STUDY

Requested by the TRAN Committee

European Parliament

Perspectives for the rolling stock supply in the EU

Study

Transport and Tourism

Policy Department for Structural and Cohesion Policies
Directorate-General for Internal Policies
PE 747.263 - July 2023

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RESEARCH FOR TRAN COMMITTEE

Perspectives for the rolling stock supply in the EU

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Abstract

The study provides an assessment of the foreseeable demand and supply of rolling stock up to the year 2030 and highlights the obstacles to the provision of rolling stock that may potentially hinder the attainment of EU goals in rail transport. The study provides the basis to consider whether or not there is a necessity to incentivise rolling stock supply within the EU (including imports and/or domestic production) and provides policy recommendations relevant to EU decision-making. The EU market is mature and expected to grow.

This document was requested by the European Parliament's Committee on Transport and Tourism.

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DISCLAIMER

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LIST OF ABBREVIATIONS

AC	Alternating Current
AGCM	Autorita' Garante della Concorrenza e del Mercato (Italian Competition Authority)
ATO	Automatic Train Operation
BDZ	Bălgarski dăržavni železnici (Bulgarian State Railways)
BEMU	Battery Electrical Multiple Unit
CAGR	Compound Annual Growth Rate
CARS	Canadian Association of Railway Suppliers
CCS	Control-Command and Signalling
CEF	Connecting Europe Facility
CF	Cohesion Fund
CIS	Commonwealth of Independent States[1]
CNC	Core Network Corridor
CNG	Compressed Natural Gas
COVID	Coronavirus Disease
CRRC	China Railway Rolling Stock Corporation
CSM	Common Safety Measures
CSTs	Common safety target
CT	Combined Transport
DAC	Digital Automatic Coupling
DC	Direct current
DMU	Diesel Multiple Unit

[1] According to Eurostat, the Commonwealth of Independent States was established in 1991 in the wake of the end of the Soviet Union. It is an association of the following States: Armenia, Azerbaijan, Belarus, the Kyrgyz Republic, Kazakhstan, Moldova, the Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

EBRD	European Bank for Reconstruction and Development
EC	European Commission
EIM	European Rail Infrastructure Managers
ELV	End of life vehicles
EMU	Electric Multiple Unit
ERA	European Union Agency for Railways
ERDF	European Regional Development Fund
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
EU	European Union
EUROFIMA	European Company for the Financing of Railroad Rolling Stock
FRMCS	Future Railway Mobile Communication System
FSR	Foreign Subsidies Regulation
GDP	Gross Domestic Product
GEC	General Electric Company
GHG	Greenhouse Gas
GNI	Gross National Income
GoA	Grade of Automation
GSM-R	Global System for Mobile Communications-Railway
HHI	Herfindahl-Hirschman Index
HMU	Hydrogen Multiple Unit
HS	High-speed
ICE	Internal Combustion Engine
IEA	International Energy Agency

IoT	Internet of Things
LNG	Liquefied Natural Gas
kV	kilo Volt[2]
MU	Multiple Unit
MW	Mega Watt[3]
NACE	Nomenclature of Economic Activities[4]
NTV	Nuovo Trasporto Viaggiatori (New Passenger Transport)
OBU	On-Board Unit
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturers
PPP	Public-Private Partnership
PSO	Public Service Obligation
RDI	Research Development and Innovation
RRF	Recovery and Resilience Facility
SITC	Standard International Trade Classification
SME	Small and Medium-sized Enterprises
TAF	Telematic Applications for Freight (services)
TAP	Telematic Applications for Passenger (services)
TEN-T	Trans-European transport network
TRAN	Committee on Transport and Tourism
TSI	Technical Specifications for Interoperability

[2] According to the international system of unit standards, the Volt is the unit of electrical potential, potential difference and electromotive force. It is equal to the difference in potential between two points in a conductor carrying one ampere of current when the power dissipated between the points is one Watt.

[3] According to the international system of units' standard, the Watt is the unit of power (i.e. energy per unit time).

[4] NACE is the acronym for the various statistical classifications of economic activities in the EU. It provides the framework for collecting and presenting statistical data distinguished by economic activity and other statistical domains.

TTR	Timetable Redesign
UIC	Union Internationale des Chemins de fer (International Union of Railways)
UITP	Union Internationale des Transports Publics (International Union of Public Transport)
UNECE	United Nations Economic Commission for Europe
UNIFE	Union des Industries Ferroviaires Européennes (Union of European Railway Industries)
USA	United States of America
VDB	Verband der Bahnindustrie in Deutschland e.V. (Association of the Railway Industry in Germany)

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EXECUTIVE SUMMARY

KEY FINDINGS

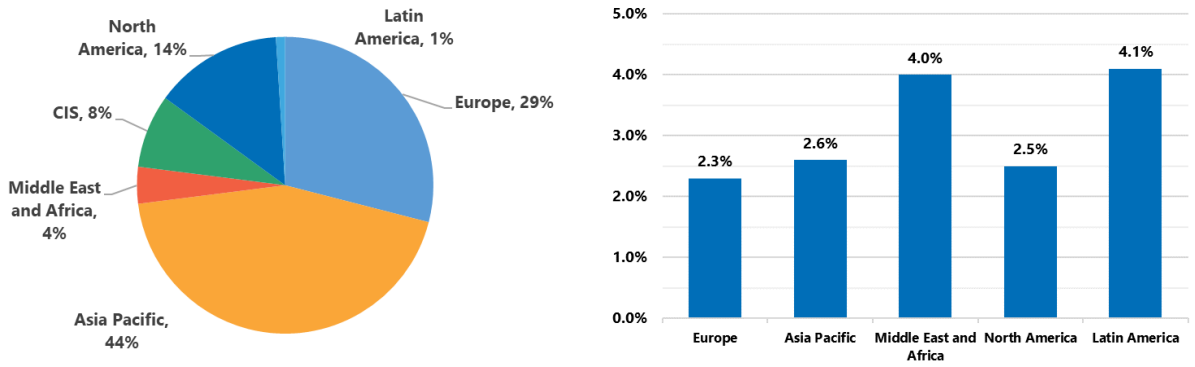
- The global rolling stock market is set to increase until 2030, with rates of growth differing by region. The European Union market, which is larger and more developed than many others, is projected to grow annually by 2-3%.
- 20 companies make up 80% of yearly sales in the global rolling stock supply industry. In the EU, manufacturers have maintained a positive balance of exports over imports in the past decade. These manufacturers are primarily situated in countries with large domestic markets and compete for contracts worldwide.
- Rolling stock demand is anticipated to fluctuate across transport segments, influenced by factors such as technological advancements, the retirement of old fleets, changes in transported goods, network electrification and the expansion of infrastructure, especially high-speed rail.
- The EU's policy framework significantly impacts factors like decarbonisation and interoperability, affecting both the supply industry and manufacturers' location choices. The harmonisation and interoperability of the single European railway area improves competitiveness and attracts foreign competition.
- The European Commission and European Investment Bank offer numerous financing tools and mechanisms that are taken up in both rolling stock purchases and technology research and development. The rail industry itself and other specialised international financial institutions (e.g. EUROFIMA, EBRD) provide alternative financing models for rolling stock purchases.

Rolling stock supply industry and perspectives for the demand of rolling stock

The global rolling stock market is expected to see substantial growth during the period to 2030 due to factors such as urbanisation, expansion of rail networks, technological advancements and greater focus on sustainable transport. Estimates suggested a Compound Annual Growth Rate (CAGR) in the range of 3% to 5% for 2021-2023 and 4% to 6% for 2023-2030.

The small markets of Latin America and Africa/Middle East are expected to experience the highest growth rates. More mature markets in Europe, Asia Pacific and North America will also grow and contribute to the largest share of overall growth. The yearly growth rates for the regions with mature markets are estimated at 2% to 3%. According to projections by the European Commission, the rolling stock fleet operated in the EU will grow by 2.1% between 2020 and 2030.

Figure ES.1: Global demand for rolling stock (2017-2019) and CAGR estimates (2021-2023)



Source: elaboration based on (OECD, 2023), (Minella & Meldebek, 2021) and other market research.

The global rail supply industry is dominated by 20 companies, accounting for 50% of the total rail supply market and 80% of the rolling stock market. The demand for locomotives, Multiple Units (MUs) and specialised freight waggons is projected to increase, resulting in lucrative opportunities for manufacturers and parts suppliers in the EU. The balance between exports and imports of manufacturers located in the EU has been positive over the period 2012-2021 and has fluctuated around EUR 4.5 billion on an annual basis.

The global demand for locomotives is more predictable than that of freight waggons. A shift towards biofuels, gas and electrification is predicted to reduce greenhouse gas (GHG) emissions from locomotives and align with decarbonisation policies. The global locomotive market is anticipated to expand in line with advancements in these technologies.

In conventional passenger transport, the demand for MUs is projected to grow at a Compound Annual Growth Rate (CAGR) of 4.5% until 2024. The ongoing phasing out of ageing fleets and the electrification of rail networks are the key drivers behind this growth. Decarbonisation policies favour electric and alternative fuel vehicles over diesel traction, indicating a shift towards cleaner transport modes. Market research specific to Germany forecasts growth in the segment of conventional push-and-pull trains until 2030, driven by the demand for intercity services, cross-border services and the revival of night trains.

High-speed (HS) rail services have experienced high growth. The global HS network is expected to expand further, with significant developments in the Asia-Pacific region and the EU. The planned expansion of the HS rail network in Europe indicates potential growth in the demand for rolling stock in this segment.

The freight waggon segment has witnessed a trend towards more specialised waggons for refrigerated and perishable goods, as well as tank waggons for hazardous materials. Forecasts for future freight wagon production in the EU suggest a continuation of the observed trend, driven by the changing mix of commodities. Rail freight is expected to benefit from the modal shift driven by decarbonisation policies, leading to demand for modern and efficient freight waggons.

EU policy framework and instruments to fund and finance rolling stock

In the EU, the implementation of decarbonisation and railway interoperability policies significantly influences the rail supply industry and the location decisions of manufacturers. Harmonisation and interoperability of the internal market not only enhance internal EU competitiveness but also attract foreign competitors. The EU's focus on sustainable transport has led to a new generation of rolling stock powered by hydrogen, batteries and advanced technologies. Lightweight materials are being used to enhance fuel efficiency and reduce costs. The deployment of the European Rail Traffic

Management System (ERTMS) necessitates equipping rolling stock with the necessary systems, creating opportunities for retrofitting and upgrading fleets.

EU financial instruments play a crucial role in financing rolling stock investments. The European Investment Bank (EIB) provides loans, advisory services and supports the issuance of bonds. European Company for the Financing of Railroad Rolling Stock (EUROFIMA) and the European Bank for Reconstruction and Development (EBRD) also offer loans and leasing options for rolling stock projects. The EU provides grants and subsidies through programmes such as the Connecting Europe Facility (CEF) and the European Regional Development Fund (ERDF) to support rolling stock investments. The EU's financing mechanisms have been instrumental in funding various rolling stock initiatives.

For example, the CEF has approved EUR 402 million in grants for retrofitting existing rolling stock to meet interoperability standards and reduce noise. The ERDF and Cohesion Fund have disbursed EUR 541 million in grants for the purchase of rolling stock for regional development and for promoting a modal shift. Horizon Europe has provided EUR 55 million for research and innovation projects. The EIB has approved EUR 16.7 billion in loans for purchases. EUROFIMA has provided EUR 2 billion in loans for rolling stock renewal projects across several countries. The Recovery and Resilience Facility has allocated other resources for loans and grants for rolling stock investments in some Member States.

The demand for locomotives, MUs and specialised freight waggons is expected to increase, presenting opportunities for manufacturers. EU financial instruments, including grants, loans and leasing options, play a crucial role in financing rolling stock investments. The involvement of the EIB and other financing organisations (e.g. EUROFIMA and the EBRD) further supports the development and purchase of rolling stock.

Policy recommendations

Most rolling stock manufacturers, typically based in countries with significant domestic markets, bid for contracts globally. Most rolling stock manufacturers bid for contracts globally. For both EU and non-EU suppliers, the difference between export and import shows a positive balance. EU suppliers have maintained a more favourable balance compared to non-EU suppliers. We therefore suggest that addressing the following issues will be important for policymakers:

- Fostering a favourable business environment
- Continued investment in research and development
- Emphasising the production of high-quality and reliable rolling stock that meets stringent safety standards
- Maintaining a reputation for delivering products that offer superior performance, durability, and passenger comfort
- Promoting skill development and workforce training
- Strengthening supply chain resilience
- Strengthening intellectual property protection mechanisms to safeguard innovative technologies and prevent unauthorised use or imitation by competitors
- Enhancing the international competitiveness of EU rolling stock manufacturers by supporting their access to international markets.
- Facilitating sustainable financing and investment.

1. OVERVIEW OF ROLLING STOCK AND RELEVANT POLICY INITIATIVES AT THE EU SCALE

KEY FINDINGS

- The **rail supply industry** evolved significantly over the past decades through multiple mergers and acquisitions. In the current situation, it consists of a **complex ecosystem** characterised by strong connections to both domestic and international markets.
- The **main segments** of the rail supply industry are: system integrators, railway infrastructure and energy suppliers, rolling stock manufacturers, signalling suppliers and railway engineering companies.
- **The rolling stock manufacturers produce not only rolling stock elements** but also electrical equipment, power supply systems and signalling systems.
- The **rolling stock consists of a diversity of vehicles**, with classifications based on the type of traction and market segment in which it operates.
- **Rolling stock itself can account for around 20% of the total life cost** and its **life cycle consists of several phases**, which total an average of **25-30 years**.

