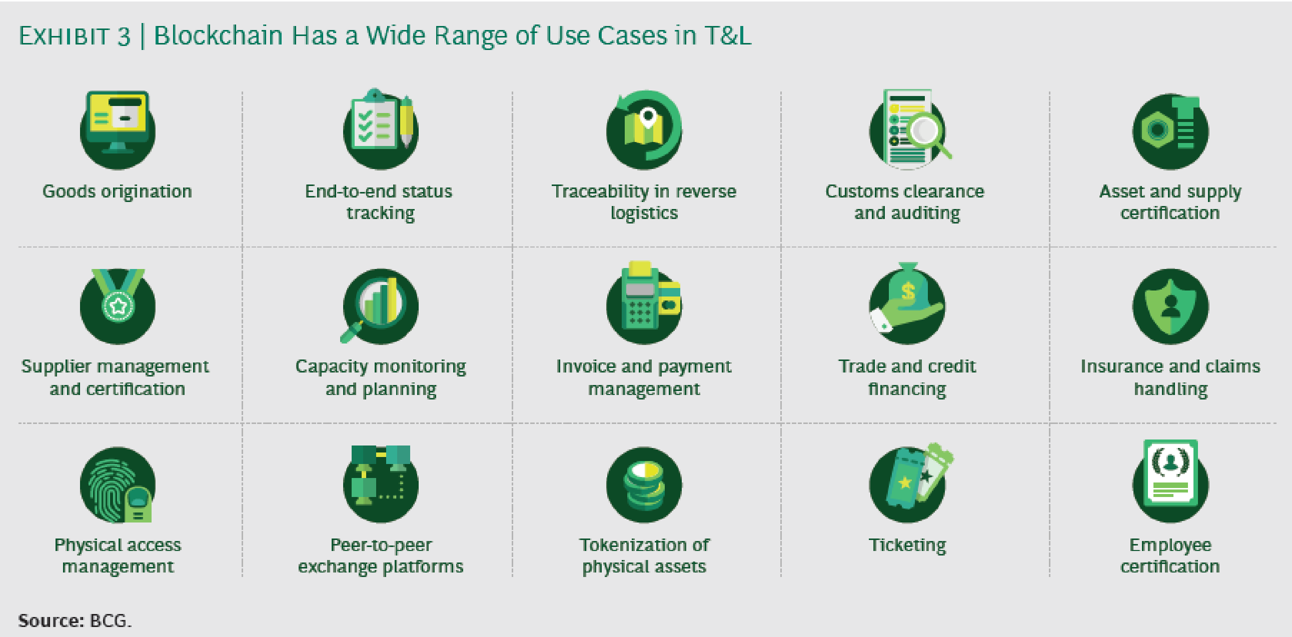

Figure 67: Resolving the blockchain paradox in transportation and logistics – Source: BCG, February 2019

6.10. Conclusions

The previous materials have shown that rail will play a fundamental role in the sectors of freight and logistics.

Market capabilities of integrated rail services in logistic systems are expected to increase as a result of the growing role of International Logistics Operators and the increased support by ICT technology. Environmental consideration and social evolution alike will push the rail services forwards, as they are a better match for tomorrow's mobility of goods throughout Europe.

Rail connections between Europe and the intercontinental flows will further increase thanks to significant driving innovations such as the Silk Road Initiatives. Intra EU traffic is also expected to increase, as a result of increasingly better rail performances.

Longer and heavier trains will contribute to increasing the role of rail in freight mobility, as a result of the savings in terms of costs, energy and capacity that these trains allow. Similarly, High-Speed Trains will enable rail to enter the same-day-delivery market, which is growing at a fast pace. At the same time, a faster, more flexible and reliable service will allow for higher competitiveness over road transport. Moreover, the employment of rail for traffics to and from seaports and in mass transportation for commodities and raw materials will allow rail to become a vital sector in freight transport.

The port of Hamburg implemented a capillary rail connections network to Europe towards East, West and South and proved rail can effectively play a key role in freight mobility. Trieste and Gdansk recently followed this approach with excellent results.

TER4RAIL
Transversal Exploratory
Research Activities for Railway
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The previous materials have shown that rail will play a more significant role in a modern co-modal freight mobility system because of its higher sustainability, capacity, energy and cost efficiency, than other transport modes.

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7. Deliverable D 3.1.4 - Social, environmental, economic variables data set collection

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7.1. Executive Summary

Transport is a crucial component of the European socio-economic system having several interrelations with other resources of which is part.

The most synthetic of such correlations is between mobility and GDP. Even if transport brings some undesired consequences, mobility curbing cannot be an answer to them as mobility growth is part of the EU progress. The EU Commission declared that curbing mobility is not an option.

In terms of **share by mode** in the year 2017, car transportation is by far the most popular used mode in Europe with 70.9% traffic share and 4.901 billion pkm. Air follows with 11.2%, while bus & coach is third with 7.4% traffic share. Rail is "only" the fourth modal choice with 6.8%. The remaining part includes tram & metro, powered-two-wheels and sea.

In terms of **market share dynamics** in the period 2000-2017, when comparing each mode with the overall growth of 17.3%, the modal evolutions are not comparable. The air mode experienced the most relevant market share change, with a 69.1% increase. Tram & Metro is following with 33.8%. In terms of growth, Railway is the third growing mode with 24.6% primarily due to High-Speed Rail.

If the period over the last 3 years is taken into account, air still is the mode which experienced the most substantial growth by far. Railway follows at a distance.

Country differences are enormous. The report investigates them in many aspects such as propensity to travel by rail, density of infrastructure and services, degree of market opening, perceived quality of service in terms of customer satisfaction, fares in terms of revenues per pkm, public service contracts, structure of territory and urbanization, development of HSR, focus on motorways investments opposed to rail modernization and fast evolvement of car mobility, availability of service of mobility integration.

These differences can be very shortly summarised with data regarding market share and its dynamics in the observed period. Therefore, the overall picture highlights the aggregation of national situations more, with evident diverging patterns than real EU harmonized dynamics.

Most rail traffic remains within the individual countries, and even the High-Speed "revolution" shows modest impact on international routes.

		Traffic dynamics 2000-2017 in absolute value of pkm			
		<0	<EU avg 24.6%	>EU avg 24.6%	>2 EU avg 24.6%
Current inland market share % (2017)	<7.0%	BG, EL, HR, LV, LT, RO, SI,	IT, PT,	LU, FI, ES	EE, IE
	7.0-8.5 % (AVG EU 7.8%)	PL	DK	BE, CZ	
	>8.5%	HU		DE, FR. NL, AT, SK,	SE, UK

Newopera elaboration based on ISTAT data 2000-2017

Thus, the overall picture regarding rail mode include different clusters of countries ranging between diverse situations where:

- marginal share and negative trends would require to stop the decline for avoiding dismantling existing resources before planning the renaissance
- significant market share and trend higher than overall mobility might be little more than "simple continued" for further developments.

The quality of transport services has a significant impact not only on the EU economy in a macroeconomic perspective but directly on people's spending and quality of life.

In general, the quality of rail service is not perceived as adequate. Lack of competition and service segmentation often limit the quality innovation process. At the same time, the transformation of stations in nodes for interchange modality appears to be progressing slowly.

The most significant technological innovation of rail in modern times is represented by High-Speed Rail (HSR) which delivered an enormous improvement in service quality and increased competitiveness with other modes such as air transport. HSR, however, is still very much a National Country business. The capability to compete with air in the fast-growing international traffic, when distances are already approachable with HSR is not exploited yet. In fact, the orientation of investments in cross border connections appear limited, and no operator with an international scope is targeting this market at present.

Relevant rail features impacting life quality are safety and sustainability:

- rail is by far the safer mode than any other surface transport - according to ERRAC it is 24 times safer than car land transport, 1.5 times better than coach;
- in terms of absolute values, the rail contribution to GHG emissions is relatively modest - looking specifically at CO2 as a representative example of all GHG, rail is 7 times more energy-efficient than cars and produces 2.6 times less CO2 than passenger-km. Rail also produce 3.6 times less CO2 per t/km, while High-Speed Rail is 3.4 times less polluting than air transport;
- noise reduction remains a point of attention – fleet renewal and widely affordable retrofitting of the current fleet are progressing.

Looking more specifically at economic aspects, the expenditure on the transport of goods and services accounts on average for about 13% of every household's budget. Transport industry accounts for about 5% of Europe's Gross Domestic Product (GDP). The segment of rail transport accounts for about 1.1% of EU's GDP.

Transport companies are amongst the biggest EU companies in terms of **employment** per enterprise. Despite their dimension, most companies have a large part of their employees concentrated in a single Country. This trand is the case for the majority of rail companies. Public transport is one of the largest employers at local level; virtuous examples are Amsterdam, Barcelona, Brussels and Dublin.

After road, rail transport is the primary mode in terms of people employed: people working in

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the rail sector, including indirect employment, are about 2.3 ml. However, gender disparity still constitutes an issue that needs to be solved in the rail sector to reach an acceptable gender balance. Age structure also needs attention since the report shows that the vast majority of employees are over 50.
Considering the capital intensity of rail investments and their long time to market, their continuous progression is vital for increasing capacity, create new offerings and improve performances generating employment. Most investments derive from medium-long term planning as the lead-time, especially for infrastructure, is quite long: significant actions up to 2030 are already in plans currently under implementation with continuity in funding intensity.

The transport industry is significantly contributing to **R&I investments** in the EU. In fact, studies quoted in this document show that transportation has the highest share of the overall spending. Between 4 and 10% of the turnover of the rail sector is dedicated to R&D.
The Shift2Rail (S2R) program represents the most important instrument for developing research activities in the rail sector. Shift2Rail was established in July 2014 as a Joint Undertaking supported by the European Union's 'Horizon 2020' programme. The Shift2Rail aim is to promote the competitiveness of the European rail industry. Research is fundamental for accelerating the integration of new and advanced technologies into innovative rail solutions necessary to:

- support the completion of the Single European Railway Area (SERA);
- increase the capacity of the European rail system;
- improve the reliability and the quality of rail services, whilst reducing costs.

Other relevant initiatives can be identified in H2020 program even excluding rail specific topics but including rail contribution in a broader co-modal perspective. Examples focus on territory and urban mobility, logistics, new concepts such as physical internet, modular unit load, hard and soft technology applications.

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7.2. Introduction

This section shows general aspects of the rail ecosystem and in particular topics related to passenger mobility. Local mobility is further addressed in the sections "2019 Worldwide Metro ridership and infrastructure data set collection" and "2020 Worldwide Light rail data set collection". Freight is addressed as well, in the specific section "Freight and logistics data set collection".

The purpose of this document is to represent the current situation of rail in the EU and its relevant dynamics within the frame of mobility and its major recent and/or ongoing evolutions.

The adopted methodology takes advantage of surfing several sources such as statistics, studies, researches, scientific articles and publications. Even if they are not necessarily all aligned in terms of observed time and scope or variables definitions, they are useful for supporting the understanding of the relevant elements to be assembled. In some cases, especially for one time studies, the coherency among different reports is not guaranteed. In these situations, the most generally accepted results are reported.

The comprehensive and systematic databases representing the mobility coherent with the objective of this study are not available since a big part of the traffic remains within the individual countries and statistics usually separates domestic (within the country) and international data flows. The EU interpretation of "internal market" is yet to be consolidated. Therefore, many pieces of available information and statistics represent the European Union as a sum of individual countries. The examples are elaborated in the following pages. Nevertheless, many efforts continue to be dedicated by the European institutions to the selection of meaningful data for achieving knowledge improvements. Due to the aggregation and the complexity of interpreting such data, the progress is not as fast as desired.

Individual snapshots originating from magazines and newspapers articles are also included, especially when providing information on emerging evolutions to be analysed in Task 3.2 "Data elaboration and impact assessment". For the same reasons, a certain number of items in the following paragraphs are not fully supported by data. To find appropriate data in the rail ecosystem is, in some cases, really challenging. For example, some weaknesses are extremely difficult to describe with quantitative elements.

In this report, the sources, when known and available together with the year of publication and/or year of figures, are shown. The evaluations trends consider the period from the year 2000 onwards.

After surfing the various sources and the selection of those relevant for this research, the methodology tries to concentrate on some "Resulting Remarks" from each data/table/or graphic set. In this way, the methodology makes an effort to give this document a dynamic dimension towards problem-solving.

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7.3. Social variables

Transport is a vital component of the European socio-economic system showing several interrelations with other elements of the broader system of which is part.

The most synthetic of such correlations is between mobility and GDP. In fact, as observed in several studies, transport growth shows a direct correlation with short and long-term GDP dynamics. In the following pages the preferred adopted measure is passenger*km and ton*km (pkm) since these are the prevailing parameters adopted in the industry.

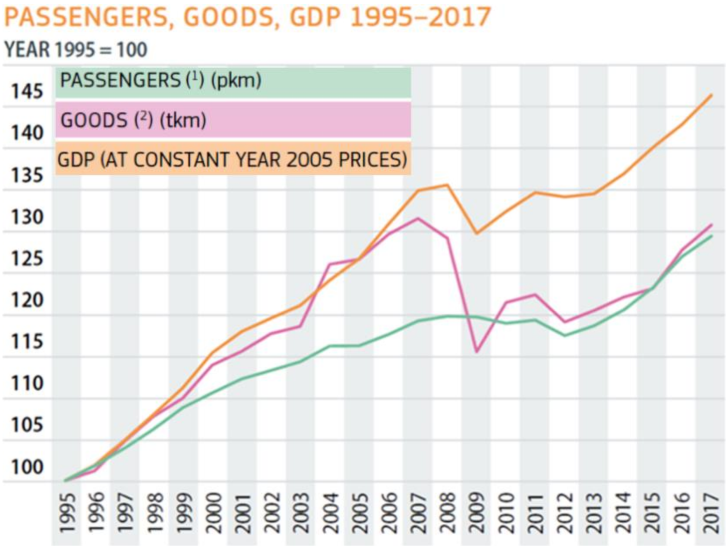

Figure 1: Transport growth EU-28 – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

Despite the social evolution is trying to limit some "avoidable" transportation such as through teleworking for employed personnel and through favouring "0 Km" consumption for goods, the correlation appears undoubtedly strong in a multi-year perspective, even if considering some temporary fluctuations.

When observing the year 2009 and the following years, the impact of GDP slowdown is "immediately" apparent for goods transportation. The correspondent impact for people transportation shows a slower dynamic in the following 2-3 years. Most recently the transportation growth seems to be recovering the past slowdown both for passengers and for freight.

Even if transport brings some undesired consequences, mobility curbing cannot be an answer to them as mobility growth is part of the EU progress. The EU Commission officially declared that curbing mobility is not an option.

The above picture is self-explaining and reinforces the theory of those that refer to the correlation of GDP and mobility as the most relevant despite more sophisticated elaborations, and segmentations could be adopted for better identifying the differentiated needs of an evolved society.

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7.4. Overview of passenger mobility – share by mode

The EU statistics segment passenger mobility by mode and track traffic in pkm. Data monitoring evolutions are updated year by year in the long period and even quarterly for certain elements.

According to these databases, the key observations are referring to:

- updated values and relative traffic share by mode currently 2017 plus more recent data when available;
- traffic share dynamics looking at the period from the year 2000 onwards.

In terms of most updated absolute values and relative share by mode, car transportation is by far the most popular used mode in Europe with 70.9% traffic share and 4.901 billion pkm.

Air follows with 11.2%, and bus & coach is the third one with 7.4%. Rail is "only" the fourth modal choice with 6.8%. All together the remaining tram & metro, powered 2 wheels and sea account 3.8% (please note: the total makes 100.1 because of rounding).

Looking at market share dynamics, when comparing each mode with the overall growth of 17.3%, the evolutions are not precisely similar. This is due partly because of country differences related to a number of factors such as population density and socio-economics structure, territory and urbanization feature, density of infrastructures and services, co-modal offerings, perception of service quality, prices policies, regulations limiting/supporting given mobility solutions, etc….

Some of these elements are commented for the railways in the following chapters, especially when they are identified as significantly explaining differences and/or influencing evolutions.

The most relevant market share change is in the air mode. Air mode is the top growing mode, with a 69.1% increase compared with the year 2000 traffic. This extraordinary growth can be interpreted as long term result of the impact of the low-cost pricing offerings revolution, which started in the past century. The air sector indeed must be given the merit of having spearheaded the "Low Cost" approach which many competing modes thought not to be possible opening the access to millions of people and new categories of travellers which started to fill the aircrafts. The price segmentation based on the booking timings has been another significant element of this revolution not yet copied by other transport modes after 20 years of colossal success.

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Figure 2: Performance for passenger transport 1995-2017 EU-28 – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

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PASSENGER TRANSPORT

billion pkm

	PASSEN-GER CARS	P2W	BUS & COACH	RAILWAY	TRAM & METRO	AIR	SEA	TOTAL
1995	3 904	113	515	343	74	348	31	5 327
2000	4 301	105	545	377	80	460	29	5 896
2005	4 508	121	542	384	86	530	29	6 201
2006	4 549	120	540	397	88	552	28	6 274
2007	4 597	116	551	404	90	575	28	6 360
2008	4 602	121	559	420	94	563	32	6 391
2009	4 675	118	536	412	93	524	27	6 386
2010	4 626	119	530	414	96	535	25	6 344
2011	4 593	123	531	423	97	577	22	6 366
2012	4 498	123	526	428	99	570	21	6 266
2013	4 549	122	523	434	99	580	21	6 329
2014	4 615	125	518	441	101	610	22	6 431
2015	4 712	125	528	448	102	640	22	6 576
2016	4 827	126	527	455	105	713	25	6 779
2017	4 901	123	510	470	107	777	24	6 913
'95/'17	25.5%	9.5%	-0.8%	37.0%	45.4%	123.3%	-21.2%	29.8%
/year	1.0%	0.4%	-0.0%	1.4%	1.7%	3.7%	-1.1%	1.2%
'00/'17	14.0%	17.8%	-6.4%	24.6%	33.8%	69.1%	-16.1%	17.3%
/year	0.8%	1.0%	-0.4%	1.3%	1.7%	3.1%	-1.0%	0.9%
'16/'17	1.5%	-2.4%	-3.1%	3.3%	1.7%	8.9%	-2.9%	2.0%

MODAL SPLIT

%

	PASSEN-GER CARS	P2W	BUS & COACH	RAILWAY	TRAM & METRO	AIR	SEA
1995	73.3	2.1	9.7	6.4	1.4	6.5	0.6
2000	72.9	1.8	9.2	6.4	1.4	7.8	0.5
2005	72.7	1.9	8.7	6.2	1.4	8.5	0.5
2006	72.5	1.9	8.6	6.3	1.4	8.8	0.4
2007	72.3	1.8	8.7	6.3	1.4	9.0	0.4
2008	72.0	1.9	8.8	6.6	1.5	8.8	0.5
2009	73.2	1.9	8.4	6.5	1.5	8.2	0.4
2010	72.9	1.9	8.3	6.5	1.5	8.4	0.4
2011	72.2	1.9	8.3	6.6	1.5	9.1	0.4
2012	71.8	2.0	8.4	6.8	1.6	9.1	0.3
2013	71.9	1.9	8.3	6.9	1.6	9.2	0.3
2014	71.8	1.9	8.1	6.9	1.6	9.5	0.3
2015	71.6	1.9	8.0	6.8	1.6	9.7	0.3
2016	71.2	1.9	7.8	6.7	1.6	10.5	0.4
2017	70.9	1.8	7.4	6.8	1.6	11.2	0.4

Figure 3: Performance for passenger by mode and modal split dynamics – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2018 - EU TRANSPORT in figures

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The overall air growth would be even higher without the competition of high-speed rail in several domestic connections; only 17% of air passenger traffic in the year 2016, in terms of number of passengers, is domestic. Most of the traffic is international both intra and extra EU. Of that the intra EU traffic, that account 47% of total air passenger traffic in terms of number of passengers is potentially addressable by high-speed rail in a number of significant connections while the high-speed international offering is still very limited.

		Total transport		National transport		International intra-EU-28 transport		International extra-EU-28 transport	
		Number of passengers	Growth (%) 2015-2016	Number of passengers	Growth (%) 2015-2016	Number of passengers	Growth (%) 2015-2016	Number of passengers	Growth (%) 2015-2016
EU-28(1)		**972 693**	**5.9**	**168 676**	**4.6**	**457 422**	**10.2**	**346 594**	**1.4**
Belgium	BE	30 116	-2.7	12	-58.1	22 514	1.2	7 590	-12.6
Bulgaria	BG	9 324	22.5	164	0.3	6 818	25.5	2 343	16.2
Czech Republic	CZ	13 672	7.9	83	-23.3	9 881	10.1	3 709	3.4
Denmark	DK	32 763	8.9	2 012	4.2	22 245	11.1	8 507	4.4
Germany	DE	200 687	3.5	23 775	2.7	110 683	7.6	66 229	-2.4
Estonia	EE	2 215	2.5	17	-11.2	1 763	8.7	435	-16.3
Ireland	IE	32 596	10.3	82	14.9	27 783	10.7	4 731	8.4
Greece	EL	45 543	8.2	8 176	9.3	29 703	7.8	7 664	8.7
Spain	ES	193 872	11.0	33 435	8.3	132 932	12.5	27 506	7.4
France	FR	145 257	3.1	28 952	2.8	65 352	5.5	50 954	0.4
Croatia	HR	7 475	13.8	488	4.5	5 734	14.7	1 254	13.2
Italy	IT	134 505	5.4	30 273	2.1	79 374	7.3	24 858	3.4
Cyprus	CY	8 962	18.1	0	-	5 951	11.3	3 011	34.1
Latvia	LV	5 384	4.6	1.0	459.8	3 943	3.9	1 440	6.5
Lithuania	LT	4 788	13.3	0.4	10.5	3 710	14.0	1 077	10.7
Luxembourg	LU	2 984	12.5	0.7	-30.1	2 686	17.8	298	-19.8
Hungary	HU	11 668	14.1	0.2	-	9 487	17.2	2 181	2.1
Malta	MT	5 080	10.0	0.3	33.6	4 648	11.0	432	0.2
Netherlands	NL	70 318	8.9	2	1.6	44 192	12.8	26 124	2.8
Austria	AT	27 182	1.6	511	-3.6	18 958	4.6	7 713	-4.7
Poland	PL	32 267	11.6	1 834	15.5	24 668	14.1	5 765	1.2
Portugal	PT	40 930	13.7	4 472	22.1	29 457	13.2	7 002	10.9
Romania	RO	15 154	20.5	895	76.9	12 356	20.5	1 903	4.5
Slovenia	SI	1 404	-2.2	0	-100.0	857	5.4	547	-12.1
Slovakia	SK	2 158	11.0	25	15.4	1 817	15.2	316	-8.3
Finland	FI	18 100	3.6	2 689	3.5	11 265	4.7	4 146	0.6
Sweden	SE	35 953	5.7	7 702	3.4	21 599	8.7	6 652	-0.6
United Kingdom	UK	248 869	7.1	23 077	1.1	153 581	11.4	72 211	0.9

(1) Double counting is excluded in the intra-EU-28 and total EU-28 aggregates by taking into consideration only departure declarations.

Figure 4: Overview of EU-28 air passenger transport by Member States in 2016 (passengers carried) - Source: Publications Office of the European Union, 2018 - STATISTICAL POCKET BOOK 2018 - EU TRANSPORT in figures

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Tram & metro is following air in terms of share growth. The traffic increase compared with the year 2000 is 33.8%. Tram & metro growth is partially due to capacity increase and partially to the demand shift because of the urban congestion. The most important countries both for growth (since year 2000) and absolute traffic in terms of pkm (above 7 billion) are Germany, France, Austria, Czech R, Rumania (for other information on local mobility see section "2019 Worldwide Metro ridership and infrastructure data set collection" and "2020 Worldwide Light rail data set collection"). Environmental consideration and urban mobility policies by local authorities will continue to play a role in favour of this mode in the future.

Railway is the third growing mode with a 24.6% increase compared with the year 2000 traffic. Country differentiates the rail growth, and a significant part of the differences is because of the contribution of High-Speed revolution (see the following specific paragraphs about Rail and High Speed).

Powered-2-wheels traffic shows a growth of 17.8% increase compared with the year 2000 traffic. The reference year 2000 shows traffic values were particularly low (see also the figure for the year 1995 that is much higher than the year 2000). Even taking into consideration a smaller growth, urban congestion has been the driver of change, together with other alternative soft modes serving urban areas and short distance needs.

Passenger cars mode shows a growth of 14.0% compared with the year 2000 traffic with limited share reduction as the overall traffic increase has been 17.3%. Car is still the largely predominant mode for historical reasons, but also because it remains without alternative for many passenger transportation needs. Nevertheless, the perception of the car as the more convenient mean seems largely to be "inertial", even if new generations less share this cultural heritage. In terms of Country differences, Italy is the only EU example of negative growth compared to the year 2000 even remaining one of the countries with the higher number of cars per inhabitants. Nederland and Lithuania are examples of flat figures.