1.1. Brief history and landscape of the rolling stock supply industry

Before the progress in European economic integration in the early 1990s, most railway operators procured their rolling stock at the national level (Sato, 2005). This had drawbacks from a finance and innovation perspective and they are explored further in Section 5.

The years **between 1980 and 2000 were characterised by a complex landscape and sequences of mergers among multinational manufacturers active in the rolling stock supply market**. After the collapse of the Iron Curtain in 1989, western European manufacturers started acquiring eastern European companies. Global economic integration then opened the door to procurement anywhere (within the EU and outside), making the rolling stock acquisition process very complex. The picture drawn for 2000 (Sato, 2005) (see Figure A.1) showed that the rolling stock supply market was highly concentrated through four major actors (Alstom (France), Adtranz (Germany), Bombardier (Canada and Germany)[5] and Siemens (Germany)). These companies had developed the capability to manufacture almost all necessary rail system components, not only rolling stock elements like carriage bodies and bogies[6], but also electrical equipment, power supply systems and signalling systems. Each was large enough to be considered a conglomerate.

According to research published by the OECD, **after 2000, the rolling stock supply industry concentrated even further at the global level** (OECD, 2023). The German Adtranz was acquired by Bombardier in 2001, which merged it into its transport division, making the conglomerate the largest rail equipment manufacturer in the world at the time and the market dominated by three suppliers (CENTRECO and DIRECCTE CENTRE, 2013). General Electric sold its signalling activities to Alstom in 2015 and the locomotive production branch to Wabtec, a company based in the USA, in 2019. Hitachi, a Japanese supplier, acquired two Italian companies in 2015 (i.e. AnsaldoBreda, a rolling stock supplier,

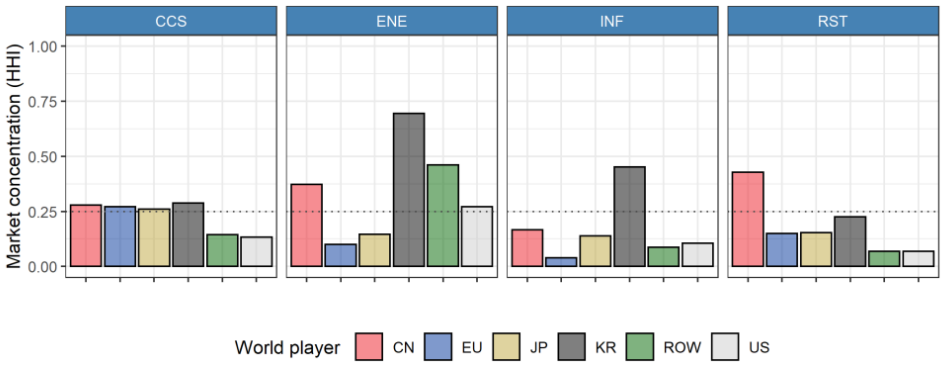
[5] Bombardier group is based in Canada and Bombardier Transportation is headquartered in Germany.

[6] The bogie is the element that supports the mass of the vehicle and provides its traction and braking. The sub-elements of a bogie are the wheels, the axle, the suspension systems, the motor and the breaks. Each vehicle has two bogies, one at each end.

and Ansaldo STS, a producer of signalling systems). That same year, Titagarh Wagons, an Indian producer, acquired the Italian company Firema. The 2015 merger of China's two state-owned rolling stock manufacturers, CNR and CSR, formed CRRC, which was the largest consolidation that happened in the global rolling stock industry outside of Europe.

A 2021 Joint Research Centre study analysed the concentration of rail supply industry innovations (through patent activity) globally (Van Balen, et al., 2021). The study provides a useful perspective on how countries/regions organise their rail supply innovation ecosystems. They used a Herfindahl-Hirschman Index (HHI)[7] consisting of the innovative output of an organisation in relation to the total size of the 'industry' to analyse concentration between 2000 and 2017. Figure 1.1 shows that the HHI outputs for the EU are relatively low, in particular for rolling stock (RST), indicating a large number of active innovators in the EU market. It also indicates that **intra-sectoral competitive dynamics in the EU are greater than in other regions of the world**.

Figure 1.1: Analysis of the rail supply industry using the Herfindahl-Hirschman Index[8]



Source: (Van Balen, et al., 2021)

In 2019, there was an unsuccessful attempt to merge Alstom and Siemens (European Commission, 2019c). The proposed consolidation was blocked by the European Commission on the grounds that it would have harmed competition in markets for railway signalling systems and very high-speed trains (European Commission, 2019a). Another attempt to merge Alstom with Bombardier was successfully cleared in 2020 (European Commission, 2020d) and eventually approved by the European Commission in 2022, according to the provisions of Regulation (EC) No. 139/2004 (European Commission, 2022a). The two mergers show how important the European regulatory authorities are in ensuring that effective competition in the market is not significantly impeded. In Section 3.1, the manufacturing industry is described in detail, illustrating how the rolling stock supply is concentrated. However, the overview of the history of the rolling stock supply industry is instrumental in illustrating that this landscape is complex and international, with rolling stock manufacturers at times also required to transfer technologies to local partners in order to reach other markets like, for example, Egypt and Turkey (SCI, 2021). **OECD research concluded that additional data is necessary to draw a more accurate picture of the current situation**, in particular for rolling stock producers located in Eastern Europe and India (OECD, 2023). Information gaps have been reported in the OECD's review for small companies or those with smaller market shares in Canada, Japan, Russia and Ukraine.

[7] The closer the HHI is to 1, the more concentrated the industry is.
[8] CCS means Control, Commands and Signalling; ENE means Energy; INF means Infrastructure; and RST means rolling stock.

1.2. Rail supply industry taxonomy and rolling stock classification

1.2.1. Taxonomy of the rail supply industry

According to studies commissioned by the Commission (Ecorys et al., 2012) and (Ecorys et al., 2019), **the rail supply industry encompasses the manufacturing of locomotives and rolling stock, railway infrastructure and signalling and telecommunication equipment**. The last category is particularly significant for its potential in the automation and AI transformation of rail operations (Zhao et al., 2021; Prasad & Jamuar 2021). Industry associations influence the sector's taxonomy. UNIFE, a European rail supply industry association, designates segments as system integrators, infrastructure and energy suppliers, rolling stock manufacturers (including subsystem suppliers), signalling suppliers and railway engineering companies (UNIFE, 2019). The USA-based Railway Supply Institute broadly defines the industry, incorporating freight and passenger rail, locomotives, infrastructure maintenance, communication, signalling and equipment leasing (Oxford Economics, 2023). Similar associations are the UK's Railway Industry Association (RIA), the Canadian Association of Railway Suppliers (CARS), Germany's Railway Industry Association (VDB) and the Australasian Railway Association. These sources provide a solid taxonomy of the rail supply industry, which is briefly described in Table 1.1.

Table 1.1: Taxonomy of the rail supply industry

System	Subsystem
Rolling stock	• High-speed trains • Multiple Units • Locomotives (including shunters) • Passenger coaches • Freight wagons • Light rail vehicles and metro vehicles • Vehicles for on-track maintenance
Infrastructure	• Tracks (permanent way) • Stations, buildings, tunnels, bridges, level crossings • Power supply
Electro-mechanical and electrical equipment	• Signalling and control • Electrification for traction • Communication tools (remote controls and fibre networks)

Sources: (Ecorys, et al., 2012), (Ecorys, et al., 2019), (UNIFE, 2019), (Minella & Meldebek, 2021), (Oxford Economics, 2023)

The infrastructure includes the track, a fixed guidance system and various civil structures like tunnels and bridges. Key subsystems include signalling and control, connecting rolling stock with the infrastructure to ensure safe train operation. The electrification subsystem provides power to trains lacking an on-board prime system, such as a diesel engine. Electricity is typically supplied via continuous contact either overhead (pantograph and catenary systems) or at ground level (third rail). Finally, communication tools facilitate information exchange between train and infrastructure staff.

1.2.2. Rolling stock classification and product types

In Directive 2008/57/EC 'rolling stock' is used to mean self-propelling thermal or electric trains, thermal or electric traction units, passenger carriages, mobile railway infrastructure construction and maintenance equipment (Official Journal of the European Union, 2008a)[9]. The rolling stock is classified based on whether the vehicles are self-propelled (e.g. locomotives) or not (e.g. passenger coaches), and by traction-type, mainly diesel or electric. Market segments consider speed, distance travelled and cargo type (OECD, 2023). Key types include (Ecorys, et al., 2019):

[9] The Directive has been repealed by Directive (EU) 2016/797 (Official Journal of the European Union, 2016a) and Directive 2016/798 (Official Journal of the European Union, 2016b).

- **High-speed trains**: Operate on dedicated lines, upgraded conventional lines or lines below 200 km/h due to topographical challenges. They either have concentrated traction with locomotives at each unit or use Multiple Units with distributed traction.
- **Multiple Units (MUs)**: Primarily for passenger transport on intercity, regional and suburban services. MUs consist of self-propelled coaches classified by power source.
- **Locomotives**: Primarily move trains, with no payload capacity. Diesel or electric vehicles are used globally for both passenger and freight trains. Smaller types are used for shunting.
- **Coaches**: Transport passengers and include specialised units (e.g. sleeping or restaurant cars). If not part of MUs, these non-self-propelled units must be coupled with locomotives.
- **Freight wagons**: Specialised vehicles for different cargo types, including tank waggons, hoppers, open waggons and intermodal waggons. Must be coupled with locomotives.
- **On-track maintenance vehicles**: Used for tasks like ballast distribution and track renewal.

1.2.3. Locomotive technology

Locomotive traction can be diesel, electric or a combination[10]. Electric locomotives, typically 1-6 MW, draw power from overhead wires, either alternating current (AC) or direct current (DC). To enable interoperability between neighbouring networks, AC motors fed by multiple voltages combined with an inverter system are standard. Diesel locomotives use various configurations to connect an internal combustion engine (ICE) to the wheels. Developments have occurred in diesel technology, but they are less radical than in electric, with ICE potentially fuelled by compressed natural gas (CNG), liquefied natural gas (LNG) or biofuels[11].

1.2.4. Components

Locomotives, MUs and other rolling stock are often developed in platforms or families, balancing technical commonality with market-specific differentiation (Ecorys et al., 2019). The industry approach involves integrating both standard and customised components into the final product. Rather than establishing new production lines, the focus is on maintaining a modular, standardised product family and adding custom components as needed. This approach arises from the need to balance diverse electric network and infrastructure interfaces, the lack of universally accepted standards and specific customer needs for customisation (Forlingieri, 2014; Kawasaki, 2016). The typical standardised components of the rolling stock are as follows.

- **Body framework:** a robust integral structure providing optimised strength and load-bearing capacity. Often made of steel, though lighter alloys are used for commuter trains and metro systems. Suppliers shape metal materials into structural elements and panels.
- **Bogies and wheels:** support the vehicle's weight and guide it along the track. A double suspension system absorbs shocks during motion (Okamoto, 1998).
- **Braking systems:** typically, pneumatic air systems. High-speed passenger rail vehicles use disc brakes for smoother operations, lower noise levels and reduced maintenance costs (Günay, et al., 2020).

[10] For example, electrical locomotives equipped with diesel engines for last-mile operations.
[11] According to the European Commission's definition, biofuels are biodiesel and bioethanol made from biomass.

- **Traction equipment:** varies based on the power source. Diesel locomotives and diesel MUs may utilise Internal Combustion Engines (ICE) from other sectors, housed within the body framework. Electric motors, located inside the bogies, involve components like wirings, inverters and transformers (SIEMENS, 2020).
- **Electronic controls and diagnostic systems:** monitor the operational life of safety-critical subsystems and maintenance scheduling (Tecec, et al., 2020).

Taking all the components into account, Table 1.2 outlines the value chain of the rail industry.

Table 1.2: Overview of the value chain of the rail industry

Tier 3	Tier 2	Tier 1	Customer
• Raw materials and alloys suppliers (e.g. metals, glass, plastic, rubber) • Intermediate products suppliers (i.e. brake parts, wirings, sensors)	• Structural component (bodies, brakes, suspensions) • Electrical, electronic and diagnostic components (transformers, inverters, rectifiers) • Traction components (engines, generators, cooling equipment)	• System integrators of self-propelled and non-self-propelled vehicles. System integrators are also original equipment manufacturers (OEM), namely firms that take all the subcomponents from tiers 2 and 3 and produce and sell the train	• Rolling stock leasing companies • Passenger and freight rail operators

Source: own elaboration based on (Hein & Ott, 2016) and (Ecorys, et al., 2019)

When it comes to the application of new general-purpose technologies, four are likely to be adopted: the Internet of Things (IoT), cloud computing, big data analytics and automation and robotics (Katsching, et al., 2020). As a result, mobile applications, e-ticketing, digital train control, signalling and traffic management and digital platforms for predictive maintenance might become integral components of the rail supply chain. Discussions of EU strategic autonomy are therefore as relevant to rail systems, as, for example, drones[12].

1.2.5. Application

Approximately 56% of the EU railway network is electrified, accommodating 80% of the traffic (IRG-Rail, 2021; European Commission, 2021h). Diverse methods combine old and new technologies due to varying vehicle traction systems. Zero-emission technologies, such as fuel cells, could replace diesel traction in remote areas, negating the need for overhead wiring. Battery technology could lower overhead wiring costs in urban areas or specific contexts (e.g. tunnels or shunting yards). Hydrogen-powered trains might replace diesel MUs over long distances, with battery trains being more suitable for shorter distances. By 2020, hydrogen and battery technology had reached a mid-range power level (up to 2 MW), appropriate for shunter locomotives and passenger trainsets (European Investment Bank, 2022) (see

Table 1.3).

[12] See for example, Drone Strategy 2.0: Creating a large-scale European drone market.

Table 1.3: Traction technologies for railway applications and level of maturity

<table>
<tr><th colspan="2" rowspan="2">Traction Technology for Railway Vehicles</th><th colspan="4">Rolling Stock Classification</th></tr>
<tr><th>High-Speed and MUs</th><th>Locomotives</th><th>Shunters</th><th>On-Track Machine</th></tr>
<tr><td>Electric</td><td>AC and DC</td><td colspan="2">Mature and significant deployment</td><td></td><td></td></tr>
<tr><td rowspan="3">ICE</td><td>Diesel</td><td colspan="4">Mature and significant deployment</td></tr>
<tr><td>CNG or LNG</td><td colspan="2">Operational demonstrations (tests)</td><td></td><td></td></tr>
<tr><td>Biofuel</td><td>Operational demonstrations (tests)</td><td>Prototype</td><td></td><td></td></tr>
<tr><td rowspan="3">Bi-mode and multi-mode based on power cell-based technologies, ICE</td><td>Bi-mode diesel and electrical under overhead wire</td><td colspan="3">Hybrid, roll out</td><td></td></tr>
<tr><td>Bi-mode with electrical traction under overhead wire with last-mile diesel</td><td></td><td colspan="2">Hybrid, roll out</td><td></td></tr>
<tr><td>Bi-mode with diesel and onboard battery</td><td>Hybrid, start of roll off</td><td></td><td>Hybrid, start of roll off</td><td>Hybrid, start of roll off</td></tr>
</table>

Source: own elaboration based on (European Investment Bank, 2022) and (UIC, 2023)

1.3. Overview of rolling stock's life cycle stages

Rolling stock is at the core of rail operations and its costs may account for about 20% of the total life cost of a rail system when considering the life cycle stages and including the upfront investment required to procure the assets, maintenance and financing (Minella & Meldebek, 2021). And several phases need to be taken into account during the rolling stock's life cycle. They span from the time period before a railway undertaking can deploy new rolling stock in its own fleet to the actual operation and subsequent maintenance and until the final decommissioning. Taking stock of the different literature sources reviewed, the **main phases of the rolling stock life cycle** are (i) service planning on the basis of future needs, (ii) tendering and design, (iii) design and development, (iv) manufacturing, (v) planning for actual operations, (vi) operating and maintenance and (vii) the useful life and decommissioning phase.

From Figure A.2 to Figure A.5 in the annex, graphical examples of rolling stock's life cycle stages are provided. The examples show, from the beginning to the end, that the sequence of phases that are necessary to develop a rolling stock product lasts for several years. **In Japan, 9 years were necessary for a new high-speed train**, from prototyping the train to its acceptance and commercialisation, whereas in **Germany, 7-8 years was the timeframe necessary for the procurement process** of the national incumbent railway undertaking, from the call for competition to the supplier's series production.

2. RELEVANT EU POLICY FRAMEWORK OR REGULATORY ACTIVITY

KEY FINDINGS

- **Transport by railway is relatively environmentally friendly** and EU transport policy consistently promotes it since it is responsible for around 5% of passenger movements and just over 10% of freight movements in the EU, but it produces only 0.4% of transport greenhouse gases (GHG) and only consumes 1.5% of transport energy.
- Several Commission strategic policy documents refer to the **general objective of boosting railway transport** as well as the need to address specific aspects that are relevant to railway performance. They emphasise the need to **boost the modal shift to rail** and strengthen cross-border coordination in the EU.
- **Four legislative packages gradually opened the market for rail service to competition**, making the national railway systems interoperable and defining the framework conditions for a single European railway area, according to the objectives set out in the strategic policy documents.
- The **operational policy framework** consists of a **landscape of telematics applications** that are functional subsystems for passengers and freight services and are meant to harmonise and standardise procedures and data and message exchanges.
- **ERTMS and ETCS** are EU-level systems designed to replace the existing national train control and command systems. They provide the conditions for smooth and efficient cross-border operations and are prerequisites for subsequent developments in rail.

2.1. Strategic policy framework

According to the European Commission's Statistical Pocketbook, in 2020, the railway performed 5.1% of intra-EU passenger transport and 11.5% of intra-EU freight transport while being responsible for only 0.4% of GHG emissions from transport at EU level (European Commission, 2022c). This can be explained by the energy efficiency of rail transport, which accounts for only 1.5% of the energy consumed by all transport activities. 56% of rail transport activities[13] in the EU are performed on electrified lines and 80% of the rail traffic in the EU is operated by electric trains. **Rail transport is projected to grow** with the completion of the core network[14] by 2030 and the comprehensive network by 2050 (European Commission, et al., 2021a).

In view of its **favourable environmental performance and high level of safety** compared with road transport, EU policy consistently promotes rail use. In particular, over the last 30 years, several strategic policy documents of the European Commission have referred and still refer to the general objective of supporting railway transport as well as the need to address specific aspects that are relevant to its performance. The overall strategic framework of the European Commission is the result of a process, including policy and legislative documents, aiming to develop rail transport in general and create an internal railway market in particular.

[13] Volume of train-km produced: measurement of the transport activities performed by the supply side (i.e., offered by the rail operators).

[14] The Trans-European transport network consists of (i) the core network, which includes the most important connections and (ii) the comprehensive network, which connects all regions of the EU to the core network.

2.1.1. Relevant policy documents

The EU's approach to transport has evolved over the decades, as reflected in its **White Papers** from 1992, 2001 and 2011. Starting with a focus on market opening (European Commission, 1992), the EU shifted its emphasis in 2001 to managing transport growth by leveraging all transport modes (European Commission, 2001). By 2011, the approach had evolved to a global look at the transport sector's challenges and potential policy initiatives, seeking to transform the transport system and promote independence from oil, among other goals (European Commission, 2011). The EU's commitment to a competitive and resource-efficient transport system, as envisioned by the 2011 White Paper, remains a cornerstone of its policy framework. The **European Green Deal Communication** of 2019 confirmed the EU's goal of climate neutrality by 2050, which would necessitate reducing transport emissions by 90% by that year (European Commission, 2019). This would entail a significant shift in freight from roads to rail and inland waterways[15].

The **Sustainable and Smart Mobility Strategy** of 2020 highlighted the need for an efficient and interconnected multimodal transport system, improved management of the rail network and the deployment of new technologies (European Commission, 2020). It also outlined ambitions to significantly increase high-speed rail and rail freight traffic by 2030 and 2050. In the **Action Plan to boost long distance and cross-border passenger rail** (European Commission, 2021c)[16], the Commission announced an initiative to improve capacity allocation and traffic management covering passenger and freight services.

The digital transformation is another critical policy area. It promises to improve manufacturing, operations and maintenance, thus offering new opportunities to the rail supply industry. The Digital Agenda of 2010 and its 2016 Digitising European Industry communication signalled the start of this focus, with subsequent communications and Council conclusions reinforcing the priority of digital transformation and its role in rail management systems (European Commission, 2016a; European Commission, 2016b; Council of the European Union, 2017). In 2021, the EU laid out its vision for digital transformation by 2030 in its "Digital Compass Communication" (European Commission, 2021d). Specifically for rail transport activities, the Commission envisioned (i) the need for further electrification of railways (including hydrogen), (ii) the deployment of new technologies for rolling stock, like digital coupling between vehicles and their automation, (iii) the implementation of rules to address rail noise, (iv) updating technical specifications for interoperability (TSI) and (v) keeping the rollout of the ERTMS a priority[17].

[15] The European Commission announced the initiative as Action 19 of the Sustainable and Smart Mobility Strategy and launched an impact assessment in 2021. The Commission Staff Working Document will present a proposal for a Regulation for measures to better manage and coordinate international rail traffic to increase the modal share of rail.

[16] The European Commission announced the action plan to boost passenger rail transport as Action 18 of the Sustainable and Smart Mobility Strategy. See also the report supporting the implementation of the action plan (European Commission, 2021e).

[17] The Commission announced as Action 42 of the Sustainable and Smart Mobility Strategy the adoption of a package of railway technical standards and specifications on ERTMS/Control-Command and Signalling (CCS) and the development of mandatory deployment plans for automatic train operation, automated traffic management and advanced CCS. Moreover, Action 51 introduced the review of the regulatory framework for interoperable data sharing in rail transport (ERTMS and TSI).

2.1.2. Relevant legislative documents

Table 2.1 gathers the legislative documents with implications to the railway supply industry.

Table 2.1: Overview of legislative documents with implications for the rail supply industry

Legislative Document		Scope and Subject Matter	Implication for Rail Supply Industry
Fourth Package - Technical pillar	Regulation (EU) 2016/796 on the European Union Agency for Railways	European Union Agency for Railways	ERA is in charge of interoperability and safety on Europe's railways. It became the authority for issuing safety certificates to rail operators and authorising railway vehicles. Using the "one-stop-shop" principle, it forms a single entry point for all applications and pre-authorises tender specifications for ERTMS projects. The Regulation eliminates the need for manufacturers and operators to apply to national authorities in each country.
	Directive (EU) 2016/797 on the interoperability of the rail system within the European Union	Interoperability Directive	Create a more homogenous European market by defining an optimal level of technical harmonisation. Outline TSIs for each subsystem and ensure cross-acceptance of rolling stock.
	Directive (EU) 2016/798 on railway safety	Railway Safety Directive	Lays down the safety requirements of the European rail system (which includes operations as well): common safety targets and common safety measures. Impact for the railway supply industry is primarily indirect, as the requirements are, in the first instance, imposed upon infrastructure managers and railway undertakings.
Fourth Package - Market pillar	Regulation (EU) 2016/2338 concerning the opening of the market for domestic passenger transport services by rail	PSO Regulation: Award of public service contracts for domestic passenger transport services by rail	Indirect: Creating a more efficient passenger rail market
	Directive 2016/2370/EU as regards the opening of the market for domestic	Governance Directive: Opening the market for passenger rail transport and	Indirect: Creating a more efficient passenger rail market

Legislative Document	Scope and Subject Matter	Implication for Rail Supply Industry
passenger transport services by rail and the governance of the railway infrastructure	the governance of railway infrastructure	
Directive 2012/34/EU establishing a single European railway area	The Single European Railway Area recasts the first railway package and merges previous directives on the development of railways, licensing of railway undertakings and railway infrastructure capacity and infrastructure charges into one package.	Indirect: framework conditions for railway infrastructure capacity allocation (i.e. rules and procedures) and traffic management.
Regulation (EU) No 913/2010[18] concerning a European rail network for competitive freight	European rail network for competitive freight	Indirect: Facilitating a modal shift towards rail freight
Proposal of revision of Regulation (EU) No 1315/2013[19] on Union guidelines for the development of the trans-European transport network (TEN-T), amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013	Priorities for the development of the TEN-T network and measures for the implementation of the TEN-T network	Indirect: developments and improved TEN-T infrastructure
Directive 2007/59/EC[20] on the certification of train drivers operating locomotives and trains on the railway system in the Community	Certification of train drivers	Indirect: Adaptation of the technical specifications of the rolling stock to the requirements of the train drivers and staff of the infrastructure managers

Source: own elaboration based on European Commission legislative documents

2.2. Operational policy framework

2.2.1. Telematics' applications for passenger and freight services

Telematics applications are crucial subsystems in the rail system, encompassing applications for both passenger and freight services. These applications are instrumental in coordinating procedures,

[18] The Commission announced the revision of the Regulation as Action 24 of the Sustainable and Smart Mobility Strategy and published the staff working document in 2021 (European Commission, et al., 2021b) and (European Commission, 2021b).

[19] The Commission announced the revision of the Regulation as Action 55 of the Sustainable and Smart Mobility Strategy and published the proposal in 2021.

[20] The Commission announced the revision of the Directive as Action 67 of the Sustainable and Smart Mobility Strategy and launched the study supporting the revision in 2022.

exchanging data and offering reliable information to various stakeholders, including passengers, railway undertakings, infrastructure managers, station managers and ticket vendors.

The European Union Agency for Railways (ERA) has developed a technical specification for interoperability for telematics applications for passenger services (TAP TSI) to standardise and harmonise the procedures, data and messages exchanged between the computer systems involved in the European railway network, thereby providing consistent and reliable information to passengers and facilitating the issuance of tickets for journeys across this network. The ERA has also drafted Telematics Applications for Freight Services (TAF TSI), functional and technical standards for the harmonised exchange of information between infrastructure managers, railway undertakings and waggon keepers. **These standards must be implemented in a uniform way by all relevant parties, which not only involves harmonised data exchange but also impacts business processes.** The TAF TSI implementation plan (i.e. Strategic European Deployment Plan) was originally developed by the rail sector in 2006-2007, with funding from the TEN-T network. However, the ERA subsequently took over this activity and included it in its technical documents. The actual implementation is driven and coordinated at the sector level to ensure effective harmonisation, with collaboration from the ERA and the European Commission as needed.