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	billion pkm								%
	1990	1995	2000	2005	2010	2015	2016	2017	CHANGE '16/'17
EU-28		3 904.4	4 300.9	4 508.3	4 625.6	4 711.8	4 826.7	4 901.4	1.5
BE	89.5	96.4	102.5	102.8	109.4	107.0	106.1	106.9	0.8
BG		25.0	26.9	35.1	46.9	56.8	56.6	57.7	1.8
CZ		54.5	63.9	68.6	63.6	69.7	72.3	74.3	2.9
DK	47.2	48.4	50.6	49.8	51.7	56.8	59.0	60.0	1.7
DE	683.1	815.3	831.3	856.9	887.0	927.0	946.3	935.7	-1.1
EE		5.1	6.7	9.9	10.1	12.3	12.8	13.1	1.9
IE	28.5	31.6	34.6	44.4	48.1	51.9	55.0	56.5	2.8
EL	35.0	44.0	63.0	85.0	99.6	98.3	99.9	101.9	2.0
ES	174.4	250.4	302.6	337.8	341.6	317.6	329.9	332.9	0.9
FR	592.5	641.2	687.7	704.6	695.9	722.9	742.5	743.4	0.1
HR		12.5	20.0	24.0	25.7	26.4	26.2	26.2	0.0
IT	522.6	614.7	713.9	677.0	698.4	676.4	704.5	744.9	5.7
CY		3.4	3.9	4.8	5.9	6.2	6.5	6.6	1.3
LV		7.5	11.5	12.1	12.3	13.5	13.9	15.0	7.8
LT		16.0	26.0	34.8	32.6	24.9	25.9	31.4	21.3
LU	4.0	4.7	5.6	6.3	6.5	7.3	7.5	7.7	2.0
HU	47.0	45.4	46.2	49.4	52.6	54.6	56.7	60.6	7.0
MT		1.7	1.8	2.0	2.2	2.5	2.6	2.6	0.9
NL	137.3	131.4	141.1	148.8	144.2	139.5	140.8	138.7	-1.5
AT	55.7	62.2	66.7	70.6	73.5	78.3	80.4	81.8	1.7
PL		110.7	130.1	152.3	188.8	200.6	203.8	205.7	1.0
PT	40.0	52.5	71.0	85.0	83.7	84.5	90.5	92.2	1.9
RO		40.0	51.0	61.0	75.5	89.9	95.6	97.3	1.8
SI	13.3	16.3	20.3	22.5	25.6	26.0	26.5	27.1	2.5
SK		18.0	23.9	25.8	26.9	27.5	27.8	28.1	1.0
FI	51.2	50.0	55.7	61.9	64.7	66.3	57.0	66.6	16.8
SE	85.9	87.6	103.7	108.0	108.0	111.9	114.5	116.0	1.3
UK	588.0	617.9	638.6	667.1	644.7	655.2	665.5	670.4	0.7

Figure 5: Performance for passenger cars – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

Bus & coach traffic share shows negative dynamics with a 6.4% decrease compared with the year 2000 traffic. Such figures may surprise also having in mind the different components. There is a market success of long-distance services both on national and on international routes. This segment has grown in recent year due to the applied low-cost approach adopted by the airlines. Also the urban surface services dynamics seems overall negligible, despite policies to encourage public transport. Country examples of the relative higher success of bus & coach mode are France and Italy in the western cluster, Rumania in the eastern one.

Sea traffic shows a negative performance as well: the overall reduction is 16.1% compared with the year 2000 traffic. The overall contribution of sea mode is, in any case, marginal and its potential is very specific on a limited number of routes.

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As anticipated for the air transport, the unit price dynamic shows limited differences between modes as from 2005 and, in a long-term perspective, seems not to be influential their share evolution. This means that the deciding factors for the market choice are a combination of the competitive profile perception of the users in relation to the service quality on offer by the different modes connected to the purchasing power of the various traveller categories which on the contrary in the last 20 years changed quite dramatically. So the relative price stability in constant terms which at first sight does not seem influential, in effect it is when in direct relationship with the purchasing power of the low and middle-class households which suffered a substantial erosion since the year 2000.

YEAR 2015 =100	TRANS-PORT SERVICES	of which:					
		Passenger transport by railway	Passenger transport by road	Passenger transport by air	Passenger transport by sea and inland waterway	Combined passenger transport	Other purchased transport services
2018	105.7	104.1	106.5	104.5	106.0	104.4	104.1
2017	103.8	102.7	104.5	102.1	105.8	102.8	100.5
2016	100.6	100.4	101.5	97.4	103.1	101.2	100.1
2015	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2010	84.2	86.9	87.2	83.5	83.8	84.3	96.1
2005	69.5	70.1	72.1	74.4	65.1	70.5	88.3

Figure 6: Consumer prices dynamics for passenger transport – Source: Publications Office of the European Union, 2019 – STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

The figures for traffic in pkm are, of course, the basis for analysing the mobility market while the use of other data would be desirable for contributing towards more comprehensive evaluations. For instance, different distances and number of trips seem not accurately represented, especially for metropolitan regions. Besides, the simple "modal" segmentation looks not enough to interpret the effectiveness of a policy-oriented for maximising mode integration. In fact, there is no structured statistics about the number of modes involved in the same trips. In addition, the boundary between "rail", "tram & metro" and "bus & coach" became progressively less significant. The meaning of distance in high-speed services is different as well when compared to other rail services. In this case, the travel time assumes greater importance since the service component is predominant.

In addition, some aggregations such as, for instance, "bus & coach" do not help to understand the different segments. Categories are grouped together while "demand" and "offer" are entirely different. Additional segmentation of traffic data in categories such as commuting, local transport, intercity transport, would help in understanding market dynamics.

Similarly, pricing figures, difficult to collect and interpret, do not represent ticket integration

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policies or offering of local first/last mile service such as taxi, bus, car rental coordinated between modes.

Resulting remarks

- The highest percentage growth of 69.1% achieved by air passenger transport was favoured by the low-cost approach revolution, connections multiplication, segmented price offerings, performance consistency attacking both national, international and intercontinental routes. The traffic continues to grow;
- Tram & Metro transportation achieved the second performance growth of 33.8% due mainly to urban congestion and No Traffic Zones in city centres. Environmental users' perceptions and local authorities' directives in favour of public transport together with increased investments in environmentally friendly vehicles, connectivity technologies, co-modal interchange infrastructures will help the continued development of this mode;
- Railway is the third growing mode with 24.6% due largely to HSR which has still a predominant national dimension. The International connections are too few to represent a valid competing challenge for air transportation on compatible distances. When the European High-Speed Network will be completed, the distances covered in 3-3 and a half hours could become accessible for providing travellers with a viable choice on medium International distances. In any case, HSR has seen the implementation of effective competition in Italy, the adoption of price segmentation and the integration with other modes including comprehensive ticketing which are very positive developments;
- Powered-2-wheels traffic shows a growth of 17.8%. Urban congestion, flexibility in use, easiness in co-modal changes are the drivers for further development;
- Private cars transport has grown 14.0%, which is 3.3% below the overall traffic growth of the period, which was 17.3%. This might be a sign of different mobility awareness shown by new generations of inhabitants combined with high costs for running cars;
- Bus & coach shows a negative dynamic of 6.4% compared to the year 2000. Within this segment, the International and long-distance transport component has grown in recent years where the low-cost approach adopted by the airlines' low fare companies has been applied. This shows that the deciding factor is very much cost competitiveness and service reliability and regularity;
- Sea traffic posted in the period a negative performance of 16.1%. The routes are limited, and the overall contribution marginal.

TER4RAIL
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7.4.1. Contribution to the Rail mode to overall EU passenger mobility

Passengers use rail very broadly in the UE, counting about 9.6 billion passenger trips in the year 2016 and 9.8 billion in 2017. These figures point out how popular is this mode in the EU, resulting in about 20 trips per inhabitant per year.

Only less than 2% of trips are cross border. National transport is always predominant, representing more than 90% of the total transport for all countries in 2017 with the exception of Luxembourg and the Czech Republic. International transport represented 30% of the total passenger transport by rail in Luxembourg and 15% in the Czech Republic.

Rail passenger transport by type of transport, 2016-2017
(thousand passengers)

	National			International			Total		
	2016	2017	Change 2017/2016 (%)	2016	2017	Change 2017/2016 (%)	2016	2017	Change 2017/2016 (%)
EU-28	**9 490 149**	**9 634 875**	**1.5**	**145 236**	**151 513**	**4.3**	:	:	:
Belgium	:c	:c	:c	:c	:c	:c	:c	:c	:c
Bulgaria	20 911	20 411	-2.4	515	784	52.3	21 425	21 195	-1.1
Czechia	173 701	176 932	1.9	5 066	5 791	14.3	178 766	182 724	2.2
Denmark	198 682	193 928	-2.4	12 717	12 638	-0.6	211 399	206 566	-2.3
Germany	2 799 851	2 815 592	0.6	13 931	15 851	13.8	2 813 782	2 831 443	0.6
Estonia	6 823	7 326	7.4	103	107	4.4	6 926	7 433	7.3
Ireland	42 478	45 130	6.2	342	375	9.5	42 820	45 505	6.3
Greece	15 561	15 337	-1.4	21	22	4.4	15 582	15 359	-1.4
Spain	568 756	592 284	4.1	1 065	1 321	24.0	569 822	593 605	4.2
France	1 197 557	1 237 353	3.3	38 966	40 126	3.0	1 236 523	1 277 479	3.3
Croatia	20 412	19 513	-4.4	298	290	-2.5	20 709	19 803	-4.4
Italy	849 248	846 081	-0.4	2 972	2 676	-10.0	852 220	848 757	-0.4
Cyprus	-	-	-	-	-	-	-	-	-
Latvia	19 419	17 327	-10.8	157	167	6.5	19 576	17 494	-10.6
Lithuania	3 807	3 855	1.2	336	322	-4.2	4 143	4 176	0.8
Luxembourg	14 838	16 523	11.4	6 378	6 407	0.5	21 216	22 930	8.1
Hungary	:c	:c	:c	:c	:c	:c	:c	:c	:c
Malta	-	-	-	-	-	-	-	-	-
Netherlands	:c	:c	:c	:c	:c	:c	:c	:c	:c
Austria	243 898	245 224	0.5	9 298	9 269	-0.3	253 196	254 493	0.5
Poland	274 302	291 500	6.3	1 143	1 548	35.5	275 445	293 048	6.4
Portugal	133 238	141 876	6.5	234	251	7.4	133 472	142 127	6.5
Romania	58 656	67 142	14.5	203	188	-7.6	58 859	67 330	14.4
Slovenia	13 231	12 592	-4.8	419	410	-1.9	13 650	13 002	-4.7
Slovakia	65 807	71 474	8.6	3 343	3 442	3.0	69 150	74 916	8.3
Finland	81 662	85 155	4.3	452	548	21.0	82 114	85 703	4.4
Sweden	208 944	216 800	3.8	12 001	12 100	0.8	220 945	228 900	3.6
United Kingdom	1 753 135	1 737 710	-0.9	19 428	19 649	1.1	1 772 563	1 757 359	-0.9

Figure 7: Performance for passenger by mode (rail) – Source: Publications Office of the European Union, 2018 - STATISTICAL POCKET BOOK 2018 - EU TRANSPORT in figures[57]

[57] https://ec.europa.eu/eurostat/statistics-explained/images/6/67/Rail_passenger_transport_by_type_of_transport%2C_2016-2017_%28thousand_passengers%29.png

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Rail traffic so remains a national business and dynamics needs to be interpreted basically as a sum of national numbers with the overall picture very slowly moving to a comprehensive EU rail system. It becomes apparent that this national dimension represents a constraint limiting the Rail system and particularly High Speed with the possibility of competing with air in cross border traffic on medium-long distances where travel time could be covered in 3-3.5 hours.

Estimated at 470 billion pkm in 2017, rail passenger transport performance at EU-28 level continued its increase by 3% compared with 2016. This steady growth observed between 2013 and 2017 is more than twice than the overall period since the year 2000.

7.4.2. Contribution of the Rail mode to EU countries'passenger mobility

While looking at the overall European area from individual countries viewpoint, it is essential to take into consideration two primary elements:

- Rail current market share is analysed below, only for land transport since sea and air compete with rail in very few routes
- Rail traffic volume dynamics are basically comparing pkm in the period 2000-2017 in absolute values. This indicator is also a proxy of market share dynamics.

Their combined observations allow to identify cluster of countries with significantly different performances.

Rail current market share

Observing current rail market share of land passenger transport, countries can be grouped in in three clusters (excluding countries without rail infrastructure and services):

- Below 6% –indicated in the following table with an oval, including BG, EE, IE, EL, HR, LV, LT, LU, PT, RO, SI, FI
- Between 6 and 9% (in the range of EU average that is 7.6%) including BE, CZ, DK, DE, ES, IT, PL, UK, HU
- Above 9% - in the following table indicated with a rectangle, including FR, NL, AT, SK, SE

Rail traffic volume dynamics

Looking at the period 2000-2017, countries can be grouped into three clusters (excluding countries without rail infrastructure and services):

- Growing more than average - includes 12 Countries (light blue colour): the most significant countries in terms of rail traffic growth, considering both increase higher than average and absolute values, are Germany, France and the United Kingdom; to be mentioned Austria, Sweden and Spain for higher growth and absolute values at intermediate level;
- Growing less than average - includes 5 countries (green colour): fewer countries including Italy despite the big role of high speed;

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- Declining in absolute values - includes 9 countries (red colour): this is even more worrying when compared with years before 2000. The risk of dismounting the rail ecosystem, at least in some countries, looks real; wherever this is likely to happen, the way back would be almost impossible.

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pkm as %	PASSENGER CARS	BUSES & COACHES	RAILWAYS	TRAM & METRO
EU-28	81.8	8.5	7.8	1.8
BE	81.1	10.1	7.7	1.1
BG	81.5	14.9	2.0	1.5
CZ	66.2	15.7	8.4	9.7
DK	81.2	9.9	8.5	0.5
DE	84.2	5.6	8.6	1.5
EE	79.9	17.2	2.2	0.7
IE	82.3	14.3	3.1	0.3
EL	81.4	16.4	0.9	1.3
ES	83.5	7.7	6.9	1.9
FR	81.0	6.2	10.9	1.8
HR	82.7	13.1	2.3	1.9
IT	82.0	11.4	5.9	0.7
CY	81.0	19.0	-	-
LV	83.8	12.1	3.3	0.7
LT	91.1	8.0	0.9	-
LU	82.9	12.4	4.7	-
HU	67.6	20.4	8.6	3.4
MT	82.5	17.5	-	-
NL	85.3	2.8	11.3	0.5
AT	72.7	9.7	11.2	6.4
PL	77.2	13.5	7.6	1.6
PT	87.6	7.0	4.3	1.1
RO	75.4	14.1	4.4	6.1
SI	86.5	11.7	1.8	-
SK	73.8	15.6	9.9	0.7
FI	83.6	10.3	5.4	0.7
SE	81.7	7.0	9.4	1.9
UK	84.5	5.0	8.7	1.8

Figure 8: Performance for passenger by mode – inland transport - Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figure

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2.3.7	1970	1980	1990	2000	2005	2010	2015	2016	2017 billion pkm	change 00/17 %	
EU-28	330,2	369,6	395,5	377,0	384,5	414,1	448,3	454,6	469,7	24,6	EU-28
BE	8,3	7,0	6,5	7,7	8,5	10,6	10,3	10,0	10,2	31,5	BE
BG	6,2	7,1	7,8	3,5	2,4	2,1	1,5	1,5	1,4	-58,7	BG
CZ			13,3	7,3	6,7	6,6	8,1	8,7	9,4	28,8	CZ
DK	3,9	3,8	5,1	5,5	6,0	6,3	6,5	6,3	6,3	13,4	DK
DE	62,4	62,5	61,0	75,4	76,8	83,9	91,7	94,2	95,8	27,0	DE
EE	1,2	1,6	1,5	0,3	0,2	0,2	0,3	0,3	0,4	40,2	EE
IE	0,6	1,0	1,2	1,4	1,8	1,7	1,9	2,0	2,1	52,8	IE
EL	2,0	1,5	2,0	1,9	1,9	1,4	1,3	1,2	1,1	-41,0	EL
ES	14,0	13,5	16,7	20,1	21,6	22,5	26,1	26,7	27,5	36,6	ES
FR	41,0	54,5	53,8	74,9	82,3	92,4	94,7	94,0	100,1	33,6	FR
HR	3,7	3,6	3,4	1,3	1,2	1,7	0,9	0,8	0,7	-41,2	HR
IT	32,5	39,6	44,7	49,6	50,1	47,2	52,2	52,2	53,2	7,4	IT
CY	-	-	-	-	-	-	-	-	-		CY
LV	3,7	4,7	5,4	0,7	0,9	0,7	0,6	0,6	0,6	-16,6	LV
LT	2,1	3,3	3,6	0,6	0,3	0,2	0,3	0,3	0,3	-48,4	LT
LU	0,3	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,4	31,9	LU
HU	16,4	13,5	11,4	9,7	9,9	7,7	7,6	7,7	7,7	-20,2	HU
MT	-	-	-	-	-	-	-	-	-		MT
NL	8,0	8,9	11,1	14,7	15,2	16,9	17,5	18,0	18,4	25,7	NL
AT	6,4	7,6	8,9	8,7	8,7	10,3	12,2	12,6	12,7	44,8	AT
PL	36,9	46,3	50,4	24,1	18,2	17,9	17,4	19,2	20,3	-15,7	PL
PT	3,5	6,1	5,7	*4,0*	3,8	4,1	4,0	4,3	4,5	12,0	PT
RO	17,8	23,2	30,6	11,6	8,0	5,4	5,1	5,0	5,7	-51,3	RO
SI	1,4	1,4	1,4	0,7	0,7	0,7	0,6	0,6	0,6	-19,1	SI
SK			6,4	2,9	2,2	2,3	3,4	3,5	3,8	30,8	SK
FI	2,2	3,2	3,3	3,4	3,5	4,0	4,1	3,9	4,3	25,4	FI
SE	4,6	7,0	6,6	8,2	8,9	11,2	12,7	12,8	13,3	61,7	SE
UK	30,6	30,5	33,4	38,4	44,6	55,8	66,6	68,0	68,9	79,4	UK

Figure 9: Performance for passenger - rail mode dynamics - Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figure – NewOpera elaboration

Trying to combine the two analysis of Rail current market share and Rail traffic dynamics, the following clusters can be identified:

- Red area – "worrying gap" – low/intermediate market share and negative trend
- Yellow area – "recovering" - low market share but positive trend
- Grey area – "inertial" – intermediate market share, but weak trend
- Blue area - "progressing" – intermediate/high market share and higher trend

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		Traffic dynamics 2000-2017 in absolute value of pkm			
		<0	<EU avg 24.6%	>EU avg 24.6%	>2 EU avg 24.6%
Current inland market share % (2017)	<7.0%	BG, EL, HR, LV, LT, RO, SI	IT, PT	LU, FI, ES	EE, IE
	7.0-8.5 % (AVG EU 7.8%)	PL	DK	BE, CZ	
	>8.5%	HU		DE, FR. NL, AT, SK	SE, UK

Figure 10: Clustering EU countries in terms of inland rail share for passenger and rail mode dynamics – Source: NewOpera elaboration on EUROSTAT data

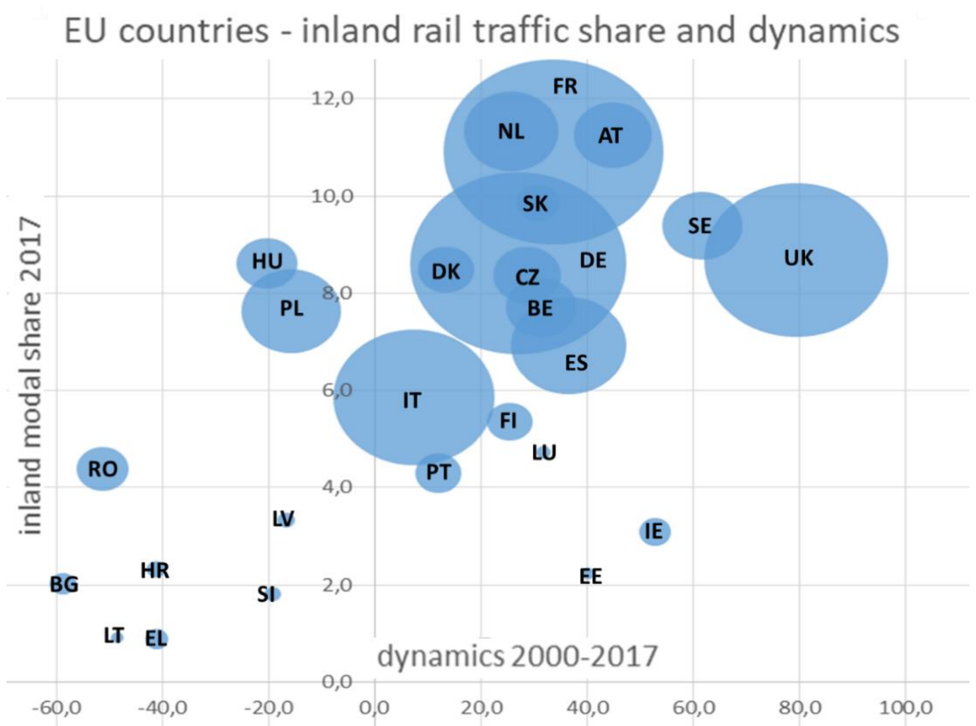

Figure 11: EU countries positioning in terms of inland share for passenger – and rail mode dynamics – Source: Newopera elaboration on EUROSTAT data (bubbles represent rail traffic in pkm)

7.4.3. Some countries' differences

Many considerations regarding country differences and dynamics are possible, and they partially depend on other modes performances. Nevertheless, in the following, the focus remains the rail mode. Such considerations about differences signify the long way ahead to achieve the objective of transforming individual national systems into a single EU rail area.

The following considerations show some relevant elements that can contribute to explaining

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differences, without discussing possible mutual relationships between mentioned items:

- Propensity to travel by rail
- Density of infrastructure and services
- Degree of market opening
- Perceived quality of service in terms of customer satisfaction
- Fares in terms of revenues per pkm
- Public service contracts
- Structure of territory and urbanization
- Development of HSR
- Focus on motorways investments opposed to rail modernization and fast evolvement of car mobility
- Availability of service of mobility integration

Propensity to travel by rail: the ratio of passenger*km/population represents Propensity to travel by rail. If this ratio is a driver or a result is a legitimate question, but conversely the same could be applied to other differences between countries.

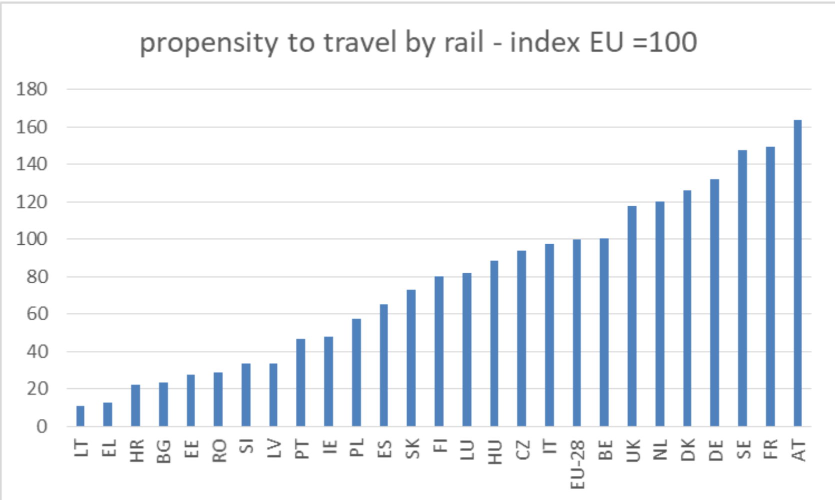

Figure 12: Propensity to travel by rail – Source: elaboration based on data Eurostat year 2016 (passenger km/population)

Density of infrastructure: Individual Countries territories are quite different, and the density of infrastructure is a remarkable discriminant. Benelux and Germany are relevant cases since electrified rail network shows a density more than twice the EU average. Indicators as train/population would measure the density of services, but data are only partially available, so the indicator has not been represented.