2.2.2. European Rail Traffic Management System (ERTMS)

ERTMS, a pivotal example of digital transformation in railways, is a unified European signalling system designed for safety and interoperability across European railways. It intends to replace existing national train control systems, facilitating seamless and efficient cross-border rail services. **ERTMS comprises two subsystems: the ETCS for automatic train protection and the GSM-R for voice and data communication between train and track.** Figure A.6 and Figure A.7 in the annex to Chapter 2 show how ERTMS and ETCS/GSM-R systems work. Three options have increasing levels of complexity. Level 1 involves continuous supervision of train movement, while non-continuous communication occurs between train and trackside. Level 2 involves continuous supervision of train movement with constant communication between train and trackside. Level 3 involves continuous train supervision with continuous communication with the trackside.

ERTMS and ETCS are enablers for other downstream technology developments in rail. For example, ETCS (Level 2) is an important foundation of the Automatic Train Operation (ATO; see also Box A.1), as it delivers the trackside safety infrastructure and all the information that a train needs to be driverless. ETCS depends on other technologies, such as lines with moving blocks[21]. They can be realised with ETCS Level 3, require a reliable train integrity proving system and can be provided in collaboration with Digital Automatic Coupling (DAC; see also Box A.2). Moving blocks increase infrastructure capacity, as trains can run with less headway, ultimately leading to more trains potentially on the tracks at the same time.

ERTMS target deployment foresaw the Core Network Corridors (CNCs) (i.e. 57 150 km) being gradually equipped with this technology by 2030 (European Commission, 2022b). In July 2021, Regulation (EU) 2021/1153 extended the Core Network Corridors by 9 680 km (Official Journal of the European Union, 2021). At the end of June 2022, 14% of the revised Core Network Corridor (i.e. 59 055 km) was in operation with ETCS (i.e. 7 965 km) and 60% with GSM-R. **The target is to complete the Core Network Corridors with ETCS technology by 2030, including 27 500 to 38 500 vehicles of the rail fleet equipped with ECTS by 2030** (PWC and INECO, 2021). According to the Rail Market Monitoring Report

[21] A moving block is a section of a rail line defined in real time as a safe zone around a train. This requires knowledge of the location and speed of all trains at any given time. The idea of the moving block is to allow trains to run closer, thereby increasing capacity.

(European Commission, 2021g) and the IRG-Rail Market Monitoring Report (IRG-Rail, 2021), in 2020, approximately 7% of the European rail network was equipped with ERTMS/ETCS (i.e. 13 487 out of about 200 000 km in total) (European Commission, 2022c). In particular, 7 200 km of the lines of the Core Network Corridors were equipped, namely 45% of the target set at 15 700 km for 2023 and 12% of the ERTMS European Deployment Plan set by 2030. According to EIM ((EIM, 2020) (and (Mazzola & Wiebe, 2022)), the ongoing development of ERTMS on the trans-European core and comprehensive transport networks is slower than planned and encountering delays for full and harmonised deployment. According to the Rail Market Monitoring Report of the Commission, it is projected that by 2040, the technology in question will be implemented on 70% of the TEN-T network covering the EU27 countries, as well as Norway and Switzerland.

ERTMS demands synchronised deployment of both trackside and on-board systems. By the end of 2020, 7 150 out of 41 665 operational vehicles were equipped with ERTMS (i.e. 17%). According to the Rail Market Monitoring Report, for a comprehensive ERTMS strategy, 27 600 to 34 600 vehicles should be outfitted with ETCS by 2030. However, current data predicts that 16 223 vehicles (7 176 existing and 9 047 to be upgraded or retrofitted) will have ERTMS by 2030. It is estimated that nearly 90% of EU's fleets on the CNCs will be renewed in the next 20 years, with 20 000 vehicles between 2021-2030 and 11 000 between 2031-2040 (Mazzola & Wiebe, 2022).

3. EU ROLLING STOCK PRODUCTION

KEY FINDINGS

- The length **of the EU railway network has not changed substantially over the past two decades** (fluctuating around 200 000 km) and the **liberalisation of commercial passenger services is developing**. The provision of rail services is still dominated by domestic incumbents.
- After liberalising rail services, **long-distance and high-speed operators have started commercial activities** in some domestic markets and the **number of operators providing freight services has increased**.
- **Rolling stock supply is a global and concentrated market.** 20 companies account for 50% of the total rail supply market and 80% of the rolling stock market; they are heterogeneous in size and in degree of integration.
- Over the **last 20 years, the global value of imports and exports** of rolling stock and associated equipment has **increased significantly**. Germany, China and the USA were the top three exporters in 2021 and Germany, Austria and Canada the top importers.
- The rolling stock manufacturing industry consists of enterprises that are totally, partially or with limited interrelation with the rail supply industry. In 2020, 13 275 enterprises formed the EU rail supply industry, plus 105 344 other suppliers. Out of the total, **783 enterprises specialised in manufacturing locomotives and rolling stock**. The **EU rail suppliers export more than their non-EU-based competitors.**
- New EU procurement rules for companies with support of non-EU governments enable investigations for tenders processes above certain (value and financial contribution) thresholds. The new rules facilitate better monitoring of the purchases of European assets.

3.1. Global background and trends in manufacturing

3.1.1. Background

Given the **large capital costs** required for investments, railway infrastructures are **natural monopolies** and tend to be either publicly owned or subject to regulations (Gomez-Ibanez & Meyer, 1993). However, the governance structure of railways varies between regions and markets, with the rail transport systems historically influenced by a number of factors, i.e. the degree of regulation itself, the strategic policy framework (see also Section 2.1), the context (i.e. sparsely or densely populated regions) and the trade and demographic trends. To different extents, these **factors contribute to shaping the rail supply market**, notably the level of competition and the balance between public and private capital across the different components of the supply system.

Among the **influencing factors**, the regulatory framework is a key determinant of the degree of openness of a railway market to private investments. The regulatory framework and its stability to changes over time represent a key parameter that long-term investors take into account when deciding to enter in a liberalised market. Moreover, the **regulatory framework** under which the providers of rail services operate can vary substantially among countries and within countries, with ownership models ranging from fully publicly-owned to fully privately-owned enterprises. And the degree of regulation introduced by the national governments or supranational institutions (e.g. European Commission) can range from setting technical and safety standards to framing economic regulation and tariff schemes for public service obligations. In the current situation, Europe and North America represent the largest

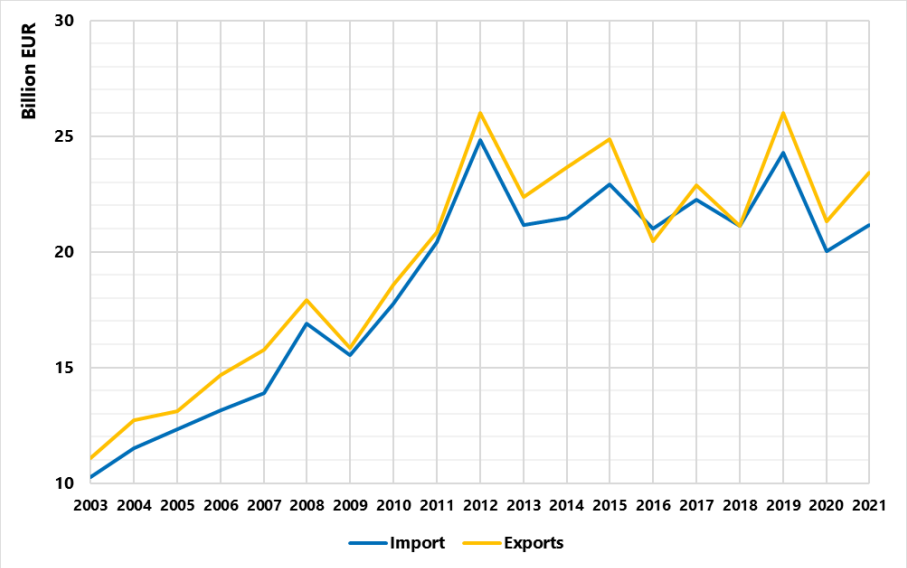
markets from a private capital access perspective, given their more mature institutional and regulatory frameworks, while the largest investment gap for new rail networks and rolling stock supply is generally in the emerging markets (Minella & Meldebek, 2021).

3.1.2. Trends

Global rolling stock supply is dominated by 20 companies accounting for 50% of the total rail supply market and 80% of the rolling stock market (see also Table A.1). Manufacturers vary in size and integration levels. Some are large conglomerates with diverse business interests (e.g. Hitachi, Siemens), others provide a full range of products (e.g. Alstom, CRRC) and some smaller companies specialise in specific rolling stock and components (e.g. PT INKA). The largest rolling stock manufacturer globally is CRRC, with a market share approximately three times that of the next largest, Wabtec (OECD, 2023). Notably, CRRC and PT INKA are government-owned entities. Based on UN trade statistics (United Nations, various years), **global imports and exports of rolling stock and associated equipment have fluctuated over the past two decades**, peaking in 2012. Post-peak, trade value reduced to under EUR 25 billion but has rebounded following the COVID-19 pandemic. From 2020 to 2021, export value rose by 9.8% to EUR 23.4 billion and imports increased by 5.7% to EUR 21.1 billion.

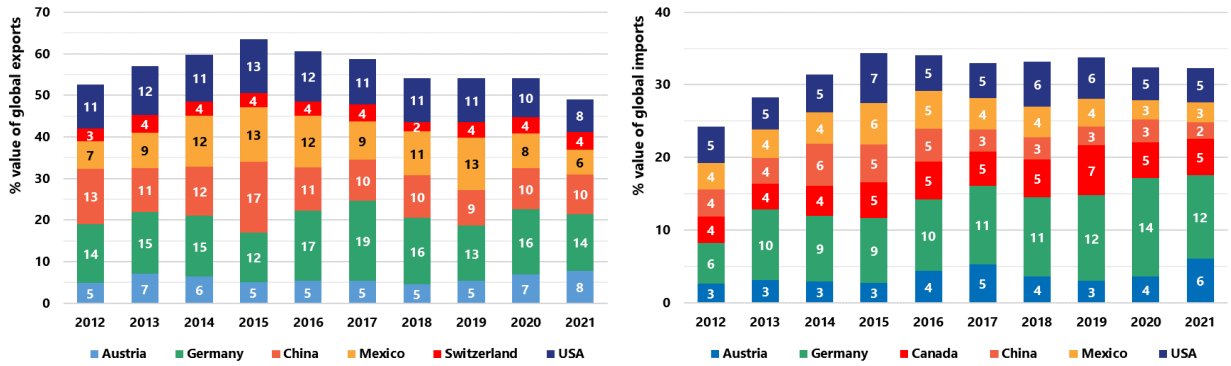
In 2021, Germany, China, and the USA were the top 3 exporters, comprising about one-third of the global supply. Including Austria, Mexico and Switzerland, these countries accounted for 50% of global exports between 2012 and 2021. **Top importers in 2021 were Germany, Austria and Canada**, contributing to over 30% of global imports when combined with China, Mexico and the USA. Demand increases for freight and passenger transport are expected to drive growth, primarily in eastern Europe, Latin America and Asia, due to railway network expansion (Minella & Meldebek, 2021). See Box A.3 for a focus on the rail supply industries of Australia and the USA.

Figure 3.1: Global value of imports and exports of rolling stocks and equipment



Source: elaboration of the authors based on UN trade statistics yearbook (United Nations, various years)

Figure 3.2: Top global exporters and importers (% of values, 2012-2021)



Source: elaboration of the authors based on UN trade statistics yearbook (United Nations, various years)

3.2. EU background and trends in manufacturing

3.2.1. Background

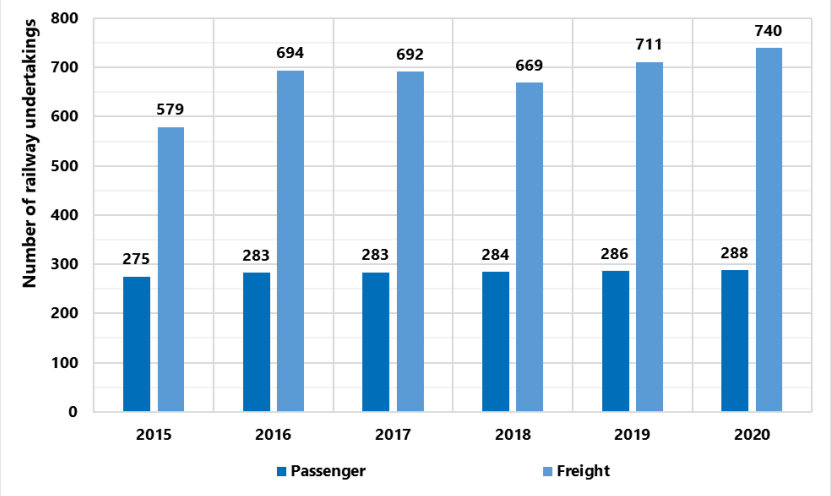
Directive 91/440 introduced the vertical unbundling of the rail network from provision of the services (Official Journal of the European Union, 1991). This legislative document established that the railway undertakings have to pay a track access charge to the infrastructure managers that, in return, ensures good-quality infrastructure and fair access to the rail service providers[22]. In the EU, the railway networks are directly or indirectly publicly owned, with companies operating under concession agreements with the national states. On the other hand, as illustrated in Section 2.1.2, rail services and rolling stock may be either managed on a commercial basis (e.g. liberalised freight services or high-speed services (see also Box A.4) or subsidised by central and local governments (i.e. passenger services provided under PSO contracts). As a result of the vertical unbundling, **private investors have increasingly played a role in financing and operating the rolling stock.** In parallel, the liberalisation of the rail market with the **fourth railway package** incentivises the private investors to consider industrial strategies focusing on building diversified rolling stock platforms operating across multiple European markets (Bertele, et al., 2019).

Presently, **commercial passenger rail liberalisation is still developing**, with domestic incumbents providing 76% of services (IRG-Rail, 2021). Yet, commercial operators are making headway in markets such as Italy and Austria, particularly in long-distance and high-speed segments. For rail freight transport, domestic incumbents continue to lead, but their share is declining, currently at 55% (IRG- Rail, 2021). Foreign incumbents' share remains steady, while non-incumbents share has seen slight growth over the past three years. In relation to the trends in manufacturing described in the next section of this chapter, it is worth observing that the total extension of the rail network at EU level has remained relatively unchanged over the period 2015-2020 (i.e. around 200 000 km[23], according to data from IRG-Rail), whereas the number of railway undertakings has increased. Notably, the variation in the number of railway undertakings is apparent for the rail freight market. Figure 3.3 shows the evolution of the number of passenger and freight railway undertakings over the period 2015-2020, according to data from the European Commission's Rail Market Monitoring Report. Figure A.8 and Figure A.9 in the annex to this chapter show that, in 2020, a substantial share of passenger and freight railway undertakings were active in Germany (i.e. 50% and 33% of the total, respectively).

[22] An overview of the track access charges by Member State is available in the Commission's Rail Market Monitoring Report.
[23] In Cyprus and Malta, railway networks are not operated.

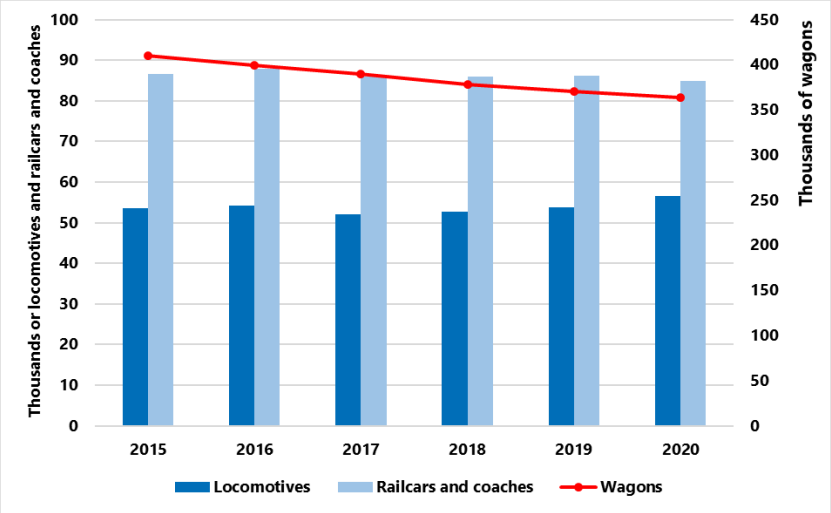
Figure 3.4 shows the **volume of rolling in the EU stock over the period 2015-2020**, according to the Commission's Statistical Pocketbook. The data shows that the number of locomotives increased from 53 495 to 56 531 units (i.e. +5.7%), the number of railcars and coaches slightly decreased from 86 554 to 84 827 units (i.e. -2.0%) and the number of waggons decreased from 410 122 to 364 019 units (i.e. - 11.2%). Figure A.10, Figure A.11 and Figure A.12 in the annex show that in 2020 the largest share of locomotives was in Germany (i.e. 30%), the largest share of railcars and coaches was in France (i.e. 22%) and the largest share of waggons was in Poland (i.e. 22%).

Figure 3.3: Passenger and freight railway undertakings providing rail services in the EU



Source: elaboration of the authors based on Rail Market Monitoring Report (various years)

Figure 3.4: Volume of rolling stock in the EU, locomotives, railcars and coaches and waggons



Source: elaboration of the authors based on (European Commission, 2022c)

3.2.2. Trends

This section focuses on the **trends of the rail supply industry in the EU,** assuming the definition according to Eurostat's NACE statistical classification, which describes the EU railway supply industry regarding its structure and interrelation with the import and export of rolling stock (see also (Ecorys, et al., 2012) and (Ecorys, et al., 2019)). Table 3.1 provides an overview of the sectors that are (i) totally interrelated (i.e. 100%), (ii) partially interrelated (i.e. 20-40%) and (iii) with limited interrelation with the railway supply industry (i.e. < 20%).

Table 3.1: Definition of the railway supply industry based on NACE statistical classification[24]

Totally Interrelated	Partly Interrelated or With Limited Interrelation
• Manufacture of railway locomotives and rolling stock (100%) (NACE 30.20) • Repair and maintenance of other transport equipment (100%) (NACE 33.17) • Construction of railways and underground railways (100%) (NACE 42.12)	• Casting of steel (38%) (NACE 24.52) • Casting of iron (17%) (NACE 24.51) • Engineering activities and related technical consultancy (17%) (NACE 71.12) • Manufacture of electrical equipment (6%) (NACE 27.9)[25] • Machining (5%) (NACE 25.62) • Manufacture of fasteners and screw machine products (3%) (NACE 25.94) • Manufacture of other plastic products (0.2%) (22.29) • Sawmilling and planning of wood (1%) (NACE 16.1) • Manufacture of basic iron and steel and of ferro-alloys (NACE 24.1) • Manufacture of other fabricated metal products n.e.c. (1%) (NACE 25.99) • Forging pressing, stamping and roll-forming of metal; powder metallurgy (3%) (NACE 25.5)

Source: elaboration of the authors based on Eurostat database and (Ecorys, et al., 2019)

Eurostat data reveals that 4 878 enterprises were closely tied to the railway supply industry in 2020, alongside another 8 398 with limited connections. Between 2011 and 2020, total enterprises rose from 10 430 to 13 272, highlighting a shift towards more closely related and less partially related enterprises. The count of other railway suppliers also escalated during this period, yet the industry structure remained unaltered. In terms of employees, despite a slight drop since 2015, the workforce grew from 2011 to 2020, particularly in firms partially related to rolling stock production. The railway supply industry's turnover, predominantly driven by enterprises completely associated with rolling stock manufacturing, was about EUR 30 billion in 2020, outpacing the EUR 13.5 billion from partially or minimally associated firms. Industry turnover swelled from EUR 40.4 billion in 2011 to EUR 43.8 billion in 2020, with other suppliers rising from EUR 49.2 billion to EUR 59.1 billion. Productivity in 2020 stood at approximately EUR 50 000 per employee in closely related enterprises, slightly less for those less integrated, between EUR 46 000 and EUR 49 000. Conversely, workers at other railway suppliers outperformed, with added value per worker ranging from EUR 57 000 to EUR 70 000.

Table 3.2 and Table 3.3 present the **structure and trends of the railway supply industry and suppliers[26] in the EU** (Box A.5 provides a focus on SMEs). Eurostat data reveals that 4 878 enterprises were closely tied to the railway supply industry in 2020, alongside another 8 398 with limited connections. Between 2011 and 2020, total enterprises rose from 10 430 to 13 272, highlighting a shift towards more closely related and less partially related enterprises. The count of other railway suppliers also escalated during this period, yet the industry structure remained unaltered. In terms of employees, despite a slight drop since 2015, the workforce grew from 2011 to 2020, particularly in firms partially related to rolling stock production. The railway supply industry's turnover, predominantly driven by enterprises completely associated with rolling stock manufacturing, was about EUR 30 billion in 2020, outpacing the EUR 13.5 billion from partially or minimally associated firms. Industry turnover swelled from EUR 40.4 billion in 2011 to EUR 43.8 billion in 2020, with other suppliers rising from EUR 49.2 billion to EUR 59.1 billion. Productivity in 2020 stood at approximately EUR 50 000 per employee in closely

[24] In brackets, the level of interrelation with the rail supply industry is expressed as an estimated percentage of the activities of the sector.
[25] For the type of solutions that a cable manufacturer can provide as a supplier of rolling stock, see (Goutille & Truflandier, 2022).
[26] Construction of railways and underground railways, engineering activities and related technical consultancy.

related enterprises, slightly less for those less integrated, between EUR 46 000 and EUR 49 000. Conversely, workers at other railway suppliers outperformed, with added value per worker ranging from EUR 57 000 to EUR 70 000.

Table 3.2: Enterprises and persons employed in the EU rail supply industry

		2011	2015	2020	2011-2015	2015-2020
Number of Enterprises						
Railway supply industry	Totally (100%)	2 455	3,310	4 483	34.8%	35.4%
	Partially (20-40%)	595	419	395	-29.6%	-5.7%
	Limited (< 20%)	7 380	7,332	8 398	-0.7%	14.5%
	Total	**10 430**	**11 061**	**13 275**	**6.0%**	**20.0%**
Other railway suppliers	Totally (100%)	1 745	2 008	2 520	15.1%	25.5%
	Partially (20-40%)	91 389	98 111	102 824	7.4%	4.8%
	Total	**93 134**	**100 119**	**105 344**	**7.5%**	**5.2%**
Persons employed (number)						
Railway supply industry	Totally (100%)	171 552	189 746	157 885	10.6%	-16.8%
	Partially (20-40%)	n. a.	n. a.	21 345	n. a.	n. a.
	Limited (< 20%)	64 601	66 044	72 733	2.2%	10.1%
	Total	**236 153**	**255 790**	**251 963**	**8.3%**	**-1.5%**
Other railway suppliers	Totally (100%)	n. a.	80 064	81 999	n. a.	2.4%
	Partially (20-40%)	278 886	299 018	324 881	7.2%	8.6%
	Total	**278 886**	**379 082**	**406 880**	**35.9%**	**7.3%**

Source: compilation of the authors based on Eurostat data

Table 3.3: Turnover and value added of the EU rail supply industry

		2011	2015	2020	2011-2015	2015-2020
Turnover (EUR million)						
Railway supply industry	Totally (100%)	26 557	29 502	29 797	11.1%	1.0%
	Partially (20-40%)	4 135	3 713	3 005	-10.2%	-19.1%
	Limited (< 20%)	9 745	9 438	10 470	-3.1%	10.9%
	Total	**40 437**	**42 654**	**43 273**	**5.5%**	**1.5%**
Other railway suppliers	Totally (100%)	18 321	19 978	19 419	9.0%	-2.8%
	Partially (20-40%)	30 874	34 902	39 659	13.0%	13.6%
	Total	**49 195**	**54 880**	**59 077**	**11.6%**	**7.6%**

		2011	2015	2020	2011-2015	2015-2020
Value added (EUR million)						
Railway supply industry	Totally (100%)	7 356	10 402	7 914	41.4%	-23.9%
	Partially (20-40%)	1 266	1 223	983	-3.3%	-19.7%
	Limited (< 20%)	3 013	3 109	3 539	3.2%	13.8%
	Total	**11 635**	**14 735**	**12 435**	**26.6%**	**-15.6%**
Other railway suppliers	Totally (100%)	4 353	6 268	5 712	44.0%	-8.9%
	Partially (20-40%)	14 107	16 123	18 696	14.3%	16.0%
	Total	**18 460**	**22 391**	**24 408**	**21.3%**	**9.0%**

Source: compilation of the authors based on Eurostat data

In the EU railway supply industry, locomotive and rolling stock manufacturing comprised 783 enterprises with 108 878 employees in 2020. It was the largest contributor to total turnover (EUR 25.0 billion, 51%) and value added (EUR 5.9 billion, 42%). Enterprises increased from 741 in 2011 to 783 in 2020, primarily located in Czechia, Germany, Italy, Spain, and Poland (73% of total companies). Growth was significant in Czechia (+33%), Poland (+170%), Germany (+94%), and Spain (+40%), while Italy saw a decline (-13%). Employee numbers rose by 7.5% between 2011 and 2020. However, patterns varied across countries, with growth in Croatia, Germany, the Netherlands, Poland, Spain and Sweden, while Bulgaria, Greece, Hungary, Italy, Latvia, Portugal and Romania saw reductions. The repair and maintenance of other transport equipment, contributing up to 30% to rail service providers' operating expenditures, was the second-largest segment fully linked to rolling stock production. Enterprises in this segment rose notably from 2011 to 2020 (+102%), except in Denmark, Portugal and Slovakia. The majority (73%) were located in Bulgaria, Czechia, Germany, the Netherlands, Poland and Spain. Employee numbers in this segment surged from 70 245 to 110 783 (+37%) between 2011 and 2014, then fell to 49 007 in 2020 (-56%). See Table A.2 toTable A.**5** in the annex for detailed breakdowns.