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Railways indexes

	billion pkm	km rail	kme	pkm/kme	population	pop/kme	kmq 000	kmq/kme
	2016	2016	of which: Electrified 2016	index	2016	index	2016	index
EU-28	**450,1**	**217 081**	**116 593**	**100**	**510,277**	**100**	**4 470,6**	**100**
BE	10,0	3 607	3 102	84	11,311	83	30,5	26
BG	1,5	4 029	2 868	13	7,154	57	111,0	101
CZ	8,7	9 463	3 217	70	10,554	75	78,9	64
DK	6,3	2 539	621	264	5,707	210	43,1	181
DE	95,8	38 990	20 585	121	82,176	91	357,1	45
EE	0,3	918	132	62	1,316	228	45,2	894
IE	2,0	1 894	*52*	*992*	4,726	*2.077*	70,3	*3.525*
EL	1,2	2 240	520	59	10,784	474	132,0	662
ES	26,7	15 922	10 138	68	46,440	105	506,0	130
FR	87,8	28 364	16 097	141	66,730	95	633,1	103
HR	0,8	2 605	970	22	4,191	99	56,6	152
IT	52,2	17 096	12 218	111	60,666	113	301,3	64
CY	-	-	-	-	0,848	-	9,3	-
LV	0,6	1 860	251	60	1,969	179	64,6	671
LT	0,3	1 911	122	59	2,889	541	65,3	1.396
LU	0,4	275	262	41	0,576	50	2,6	26
HU	7,7	7 749	3 090	64	9,830	73	93,0	79
MT	-	-	-	-	0,450	-	0,3	-
NL	18,0	3 058	2 314	201	16,979	168	41,5	47
AT	12,6	4 917	3 537	92	8,700	56	83,9	62
PL	19,2	18 429	11 786	42	37,967	74	312,7	69
PT	4,3	2 553	1 657	67	10,341	143	92,1	145
RO	5,0	10 766	4 030	32	19,760	112	238,4	154
SI	0,6	1 209	500	32	2,064	94	20,3	106
SK	3,5	3 626	1 587	57	5,426	78	49,0	81
FI	3,9	5 926	3 270	31	5,487	38	338,4	270
SE	12,8	10 882	8 184	41	9,851	28	450,3	143
UK	68,0	16 253	5 483	321	65,383	272	243,8	116

Figure 13: Rail indexes of density of infrastructure and use of services – Source: elaboration based on Publications Office of the European Union, 2018 - STATISTICAL POCKET BOOK 2018 - EU TRANSPORT in figure

Degree of market opening: "in most countries, incumbent rail companies control over 80% of the market, except for Poland (48%), Sweden (67%), Italy (77%) and the United Kingdom (where

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there is no incumbent). In 10 countries still there were no alternative operators in 2015."[58]

SHARE OF ALL BUT THE PRINCIPAL UNDERTAKINGS

%	2010	2015	2016	2017	Of which: Market share PSO (*) 2017	Of which: Market share Commercial 2017
BE	0.2%	3.3%			0.0%	
BG	2.6%	0.0%	0.0%	0.0%	0.0%	0.0%
CZ	0.2%	5.0%		12.6%	1.5%	72.0%
DK	18.0%	7.0%	12.0%		7.2%	
DE	8.0%	13.5%	15.7%	15.9%	26.6%	0.8%
EE	50.0%	0.0%	6.0%	5.6%	0.0%	100.0%
IE	0.0%		0.0%	0.0%	0.0%	100.0%
EL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ES	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FR	1.0%	5.0%	0.0%	1.0%	0.0%	1.0%
HR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
IT	8.3%	23.0%	25.2%	25.0%	24.3%	25.5%
CY	-	-	-	-	-	-
LV	10.5%	8.3%	7.0%	7.2%	0.1%	99.9%
LT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LU		0.0%	0.0%		0.0%	0.0%
HU	1.8%	3.5%	3.5%	3.4%	3.3%	4.5%
MT	-	-	-	-	-	-
NL	4.8%	14.9%	5.0%	5.0%	5.0%	
AT	5.4%	12.2%	11.7%	11.5%	6.9%	21.1%
PL	48.3%	51.7%	44.7%	43.1%	48.2%	2.2%
PT	9.0%	5.4%	8.3%	14.5%	100.0%	6.9%
RO	3.9%				9.8%	
SI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SK	0.0%	6.0%	15.3%	4.1%	2.6%	26.7%
FI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE		33.5%	35.2%	43.2%	71.0%	14.0%
UK	89.9%		86.9%	87.3%	86.9%	100.0%

Figure 14: Rail degree of market opening (passengers) – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

Perceived quality of service in terms of customer satisfaction: this is another item with substantial differences. It is important to remind that perceptions scores can be different from actual service performance as there is a subjective component. So their values need to be

[58] https://ec.europa.eu/transport/sites/transport/files/2018-transport-in-the-eu-current-trends-and-issues.pdf

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interpreted when comparing countries. Nevertheless, individual customer decisions strongly depend on such perceptions.

The above ranking is based on the 'Market Performance Indicator' (MPI) — a composite index which indicates how well a given market performs, according to consumers. The MPI is calculated based on the components: comparability, trust, problems & detriment, expectations and choice (as a weighted average of the components with the weights being equal to the relative importance of each component). This calculation is computed for each market-respondent combination before being aggregated for reporting purposes. Due to a change in methodology in the 2015 report, the MPIs are not comparable with the MPIs the previous report.

This analysis identifies 3 clusters: green with a higher score (>84%), grey with intermediate positioning and red with lower scores (<70.9%).

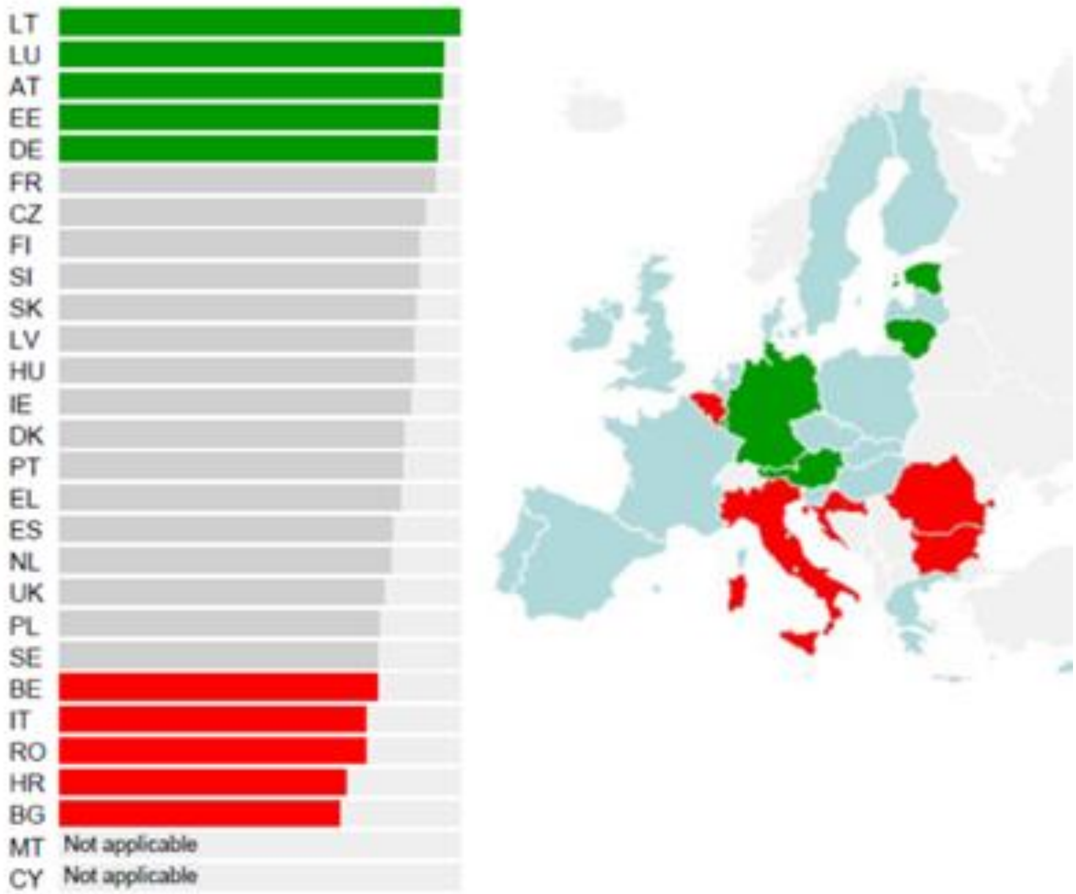

Figure 15: Perceived quality for rail transport – Source: https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/rail-transport-consumer-satisfaction_en# 2015

Fares in terms of revenues per passenger-km: the differences are part of a comprehensive pricing topic. In fact, this is a complex item involving a number of factors.

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It is complex because each year a wide range of national, regional, local and urban authorities and operators calculated and marketed millions of fares. Databases of fares may not be saved or made available to third parties. Nevertheless, several sources provide some indications, although each source is subject to some caveats the most relevant regards the relationship between fares and average yields, reflecting the mix of bought fares.

It is not in the scope of this project to update these studies but just to take note of the issue of pricing harmonization. A relevant issue affecting pricing, and often a source of discussions within the rail ecosystem, is the Rail infrastructural charge. Individual countries have different approaches to this issue so that the EU harmonization process has a long way to go before becoming effective. This is in evident contrast with the road network, which has much easier access and uniformity of principles all over Europe.

Figure 2.5: Fare revenue per passenger kilometre (2012)

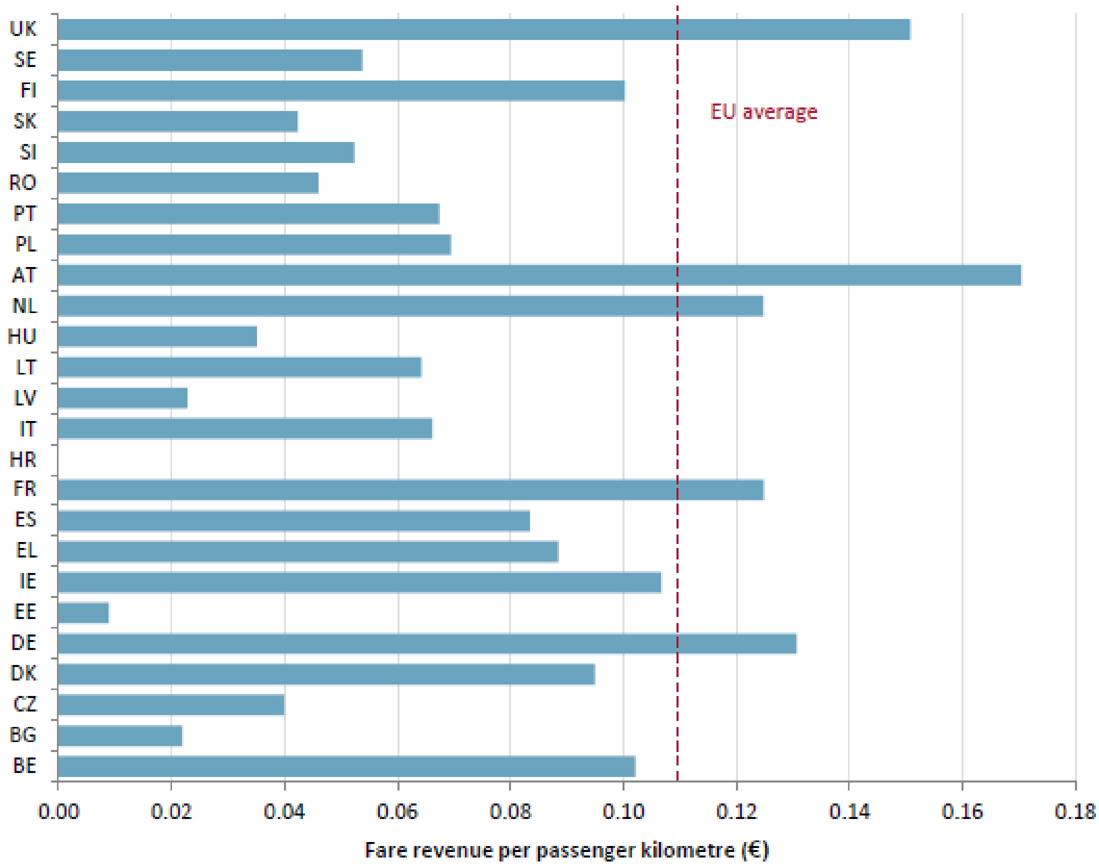

Figure 16 : Fare revenue per pax/km and train/km habitant 2012 – Source: https://ec.europa.eu/transport/sites/transport/files/modes/rail/studies/doc/2015-09-study-on-the-cost-and-contribution-of-the-rail-sector.pdf

Public service contracts – "In 2016, over 60 % of total EU rail passenger kilometres were travelled on services provided under a PSO, and PSO compensation remains a significant source

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of revenue for railway undertakings in a majority of Member States. PSO is used more for domestic and regional rail services than for long-distance services; only a few countries reported having a PSO on international services."[59]

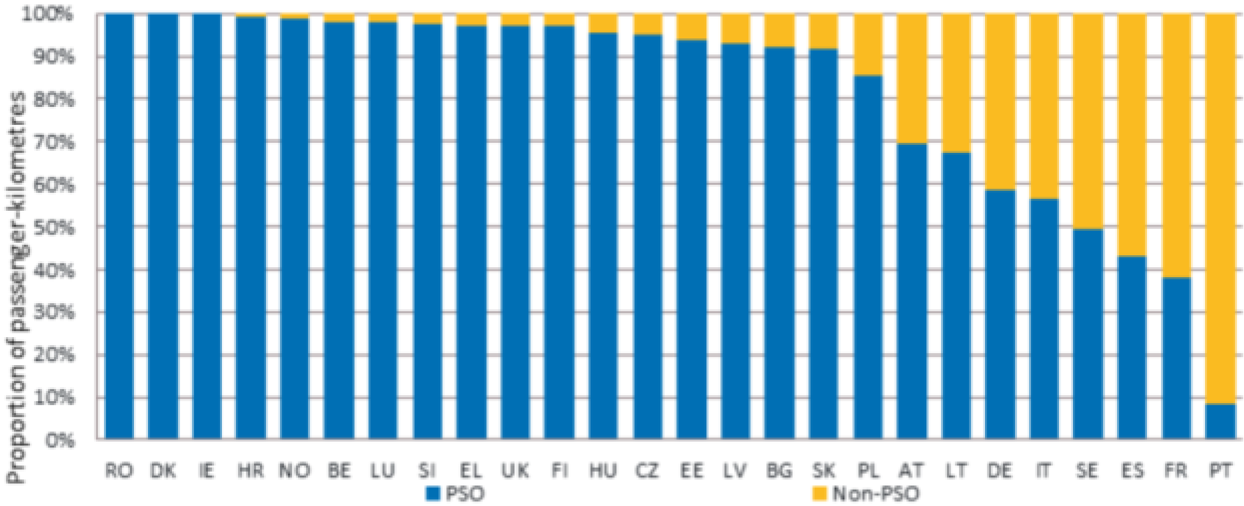

Figure 17: Pkm on PSO and commercial rail services, 2016 – Source: RMMS, 2018. No recent data for NL.

The Structure of territory and urbanization: it is relevant because a network of big cities with relatively limited distances such as in Germany represents a condition of intercity mobility that is different than France where the population is more dispersed in the country.

The structure of territory and urbanization is also relevant to the success of the different type of rail services. In particular, it is immediate to think about the convenience of rail commuting as opposed to alternative modes. High-Speed Rail is also more successful in connecting big distant cities such as in Italy and Spain than big but less distant cities such as in Germany where the saving of the travel time delivered by High-Speed Rail is relatively smaller compared to standard inter-city rail services produced at lower costs, or alternative modes such as private cars.

[59] http://www.cer.be/sites/default/files/publication/The_Economic_Footprint_-_web_-_final_final_30_Sept.pdf

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City	Metropolitan area	Habitans	Area	Country
Vienna	1.775.000 ab.	1.775.000 ab.	453 Km²	Austria
Bruxelles	2.105.000 ab.	179.000 ab.	803 Km²	Belgio
Anversa	1.015.000 ab.	517.000 ab.	635 Km²	Belgio
Sofia	1.320.000 ab.	1.230.000 ab.	207 Km²	Bulgaria
Copenaghen	1.280.000 ab.	591.000 ab.	616 Km²	Danimarca
Helsinki	1.220.000 ab.	632.000 ab.	641 Km²	Finlandia
Parigi	10.870.000 ab.	2.230.000 ab.	2.845 Km²	Francia
Lione	1.635.000 ab.	509.000 ab.	1.178 Km²	Francia
Marsiglia	1.610.000 ab.	864.000 ab.	689 Km²	Francia
Lilla	1.060.000 ab.	238.000 ab.	443 Km²	Francia
Düsseldorf	6.675.000 ab.	612.000 ab.	2.655 Km²	Germania
Berlino	4.085.000 ab.	3.520.000 ab.	1.347 Km²	Germania
Colonia	2.115.000 ab.	1.060.000 ab.	932 Km²	Germania
Amburgo	2.095.000 ab.	1.785.000 ab.	777 Km²	Germania
Monaco di Baviera	2.000.000 ab.	1.450.000 ab.	466 Km²	Germania
Francoforte	1.930.000 ab.	733.000 ab.	648 Km²	Germania
Stoccarda	1.385.000 ab.	624.000 ab.	479 Km²	Germania
Atene	3.480.000 ab.	664.000 ab.	583 Km²	Grecia
Dublino	1.190.000 ab.	553.000 ab.	318 Km²	Irlanda
Milano	5.270.000 ab.	1.345.000 ab.	1.891 Km²	Italia
Roma	3.930.000 ab.	2.865.000 ab.	1.114 Km²	Italia
Napoli	3.700.000 ab.	974.000 ab.	1.023 Km²	Italia
Torino	1.525.000 ab.	891.000 ab.	376 Km²	Italia
Rotterdam	2.665.000 ab.	620.000 ab.	984 Km²	Paesi Bassi
Amsterdam	1.635.000 ab.	842.000 ab.	505 Km²	Paesi Bassi
Varsavia	2.270.000 ab.	1.750.000 ab.	544 Km²	Polonia
Katowice	2.180.000 ab.	300.000 ab.	673 Km²	Polonia
Lisbona	2.685.000 ab.	553.000 ab.	958 Km²	Portogallo
Porto	1.480.000 ab.	238.000 ab.	777 Km²	Portogallo
Londra	10.350.000 ab.	8.675.000 ab.	1.738 Km²	Regno Unito
Manchester	2.660.000 ab.	530.000 ab.	630 Km²	Regno Unito
Birmingham	2.530.000 ab.	1.110.000 ab.	599 Km²	Regno Unito
Leeds	1.925.000 ab.	774.000 ab.	488 Km²	Regno Unito
Glasgow	1.235.000 ab.	606.000 ab.	368 Km²	Regno Unito
Praga	1.380.000 ab.	1.275.000 ab.	298 Km²	Rep. Ceca
Bucarest	2.115.000 ab.	2.115.000 ab.	412 Km²	Romania
Madrid	6.240.000 ab.	3.140.000 ab.	1.321 Km²	Spagna
Barcellona	4.740.000 ab.	1.605.000 ab.	1.075 Km²	Spagna
Valencia	1.570.000 ab.	786.000 ab.	272 Km²	Spagna
Siviglia	1.110.000 ab.	694.000 ab.	272 Km²	Spagna
Stoccolma	1.515.000 ab.	1.515.000 ab.	382 Km²	Svezia
Budapest	2.500.000 ab.	1.760.000 ab.	971 Km²	Ungheria

Figure 18: EU cities with more than half million people – Source: elaboration based on http://www.citymayors.com/statistics/largest-cities-country-by-country.html data 2018

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Development of High Speed Rail: this is a crucial driver of rail traffic growth with a share on total rail traffic of 26.1% in 2016. Its importance is particularly relevant in countries like Germany, Spain, France and Italy. In such countries, the share of High Speed is between 25 and 60% of rail pkm. High-Speed Rail is elaborated for its relevance in a separate paragraph.

HIGH-SPEED RAIL TRANSPORT (*)

	BE	CZ	DE	ES	FR	IT	NL	PL	PT	SI	FI	SE	UK	EU-28 (billion pkm)	% CHANGE
1990	-	-	-	-	14.92	0.30	-	-	-	-	-	0.01	-	15.23	-
1995	-	-	8.70	1.29	21.43	1.10	-	-	-	-	-	0.42	-	32.94	7.2%
2000	0.87	-	13.93	1.94	34.75	5.09	0.11	-	-	-	0.07	2.05	-	58.80	11.6%
2005	0.98	0.01	20.85	2.32	43.13	8.55	0.69	-	0.49	-	0.31	2.33	0.45	80.11	5.3%
2006	1.00	0.15	21.64	2.70	44.85	8.91	0.73	-	0.51	-	0.44	2.49	0.90	84.32	5.2%
2007	1.02	0.33	21.92	2.59	47.97	8.82	0.80	-	0.51	-	0.58	2.78	1.39	88.70	5.2%
2008	1.08	0.25	23.33	5.48	52.56	8.88	0.87	-	0.53	0.01	0.62	2.99	0.99	97.60	10.0%
2009	1.06	0.24	22.56	11.51	51.86	10.75	0.92	-	0.53	0.02	0.60	3.05	1.01	104.10	6.7%
2010	1.06	0.27	23.90	11.72	51.89	11.61	0.29	-	0.52	0.02	0.65	2.94	1.01	105.87	1.7%
2011	0.91	0.29	23.31	11.23	51.37	12.28	0.31	-	0.47	0.01	0.71	2.83	4.36	108.06	2.1%
2012	0.91	0.27	24.75	11.18	51.09	12.79	0.32	-	0.46	0.01	0.71	2.95	4.36	109.80	1.6%
2013	0.91	0.25	25.18	12.74	50.79	12.79	0.36	-	0.47	0.01	0.76	3.06	4.36	111.67	1.7%
2014	0.91	0.25	24.32	12.79	50.66	12.79	0.24	-	0.54	0.01	0.65	3.23	2.90	109.28	-2.1%
2015	1.20	0.57	25.28	14.13	49.98	12.79	1.00	0.47	0.57	0.01	0.57	3.37	2.90	112.82	3.2%
2016	1.50	0.70	27.21	15.06	50.54	12.79	0.37	1.44	0.61	0.00	0.61	3.48	2.80	117.12	3.8%
2017	1.56	0.77	28.50	15.54	58.28	12.79	0.41	1.44	0.65	0.00	0.68	3.60	2.80	127.03	8.5%

SHARE OF HIGH-SPEED RAIL TRANSPORT IN TOTAL PASSENGER-KILOMETRES IN RAIL TRANSPORT (**)

%	BE	CZ	DE	ES	FR	IT	NL	PL	PT	SI	FI	SE	UK	EU-28
2000	11.2	-	18.5	9.6	46.4	10.3	0.8	-	-	-	2.1	24.8	-	15.6
2005	11.5	0.1	27.2	10.7	52.4	17.1	4.5	-	12.9	-	8.9	26.2	1.0	20.8
2006	11.2	2.1	27.4	12.2	52.3	17.8	4.6	-	13.1	-	12.3	25.9	1.9	21.3
2007	10.8	4.8	27.7	11.9	54.6	17.7	4.9	-	12.7	-	15.4	27.0	2.8	22.0
2008	10.6	3.7	28.3	22.9	56.4	17.9	5.3	-	12.5	1.8	15.4	26.8	1.9	23.3
2009	10.4	3.6	27.4	49.7	56.2	22.3	5.6	-	12.6	2.1	15.6	26.9	1.9	25.3
2010	10.0	4.1	28.5	52.2	56.2	24.6	1.7	-	12.6	2.1	16.4	26.3	1.8	25.6
2011	8.5	4.3	27.3	49.3	54.4	26.2	1.7	-	11.0	1.9	18.3	24.8	7.5	25.7
2012	8.3	3.8	27.9	49.7	53.3	27.4	1.8	-	12.1	1.8	17.5	25.0	7.2	25.7
2013	8.3	3.3	28.1	53.6	53.4	26.3	1.9	-	12.7	1.6	18.7	25.8	7.0	25.7
2014	8.3	3.2	26.7	51.0	53.7	25.6	1.2	-	14.0	1.2	16.8	26.6	4.5	24.8
2015	11.6	7.0	27.6	54.0	52.8	24.5	5.7	2.7	14.4	0.9	13.9	26.4	4.4	25.2
2016	15.0	9.5	28.4	56.5	53.8	25.1	2.0	7.5	16.2	0.6	15.8	27.2	4.1	25.8
2017	15.3	8.8	29.8	56.5	58.2	24.0	2.2	7.1	14.5	0.3	15.9	27.1	4.1	27.0

Figure 19: High Speed Rail traffic – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

High-Speed Railways are being deployed through several countries all over the world. The

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following graphics put in context the developments of high-speed in Europe in the framework of the world developments of commercial operation.

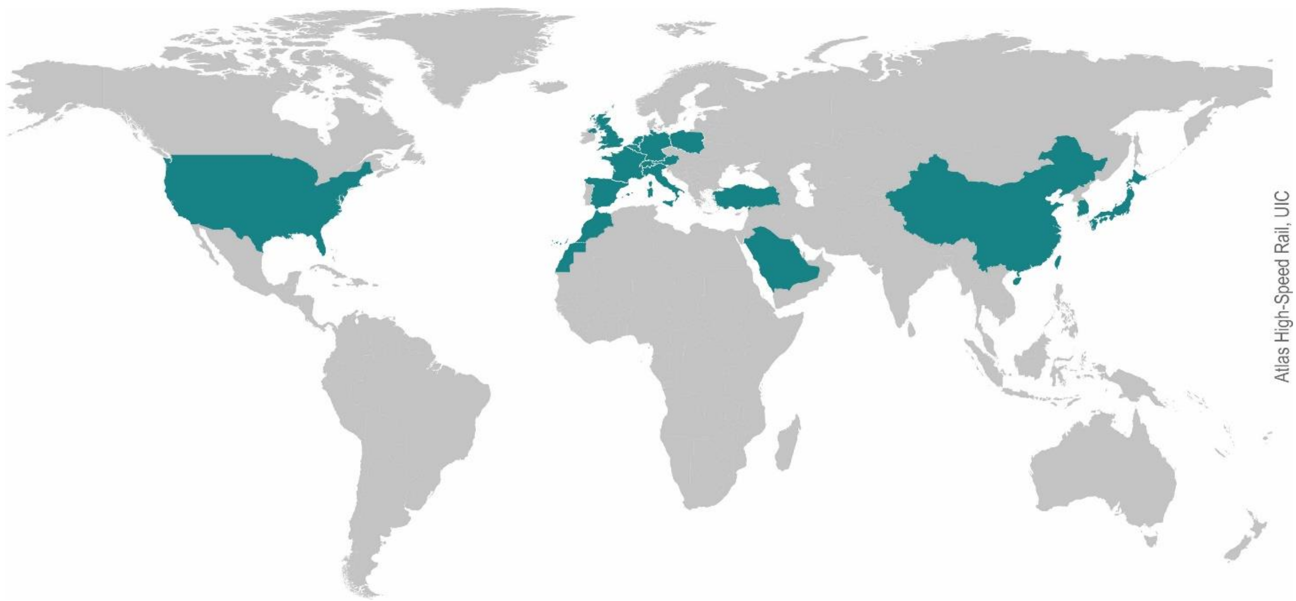

Figure 20: Countries with a high-speed rail network in commercial operation - Source: Atlas High-Speed Rail – UIC, December 2018.