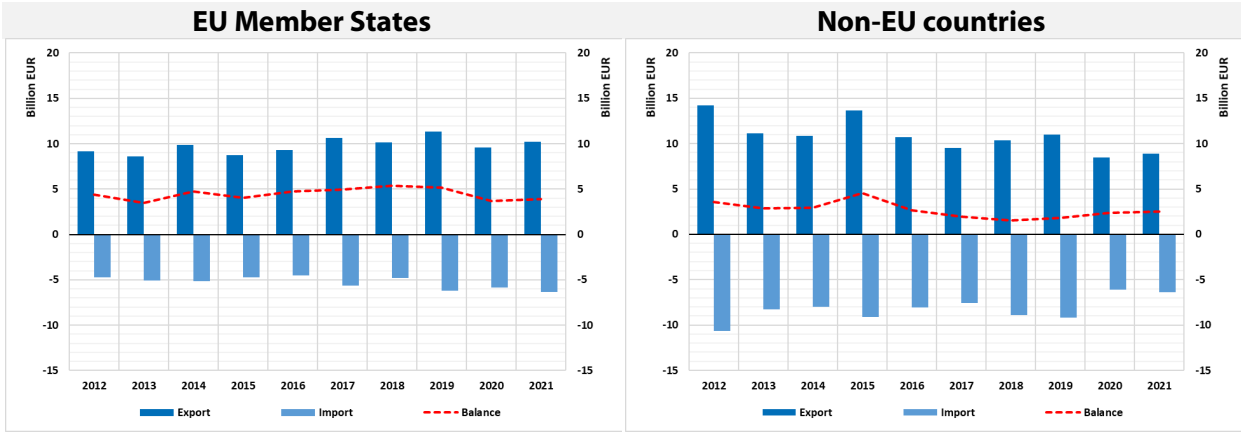
3.3. Current EU balance

According to trade statistics of the United Nations (United Nations, various years) on the production of railway vehicles and equipment, the **balance between exports and imports of manufacturers located in the EU is positive over the period 2012-2021.** The balance of top EU exporters and importers[27] has **fluctuated around EUR 4.5 billion on an annual basis**. Data shows also that the balance of manufacturers located in non-EU countries[28] has been positive over the same period; however, the positive result on the traded rail products of the top manufacturers is smaller than that observed for the competitors based in the EU (i.e. EUR 2.7 billion).

[27] EU countries: Austria, Belgium, Czechia, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain, Slovakia and Sweden.

[28] Non-EU countries: Australia, Argentina, Brazil, Belarus, Canada, China, Egypt, Hong Kong, India, Mexico, Japan, Kazakhstan, Kenya, Republic of Korea, Russian Federation, Saudi Arabia, South Africa, Switzerland, Turkey, UK, Ukraine and USA.

Figure 3.5: Balance of top global exporters and importers (EUR billion, 2012-2021)



Source: elaboration of the authors from UN trade statistics yearbook (United Nations, various years)

When it comes to the competition between manufacturers located in EU and non-EU countries, it is worth observing that in January 2023 the new European public procurement rules for companies with state support from non-EU countries came into force (i.e. the Foreign Subsidies Regulation, FSR) (Official Journal of the European Union, 2022)[29]. The FSR enables the Commission to investigate tenders with an estimated value above EUR 250 million with financial contributions from non-EU governments and tender bids by companies that received over EUR 4 million from non-EU governments in the previous three years. The Commission will also monitor purchases of European assets where the acquired company, one of the merging parties, or the joint venture generates an EU turnover of at least EUR 500 million and such companies received more than EUR 50 million from non-EU governments in the previous three years. The first non-EU company affected by the FSR is the Chinese manufacturer CRRC. Benefiting from the government's support, the manufacturer made offers with significantly lower prices compared to its European competitors (Belov & Savenkova, 2023). According to UNIFE research on bids of third-country state-owned enterprises submitting offers in the European procurement market, in 2019-2020 CRRC lost 8 EU tenders worth almost EUR 2.8 billion and won 4 tenders worth EUR 236 million[30].

[29] The new EU Regulation is expected to apply to procurement procedures initiated in July 2023.
[30] See also https://soes-in-europe.eu/map.php.

4. DEMAND FOR ROLLING STOCK BASED ON EU POLICY

KEY FINDINGS

- **Several factors** that affect the demand for rolling stock are **linked with the EU strategic policy framework and legislative documents**, notably: decarbonisation and liberalisation of the internal transport market.
- **Other factors may affect the future demand for rolling stock in the EU**: the procurement process, the global trade and mix of cargo and technology and economic and social developments.
- **Manufacturers** of rolling stock tend to be **located close to or in countries with a sizeable domestic market**. However, most of them also have the **capability to bid for contracts worldwide and supply rolling stock abroad**.
- **Globally, market analyses and research predict that the demand for rolling stock until 2030 will grow.** Forecasts are available for specific segments of the rolling stock supply industries and regions.
- Projections suggest that there might be **opportunities for production over the coming years**, pushed by the growing emphasis on transport sustainability. **Other opportunities might come from new generations of rolling stock** incorporating alternative traction systems and advanced technologies.
- The **demand for rail products may fluctuate significantly over time** because of the cyclical infrastructure planning of the public sector. This aspect should be regarded as a **challenge for the rail sector**.

4.1. Factors that affect demand of rolling stock

4.1.1. EU policy activity

Several factors impacting rolling stock demand are tied to EU policy activity. As outlined in Chapter 2, EU policies centre on transport decarbonisation and market liberalisation, alongside other elements like new technologies and harmonised standards.

- **Decarbonisation:** According to the European Commission, their ambitious targets to reduce GHG emissions by 55% by 2030 would necessitate investments in new rolling stock capacity to meet the expected increased demand for rail transport (European Commission, 2021f).
- **Market liberalisation:** Since the 'market' pillar of the Commission's fourth rail package in 2016 (CER, 2017), liberalisation of the rail market has encouraged competition and could result in a demand for new rolling stock or leasing of existing stock.
- **Railway infrastructure development and harmonisation of standards:** The EU aims to develop a harmonised and fully interoperable European railway network. Implementing standard track gauge, axle load, minimum line speed, train length and loading gauge can lead to increased demand for compatible rolling stock (European Commission, 2021f).
- **Electrification of the railway infrastructure:** According to the International Energy Agency (IEA, 2019), electrification offers cost and environmental benefits. In some cases, hydrogen or battery-powered trains could replace diesel traction, thus driving demand for such rolling stock (European Investment Bank, 2022; European Commission, 2020).

- **Intermodal and combined transport:** The growth of combined transport, especially for freight, is expected to drive demand for rail freight and intermodal waggon rolling stock (UIRR, 2022; UIC and UIRR, 2023; Official Journal of the European Union, 1992).
- **Long-distance passenger transport:** The Commission's action plan on boosting long-distance and cross-border passenger rail could lead to an increased demand for new rolling stock due to the poor condition of existing ones (Steer Davies Gleave and Politecnico di Milano, 2017; Steer and Kwc, 2021).
- **Air-rail intermodality for passenger transport:** Encouraging air passengers to use rail transport for part of their journey can also drive demand for rolling stock, as studies suggest (Savelberg & de Lange, 2018; Reiter et al., 2022; European Commission, 2011; Airport Technology, 2022).
- **Social developments:** Meeting the sustainability goals also requires addressing the ageing workforce in rail. The EU plans to digitalise rail operations and provide continuous learning and training for train drivers, which could influence the types of rolling stock required (Voss, 2022; European Commission, 2020).
- **Government policies:** Government initiatives, such as France banning short-haul flights when there is a train or bus alternative, also influence the demand for railway rolling stock (Airport Technology, 2022).

The convergence of these factors indicates a likely rise in European railway rolling stock demand, propelled by climate concerns, market liberalisation, infrastructure enhancement, intermodal transport growth and policy shifts.

4.1.2. Additional developments

Besides the factors that affect demand based on EU policy activity, a number of other factors may affect the future demand for rolling stock in the EU.

- **Procurement Process:** National governments heavily influence rolling stock purchasing due to high costs and because central transport authorities often act as buyers (European Parliament, 2016; Roland Berger, 2017; Oxford Economics, 2021; OECD, 2023). However, these governments sometimes favour their national rail supply industry, creating a 'home bias' in procurement and obstructing open competition. Such implicit preferences are hard to detect, but may include a favouring of suppliers with a national track record, localisation requirements or long-standing relationships with domestic manufacturers (Gourdon & Messenet, 2017). Interestingly, freight operators are increasingly leasing for flexible fleet management and outsourcing non-core business, given the complexity and duration of the procurement process (Minella & Meldebek, 2021).
- **Global Trade and Cargo Transport:** Shippers' choice of transport mode typically hinges on past experience, goods type, and distance and time requirements (Steer Davies Gleave, 2015). Retaining rail's current modal share (18%) will pose challenges due to evolving goods structures and logistic trends (Rail Freight Forward, 2016). Compared to the mix of goods transported in 2015, those with low rail affinity increased (+2.2%), while those with high rail affinity decreased (-1.5%)[31].

[31] Goods with low affinity for rail are small shipments that require short transport times (e.g. goods with high value density or perishables). Goods with high affinity for rail transport are typically bulk and heavy goods with high volumes to be carried.

- **Technology Developments:** Future rolling stock demand will be shaped by information services, signalling systems and automation. Increased digitalisation may allow real-time remote diagnostics, improving safety and reducing costs (Katsching et al., 2020). Emerging ATO solutions could optimise traffic management and reduce energy consumption.
- **Economic and Social Developments:** Passenger and freight transport demand derives from population size, travel time and goods consumption income. The post-COVID-19 pandemic and migration flows from Ukraine saw the EU population reach 451 million in 2023, with a projected rise to 453 million in 2026 and a decrease to 420 million by 2100. The urbanisation trend may also affect rolling stock demand, especially for commuter rail. According to the Commission's Competence Centre on Foresight, the urban population is expected to reach 83.7% by 2050, with built-up areas likely expanding by over 3% until 2030.

4.2. Existing forecasts: strengths and weaknesses

4.2.1. Aggregation of existing forecasts

At the global level, the insights drawn from existing market analyses and research for forecasts about the **demand for rolling stock until 2030** show that the size of the fleet is, in general, **projected to grow**. The global projections report that the value of the rolling stock market might increase from EUR 52-62 billion in 2022-2023 to 76-86 billion in 2030, with a CAGR in the interval 4.2-6.0% (GVR, 2018), (Automotive & Transportation, 2022) and (The Business Research Company, 2023)[32]. Table 4.1 summarises the global forecasts for rolling stock demand.

Table 4.1: Existing global forecast for rolling stock demand

Region	Share Demand for Rolling Stock (2017-2019) (OECD, 2023)[33]	CAGR 2021-2023 (Minella & Meldebek, 2021)	CAGR 2023-2030
Europe	29%	2.3%	4.2-6.0%
Asia Pacific	44%	2.6%	
Middle East and Africa	4%	4.0%	
CIS	8%	n. a.	
North America	14%	2.5%	
Latin America	1%	4.1%	

Source: elaboration based on (OECD, 2023), (Minella & Meldebek, 2021) and excerpts from other market researches

For the market of **locomotives, a global positive trend is foreseen**, as it could be linked with the liberalisation of freight and passenger operations (Minella & Meldebek, 2021). The global market size of this segment is projected to increase from EUR 6 billion to EUR 8 billion for the period 2020-2027. For the locomotives, it is worth observing that they have no payload capacity and their sole purpose is to push or pull the convoy. Therefore, for example, for freight transport, the demand for locomotives should be more predictable than the demand for freight waggons, which in theory depend on the volume of demand and mix of commodities. As decarbonisation policies evolve, market research foresees (i) more vehicles relying on biofuels and gas (i.e. CNG or LNG) to reduce the emissions of diesel traction and (ii) more electrification of the networks to reduce GHG emissions (see also Table 1.3). For the short-term horizon, as technology progresses relatively quickly, new locomotives relying on biogas

[32] Information retrieved from excerpts of the reports containing the analyses. The forecasts analysed are based on assumptions, estimates, views and hypothetical models or analyses of other authors, which might prove inaccurate or incorrect.

[33] The global rolling stock market was estimated at about EUR 67-71 billion in the analysis developed by UNIFE and Roland Berger in 2020. See UNIFE and Roland Berger GmbH (2020), UNIFE World Rail Market Study 2020, UNIFE.

or hydrogen may enter the transport market soon (i.e. by 2024). Overall, the **global locomotive market is anticipated to expand over the coming years, in line with the evolution path of the technologies** described earlier in
Table 1.3 (European Investment Bank, 2022).

For conventional passenger transport, the global **demand for MUs is expected to grow at a CAGR 4.5% until 2024**, driven by the ongoing phasing out of aging fleets and, again, the electrification of rail networks (Minella & Meldebek, 2021). Decarbonisation policies are likely to favour electric vehicles or those relying on alternative fuels with respect to diesel traction. It is worth reporting that market research developed for Germany (Borchers & Wille, 2022) forecasts that the segment of conventional push-and-pull trains[34] could grow until 2030, driven by the past demand trend observed for intercity services, cross-border services and the revival of night trains. The market for push-and-pull trains is projected to increase from EUR 450 million in 2021 to EUR 1.2 billion in 2026, whereas the market for night trains is projected to grow to over EUR 250 million by the mid-2020s, driven by the ageing of the current fleet (i.e. 37 years on average).

Since its early stages, **high-speed services have been one of the fastest-growing segments in rail**. In the current situation, 58 840 km of lines are in operation with around 6 500 vehicles at the global level. According to UIC data (UIC, 2021), the global high-speed network will expand further over the coming years, as 19 709 km of lines are under construction. Moreover, 19 643 km are planned for construction and additional 33 607 km are in long-term programmes. As Figure A.16 shows, the bulk of the high-speed network expansion will be in the Asia-Pacific region, followed by the EU. Over the past three decades, UIC's data show that the size of high-speed rolling stock in the EU has developed following the development path of the high-speed network (see Figure A.17). The Commission's strategy to double high-speed rail traffic by 2030 for sustainable and smart mobility and **the anticipated expansion of Europe's high-speed rail network indicates potential strong growth in rolling stock demand for this segment in the coming years.** However, the actual demand for high-speed rolling stock will depend on the actual future demand for transport.

For **freight transport**, with a large global fleet, the **waggon segment looks mature** as far as the current situation is concerned. In recent years, there has been a **trend towards more specialised waggons**, such as those for refrigerated and perishable goods or tank waggons for hazardous materials. For Europe, in order to follow and accommodate the changing mix of commodities (Rail Freight Forward, 2016), the forecasts elaborated for future **production of freight waggons** foresee that the **past pattern observed could also continue over the coming years** (Minella & Meldebek, 2021). The forecasts by type of freight waggon and product transported are summarised in Table A.6.

The **projections of the EU Reference Scenario 2020** (European Commission, et al., 2021a)[35] provide the basis for the core policy scenarios implementing the European Green Deal. In particular, the MIX scenario assumes the implementation of initiatives delivering carbon pricing instruments and regulatory-based measures to achieve at least 55% emissions reductions by 2030 and climate neutrality by 2050. The results of the MIX scenario foresee that the EU's GDP will grow up to EUR 14 814 billion in 2030, from the pre-pandemic level of EUR 12 213 billion in 2015 (i.e. +21.3%). For passenger and freight transport activities, the rail mode is projected to grow significantly in terms of activities performed. The modal share of passenger and freight rail is expected to grow, eroding demand from road transport modes. **The size of the rolling stock fleet in the EU is projected to increase by 2.1% between 2020 and 2030**. The projections of passenger and freight rail transport activities and the modal shares of

[34] Push-pull trains consist of locomotives coupled with coaches and are suitable for intercity services (maximum speed < 250 km/h).
[35] See also the report on the EU reference scenario 2020, which is available on the European Commission's website.

road and rail from the EU Reference Scenario are summarised in Figure A.19 and Figure A.20. Box A.6 summarises rail industry forecasts for the UK and the USA.

4.2.2. Equating EU supply capability and future demand

The rolling stock value chain features an ecosystem of specialised firms linked through a concise production process, with numerous, sometimes non-rail-specific, suppliers providing materials for final assembly by larger companies. These can vary in their rail sector specialisation and product range. **Around 20 manufacturers dominate the global rolling stock ecosystem, accounting for 50% of the total rail supply market and 80% of the rolling stock market. Five of them produce 20% of the annual sales and 14% of the supply and are EU-based**. Manufacturers tend to locate in regions with operational railway networks, addressing local rolling stock demand.

Rolling stock demand depends on projected passenger and freight rail transport demand, which is influenced by a myriad of interconnected factors. Rail service providers need to renew, refurbish or upgrade existing stock due to ageing or technological advancement also shapes demand. For instance, in the EU, deploying ERTMS necessitates equipping rolling stock with ETCS. **This analysis suggests prospective demand for rolling stock products.** Most rolling stock manufacturers, typically based in countries with significant domestic markets, bid for contracts globally. **Export and import value trends show a positive balance for both EU and non-EU suppliers, as their production exceeds import needs.** Over the past decade, EU manufacturers have maintained a favourable balance. However, non-EU countries, while still positive, have seen a recent downward trend (see Figure 3.6).

5. EU FINANCIAL INSTRUMENTS

KEY FINDINGS

- **Historically, national and regional rail operators, often public entities, directly procured rolling stock.** However, this model suffers from budget constraints and long procurement cycles. There is a need for more efficient and sustainable funding mechanisms, in particular to decarbonise the rail system.
- **Companies that own and lease rolling stock have become increasingly prevalent in the EU.** They provide rail operators with flexible leasing options and enable better risk management. The private sector involvement can enhance flexibility and efficiency, but oversight is necessary.
- The **EU provides a diversity of grants and subsidies** that can be applied to decarbonisation of rolling stock through manufacturing, purchase and lease.
- The **EIB provides financing instruments** for rolling stock focusing on innovative, green and cross-border projects, but a more streamlined process could enhance access to these instruments. There are also **specialised financial institutions, such as EUROFIMA, set up to provide loans and leases.**
- **Green financing tools are increasingly necessary for rolling stock that supports decarbonisation goals.** There is a need for clearly agreed-upon standards and the EU Taxonomy specifically addresses rolling stock manufacture and acquisition.

5.1. Overview of relevant EU financing mechanisms

Developing or purchasing rolling stock involves large amounts of capital and therefore requires the use of several financial instruments, often in combination. Here are some **common financial instruments** used.

- **Loans:** A straightforward way for railway undertakings to finance the purchase of rolling stock is to take out a loan from a bank or other financial institution. These loans might be secured (i.e. backed by collateral) or unsecured.
- **Leasing:** Leasing is a common financial instrument for acquiring rolling stock without the upfront capital expense. In this case, a leasing company owns the stock and leases it. There are different forms of leases, such as operational and financial leases, each with different conditions and balance sheet impacts.
- **Bonds:** Large railway undertakings, particularly incumbents with state backing, might issue bonds to finance the purchase of rolling stock. As the EU seeks to decarbonise, green bonds and other sustainable finance tools could be used for rolling stock that supports this goal. The standards for what constitutes 'green' need to then be consistent. The issue is largely being addressed by the EU Taxonomy Regulation and supporting regulations that include provisions for rolling stock.
- **Public-Private Partnerships (PPPs):** They are used to finance rolling stock, combining public oversight with private sector efficiency, spreading risks and potentially driving innovation. However, complex contracts and long negotiation periods can have drawbacks, so they require careful planning and management.

- **European Investment Bank (EIB) Financing:** The EIB offers loans and guarantees for large infrastructure projects, including rolling stock purchases.
- **EU Grants and Subsidies:** The EU provides grants and subsidies for rolling stock development and purchase geared towards promoting specific goals, such as enhancing regional connectivity or reducing carbon emissions.

The next section focuses on **EU grants and subsidies** and financial institutions like the **EIB**.

5.1.1. EU grants and subsidies

- The **Connecting Europe Facility (CEF)** is a funding instrument developed to (i) invest in transport, energy and digital infrastructures and (ii) address missing links and bottlenecks. It can provide funds for railways and rolling stock, particularly those that contribute to the creation of a single European transport area.
- The **European Regional Development Fund (ERDF)** supports development and sustainable growth in various sectors, including railways and rolling stock purchases.
- The **Cohesion Fund (CF)** is geared towards Member States whose Gross National Income (GNI) per inhabitant is less than 90% of the EU average. It can fund environmental and transport projects, including rolling stock purchases.
- The **InvestEU Programme** provides a budget guarantee to mobilise public and private investment for operations carried out by the implementing partners (e.g. the EIB) that contribute to the policy objectives. It focuses on rolling stock for urban contexts.
- The **Recovery and Resilience Facility (RRF)** can be used for low- or zero-emission rolling stock. The only Recovery and Resilience Plan for rolling stock has been found in Romania.
- **Europe's Rail and Horizon Europe** do not fund rolling stock purchases directly. They indirectly support the research and development of innovative rolling stock.
- The **Green Deal Call** is an important part of Horizon Europe and EU's Green Deal. The initiative provides funding for research and innovation projects that contribute to climate neutrality by 2050. It could include projects related to low-emission or energy-efficient rolling stock.

5.1.2. EIB, EBRD and EUROFIMA

When it comes to financing the purchase of rolling stock, the **EIB offers several possibilities.**

- **Direct Loans** for large projects (i.e. > EUR 25 million). The terms of these loans are usually very favourable, with low interest rates and long repayment periods.
- **Intermediated Loans** (or Indirect Loans) for small projects (i.e. < EUR 25 million). The EIB lends to local banks and financial intermediaries, which then lend to the final beneficiaries, such as SMEs and mid-cap companies.
- **EIB Advisory Services** are provided to prepare and implement projects, which can be helpful for complex projects or for entities that are new to large-scale project financing.
- **Project Bonds** are designed for very large projects. They are issued by the project company itself to raise financing, with the EIB providing a partial risk guarantee for the bonds. It can improve the credit rating and make a project more attractive to investors.
- In some cases, the EIB might take an **equity stake** in a project, but this is less common.

- The EIB often works with other EU programmes to provide **blended finance**, which combines EIB loans with EU grants or guarantees. This can lower the overall cost of financing and help attract additional private sector investment.

The other specialised institutions that finance rolling stock supply in the EU are **EUROFIMA**, the European Company for the Financing of Railroad Rolling Stock and the **European Bank for Reconstruction and Development** (EBRD). They provide financing (i.e. loans and leases) for railway rolling stock to support the rail transport policies of the Member States. Similar to the EIB, **EUROFIMA provides loans for capital investments in the rail sector.** EUROFIMA raises funds for its activities primarily by issuing bonds on the international capital markets. They are generally guaranteed by its Member States, providing EUROFIMA with favourable financing conditions.

5.2. Specific initiatives to facilitate rolling stock investment

- **The CEF (Transport) has approved the disbursement of EUR 402 million for 76 projects** related to suburban, regional and national rolling stock. The grants have been provided between 2014 and 2021 across the EU. The projects do not directly concern the purchase of new rolling stock but rather retrofitting the existing stock, which still has a comparable impact on keeping the rolling stock modern. A large majority of these retrofitting projects concern the equipment of On-Board Units (OBUs) for ERTMS deployment, in line with ambitions to create a single railway area. A small fraction of the funds is also destined for the retrofitting of quieter and more modern brake systems on rolling stock for environmental noise reduction (see also Regulation (EU) 2015/429).
- **The EFRD and the CF** have approved, between 2019 and 2022, disbursing **EUR 541 million in 5 different projects** in Poland, Croatia, Czechia and Latvia. The grants can be used to purchase rolling stock that adheres to EU interoperability standards for both passenger and freight railways as well as for the modernisation of the railway system to encourage a shift towards its usage.
- **Horizon Europe** approved the disbursement of **EUR 55 million in nine RDI** initiatives related to rolling stock between 2015 and 2019. The initiatives focused on innovations in vehicle design and performance, telematics and train controls and systems. The projects funded by Horizon Europe are international, with many partners, mainly from the rail industry, across different countries collaborating on a single project.
- **Europe's Rail** is a European Joint Undertaking and has been established by Regulation (EU) 2021/2085 to design and implement research and innovation activities covering traffic management, rolling stock, railway infrastructure and services. Its Innovation Programmes 1 and 5 focus on rolling stock to different extents and provide funds to academia and industry for **EUR 215 million and EUR 85 million,** respectively, between 2016 and 2023.
- The **EIB** is among the European institutions providing the largest financing to rolling stock renewal, with **EUR 16.7 billion in loans approved for 65 different initiatives between 2014 and 2022**. The large majority of its initiatives concern the purchase of rolling stock by railway undertakings providing suburban, regional, national and international services in the EU. **EIB's loans have also been issued to retrofit OBUs for ERTMS readiness** and, on two occasions, loans totalling EUR 155 million have been issued to institutions that lease rolling stock. Another initiative worth highlighting is the issuance of green bonds through the Green Bond Purchase Programme to fund the purchase of rolling stock for high-speed services in Spain and Italy. Box

A.7 provides examples of EIB's loans to finance rolling stock in (i) Bulgaria, Poland and Spain and (ii) for a major European rolling stock leasing company.

- Investments from the **EBRD** for railways almost never include Member States, although they do include candidate and neighbouring countries. Since 2014, only one rolling stock project in the EU has received EBRD financing, namely disbursing a **EUR 27 million loan** to a rolling stock parts manufacturer in Poland.
- **EUROFIMA** contributed **EUR 2 billion in the form of loans** approved to railway undertakings for the purchase of rolling stock. Fourteen initiatives between 2020 and 2023 received loans with a debt maturity usually in the range of ten years. These loans have been concentrated in rolling stock renewal projects in Belgium, Croatia, Czechia, Denmark, Italy, Luxembourg and Spain (and Switzerland from outside of the EU).
- The **RRF** has also designated **EUR 1.57 billion in the form of loans and grants** for rolling stock, with Bulgaria, Poland and Romania on the receiving end.

6. POLICY RECOMMENDATIONS

KEY FINDINGS

- **The EU policy and legislative framework** on transport identified the need to boost railway transport and foster a modal shift from road to rail as overarching objectives. It provides key preconditions for the railway supply industry to grow, including funding and financing instruments enabling investments in rolling stock and research in advanced technology and solutions for further developments.
- **The EU railway network is still patchy and based on legacy systems** developed at the national level. Although the advantage of a single European Railway area is apparent, the process to harmonise both infrastructure and rolling stock standards is slow. The rail services are dominated by domestic incumbents, especially for passenger services.
- **Overall, the European rail supply industry shows a positive balance** between exports and imports, with some Member States placed at the top of the ranking. Available projections suggest that there might be opportunities for production pushed by the growing emphasis on transport sustainability and new generations of trains.
- **The competition from other transport modes** poses a significant challenge for rail transport and rolling stock demand. A large-scale modal shift seems difficult. China is the country with the largest rolling stock manufacturing capacity and is dominated by a supplier under public administration serving the largest domestic market. On exports, it can offer significantly lower prices compared to its European competitors.