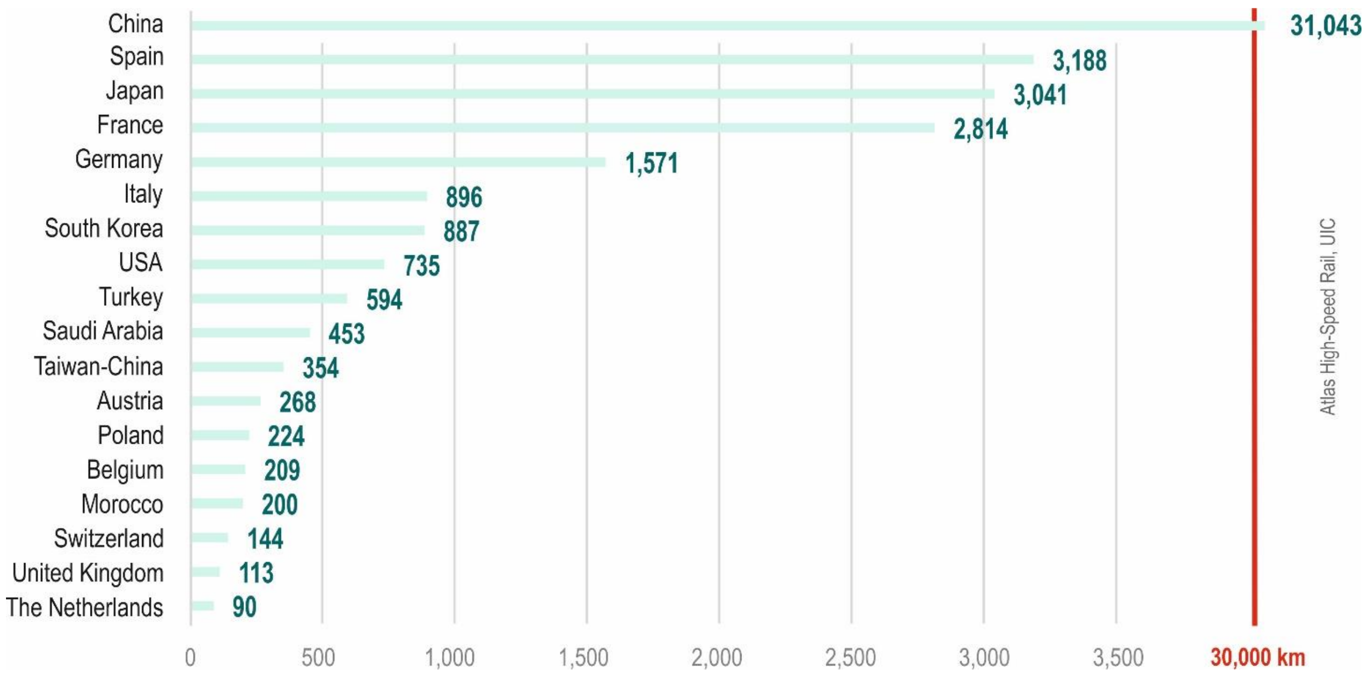

Figure 21: Length of the high-speed network in commercial operation by country - Source: Atlas High-Speed Rail – UIC, December 2018.

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Focus on motorways investments opposed to rail modernisation and fast evolvement of car mobility - Some quick reflections on the negative effects on the use of rail on Countries where a marked decline is shown can be attributed to the focus on motorways investments opposed to rail modernisation. The development of car mobility for both the citizens' ambition to own a car in fast-developing Countries and the increased presence in such countries' territories of a motor car industry are elements of the picture.

Availability of service of mobility integration – The integration of rail transport additional mobility service in terms of space (such as bike parking, bus station) and time (such as links with air and other transport modes) is a key element for the success of rail transport compared to other modalities especially motor cars that do not need such integration. Modern rail station concepts also including additional non-mobility services such as shopping, travel up to the social hub, need to be analysed and exploited with additional data set. Also ICT technology is important for contributing to service integration and travellers' experience.

Resulting remarks

- The lack of competition on rail services seems to be a constraint for the development of rail and the service quality;
- The lack of service segmentation for different categories of travellers failed to intercept the "travel experience" requirements of an evolving Society whose mobility habits and ambitions are international and many times global;
- Likewise, stations and interchange places where co-modal integration could take place are not adequate to the travellers' needs;
- The different infrastructure charges represent a constraint for achieving uniformity and price competitiveness for accessing a single EU Rail area.

7.4.4. High-Speed Rail – in high speed development?

High-Speed is the true rail macro technological innovation of this century. In fact, initiated in Europe in the last decades of the past century, High-Speed became progressively relevant investments in new infrastructures, technologies, rolling stock and traffic. Since the year 2000 up to 2016 the High-Speed Rail infrastructure in terms of length of lines in Europe, grew about 3 times reaching 7,700 km (and exceeding 9,000 km in the year 2019). Other significant connections are under construction. In the same period, the traffic of pkm more than doubled.

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Figure 22: Length of the High-Speed network in commercial operation in Europe (1977-2018) - Source: Atlas High-Speed Rail – UIC, December 2018.

Figure 23: High-Speed network lines in operation in Europe: 2018 - Source: Atlas High-Speed Rail – UIC, December 2018.

High Speed Rail is modifying several major aspects of rail travel towards becoming a service product of choice:

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A) HSR becomes more competitive towards air and motor cars in terms of costs, timing, comfort and consistency;
B) HSR starts to deliver this perceived dimension of "travel experience";
C) HSR develops the market by providing services to completely new demand segments with new offerings in prices and services;
D) HSR improves its accessibility towards decentralized areas introducing the Hub and spoke approach by concentrating on strategic stations surface regular bus connections attracting new travellers that otherwise would have opted for private cars. By so doing HSR implements effectively co-modal transportation;
   HSR stations, completely modernized, or newly built with attractive architectures show features and services similar to airports. Such new stations in traffic attraction zones apply the Hub and Spoke concept intercepting totally new categories of travellers which otherwise not having proper accessibility to rail would have used other means of transport.

As anticipated, High-Speed Rail contribution affected the national rail performance and in particular specific routes connecting big metropolitan regions.

Countries with major connections include:

- Italy – Milan-Rome as the main route, then extended to Turin-Milan-Rome-Naples[60]. Extensions are in progress for Milan-Venice and Naples-Bari so that the North-South, and West-East axes are completely covered.
- Spain – Madrid-Lleida as main route, built after Madrid-Seville, and 2010 Madrid-Valencia (1 h 35 min); to be underlined that all HSR in Spain are completely new lines because of the gauge difference. In this way through HSR Spain is completely integrated with mainland Europe.
- France – Paris-Lyon and related extensions (such as Marseille, Perpignan, Bordeaux, Genève, Brussels, London)[61]
- Germany – a number of connections are also due to upgrading of existing infrastructures.

The following graphics show the evolution of travel time from some European cities and specific routes, comparing 1989 and 2018.

[60] https://italospa.italotreno.it/static/upload/_con/concorrenza-tra-treno-e-aereo.pdf

[61] http://www.cer.be/sites/default/files/publication/The_Economic_Footprint_-_web_-_final_final_30_Sept.pdf

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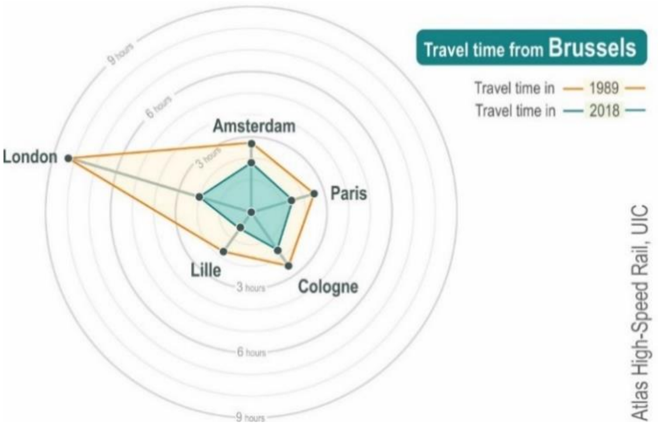

Figure 24: Evolution of travel time from Brussels - Source: Atlas High-Speed Rail – UIC, December 2018

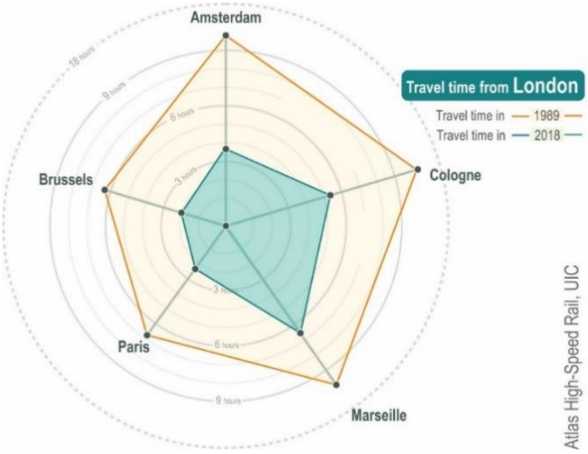

Figure 25: Evolution of travel time from London - Source: Atlas High-Speed Rail – UIC, December 2018.

Figure 26: Evolution of travel time from Madrid - Source: Atlas High-Speed Rail – UIC, December 2018.

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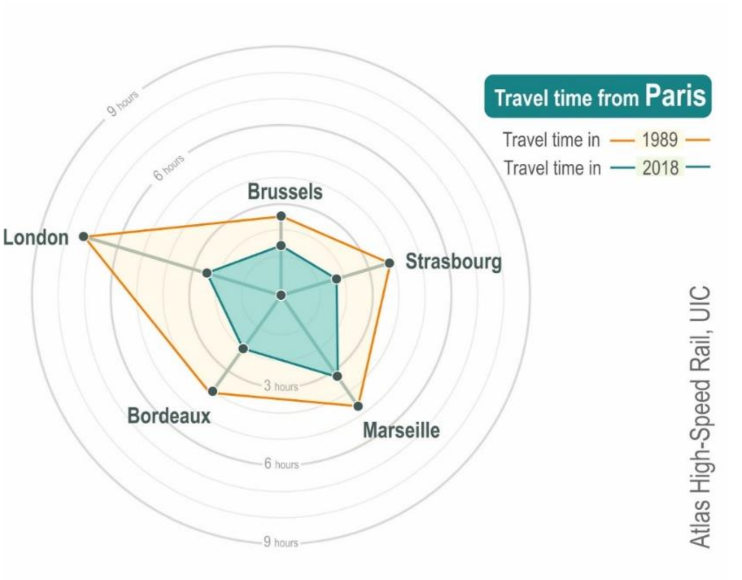

Figure 27: Evolution of travel time from Paris - Source: Atlas High-Speed Rail – UIC, December 2018.

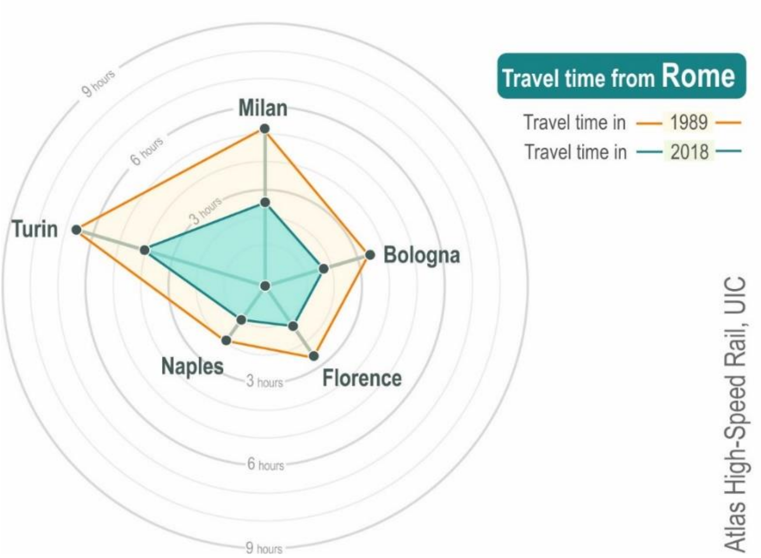

Figure 28: Evolution of travel time from Rome - Source: Atlas High-Speed Rail – UIC, December 2018.

More figures provided by the STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures, are shown at the following pictures.

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LENGTH OF LINES

km (at end of year)

	BE	DE	ES	FR	IT	NL	AT	PL	UK	EU
1985	-	-	-	425	174	-	-	-	-	599
1990	-	90	-	717	194	-	-	-	-	1 001
1995	-	447	471	1 290	238	-	-	-	-	2 446
2000	72	636	471	1 290	238	-	-	-	-	2 707
2005	137	1 183	919	1 549	238	-	-	-	74	4 100
2010	209	1 272	1 866	1 912	856	90	-	-	113	6 318
2015	209	1 475	2 413	2 058	856	90	50	224	113	7 488
2016	209	1 475	2 413	2 180	896	90	50	224	113	7 650
2017	209	1 658	2 852	2 814	896	90	268	224	113	9 124
2018	209	1 571	2 852	2 734	896	90	263	224	113	8 952

Note: Length of lines or of sections of lines designed for trains that can go faster than 250 km/h at some point during the journey.

HIGH-SPEED LINES CURRENTLY UNDER CONSTRUCTION

	LINE	LENGTH km	START OF OPERATION
DK	Copenhagen - Ringsted	60	2019
DE	Wendlingen - Ulm	60	2022
DE	Stuttgart - Wendlingen	25	2024
DE	Karlsruhe - Rastatt (Basel)	17	2024
DE	(Karlsruhe) Buggingen - Katzenbergtunnel (Basel)	32	2025
DE	(Karlsruhe) Katzenbergtunnel - Basel	13	2025
ES	Monforte del Cid - Murcia	62	2019
ES	Vitoria - Bilbao - San Sebastian	175	2022
ES	León - Asturias Variante de Pajares	50	2020
ES	Bobadilla - Granada	109	2019
ES	Plasencia - Caceres / Badajoz	193	2020
ES	Venta de Banos - Burgos	91	2019
ES	Zamora - Orense	224	2020
IT	Genoa - Milan (Tortona)	53	2022
AT	Wien Stadlau - Staatsgrenze (AT/SK)	38	2022
AT	Wien Inzersdorf Ort - Wr. Neustadt (Pottendorfer Linie)	47	2023
AT	Graz - Klagenfurt (Koralmbahn)	122	2025
AT	Gloggnitz - Mürzzuschlag (Semmering-Basistunnel)	28	2026
AT	Volders - Baumkirchen / Innsbruck - Staatsgrenze AT/IT (Brenenr-Bassis-Tunnel)	46	2027
SE	Arlöv - Lund	11	2024
UK	London - Birmingham	230	2026

Note: The length indicated above is the length of the line under construction and not necessarily the distance between the places named.

Figure 29: High Speed Rail network + lines under construction – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no. 826055 (TER4RAIL)

Germany, being a "poly-centric" country has different interest for speed compared to a "mono-centric" country such as France. In fact, the "network effects have to be taken into account, mostly by ensuring that integrated clock-face timetables are best integrated with speed needs"[62]. Beside distances, the offering integration with other services may be influential.

	MADRID, Puerta del Sol - BARCELONA, Plaça de Catalunya		ROME, Piazza del Campidoglio - MILAN, Piazza del Duomo		BERLIN, Potsdamer Platz - MUNICH, Marienplatz		PARIS, Place de la Concorde - STRASBOURG, Place du Château	
Distance	607-698 km		572-661 km		587-654 km		466-548 km	
Mode of transport	Time	Price *(euro)*	Time	Price *(euro)*	Time	Price *(euro)*	Time	Price *(euro)*
Car	10:40-18:20	138-190	10:40-18:40	180	10:00-16:40	95-142	8:40-12:20	44-79
Air	6:30-8:00	227-253	6:30-7:00	140	6:30-8:00	146	N/A	N/A
Coach	16:20-18:00	36-49	15:00-21:00	40	17:00-23:00	45-79	13:00-22:40	33-55
Conventional rail	11:30-12:00	124-128	9:00-23:00	61-103	N/A	N/A	N/A	N/A
High-speed rail	6:00-8:20	159-181	6:50-9:00	23-205	8:30-10:30	66	5:10-5:30	158-165

Figure 30: High Speed Rail - Door to door travel analysis - Source special report 19/2018 - A European high-speed rail network: not a reality but an ineffective patchwork[63]

The above examples of high-speed connections demonstrate success in competing with other modes. The financial success of companies managing the service shows how innovation brings results.

In Spain, the picture below shows how the High-Speed services allowed to double the passenger rail traffic in the segment of "long distance".

[62] http://www.sipotra.it/wp-content/uploads/2018/02/Trans-European-Railway-High-Speed.-Master-Plan-Study.pdf

[63] http://publications.europa.eu/webpub/eca/special-reports/high-speed-rail-19-2018/en/

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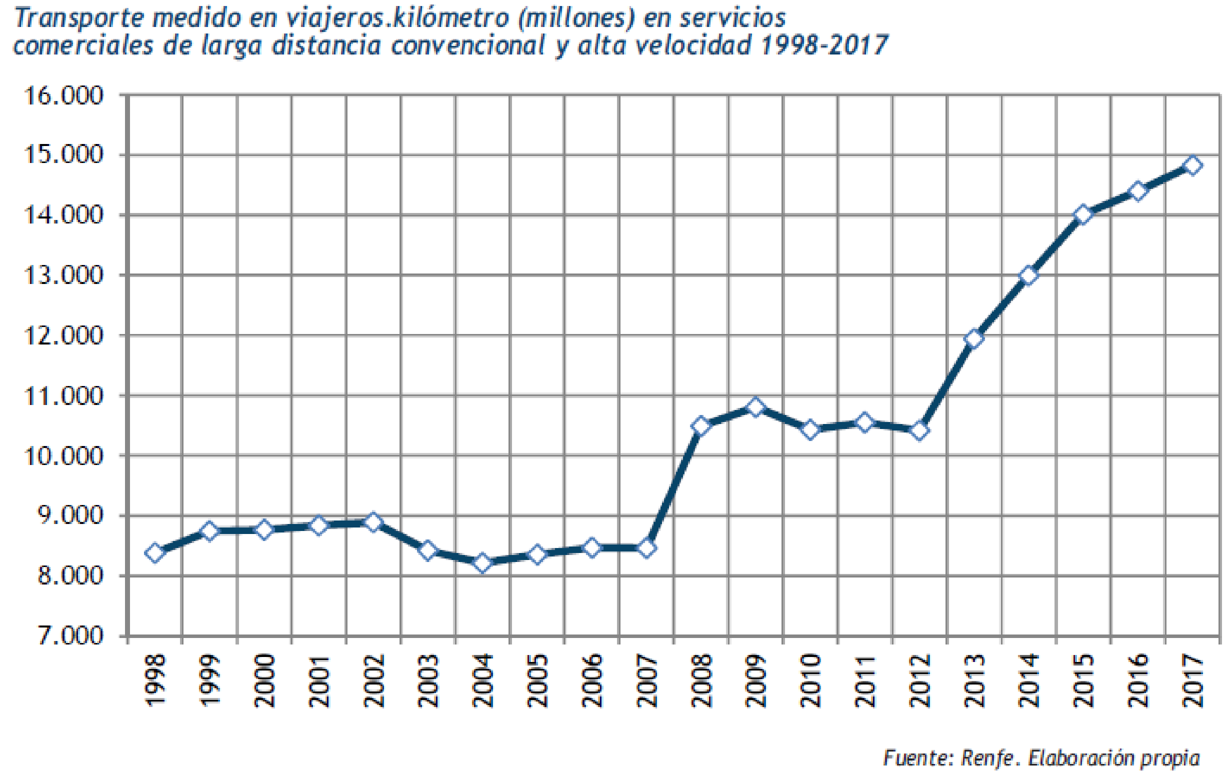
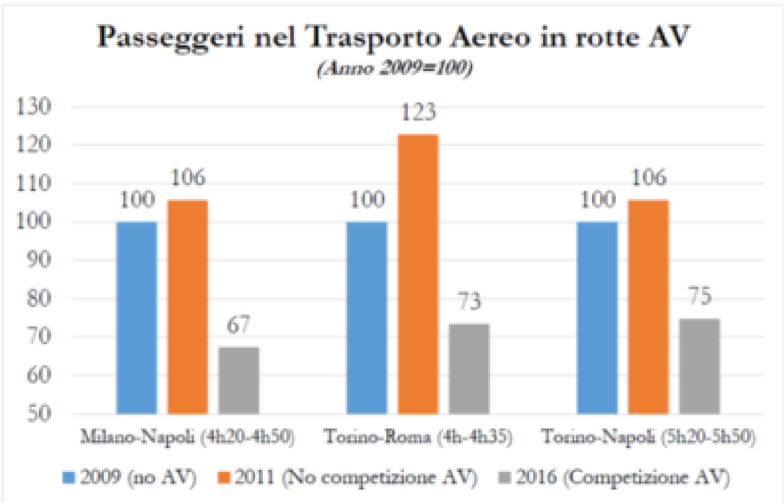


Figure 31: High Speed Rail traffic in Spain – Source: Observatorio del Ferrocarril en España 2017 by Foundación de los Ferrocarriles Españoles published December 2018

The successful competition between high-speed rail carriers in the same routes is a specific aspect to mention, given the positive experience in Italy.

Considering their "competitive specificity", the Italian examples show a shift from air to rail in the pictures below.



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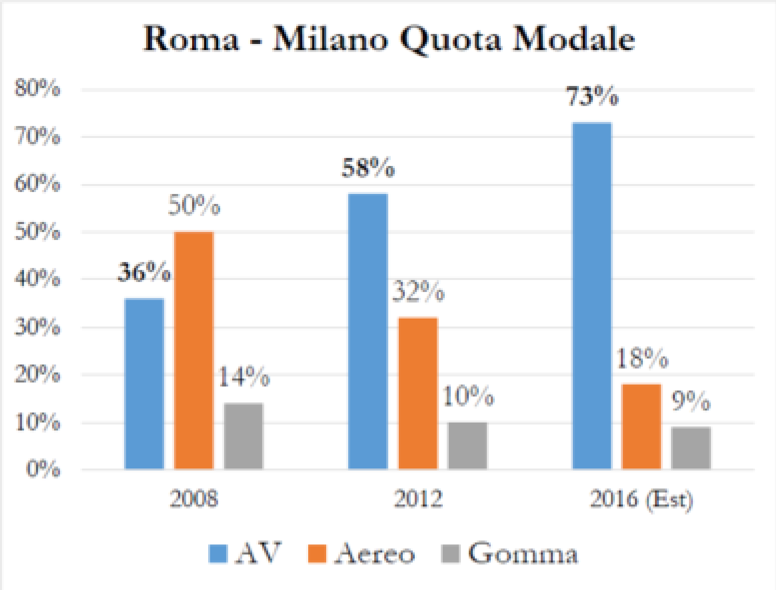

Figure 32: Competition between Air and High-Speed Rail Milan-Rome – Source: Tra Consulting for NTV[64] https://italospa.italotreno.it/static/upload/_con/concorrenza-tra-treno-e-aereo.pdf

As said, both new lines and upgraded lines mainly connect domestic traffic relations. However, some relevant cross border connections exist between Germany with Nederland, France, Switzerland and Austria, and between France and the UK.

Weakness in progressing with EU plans seems more relevant in corridor connections since Countries with significant domestic investments and services looks in the cluster of "less performing" like Italy and Spain (about 40% of implementation in below picture – green >58%, red <37%).

The current status justifies evaluations in terms of consistency with the EU ambition of rail role in the comprehensive mobility arena.

[64] https://italospa.italotreno.it/static/upload/_con/concorrenza-tra-treno-e-aereo.pdf

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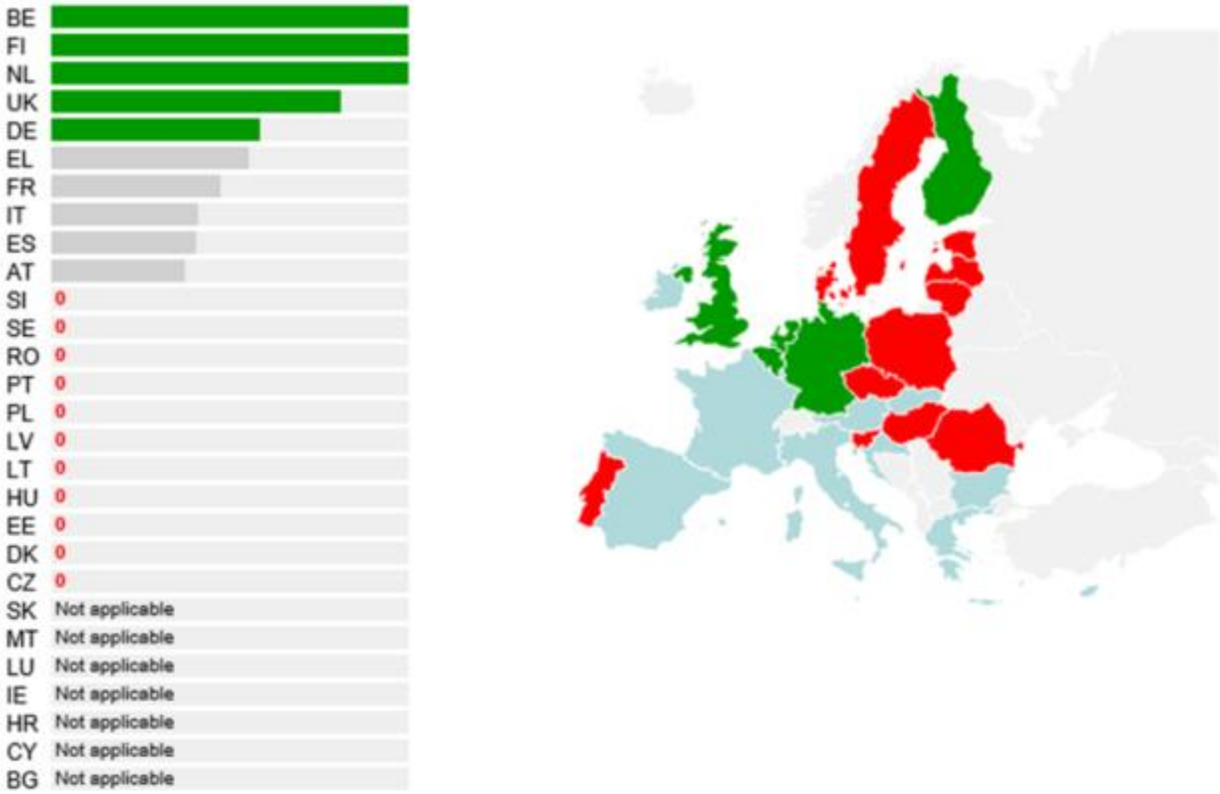

Figure 33: Completion of TEN-T High Speed Rail Core Network – Source: https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/investments-infrastructure/ten-t-completion-rail-hs_en (data 2015)

Even if the high-speed continues its progress some considerations become apparent: "the EU's current long-term plan if not supported by credible analysis, is unlikely to be achieved, and lacks a solid EU-wide strategic approach. Although the length of the national high-speed rail networks is growing, the Commission's 2011 target of tripling the number of kilometres of high-speed rail lines by 2030 will not be reached: 9,000 km of high-speed line is currently in use, and around 1,700 km of line was under construction in 2017. On average, it takes around 16 years for new high-speed lines to proceed from the start of the works to the beginning of operations"[65].

The capability to compete with air in the fast-growing international traffic, when distances are already approachable with high-speed rail is not exploited. In fact, the orientation of investments in cross border connections appear limited, and no operators with international scope target this market at present.

Resulting remarks

- HSR has been and is a major success story and a revolution in Rail services after decades of decay and oblivion;
- HSR is an advanced technological innovation;
- HSR delivers effective and efficient services at competitive costs to old and new categories of users;

[65] http://publications.europa.eu/webpub/eca/special-reports/high-speed-rail-19-2018/en/

- HSR demonstrates its profitability and long-term sustainability;
- HSR has eroded dramatically market share to air in medium-long distances;
- HSR proved the viability of co-modal integration extracting the best value performance from each mode;
- HSR has a long way to go for exploiting its full potential in cross border traffic;
- HSR should evolve from a National to an International Experience giving the customers a new modal choice which today is not available for travel time between cities of 3 and 3.5 hours.

7.4.5. Safety

Safety is still a big issue in transport, especially in road transport, even if, from a multi-year perspective, enormous improvements can be recognized.

In road transport, the reduction of accidents involving personal injury is of about one third when compared to the period since the year 2000 with the previous one. The reduction in fatalities in the same period is more than half. The positive trend is even better than just said if weighted with the traffic increase. The improvements are attributable to enhanced active and passive technological solutions both in transport means, advanced equipment and in infrastructure improvements, signalling as well as better control of speed limits associated with stronger penalties. Other elements, such as other road regulation, played their role.

Despite these signs of progress, somehow present also in other modes, the safety gap between road and other modes appears not fillable even in future decades for structural reasons.

In fact, in the other modes, the accidents with passenger injury or fatalities have by far different incidence, one or two orders of magnitude, compared to road.

In particular, rail remains by far the safer mode than any other surface transport. According to ERRAC, it is 24 times safer than car land transport, 1.5 times better than coach[66].

Because of episodic features, trend considerations appear not significant for modes different from road.

[66] http://errac.org/publications/rail-2050-vision-document/

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Road Fatalities

	1990	2000	2005	2010	2015	2016	2017	% CHANGE '16/'17	% CHANGE '01/'17
EU-28	77 176	57 082	45 943	31 506	26 130	25 644	25 256	-1.5	-54.0
BE	1 976	1 470	1 089	840	732	637	615	-3.5	-58.6
BG	1 567	1 012	957	776	708	708	682	-3.7	-32.5
CZ	1 291	1 486	1 286	802	734	611	577	-5.6	-56.7
DK	634	498	331	255	178	211	175	-17.1	-59.4
DE	11 046	7 503	5 361	3 648	3 459	3 206	3 180	-0.8	-54.4
EE	436	204	170	79	67	71	48	-32.4	-75.9
IE	478	418	400	212	162	185	156	-15.7	-62.1
EL	1 737	2 037	1 658	1 258	793	824	731	-11.3	-61.1
ES	9 032	5 777	4 442	2 479	1 689	1 810	1 830	1.1	-66.8
FR	11 215	8 079	5 318	3 992	3 461	3 471	3 444	-0.8	-57.8
HR	1 360	655	597	426	348	307	331	7.8	-48.8
IT	7 151	7 061	5 818	4 114	3 428	3 283	3 378	2.9	-52.4
CY	101	111	102	60	57	46	53	15.2	-45.9
LV	947	635	442	218	188	158	136	-13.9	-75.6
LT	1 001	641	773	299	242	192	191	-0.5	-72.9
LU	71	76	47	32	36	32	25	-21.9	-64.3
HU	2 432	1 200	1 278	740	644	607	625	3.0	-49.6
MT	4	15	17	13	11	23	19	-17.4	18.8
NL	1 376	1 082	750	537	531	533	535	0.4	-46.1
AT	1 558	976	768	552	479	432	414	-4.2	-56.8
PL	7 333	6 294	5 444	3 908	2 938	3 026	2 831	-6.4	-48.8
PT	2 646	1 877	1 247	937	593	563	602	6.9	-64.0
RO	3 782	2 466	2 629	2 377	1 893	1 915	1 951	1.9	-20.4
SI	517	314	258	138	120	130	104	-20.0	-62.6
SK	662	628	606	371	310	275	276	0.4	-55.0
FI	649	396	379	272	266	258	238	-7.8	-45.0
SE	772	591	440	266	259	270	253	-6.3	-56.6
UK	5 402	3 580	3 336	1 905	1 804	1 860	1 856	-0.2	-48.4

Road Accidents

NUMBER OF ACCIDENTS INVOLVING PERSONAL INJURY (1 000)

	1990	1995	2000	2005	2010	2015	2016	2017	% CHANGE '16/'17
EU-28	*1502.077*	1433.020	*1505.653*	1341.981	1130.398	1090.888	1099.075	1084.469	-1.3
BE	62.446	50.744	49.065	49.307	40.569	40.303	40.096	38.020	-5.2
BG	6.478	7.435	6.886	8.224	6.610	7.226	7.404	6.888	-7.0
CZ	21.910	28.746	25.445	25.239	19.675	21.561	21.386	21.263	-0.6
DK	9.155	8.373	7.346	5.413	3.498	2.853	2.882	2.789	-3.2
DE	389.350	388.003	382.949	336.618	288.297	305.659	308.145	302.656	-1.8
EE	2.099	1.644	1.504	2.341	1.347	1.391	1.468	1.405	-4.3
IE	6.067	8.117	7.749	6.533	5.779	5.831	5.893	6.066	2.9
EL	19.609	22.798	23.001	16.914	15.032	11.440	11.318	10.848	-4.2
ES	101.507	83.586	101.729	91.187	85.503	97.756	102.362	102.233	-0.1
FR	162.573	132.949	121.223	84.525	67.288	56.600	57.515	58.609	1.9
HR	14.471	12.668	14.430	15.679	13.274	11.038	10.457	10.939	4.6
IT	161.782	182.761	256.546	240.011	212.997	174.539	175.791	174.933	-0.5
CY	3.172	3.052	2.411	1.382	1.198	0.660	0.650	0.607	-6.6
LV	4.325	4.056	4.482	9.310	3.193	3.692	3.792	3.875	2.2
LT	5.135	4.144	5.807	6.772	3.530	3.031	3.201	3.059	-4.4
LU	1.216	1.145	0.899	0.775	0.787	0.983	0.941	0.955	1.5
HU	27.801	19.817	17.493	20.777	16.308	16.333	16.627	16.489	-0.8
MT	*0.238*	*0.969*	*1.253*	0.848	0.577	1.367	1.437	1.497	4.2
NL	44.892	42.641	42.271	27.007	10.778	18.523	18.749	18.706	-0.2
AT	46.338	38.956	42.126	40.896	35.348	37.960	38.466	37.402	-2.8
PL	50.532	56.904	57.331	48.100	38.832	32.967	33.664	32.760	-2.7
PT	45.110	48.339	44.463	37.066	35.426	31.955	32.299	34.416	6.6
RO	9.708	9.119	7.889	19.819	25.995	28.944	30.751	31.106	1.2
SI	5.177	6.567	8.951	10.509	7.659	6.578	6.495	6.185	-4.8
SK	8.236	8.713	7.884	7.903	8.119	5.502	5.602	5.317	-5.1
FI	10.175	7.812	6.633	7.020	6.072	5.164	4.752	4.432	-6.7
SE	16.975	15.626	15.770	18.094	16.627	14.829	14.086	14.951	6.1
UK	265.600	237.336	242.117	203.712	160.080	146.203	142.846	136.063	-4.7

Figure 34: Road fatalities and accident – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figure

Transport mode	Fatalities per billion passenger-kilometres
Airline	0.06
Railway	0.13
Bus/coach	0.20
Car	3.14
Powered two-wheelers	48.94

Figure 35: Fatalities by mode – Source: "The economic footprint of railway transport in Europe", CER 2014

When looking in particular at the numbers of fatalities in rail accident, these numbers are limited even if classification and scope of observation can be different as in the tables below. Despite the citizens' ambition to reduce these to null, the human error most of the times play a role.

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NUMBER OF RAILWAY PASSENGERS KILLED IN ACCIDENTS INVOLVING RAILWAY

	1990	2000	2005	2010	2013	2014	2015	2016	2017
EU-28			66	63	97	15	27	44	15
BE	0	3	0	18	0	0	0	2	1
BG			3	0	0	2	2	1	0
CZ		1	4	2	0	2	6	4	1
DK	1	3	0	0	0	0	0	0	0
DE	50	38	7	0	0	0	3	7	2
EE			0	0	0	1	0	0	0
IE	1	2	0	0	0	0	0	0	0
EL	0	20	0	1	0	0	0	0	1
ES	4	0	1	15	79	3	0	3	1
FR	30	15	5	2	4	0	4	2	1
HR			1	1	0	0	0	0	0
IT	9	8	22	7	2	1	2	19	2
CY	-	-	-	-	-	-	-	-	-
LV			0	0	0	0	0	0	0
LT			0	0	0	0	0	0	0
LU	0	0	0	0	0	0	0	0	0
HU	33	11	6	3	4	3	3	4	1
MT	-	-	-	-	-	-	-	-	-
NL	2	0	0	0	0	0	0	1	0
AT	6	4	1	0	0	0	1	0	0
PL	21	20	0	7	6	2	3	1	1
PT	22	2	7	1	1	0	0	0	0
RO		0	1	4	1	1	3	0	0
SI		0	0	0	0	0	0	0	0
SK		0	0	0	0	0	0	0	1
FI	0	2	0	0	0	0	0	0	0
SE	3	0	0	2	0	0	0	0	0
UK	37	20	8	0	0	0	0	0	3

Figure 36: Railway fatalities – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

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GEO/TIME	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
European Union EU28	:	:	1.270	1.206	1.136	1.129	1.054	971	964	977
Belgium	21	16	34	27	18	15	22	13	14	20
Bulgaria	44	28	16	37	21	12	23	20	22	16
Czechia	44	26	48	29	26	24	31	29	34	35
Denmark	11	14	9	4	8	8	12	7	1	6
Germany	164	170	146	140	138	137	160	130	150	157
Estonia	8	10	12	9	7	4	9	2	0	7
Ireland	3	1	3	1	0	1	2	0	0	2
Greece	17	22	29	13	18	9	9	14	10	21
Spain	46	31	37	25	27	105	25	20	28	29
France	94	76	69	88	71	85	65	54	81	94
Croatia	:	:	27	26	14	18	19	15	11	20
Italy	64	80	69	64	68	61	53	46	85	55
Latvia	29	17	22	13	18	14	15	9	15	16
Lithuania	40	33	31	26	19	17	11	8	16	17
Luxembourg	:	3	0	0	0	3	0	0	0	1
Hungary	115	92	82	84	72	102	108	109	97	101
Netherlands	20	14	10	14	16	17	9	18	8	12
Austria	39	34	30	35	33	26	25	35	31	18
Poland	308	365	283	320	271	227	206	227	167	171
Portugal	42	32	22	14	24	26	19	18	25	20
Romania	208	150	139	100	126	101	96	81	87	59
Slovenia	13	11	14	4	5	5	3	1	5	5
Slovakia	56	72	58	49	68	55	76	51	26	30
Finland	21	14	13	5	9	6	6	7	10	10
Sweden	13	19	42	24	15	17	25	16	13	14
United Kingdom	58	53	25	55	42	34	25	23	28	41
Channel Tunnel	0	0	0	0	1	0	0	9	0	0
Norway	1	3	9	6	1	4	1	2	3	3
Switzerland	:	22	11	10	19	17	18	10	18	17
Montenegro	:	:	:	:	:	2	6	1	5	:
FYROM	:	7	0	5	14	8	18	22	6	2
Turkey	111	89	69	71	55	45	65	50	81	:

Figure 37: Rail accidents victims – Source: Publications Office of the European Union, 2018 - STATISTICAL POCKET BOOK 2018 - EU TRANSPORT in figures

Because of the episodic features and to make available a more comprehensive representation of systemic rail safety performances, DG Move developed a specific indicator dedicated to rail.

This indicator is calculated with 5-year moving averages of railway fatalities divided by the average rail transport activity over the same period, measured in million train-km. It includes fatalities of workers, passengers, crossing users and unauthorised persons.

In the picture, having an average EU indicator of 0.5 per million train km, the segmentation for the period 2011-15 includes countries in the

- green area with indicator below 0.2
- grey area with indicators between 0.2 and 0.8
- red area with indicators above 0.8

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Transversal Exploratory Research Activities for Railway
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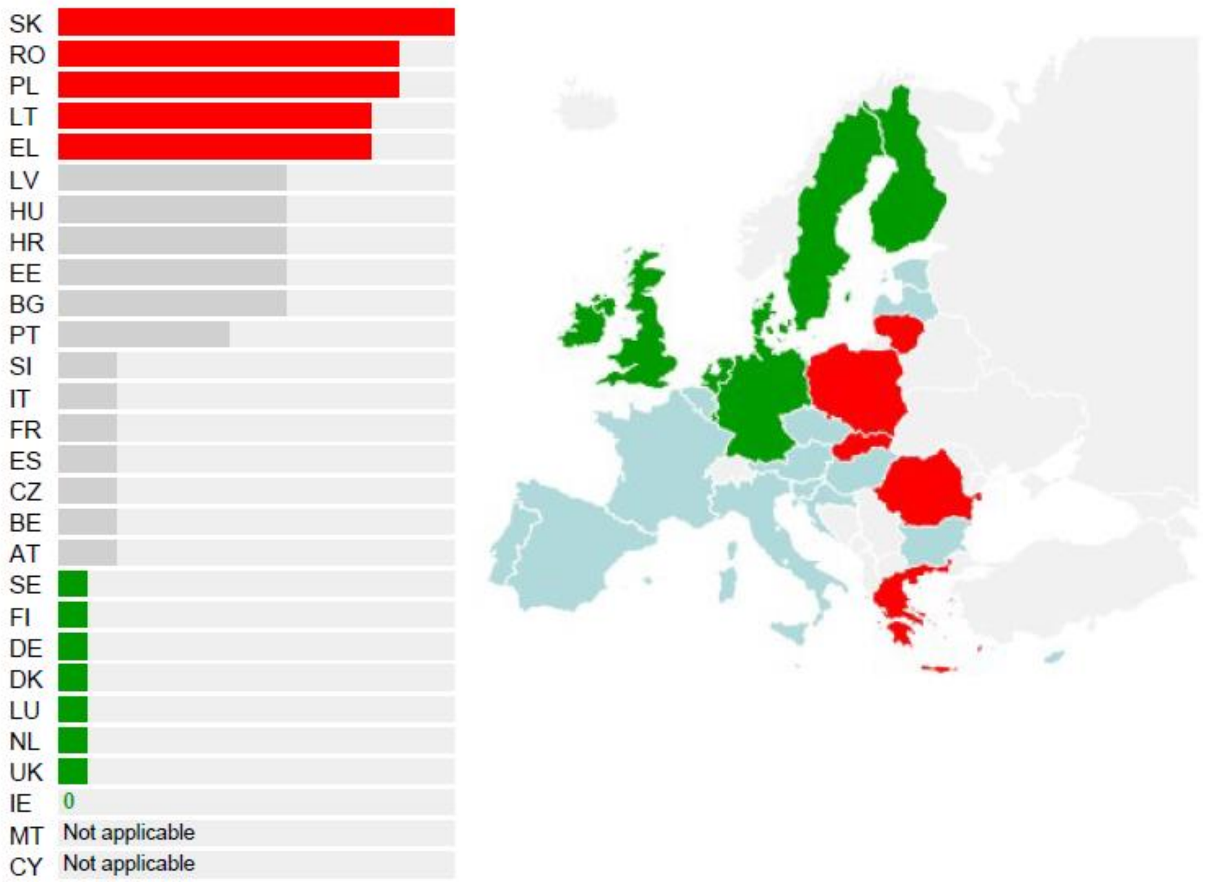

Figure 38: Railway fatalities - Source: DG MOVE calculation - data from European Railway Agency and Eurostat period 2011-15[67]

Looking at the period 2008-12, the colour of the countries is lightly different, but the average is the same[68]. This "colour" difference is mainly because of the episodic features.

Resulting remarks

- History and numbers demonstrate that rail is by far the safest means of transport in surface mobility;
- Similar to air accidents and casualties seem to be provoked by single events which affect statistics in a given year;
- Due to the structure of the business and the crossing of densely populated areas when accidents happen they are likely to be classified as major events. This is a feature common also with air;
- The travellers tend to take safety in rail transport for granted as "zero" risk opposed to other surface transport where the risk is greater. May be comfort, safety, accessibility

[67] https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/rail-fatalities_en#2011-2015

[68] https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/people/rail-fatalities_en#2008-2012

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and environment respect are characteristics not marketed effectively enough for stimulating the susceptibility of the various categories of travellers through properly targeted segmentation.

7.4.6. Employment and gender issues

The employment of a large number of workers in the industry is itself a key social indicator of social value while being part of the economic value. Transport companies are among the biggest EU companies in terms of employment per enterprise. Despite their dimension, most companies have a large part of their employees in a single country, as is the case for rail companies. Public transport is one of the largest employers at the local level. Typical examples are Amsterdam, Barcelona, Brussels and Dublin.

After road, rail transport is the main mode in terms of people employed. The total number of people directly involved in transport in Europe – including the operation of trains between cities and rail infrastructure management – is about 11.3 million, working in about 1.2 million enterprises[69].

This is at least the immediate picture coming out by recurring basic statistics of employment by mode of transport as in the following picture (data 2016). According to these figures, the share of rail is about 5.8% of the total. This data seems to be limited to direct RUs people.

[69] http://errac.org/publications/rail-2050-vision-document/

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2.1.5 Employment by Mode of Transport (*) 2016 – in 1000

	TOTAL	ROAD freight transport	ROAD passenger transport (**)	Railways	Pipelines	Inland water transport	Sea transport	Air transport	Warehousing and support activities	Postal and courier activities
EU-28	11328.3	3235.1	2075.2	660.7	29.1	43.2	176.2	366.7	2909.1	1833.0
BE	211.4	59.8	18.8	34.1	1.0	0.9	1.0	5.9	56.1	33.9
BG	169.3	69.1	32.0	11.0	0.3	0.9	0.7	2.1	33.1	20.1
CZ	279.8	125.4	38.3	27.0	0.3	0.4	0.2	2.3	45.9	40.0
DK	146.8	30.0	25.9	6.2	0.3	0.2	19.2	5.5	30.1	29.5
DE	2341.9	433.5	448.8	47.5	3.4	10.5	21.3	66.0	753.4	557.5
EE	38.2	16.1	3.3	1.4	0.0	0.0	0.9	0.2	13.0	3.4
IE	97.7	21.0	28.4	4.6	0.1	0.0	0.9	8.0	17.3	17.5
EL	184.2	35.7	61.0	9.5	0.2	0.0	15.9	3.7	43.5	14.6
ES	854.4	320.6	176.8	14.8	2.5	0.5	6.8	29.3	219.7	83.3
FR	1382.2	357.9	264.9	198.3	3.1	4.0	11.0	64.8	241.8	236.6
HR	83.2	22.0	19.4	3.9	0.7	0.1	4.1	1.2	21.5	10.3
IT	1117.0	325.0	168.0	38.3	2.2	2.9	46.4	20.4	356.2	157.6
CY	17.4	1.9	3.3	0.0	0.0	0.0	0.4	0.1	10.2	1.6
LV	78.6	25.7	14.1	3.5	0.2	0.2	0.6	1.5	27.1	5.6
LT	120.3	63.5	15.7	10.0	0.2	0.1	1.1	0.7	21.3	7.6
LU	20.7	7.5	3.5	1.2	0.0	0.3	0.0	2.3	4.3	1.5
HU	247.1	76.4	49.7	19.2	0.4	0.8	0.0	1.1	65.0	34.5
MT	11.8	1.6	1.7	0.0	0.0	0.0	0.3	1.7	4.1	2.5
NL	401.1	120.4	51.8	21.0	0.1	13.4	8.7	25.5	92.9	67.3
AT	199.1	61.9	57.4	9.8	1.4	0.6	0.0	7.3	36.8	23.9
PL	789.2	356.8	136.3	49.0	4.0	1.4	2.1	4.4	143.5	91.9
PT	159.9	67.0	33.4	0.7	0.0	0.7	1.0	11.4	31.0	14.7
RO	365.8	146.0	78.3	27.3	6.2	2.0	0.3	3.8	62.8	39.1
SI	46.9	23.8	5.4	1.4	0.0	0.1	0.2	0.6	8.5	6.8
SK	105.2	45.7	14.4	7.5	0.2	0.4	0.0	0.4	20.0	16.6
FI	143.0	45.2	25.2	9.0	0.0	0.3	8.7	4.5	27.7	22.5
SE	273.9	81.0	71.0	10.2	0.0	1.5	12.0	5.8	52.8	39.4
UK	1442.4	294.6	228.4	94.4	2.4	1.1	12.5	86.5	469.4	253.1

Figure 39: Employment by mode of transport – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

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However, applying broader classifications, Rail related figures appear much more relevant.

According to research developed in 2014 on behalf of CER[70] by a specialized company, people working in the rail sector are about 2.3 ml people of which:

- Direct employees 1.06 ml persons directly employed in the RUs and at IMs
- Indirect employees 1.21 ml persons involved in activities including manufacturing vehicles and equipment, building infrastructures, private sidings, intermodal facilities, terminals, marketing activities such as advertising and marketing researches, administrative and financial services, catering, and any other connected service for making the travellers comfortable during their journeys, etc…

For Direct employees following data quoted in the Commission's RMMS report 2019 with data 2016, show similar figures with a total of 1.04 ml (of which 0.6m at RUs and 0.44m at IMs)[71].

Moreover, it seems reasonable to assume that the ratio of indirect to direct employment in the sector has remained broadly stable.

Figure 40: Employment in rail sector – Source: "The economic footprint of railway transport in Europe", CER 2014

"Data show that 90 % or more of staff have permanent contracts, reflecting both the need for highly trained staff such as train drivers and signal operators to be retained and historic employment policies. 80 % or more of the staff are also employed full time.

Only a few Member States reported the use of apprenticeship and traineeship programmes, which are more common in Austria for railway undertakings and in Germany for infrastructure managers." [72]

Employees' age in the rail sector is becoming high, in general and especially for Spain, Greece and Italy. So a new generation is entering in the industry. This is promising because of the enthusiasm that new forces may bring in realizing expected evolutions.

[70] http://www.cer.be/sites/default/files/publication/The_Economic_Footprint_-_web_-_final_final_30_Sept.pdf

[71] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL, Sixth report on monitoring development of the rail market, 2019

[72] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL, Sixth report on monitoring development of the rail market, 2019

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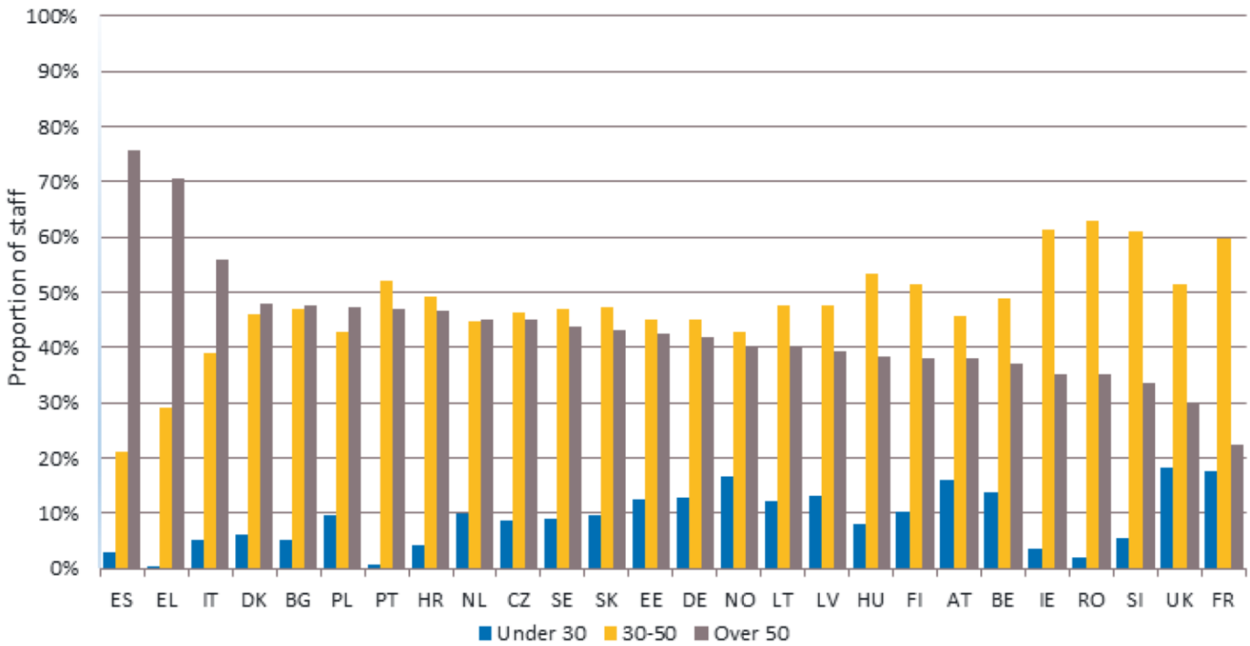

Figure 41: Employees by age group and country, 2016 – Source: RMMS, 2018. No data for LU

	2010	2015	2020	2025	2030
Road freight	136.012	173.720	144.900	144.958	139.624
Public Transport	71.014	87.796	84.515	79.904	78.252
Rail	7.823	32.468	33.889	37.835	38.821
Aviation	17.287	39.604	42.805	39.681	40.689
TOTAL	**232.135**	**333.587**	**306.109**	**302.378**	**297.385**
Mobile	156.204	217.928	198.420	196.432	195.088
Technical	28.612	55.565	55.402	57.408	58.360
Administrative	47.319	60.094	52.287	48.538	43.937

Figure 42: Skills and competences required in the transport sector – Source: Skilfull Project D1.1[73] (Skilfull project 2016-19)

The turnover is accelerated by retirement policies that are changing, particularly in Germany and Italy, with discontinuities versus the inertial trends. In particular in Germany in 2019, a shortage of 900 locomotive drivers in DB is estimated (out of about 18,000), and voluntary retirement may increase this figure up to 1,500 units (estimation on March 2019). It is to be noticed that for this specific role, it appears to be difficult to interest new applicants. The improving knowledge of the German language by immigrates may contribute to face this issue.

[73] http://skillfulproject.eu/library?id=7603

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The turnover with the new workers' generations, in parallel to the introduction of new technologies and working methodologies, will contribute to continuing the labour productivity trend already observed in recent years.

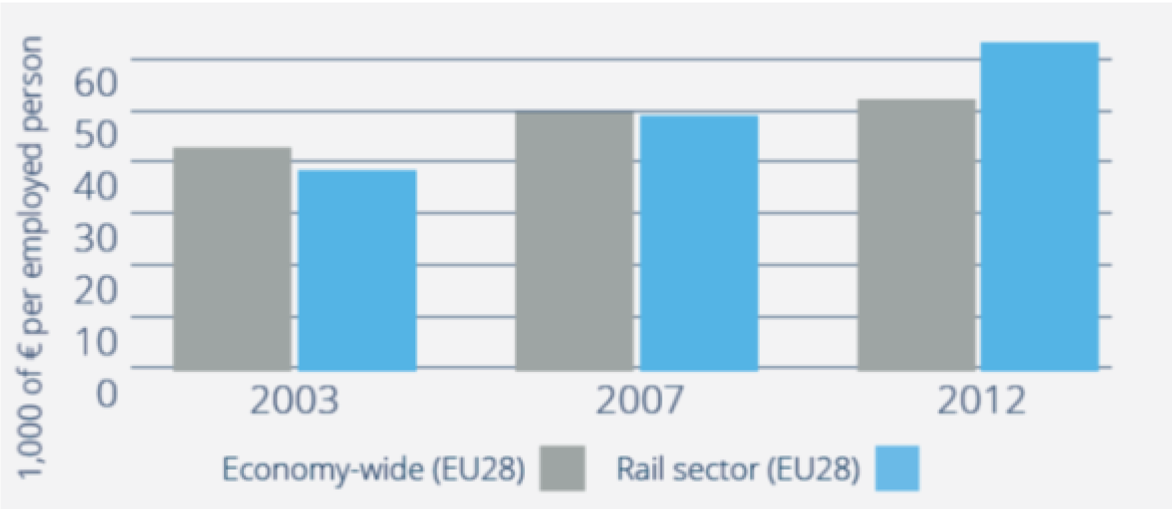

Figure 43: Labour productivity in the rail sector – Source: "The economic footprint of railway transport in Europe", CER 2014

Looking at some indexes of people employed in respect to population (following table), passenger traffic and line length differences between Countries, justify a number of questions. Even if the analysis of these data is not in the objective of this research they demonstrate once more the statement that the rail system still is reflecting the efficiency of a given of Country situations.

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	t. employees	m. population		billion pkm		km rail		kme		
	2015	2016	index	2016	index	2016	index	of which: Electrified 2016	index	
EU-28	**496,4**	**510,277**	**100**	**450,1**	**100**	**217 081**	**100**	**116 593**	**100**	**EU-28**
BE	35,6	11,311	31	10,0	31	3 607	23	3 102	37	**BE**
BG	*10,9*	7,154	64	1,5	15	4 029	85	2 868	112	**BG**
CZ	*27,2*	10,554	38	8,7	35	9 463	79	3 217	50	**CZ**
DK	*8,6*	5,707	64	6,3	81	2 539	67	621	31	**DK**
DE	*47,7*	82,176	167	95,8	221	38 990	187	20 585	184	**DE**
EE	*1,1*	1,316	118	0,3	32	918	194	132	52	**EE**
IE	*4,7*	4,726	97	2,0	46	1 894	92	*52*	*5*	**IE**
EL	*0,7*	10,784	1408	1,2	176	2 240	688	520	297	**EL**
ES	14,6	46,440	310	26,7	202	15 922	250	10 138	296	**ES**
FR	*47,5*	66,730	137	87,8	204	28 364	136	16 097	144	**FR**
HR	4,1	4,191	100	0,8	22	2 605	146	970	101	**HR**
IT	38,7	60,666	153	52,2	149	17 096	101	12 218	134	**IT**
CY	0,0	0,848		-		-		-		**CY**
LV	3,6	1,969	53	0,6	18	1 860	117	251	29	**LV**
LT	10,3	2,889	27	0,3	3	1 911	42	122	5	**LT**
LU	*0,7*	0,576	77	0,4	63	275	86	262	152	**LU**
HU	*19,5*	9,830	49	7,7	43	7 749	91	3 090	67	**HU**
MT	*0,0*	0,450		-		-		-		**MT**
NL	*13,4*	16,979	123	18,0	148	3 058	52	2 314	73	**NL**
AT	*23,6*	8,700	36	12,6	59	4 917	48	3 537	64	**AT**
PL	49,8	37,967	74	19,2	42	18 429	85	11 786	101	**PL**
PT	*0,5*	10,341	2012	4,3	941	2 553	1 168	1 657	1 411	**PT**
RO	27,0	19,760	71	5,0	20	10 766	91	4 030	63	**RO**
SI	*1,1*	2,064	181	0,6	61	1 209	250	500	192	**SI**
SK	*13,0*	5,426	41	3,5	30	3 626	64	1 587	52	**SK**
FI	*6,0*	5,487	89	3,9	72	5 926	227	3 270	233	**FI**
SE	8,9	9,851	108	12,8	159	10 882	280	8 184	392	**SE**
UK	*77,4*	65,383	82	68,0	97	16 253	48	5 483	30	**UK**

Figure 44: Labour productivity indexes in the rail sector by country (direct RUs) – Source: Elaboration based on Eurostat figures

In Europe only 23% of transport workers are represented by women. The lowest presence of women is in the rail business and also in road freight transport. No significant change can be observed in the last years in these two segments[74].

[74] https://ec.europa.eu/transport/sites/transport/files/connect-to-compete-all-v3_en.pdf

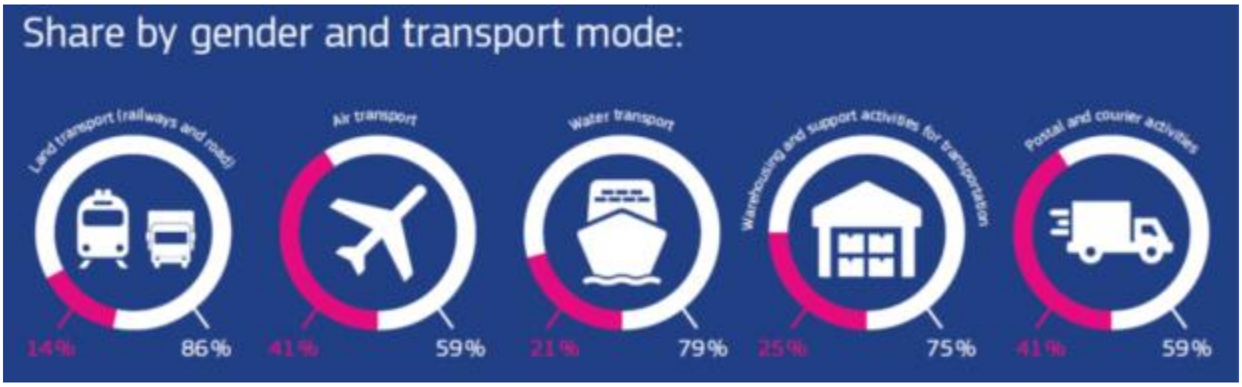

Figure 45: Women employed in the transport sector – Source: https://ec.europa.eu/transport/sites/transport/files/connect-to-compete-all-v3_en.pdf data 2014

Looking more specifically at rail, while on average 21 % are women. The proportion of female staff varies very much by country with oscillation between 50 % in Estonia and 8 % in Austria.

The entering of the new generation of workers will be an opportunity also to rebalance the gender mix. This could also bw helped by the fact that many women are accessing technical and technological universities studies such as different engineering specialization previously preferred by male candidates.

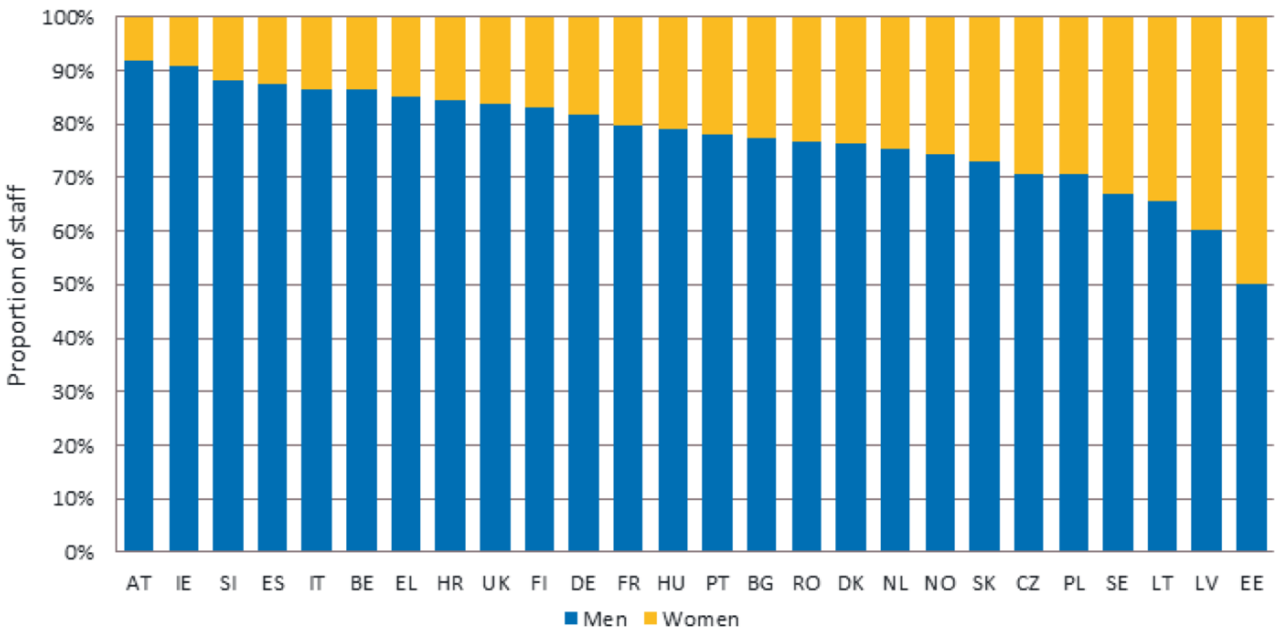

Figure 46: Employees by gender and country, 2016 – Source: RMMS, 2018. No data for LU

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7.5. Economic variables

7.5.1. Transport, rail transport and GDP

Transport plays an important role in the EU economy and society, directly and indirectly because of the large impact on related sectors. The transport industry accounts for about 5% of gross domestic product (GDP)[75]. The quality of transport services has a major impact not only on the EU economy in a macroeconomic perspective, but directly on people's spending and quality of life. On average about 13% of every household's budget is spent on transport goods and services.

	FINAL CONSUMPTION OF HOUSEHOLDS FOR TRANSPORT	of which: purchase of personal transport equipment	of which: operation of personal transport equipment	of which: purchased transport services	TRANSPORT AS A % OF TOTAL FINAL CONSUMPTION OF HOUSEHOLDS	EXPENDITURE PER HEAD ON TRANSPORT
	million EUR				%	EUR
EU-28	1 089 275	313 393	541 746	234 135	13.0	2 100
BE	23 602	6 915	14 284	2 404	11.1	2 100
BG	4 614	635	2 544	1 435	13.9	700
CZ	9 360	3 766	4 185	1 409	10.1	900
DK	16 153	5 147	9 238	1 768	12.1	2 800
DE	241 094	81 154	100 384	59 556	14.7	2 900
EE	1 375	267	809	299	11.6	1 000
IE	12 110	4 197	4 449	3 464	13.1	2 500
EL	17 879	3 971	6 296	7 612	13.6	1 700
ES	80 225	23 094	43 715	13 416	11.6	1 700
FR	164 575	42 929	92 408	29 238	13.6	2 500
HR	3 803	1 082	1 346	1 374	12.1	*926*
IT	129 956	31 848	76 880	21 228	12.3	2 100
CY	1 943	578	853	512	13.0	2 300
LV	1 938	342	1 192	404	12.1	1 000
LT	4 245	828	3 004	413	16.0	1 500
LU	2 740	765	1 836	140	14.4	4 600
HU	8 236	1 808	5 300	1 127	13.2	800
MT	710	183	365	162	11.8	1 500
NL	38 054	9 273	21 510	7 271	11.8	2 200
AT	23 168	6 378	12 349	4 441	12.0	2 600
PL	33 602	9 471	20 711	3 421	12.3	900
PT	17 063	6 465	8 462	2 136	12.8	1 700
RO	12 869	2 248	6 773	3 849	11.2	700
SI	3 865	1 082	2 529	255	16.3	1 900
SK	3 644	855	1 564	1 225	7.9	700
FI	13 766	3 724	7 554	2 488	11.9	2 500
SE	26 378	8 002	12 264	6 112	12.8	2 600
UK	192 310	56 390	78 943	56 977	13.2	2 900

Figure 47: Final consumption of households for transport – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures - data 2017

[75] https://ec.europa.eu/jrc/en/research-topic/transport-sector-economic-analysis

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The segment of rail transport accounts for 1.1% of GDP, up to 1.8% with a larger definition of rail sector[76] (or even more according to a number of studies) extended to indirect activities with analogue definition so including manufacturing vehicles and equipment, building infrastructures, private sidings, intermodal facilities, terminals, marketing activities such as advertising and marketing researches, administrative and financial services, catering, and any other connected service for making the travellers comfortable during their journeys, etc.…

In reality, the above measure is not "fully correct" but is a good proxy. In fact Gross Value Added (GVA) is linked as a measurement to Gross Domestic Product (GDP), as both are measures of output. The relationship is defined as GVA + taxes on products - subsidies on products = GDP. As the total aggregates of taxes on products and subsidies on products are only available at whole economy level, Gross value added is used for measuring the output of entities smaller than a whole economy. So it can be applied to an industry as a proxy for understanding its contribution to the overall economy.

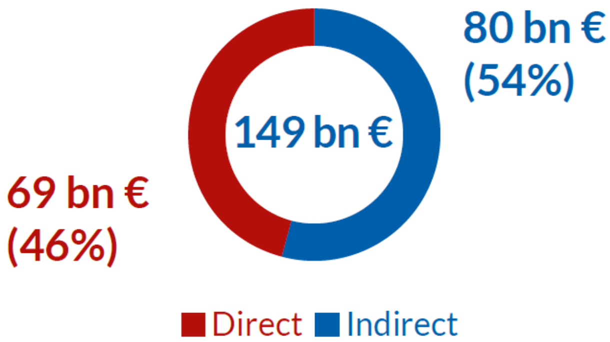

Figure 48: Economic size of Europe´s rail sector (GVA) – Source: CER's "Who we are brochure", CER 2019

7.5.2. Infrastractural investments for rail

Considering the capital intensity of rail and lead time for most actions, investments and their continuous progression are key for increasing capacity, create new offerings and improve performances.

The focus of the following consideration is limited to infrastructural investments.

In this regards, the following observation are grouped in:

- Speed of implementation of ongoing programs
- Level of planned investments.

About **speed of implementation of ongoing programs**, most investments derive from medium-long term planning as the lead-time, especially for infrastructure, is quite long. In fact major

[76] http://errac.org/publications/rail-2050-vision-document/

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actions up to 2030 are already in plans whose implementation is ongoing.

As mentioned in the high-speed section, the speed in progressing versus plan seems lower than expected.

In the following, a picture about conventional line shows that much is still to do versus 2030 plan. The picture represents the "Length of the TEN-T Conventional Rail Core Network completed at the end of the respective year, compared to the total, including planned sections and sections to be upgraded. The statistics reflect the official maps contained in Annex I of Regulation (EU) No 1315/2013. The term completed refers to *existing* infrastructure, which doesn't necessarily mean that infrastructure requirements, as stated in the above mentioned regulation, are already implemented. Time horizon for the completion of the TEN-T Core Network is 2030. Therefore, the categories *completed*, *to be upgraded* and *planned* give a rather general overview as defined by Member States, since there is no systematic definition of these categories on EU level. Some data discrepancies might be observed across Member States, due to the geographical position and size of the transport infrastructure network of the countries concerned." (Source: DG MOVE TENTec)

In the picture the green area includes scores between 100 and 94.07, the grey area between 8 and 91.57, the red area between 0 and 6.47.

Another important aspect to be considered when evaluating the "economic" issues related to road and rail, is the distance-based infrastructure charging road vs rail. As shown in the following picture, taken from a re-elaboration of the CER 2014 study on the economic footprint of rail in Europe, the road charges are the 20% of the rail ones for freight and 7% of the rail ones for the passengers.

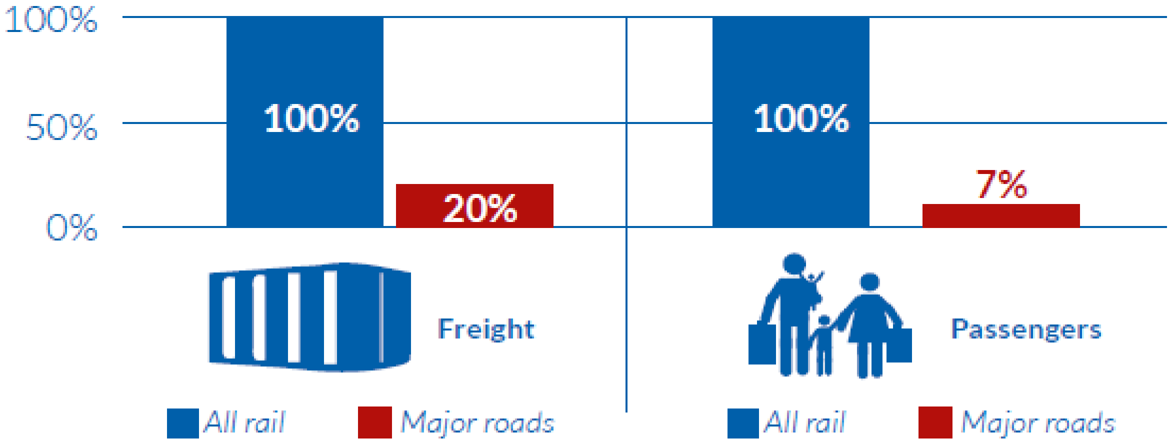

Figure 49: Distance-based infrastructure charging road vs rail – Source: 2018 Re-elaboration on "The economic footprint of railway transport in Europe", CER 2014

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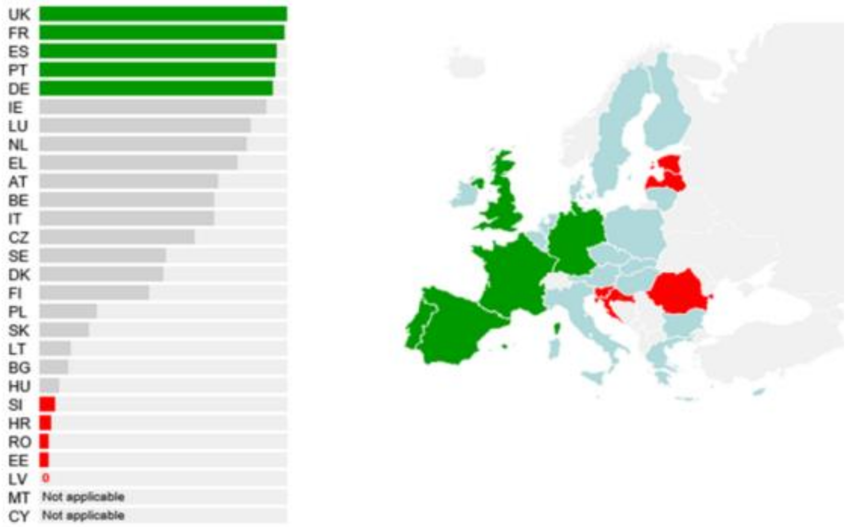

Figure 50: Completion of TEN-T Conventional Rail Core Network (2015) – Source: https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/investments-infrastructure/ten-t-completion-rail-conventional_en

While the above picture takes in limited account quality features, focus of the following picture is the quality of the rail infrastructure. The rating is based on a survey by the World Economic Forum, using a scale from 1 (extremely underdeveloped) to 7 (extensive and efficient). EU value is calculated as a simple average. The green area includes scores between 5.46 and 5.76, the grey area between 3.56 and 5.26, the red area between 2.60 and 3.01.

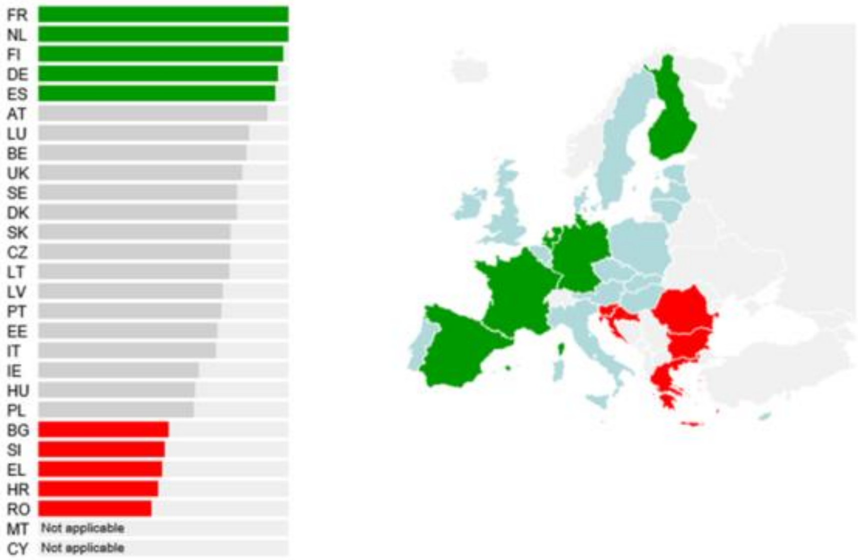

Figure 51: Quality of railroad infrastructure – Source: World Economic Forum Global Competitiveness Report[77]

[77] https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/investments-infrastructure/quality-rail-infrastructure_en data 2016-17

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About **level of planned investments**, two main items need to be considered: requirements and funding.

"The cost of EU transport infrastructure development has been estimated at over EUR 1.5 trillion for 2010-2030. The completion of the TEN-T network alone requires about EUR 550 billion until 2020 out of which some EUR 215 billion can be referred to the removal of the main bottlenecks. This compares with total investment on transport infrastructure during the period 2000-2006 of EUR 859 billion"[78]. Even if the figures are not segmented by mode, their amount is really relevant also compared to GDP. A number of sources compose funding: member states government funds, corporate PPP funds and other funds.

The EU Commission contribution at present is based on CEF according to January 2014 Communication setting the transport funding priorities for the CEF implementation 2014-2020. 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. The total budget for CEF Transport is €24.05 billion for the period 2014-2020.

This amount represents a limited contribution to the overall need.

So again, it comes evident the limited direct impact of EU funding versus the total investments.

In any case investments efforts are continuing and growing. The total EU infrastructure expenditure rose from EUR 29 billion in 2011 to EUR 50 billion in 2015, falling by EUR 3.5 billion in 2016 (Norway not included). Maintenance and renewal still represent the main part of the spending.

78 http://www.europarl.europa.eu/meetdocs/2014_2019/documents/tran/dv/exanteassessmentcef_/exanteassessmentcef_en.pdf

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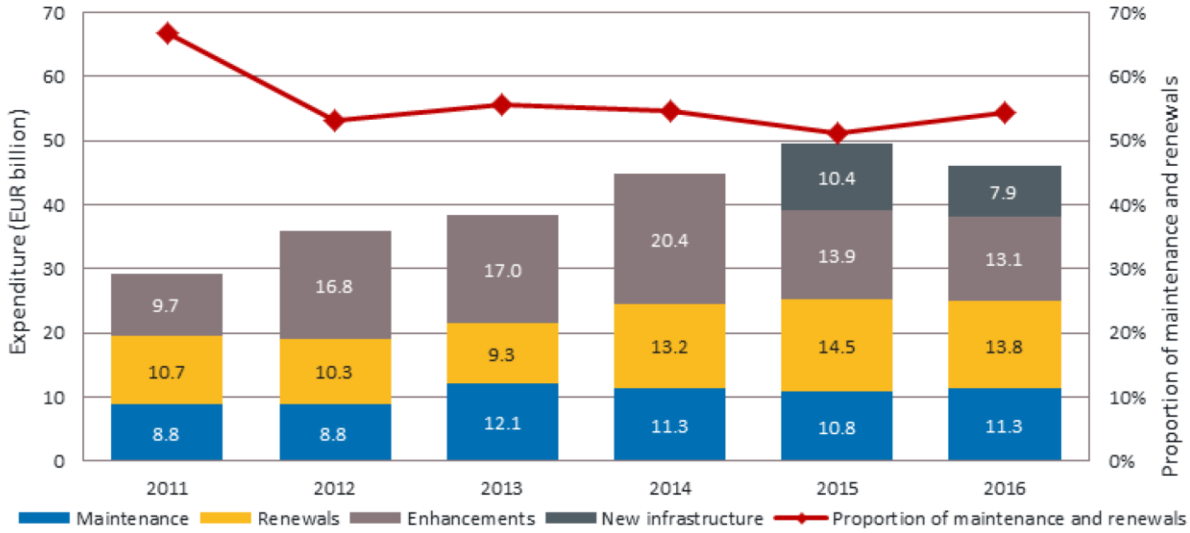

Figure 52a: Expenditure on infrastructure and proportion of maintenance and renewals, 2011-2016 – Source: Source: RMMS, 2018

Looking at country participation to rail investments as in the below picture, it is evident that the countries of France and Germany with a level of investments are in the green part of the two above pictures (plan implementation and quality). Relevant is the position of the UK.

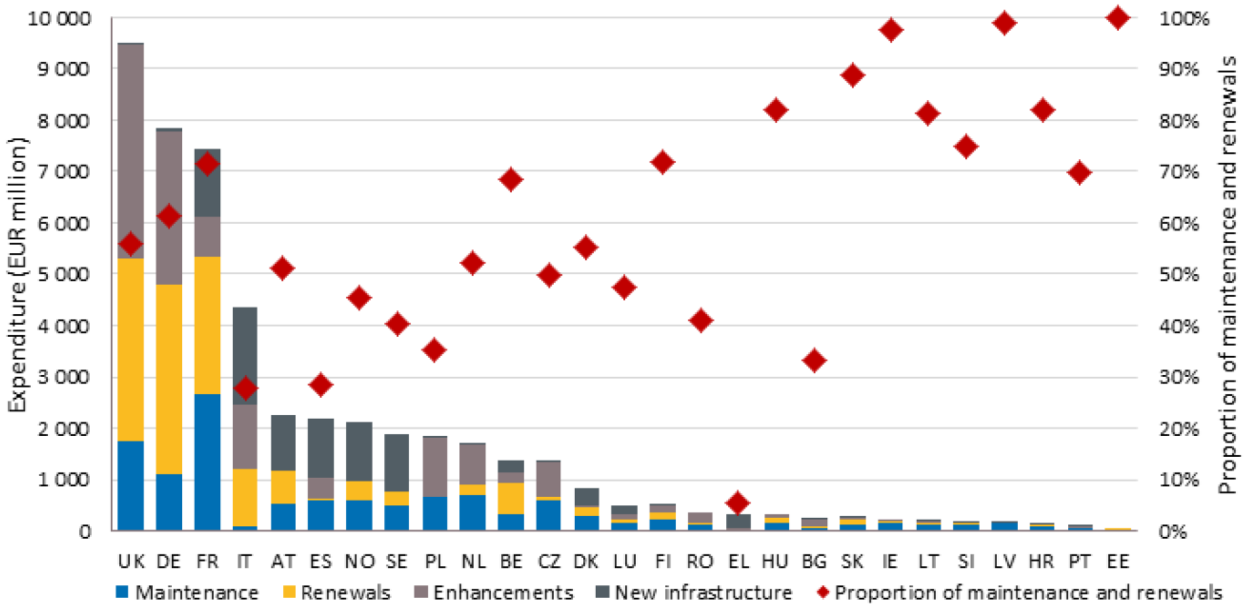

Figure 52b: Expenditure on infrastructure and proportion of maintenance and renewals per country, 2016 – Source: Source: RMMS, 2018. NO, SE included enhancements with renewals

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7.5.3. Research and Innovation (R&I)

The transport industry is significantly contributing to R&I investments in EU. In fact, studies show that transportation has the higher share of the overall spending.

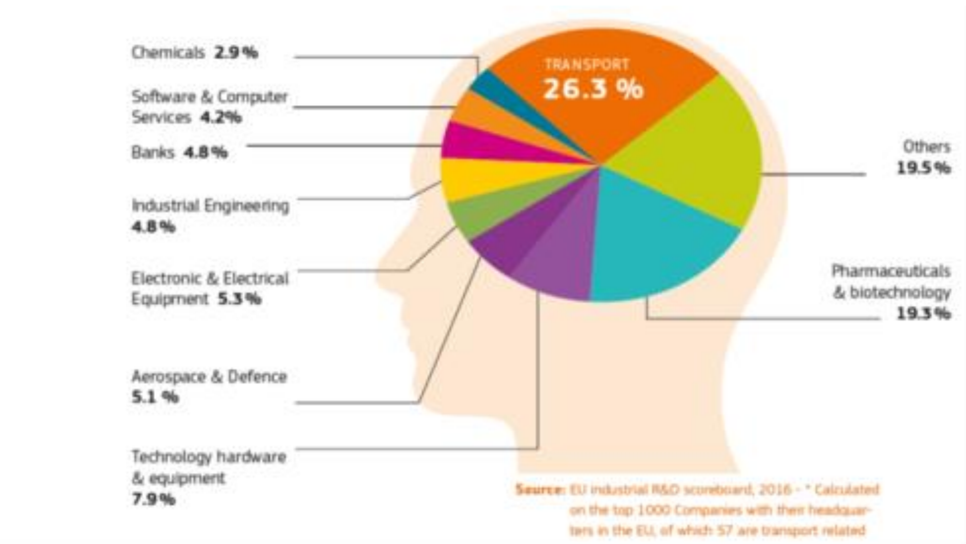

Figure 53: Share of R&D expenditure by industry (2016) - Source: https://ec.europa.eu/transport/sites/transport/files/connect-to-compete-innovation_2016_en.pdf

The biggest part of the investments come from the automotive industry, especially for developing new products and technologies. For this reason, countries with relatively higher contribution to the overall spending are the countries where the automotive industry is more significant.

The below picture shows the country situations about private expenditure in R&I in transport. Private funding is the biggest part of overall funding (see in the following).

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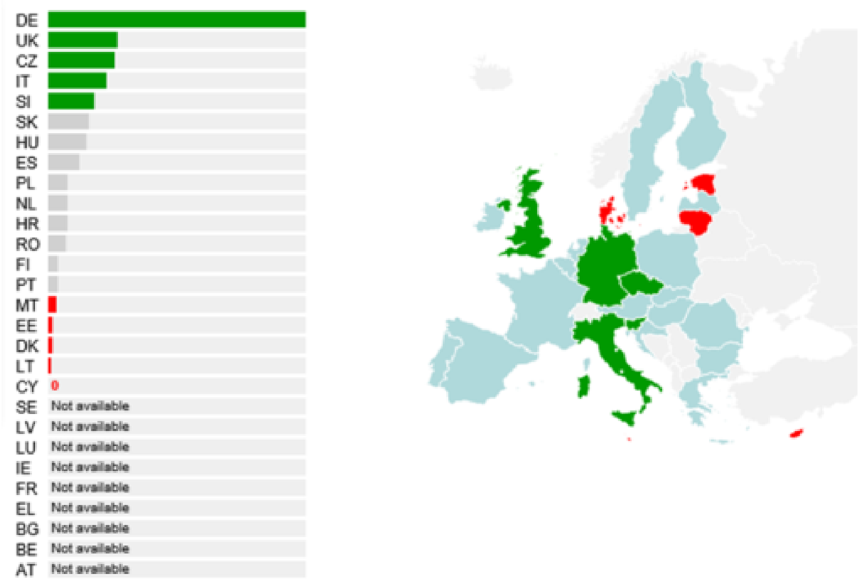

Figure 54: Private expenditure in R&D in transport (2014) - Source: https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/energy-union-innovation/expenditure-rd_en

Regarding rail, between 4 and 10% of the turnover of the Rail sector is dedicated to R&D[79].

Public funds, even if with minority share, are a relevant source for all modes. Notably the role of member states (MS) funding while 7FP have been relative minor sources for transport research.

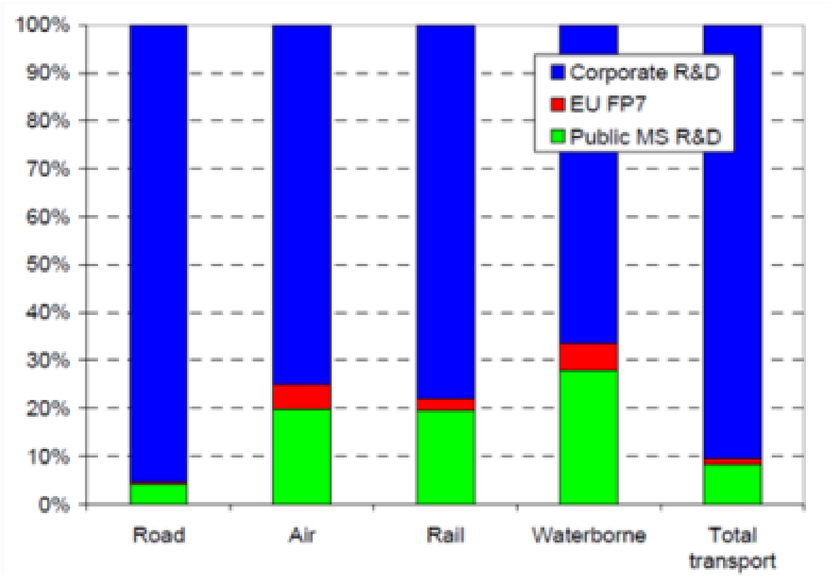

Figure 55: Transport R&D investments – Source: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26129/1/lfna24771enn.pdf data 2008

[79] http://www.cer.be/sites/default/files/publication/The_Economic_Footprint_-_web_-_final_final_30_Sept.pdf

The Shift2Rail (S2R) program represents the most important environment for Rail research is. Shift2Rail was established in July 2014 as a Joint Undertaking supported by the European Union's 'Horizon 2020' programme. The Shift2Rail aim is to promote the competitiveness of the European rail industry. In fact research is fundamental for accelerating the integration of new and advanced technologies into innovative rail solutions necessary to

- help complete the Single European Railway Area
- increase the capacity of the European rail system
- improve the reliability and quality of rail services, whilst reducing costs.

Shift2Rail and overall Rail industry major research topics include:

- ICT and digitalization covering automation for performance controls total transport chain and safety applications. These include operations support, planning/decision support/KPI monitoring/transaction, customer information management and customer experience applications, intelligent infrastructure, traffic management and control, internet of things applications, ticketing integration, dynamic pricing, smart - fail-safe communications and positioning, virtual coupling, cybersecurity, business analytics, smart radio connections, etc… (project examples: Impact, Foster rail, e-freight, Sestris, Smarte, Blockchains, Attracktive, Coactive, Crail, Emulradio4rail, Gate4rail, Marathon2operations, Maasive, Mistral, Movingrail, Plasa, Sfith2maas, Sprint, St4rt, X2rail)
- Rolling stock covering internal and external noise reduction, vibration lightweight, traction, train control and monitoring system, car body shell, running gear, brakes, doors and Intelligent access systems, train interiors, heating-ventilation-air-conditioning, interoperability, predictive maintenance, modularization, moving block and train integrity, smart procurement and testing, smart materials, autonomous train operations, passenger and freight locomotives, etc. (project examples: Fine, Destinate, Vel-wagon, Viwas, Arcc, Connecta, Connective, Dynafreight, FFL4E, Innowag, Mat4rail, Pinta, Pivot, Run2rail, Safe4rail, Smart, Vite)
- Infrastructure covering dry ports, network modelling, city hub and multi-modal hub integration, hubs-marshalling yards-sidings, security, new directions in switches and crossings, innovative track design and materials, cost-effective tunnel & bridge solutions, intelligent asset management, predictive maintenance, energy efficiency, improved station concepts, freight electrification, traction power, etc… (project examples: Fox, Optiyard, Tiger & Tigerplus, C4R, Refinet, Asser4rail, Etalon, Fair station, FR8HUB, FR8rail, Gos afe rail, In2dreams, In2Smart, In2stempo, In2track, Momit, MVDC ERS, Opeus, Scode)
- New concept, business models and long term visioning covering one-stop shop, corridor management, horizontal/vertical collaboration, sustainability and externalities, multimodal travel services, sustainable rail transport of dangerous goods, new freight propulsion concepts, BIM and new design methodologies, capacity efficiency, etc… (project examples: Near 2050, Fr8rail, Marathon, Spiderplus, Living rail, Mobility4eu, Flex rail, Ter4rail)
- People and gender covering human capital, new profiles, turn over, quality of life, productivity, human-machine interaction, braking language barriers, etc… (project examples: Skilful, My track)

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Most of the topics are on the list of research items since decades as long-term evolution process and are in the list of H2020 initiatives and in particular of S2R. Some items, especially ICT, are not rail and even transport specific but can have relevant rail ecosystem application as well as application in a number of different systems.

Examples of projects are listed by category even if most of them refer to multiple categories.

The S2R Joint Undertaking shall, more specifically, seek to develop, integrate, demonstrate, and validate innovative technologies and solutions that uphold the strictest safety and security standards, the value of which can be measured against, inter alia, the following key performance indicators:

- 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;
- a 100 % increase in the capacity of the railway transport system, to meet the increased demand for passenger and freight railway services;
- a 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, product implementation 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 JU are fully interoperable and fitted, where appropriate, for upgrading;
- the reduction of negative externalities linked to railway transport, in particular noise, vibrations, emissions and other environmental impacts.

Other relevant initiatives can be identified in H2020 program even excluding rail specific topics but including rail contribution in a wider co-modal perspective. Examples can show focus on territory and urban mobility or for logistics, new concepts as internet of goods, modular unit load, etc.…

At least a special mention is due to Hyperloop technology potentially bringing completely new features.

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7.6. Environmental variables

7.6.1. Energy consumption, emissions and pollution

Transport (here including freight) remains one of the sectors requiring the biggest final energy consumption.

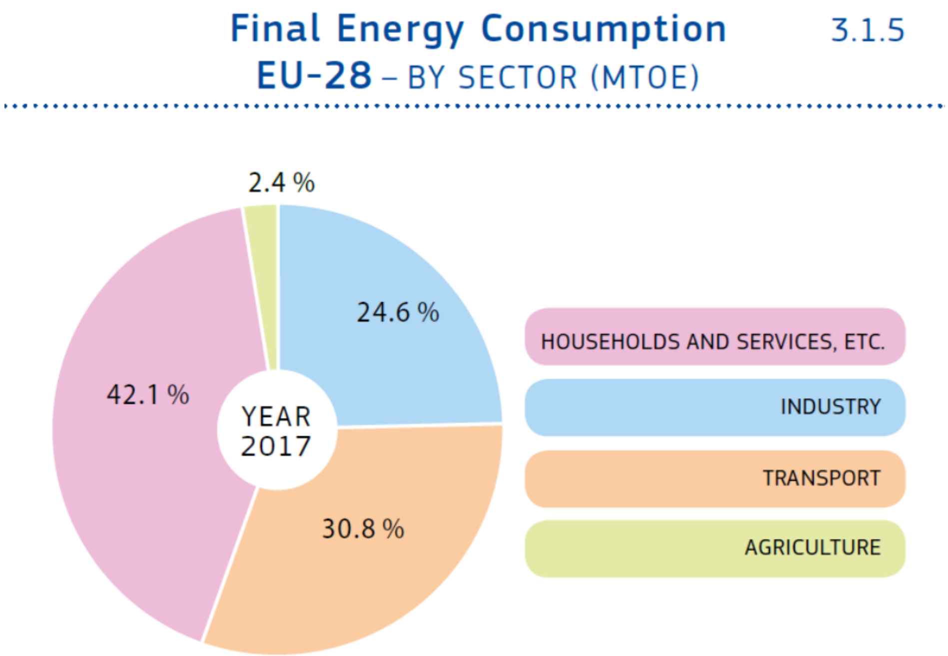

Figure 56: Final energy consumption by sector – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures – data 2017

However, differently from other sectors with a significant reduction in the last years (for instance looking at years since 2000 and even more if taking 1990 as reference year as in the below picture), the greenhouse gas (GHG) emissions generated by transportation remains high. In the most recent years, it is even growing again after some reduction as in the period between years 2007 and 2012. Transport represents almost a quarter of Europe's greenhouse gas emissions and is among the main causes of air pollution in cities. The transport sector has not seen the same gradual decline in emissions as other sectors: emissions only started to decrease in 2007 and still remain higher than in 1990.

Within this sector, road transport is by far the biggest emitter accounting for more than 70% of all GHG emissions from transport in 2014.

With the global shift towards a low-carbon, circular economy already underway, the Commission's low-emission mobility strategy, adopted in July 2016, aims to ensure Europe stays competitive and able to respond to the increasing mobility needs of people and goods.

The below table (figure 45) shows the utilization of renewable energies in the transport sector from 2004 to 2016. A substantial increase can be evidenced in the average data. From 1.4% of the year 2004, in 2016 the penetration of green energies reached 7.1%. Some countries like Norway and Sweden are the best performers in this field (30% Sweden, 17% Norway). Eurostat data shows that something is moving in Europe in this sense, but a lot remains to be done to increase the share and reach the environmental goals of Paris and Katowice.

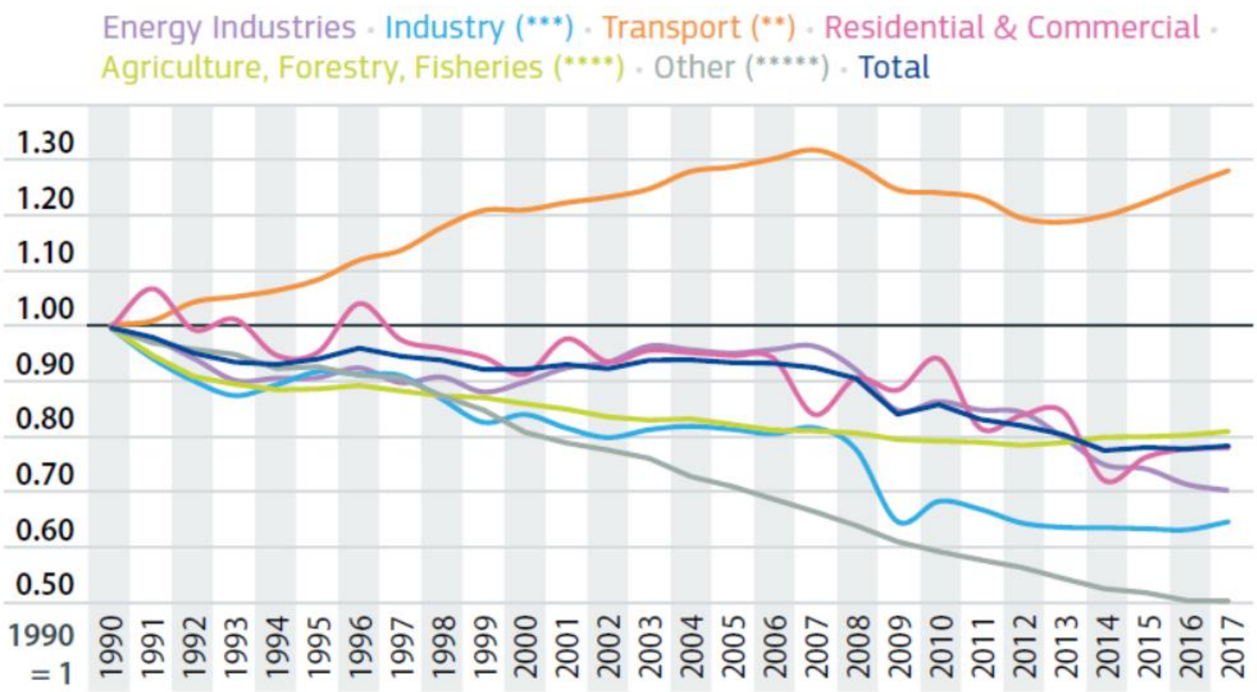

Figure 57: GHG emissions by sector – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

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geo\time	2004	2014	2015	2016
EU (28 countries)	1,4	6,5	6,6	7,1
Belgium	0,5	5,7	3,8	5,9
Bulgaria	0,9	5,8	6,5	7,3
Czechia	1,6	6,9	6,5	6,4
Denmark	0,4	6,7	6,7	6,8
Germany	2,2	7,2	6,6	6,9
Estonia	0,2	0,4	0,4	0,4
Ireland	0	5,1	5,7	5
Greece	0,1	1,3	1,1	1,7
Spain	1	0,8	1,2	5,3
France	1,5	8,4	8,5	8,9
Croatia	1	4,2	3,6	1,3
Italy	1,2	5	6,4	7,2
Cyprus	0	2,7	2,5	2,7
Latvia	2,1	4,1	3,9	2,8
Lithuania	0,4	4,3	4,6	3,6
Luxembourg	0,1	5,4	6,5	5,9
Hungary	0,9	6,9	7	7,4
Malta	0	4,6	4,7	5,4
Netherlands	0,5	6,2	5,3	4,6
Austria	4,5	10,9	11,4	10,6
Poland	1,4	6,2	5,6	3,9
Portugal	0,4	3,7	7,4	7,5
Romania	1,6	4,7	5,5	6,2
Slovenia	0,9	2,9	2,2	1,6
Slovakia	1,5	7,6	8,5	7,5
Finland	1	22	22	8,4
Sweden	6,3	21,1	24	30,3
United Kingdom	0,3	5,3	4,4	4,9

Figure 58: Share of renewable energies in transport sector – Source: Publications Office of the European Union, 2018 - STATISTICAL POCKET BOOK 2018 - EU TRANSPORT in figures

Looking at the different modes, road transportation is by far producing most of the emissions with significant contribution of air and sea. Road is also the mode that demands the highest quantity of energy, followed by Air and Sea.

	TOTAL CIVIL AVIATION	Civil Aviation (domestic) (*)	International Bunkers – Aviation	ROAD TRANSPORTATION	RAILWAYS	TOTAL NAVIGATION	Navigation (domestic) (*)	International Bunkers – Maritime Transport	OTHER TRANSPORTATION	TOTAL TRANSPORT (***)	TOTAL EMISSIONS (**)
EU-28	13.9	9.2	90.8	71.7	0.5	13.4	12.7	87.3	0.5	27.0	100

Figure 59: GHG emission from transport by mode share including international bunkers (data 2017) – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

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All modes are working on improving their performances in terms of sustainability.

Looking at the contribution to GHG emissions of different modes, in particular at CO2, the most significant share variations, while reducing the absolute values, from the year 2000 are:

- Air with increase
- Sea and Rail with decrease

A detailed picture of the transport sector contribution to CO2 emissions (in tonnes) in the different European States from 1990 to 2017 can be found in the table here below.

	1990	1995	2000	2005	2010	2015	2016	2017
EU-28	956.6	1 025.7	1 160.7	1 257.3	1 217.6	1 179.5	1 212.0	1 235.9
BE	37.0	38.4	45.4	55.1	55.2	49.7	52.2	53.9
BG	7.3	6.0	5.9	8.6	8.7	9.9	10.1	10.3
CZ	11.7	10.8	12.4	18.1	17.5	18.1	18.9	19.5
DK	15.4	18.7	18.7	18.4	17.7	17.5	17.6	17.4
DE	180.2	195.6	205.6	189.9	184.9	192.5	198.8	201.7
EE	3.1	1.9	2.0	2.6	3.0	3.3	3.3	3.5
IE	6.2	7.6	12.9	15.7	14.1	14.7	15.2	15.4
EL	24.7	30.1	32.4	33.2	33.4	25.5	25.8	27.3
ES	74.1	85.7	113.8	138.2	129.7	120.3	125.0	126.2
FR	137.2	148.2	162.7	164.9	157.3	154.9	154.9	155.8
HR	4.4	3.6	4.6	5.8	6.2	6.2	6.5	7.0
IT	109.1	121.4	133.5	141.9	129.7	120.0	119.0	116.7
CY	2.1	2.5	3.2	3.8	3.7	3.4	3.8	3.9
LV	4.7	2.6	2.3	4.1	4.4	4.2	4.5	4.5
LT	6.4	3.6	3.5	4.7	4.9	5.5	6.2	6.6
LU	3.0	3.9	5.8	8.4	7.7	7.0	7.0	7.3
HU	9.2	7.9	9.6	12.6	12.2	12.6	12.9	13.7
MT	1.4	2.3	3.0	2.8	5.4	6.1	6.4	8.0
NL	67.2	72.4	84.8	96.3	89.2	79.7	79.9	80.2
AT	14.7	17.1	20.4	26.8	24.5	24.6	25.7	26.4
PL	22.3	24.4	29.8	37.5	50.8	49.8	56.6	65.8
PT	13.0	16.0	22.8	23.4	23.0	21.3	22.4	23.3
RO	12.8	8.9	10.0	12.7	14.6	16.3	17.6	18.8
SI	2.7	3.7	3.7	4.5	5.3	5.6	6.1	6.0
SK	6.8	5.5	5.7	7.7	7.6	7.4	7.6	7.7
FI	14.7	13.1	15.0	15.7	14.9	13.6	14.8	14.6
SE	22.2	24.1	26.2	29.5	29.0	25.9	26.1	26.9
UK	142.9	149.9	165.0	174.3	162.8	163.7	167.1	167.5

Figure 50: CO2 emission from transport sector including international bunkers – million tons - Source: Publications Office of the European Union, 2018 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

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Greenhouse Gas Emissions (GHG) from Transport by Mode, including

Million tonnes CO2 equivalent

3.2.5	Total Civil Aviation:	Road Transportation	Railways ***	Total Navigation:	Other Transportation ****	Total Transport	Total Emissions **
2000	135,0	863,0	9,9	164,0	6,6	1 178,6	5 423,4
2001	132,9	877,4	9,0	169,3	6,5	1 195,2	5 481,1
2002	129,6	889,2	9,0	174,3	6,5	1 208,6	5 442,8
2003	133,8	898,4	8,9	176,6	6,5	1 224,1	5 532,0
2004	142,1	916,2	8,9	186,0	7,6	1 260,8	5 549,0
2005	150,6	915,5	8,2	189,8	8,2	1 272,2	5 524,3
2006	156,1	922,9	8,1	201,3	8,2	1 296,6	5 527,6
2007	161,0	933,2	8,5	208,3	7,5	1 318,5	5 487,9
2008	161,1	909,6	8,2	208,7	8,1	1 295,8	5 374,4
2009	149,3	885,4	7,5	189,4	7,0	1 238,6	4 979,4
2010	149,6	880,7	7,5	186,1	6,8	1 230,8	5 079,0
2011	153,3	871,1	7,5	185,6	6,6	1 224,1	4 927,0
2012	150,1	844,8	7,4	171,7	6,1	1 180,0	4 849,1
2013	150,1	840,3	7,0	161,9	6,6	1 165,9	4 747,9
2014	151,9	850,0	6,6	158,2	5,6	1 172,3	4 575,6
2015	156,4	866,2	6,6	158,0	5,6	1 192,7	4 608,5
2016	163,6	884,4	6,5	165,4	5,8	1 225,6	4 598,2
2017	174,3	895,8	6,6	167,0	6,1	1 249,9	4 628,9

Shares %

	Total Civil Aviation:	Road Transportation	Railways ***	Total Navigation:	Other Transportation ****	Total Transport*****	Total Emissions **
2000	11,5	73,2	0,8	13,9	0,6	21,7	100
2001	11,1	73,4	0,8	14,2	0,5	21,8	100
2002	10,7	73,6	0,7	14,4	0,5	22,2	100
2003	10,9	73,4	0,7	14,4	0,5	22,1	100
2004	11,3	72,7	0,7	14,8	0,6	22,7	100
2005	11,8	72,0	0,6	14,9	0,6	23,0	100
2006	12,0	71,2	0,6	15,5	0,6	23,5	100
2007	12,2	70,8	0,6	15,8	0,6	24,0	100
2008	12,4	70,2	0,6	16,1	0,6	24,1	100
2009	12,1	71,5	0,6	15,3	0,6	24,9	100
2010	12,2	71,6	0,6	15,1	0,6	24,2	100
2011	12,5	71,2	0,6	15,2	0,5	24,8	100
2012	12,7	71,6	0,6	14,6	0,5	24,3	100
2013	12,9	72,1	0,6	13,9	0,6	24,6	100
2014	13,0	72,5	0,6	13,5	0,5	25,6	100
2015	13,1	72,6	0,6	13,2	0,5	25,9	100
2016	13,4	72,2	0,5	13,5	0,5	26,7	100
2017	13,9	71,7	0,5	13,4	0,5	27,0	100

Figure 61: GHG emission from transport by mode share - CO2 component – Source: Publications Office of the European Union, 2019 - STATISTICAL POCKET BOOK 2019 - EU TRANSPORT in figures

In terms of absolute values, the rail contribution to GHC emissions is relatively modest, so confirming its best positioning[80].

Looking specifically at CO2 as an example representative of all GHC cluster, rail is 7 times more energy-efficient than cars, 2.6 times less CO2 than passenger-km and 3.6 than t km-High Speed 3.4 times less polluting than air transport[81].

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[80] http://www.cer.be/sites/default/files/publication/CER%20Factsheet%20Climate%202018.pdf

[81] http://errac.org/publications/rail-2050-vision-document/

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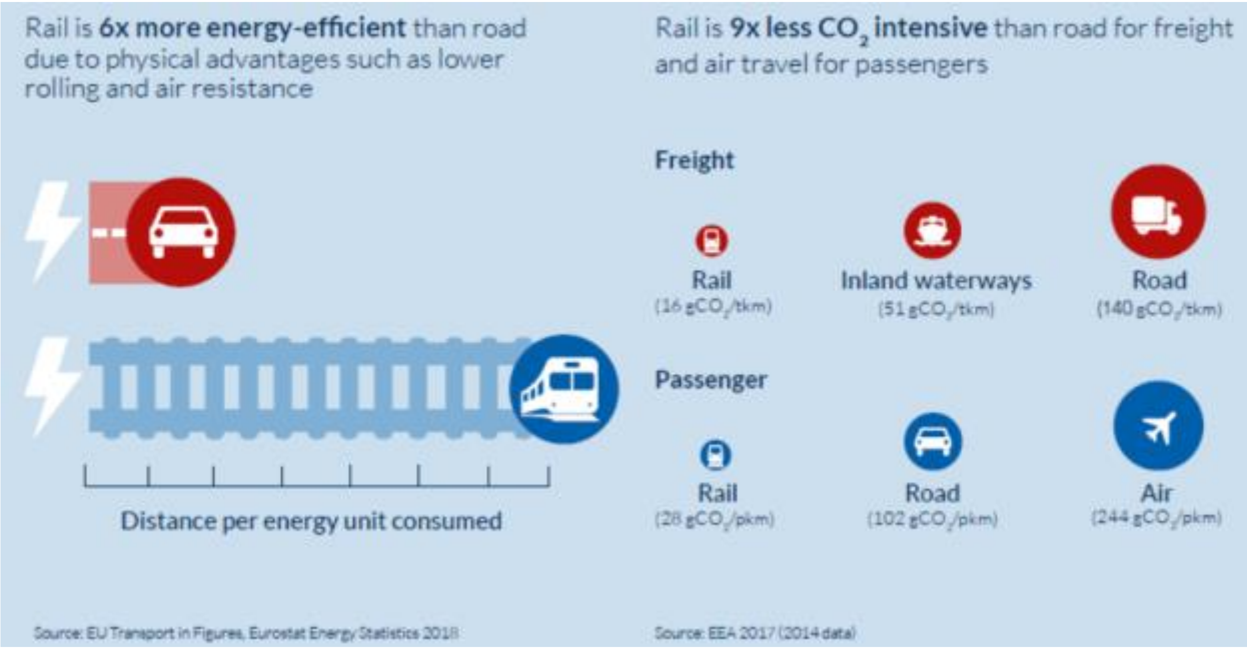

Figure 62: Comparison of energy efficiency and CO2 emissions – Source: CER Factsheet (2014) http://www.cer.be/sites/default/files/publication/CER%20Factsheet%20Climate%202018.pdf

As said, all modes are working on improving their performances in terms of sustainability. Nevertheless, the emissions gap between road and rail remains unfillable because of the different energy consumption.

In particular, for road transport a number of actions are contributing to the same objective: improvements to fuel efficiency through new vehicle technologies, wider uptake of alternative fuels, measures to improve logistics operations, eco-driver training and a shift from private car use to collective transport[82].

The use of alternative fuel is the major expected evolution in road transport even if the fleet renewal will take time. Nevertheless, where specific policies are in place, the introduction of alternative fuel means is progressing with by far a pace different from other countries.

82 https://www.iru.org/system/files/IRU%20vision%20for%20decarbonising%20commercial%20road%20transport%20leading%20up%20to%202050.pdf?utm_medium=email&utm_campaign=PR%20Industry%20reaffirms%20commitment%20to%20decarbonise%20with%20a%202050%20vision&utm_content=PR%20Industry%20reaffirms%20commitment%20to%20decarbonise%20with%20a%202050%20vision+Preview+CID_3a2151375bdaaa215abb223e6c170b11&utm_source=Campaign%20Monitor&utm_term=Download%20IRUs%202050%20Decarbonisation%20Vision

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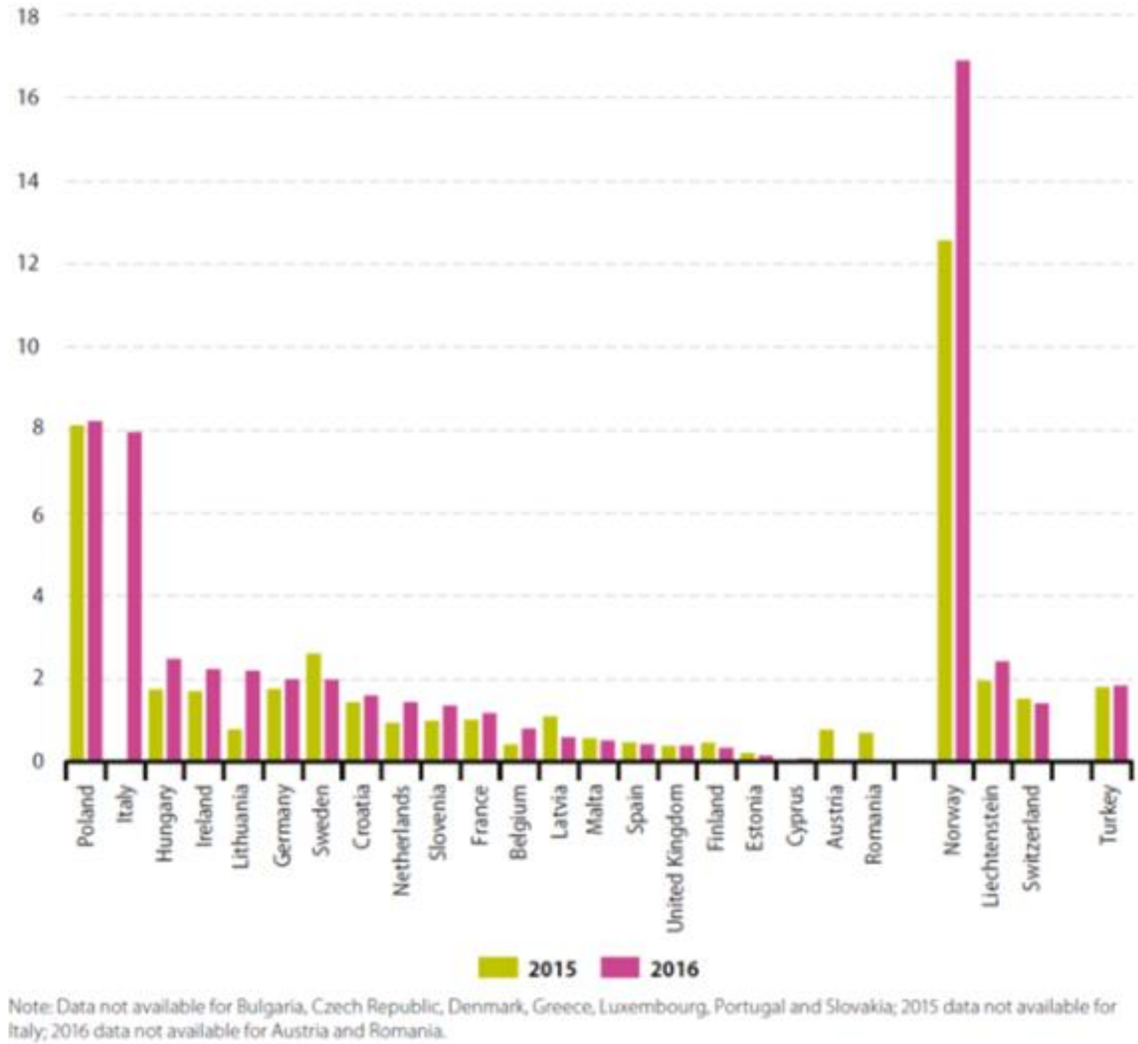

Figure 63: New passenger cars with alternative fuel - Source: Eurostat - Energy, transport and environment indicators 2018 edition[83]

The overall cost of pollution and more generally of the "externalities" seems not yet fully considered in comparing different modes. Comprehensive studies incorporating evolutions and updated projections look not frequent as desirable.

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83 https://ec.europa.eu/eurostat/web/products-statistical-books/-/KS-DK-18-001?inheritRedirect=true&redirect=%2Feurostat%2Fpublications%2Fstatistical-books

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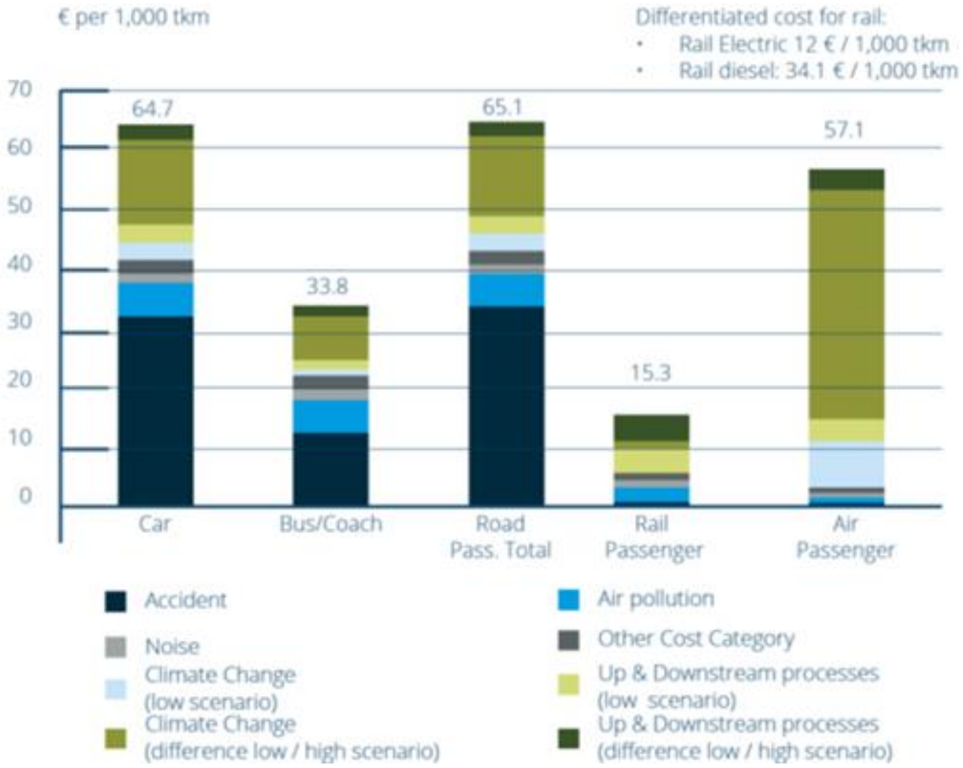

Figure 64: Average external cost by mode for passenger transport – Source: The economic footprint of railway transport in Europe", CER 2014

7.6.2. Noise

Noise is an undesired effect of all modes of transport and is a key concern for people living near transport infrastructure and cities. Noise is considered the second greatest environmental and health hazard after bad air quality

Rail Noise is considerably less annoying than noise from road transport in terms of people involved since it affects only 4% of Europeans. Nevertheless, rail freight noise is the main remaining environmental challenge for the rail sector, and it has become a real priority topic.

A number of solutions that appear largely affordable can improve this indicator. The retrofitting of the current fleet can take place as well as a fleet renewal that can benefit from new technical solutions.

Other measures can involve noise barriers and other infrastructural solutions or speed limits at night and/or in given sensitive areas.

For more information proving the commitment of the rail industry on this problem, the following links can be accessed:

http://www.cer.be/sites/default/files/press-release/CER%20Fact%20Sheet_Reducing%20Rail%20Noise_April%202017.pdf

http://www.cer.be/sites/default/files/press-release/170504%20CER%20event%20rail%20noise_FINAL.pdf

https://shift2rail.org/innotrans/the-sound-of-silent-trains/

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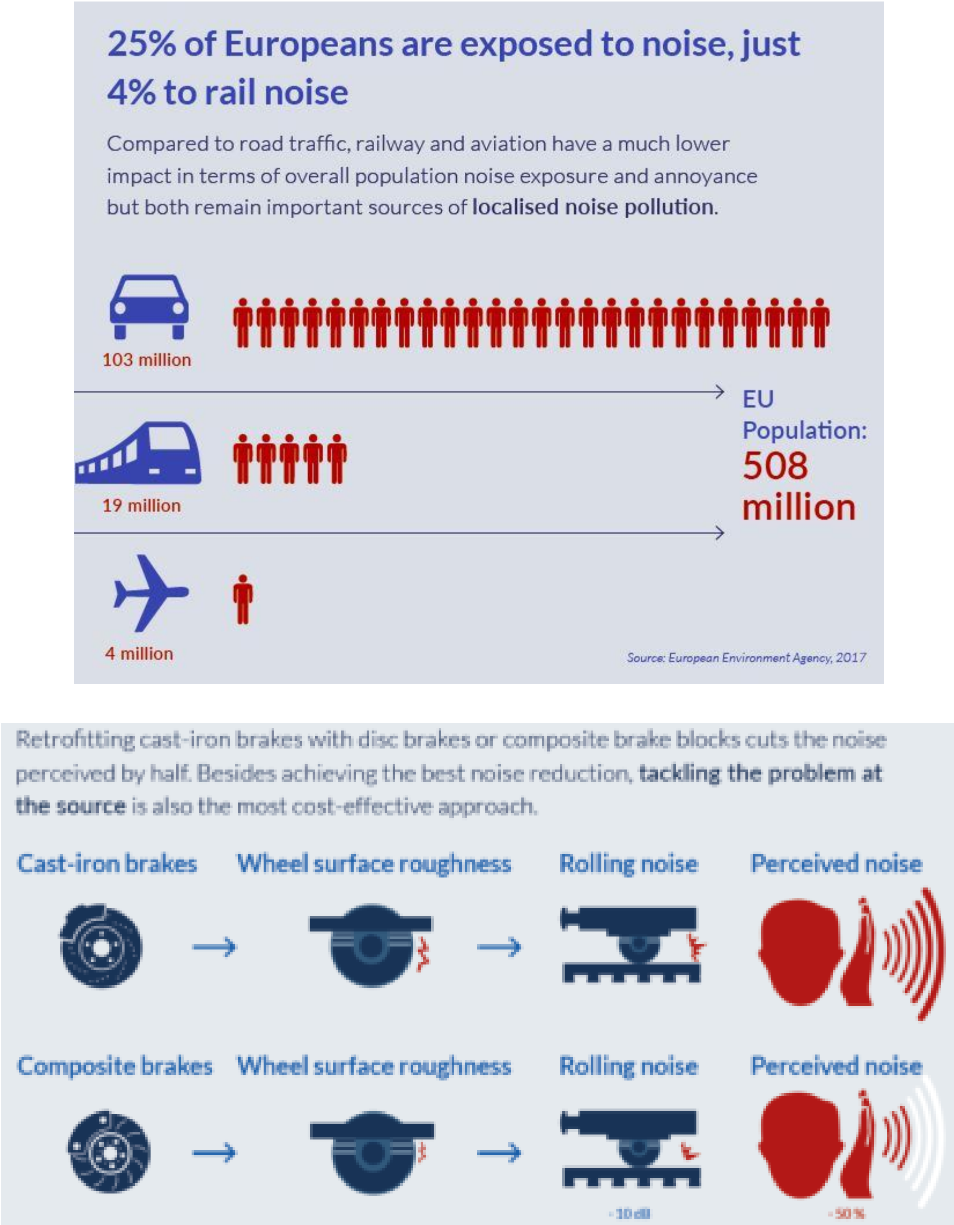

Figure 65: Noise exposure and solutions in place for reducing rail noise – Source: CER Factsheet (2017)

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8. Conclusions

Tram and metro are the second most growing mode with an increase compared to 2000 of 33.8%. Their growth is partially due to capacity increase and partly to the demand shift resulting from urban congestions and higher sustainability. Germany, France and Austria are the countries which experienced a higher increase in this mode. Similarly, the railway is the third growing mode, being the preferred choice for 6.8% of the European population, a 24.6% increase compared with the year 2000. Rail is particularly appreciated by passengers, accounting for about 9.6 billion passenger trips in the year 2016 and 9.8 billion in 2017. These figures point out how popular is this mode in the EU, resulting in about 20 trips per inhabitant per year. High-Speed Rail is a crucial driver of rail traffic growth with a share on total rail traffic of 26.1% in 2016. Germany, Spain, France and Italy are particularly relying on HSR, which in Europe grew about three times between 2000 and 2016, reaching 7,700 km of lines. As a result of its growth, HSR became competitive regarding flights and cars in terms of costs, timing, comfort and consistency.

Environmental considerations and urban mobility policies are keys in understanding the growth of tram, metro and rail, which will further benefit from investments in environmentally friendly vehicles, connectivity technologies and co-modal interchange infrastructures. Rail is seven times more energy-efficient than cars and produces 2.6 times less CO2 than cars in passenger-km. Rail also produce 3.6 times less CO2 per t/km, while High-Speed Rail is 3.4 times less polluting than air transport. Railway enjoys significant support from travelling public throughout Europe as it proved to be clean and environmentally friendly.

The previous materials have shown that in public transport rail played and plays a fundamental role, as a result not only of the size of the rail transport sector but also of its safety and relation with the economy.

On one side, rail remains by far the safer mode than any other surface transport: it is 24 times safer than car transport, 1.5 times better than coach.

Secondly, the segment of rail transport accounts for about 1.1% of the EU's GDP, in comparison to the entire transport sector, which accounts for about 5% of the EU's GDP. If rail can have positive impacts on the European GDP with a relatively marginal share of passengers, the expected growth of rail will have even more profound relevance to the continent's economy. At the same time, rail transport is the primary mode in terms of people employed after the road sector: people working in the rail sector, including indirect employment, are about 2.3 million.

Rail plays a prominent role in public transport, a position which is bound to grow even further.

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Innowag
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Marathon
Mobility4EU
Near 2050
REFINET
Score
Setris
Skillful
Smarte
Spectrum
Spiderplus
Tiger
Tiger Demo
VEL-WAGON
ViWas