6.1. Key challenges and opportunities

The analysis of the demand for rolling stock suggests that, at a global level, the rail supply industry will grow until 2030. All regional markets are projected to grow, with the highest rates foreseen in Latin America, the Middle East and Africa. More mature markets such as the EU, Asia Pacific and North America will continue to grow and contribute to the largest share of the overall growth.

The analysis of the rail supply industry showed that it consists of a competitive ecosystem. The EU's rolling stock supply industry is the leading exporter worldwide for the locomotives and rolling stock segment. The EU manufacturers are also the global leaders when it comes to signalling and electrification technologies. The technological leadership and positive balance between exports and imports highlighted for EU manufacturers suggest that they have the supply capabilities to outperform their competitors, especially American, Chinese and Japanese, who can rely more on the products developed for their own domestic markets. The competitive pressure at the global level stems mainly from the Chinese manufacturer. Its competition in the EU market has developed slowly over the past years; however, the Chinese government support and overcapacity in the domestic market might encourage it to pursue more attempts to penetrate the EU market.

The outdated and inconsistent national regulations are an important challenge for future developments in the EU. Although harmonisation and interoperability are prominent topics in the strategic and operational policy frameworks of the European Commission, there is a persistent lack of consensus amongst the stakeholders to change the national standards. This implies that the rolling stock supply industry is fragmented and faces a slow transition process. Another reason for the slow transition is the long operational life of the rolling stock. It should be noted that the harmonisation and interoperability of the single European Railway Area not only favour internal competitiveness in the EU

but it also makes the internal market more attractive for foreign competitors. A large market becomes more accessible when certification and authorisation procedures are unified and compliance does not depend on national rules.

Against this background of future demand and supply capabilities, the key challenges and opportunities for EU policymakers are reasonably clear.

Over a short-term horizon, EU policymakers should continue to:

- **promote interoperability and standardisation** to facilitate seamless operation and connectivity across the EU. The adoption of common specifications should be pursued to enhance compatibility and efficiency. Equally important is to (i) foster the elaboration of robust transport demand analyses and (ii) provide support to research and development initiatives to advance interoperable technologies and promote their implementation.
- **prioritise decarbonisation and electrification** by implementing and enforcing ambitious decarbonisation targets for rail and promoting the use of renewable energy sources to power trains. Investments in the electrification of rail networks are important, particularly in high-demand corridors and major urban areas, to reduce GHG emissions. Incentives and funding mechanisms should be provided to encourage the shift from diesel traction.
- **support research and innovation** by allocating funding for projects focused on innovative technologies. Collaboration between stakeholders should be fostered to drive technological advancements and improve the performance and efficiency of rolling stock. The use of digital technologies, such as IA, IoT and big data analytics, should be promoted.

Over a long-term horizon, EU policymakers should:

- **support the provision of high-speed rail services in competition,** notably (i) between major urban areas and (ii) over connections that would allow for substitution of air transport to free capacity from major airports. These objectives should be pursued in developing the high-speed network, where viable from a socio-economic perspective.
- **strengthen freight rail transport**. Policies and initiatives should be implemented to encourage a modal shift from road to rail, particularly for long-haul and goods with affinity with rail. Given the international dimension of rail freight transport, cross-border cooperation and harmonisation should be facilitated by the legislators to guarantee seamless operations and reduce administrative barriers.
- **support sustainable financing mechanisms,** enhancing the availability of EU financing instruments, specifically tailored for rolling stock. PPPs should be encouraged where there might be competition in rail services to leverage private sector expertise efficient allocation of financial resources. Innovative financing models, such as green bonds and blended finance, should also be explored to attract additional investment.
- **promote international collaboration and harmonisation,** strengthening cooperation with non-EU countries and sharing best practices and lessons learned to promote the development and standardisation of rolling stock technologies. International partners should be engaged in dialogue, particularly those with high-speed rail networks to foster knowledge exchange and collaboration in rolling stock development and operation.

6.2. What to do next for the rail supply industry?

Specifically, from a rail supply industry perspective, addressing the following issues is important.

- **Foster a favourable business environment** by implementing policies that promote stability, transparency and predictability, while also providing a conducive environment for rolling stock manufacturers and suppliers. The regulatory processes and administrative procedures should be streamlined to reduce bureaucratic hurdles and facilitate timely approvals for rolling stock projects. Public procurement practices should be encouraged to prioritise quality, innovation and lifecycle cost considerations.
- **Continue investment in research and development** by allocating dedicated funds for research and development initiatives to advance rail technologies and improve the performance and sustainability of rolling stock. Collaborative platforms and innovation clusters should bring together manufacturers and research institutions to drive innovation and accelerate the development of cutting-edge solutions.
- **Promote skills development and workforce training** by investing in vocational training programmes and initiatives that equip the workforce with the necessary skills to meet the evolving needs of rail services and the supply industry. Partnerships between educational institutions, industry and trade associations should be fostered to develop curricula and apprenticeship programmes that address the requirements of rolling stock production.
- **Strengthen supply chain resilience** by promoting robustness and diversification within the EU to reduce dependency on components and materials. Initiatives to encourage the localisation of manufacturing and the sourcing of key components should be supported, fostering the growth of domestic suppliers and reducing vulnerabilities to disruptions.
- **Enhance international competitiveness** by supporting EU rolling stock manufacturers in accessing international markets. Fair and open competition in international procurement should be advocated for a level playing field for EU producers competing against foreign manufacturers. Partnerships between EU rolling stock manufacturers and rail operators worldwide should be fostered to facilitate joint ventures and collaborations.
- **Facilitate financing and investment** by enhancing access to financing for rolling stock manufacturers through EU financial institutions by offering tailored loans, guarantees and financial instruments. The development of private investment funds and PPPs should be encouraged to attract institutional investors and diversify sources of funding. The integration of environmental, social and governance criteria into financing decisions should be promoted to incentivise sustainable and responsible rolling stock projects.

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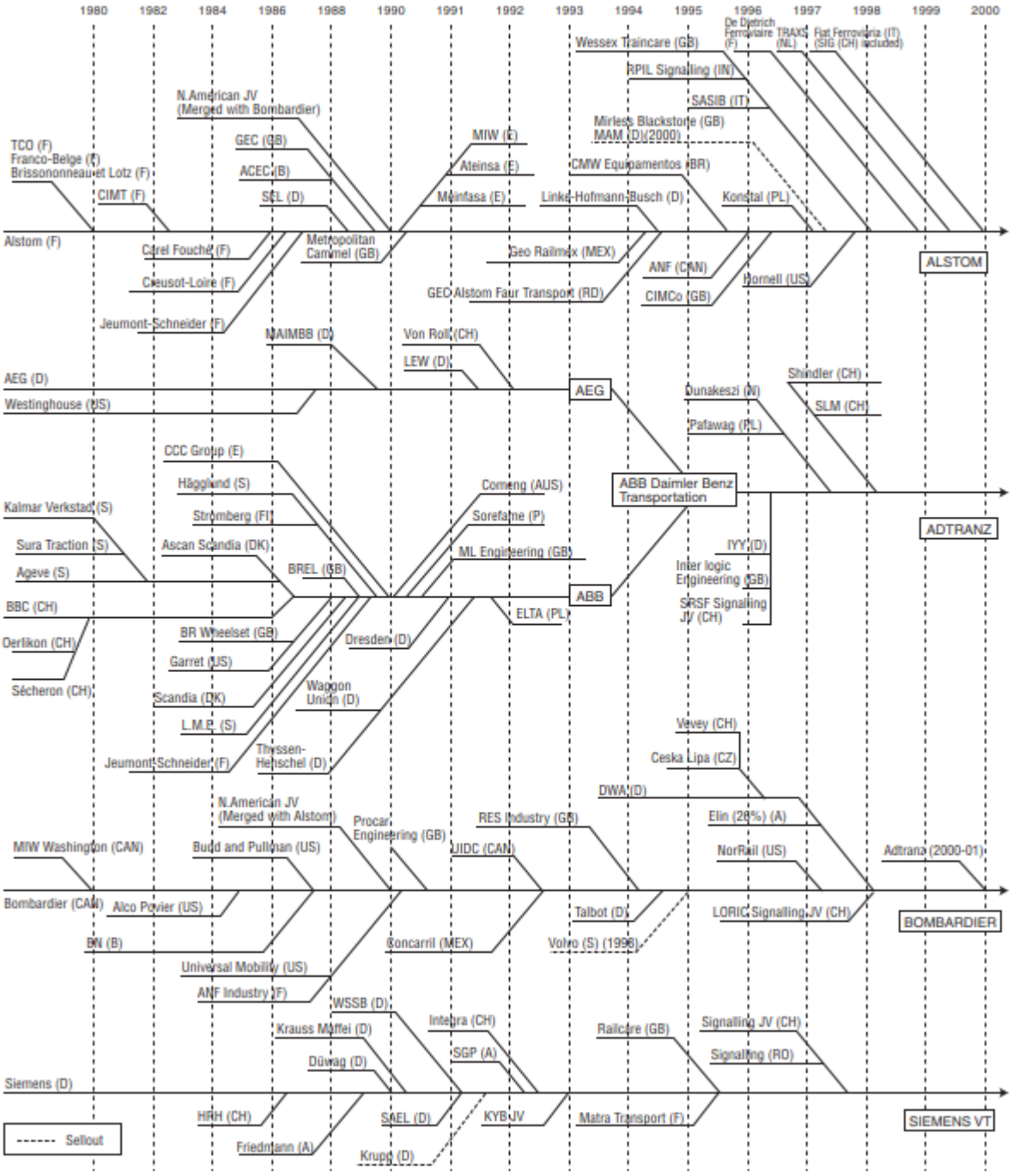
ANNEX

Additional information to Chapter 1 – Overview of rolling stock and relevant policy initiatives at EU scale

Figure A.1: Consolidation of the rolling stock market between 1980 and 2000[36]

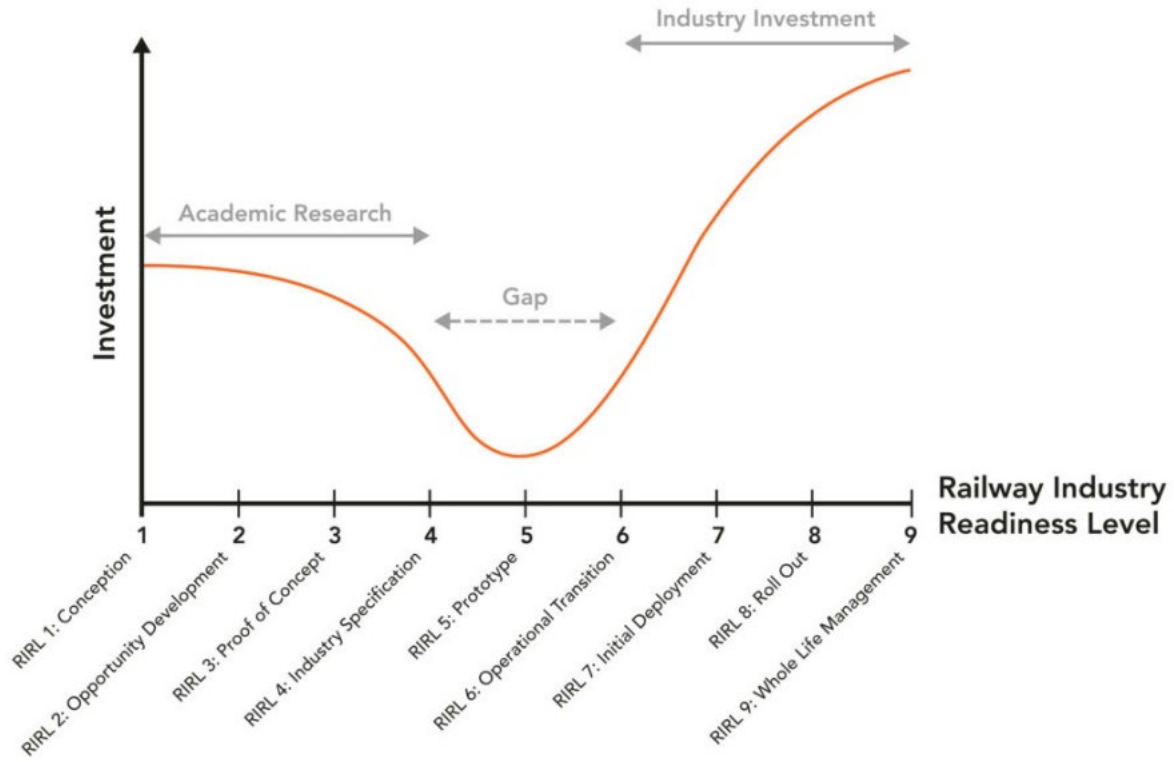


Source: (Sato, 2005)[37]

[36] A=Austria, AUS=Australia, B=Belgium, CAN=Canada, CH=Switzerland, CZ=Czech, D=Germany, DK=Denmark, E=Spain, F=France, FI=Finland, H=Hungary, GB=Great Britain, IN=Indonesia, IT=Italy, MEX=Mexico, N=Norway, NL=Netherlands, P=Portugal, PL=Poland, RO=Romania, RU=Russia, S=Sweden, US=United States.

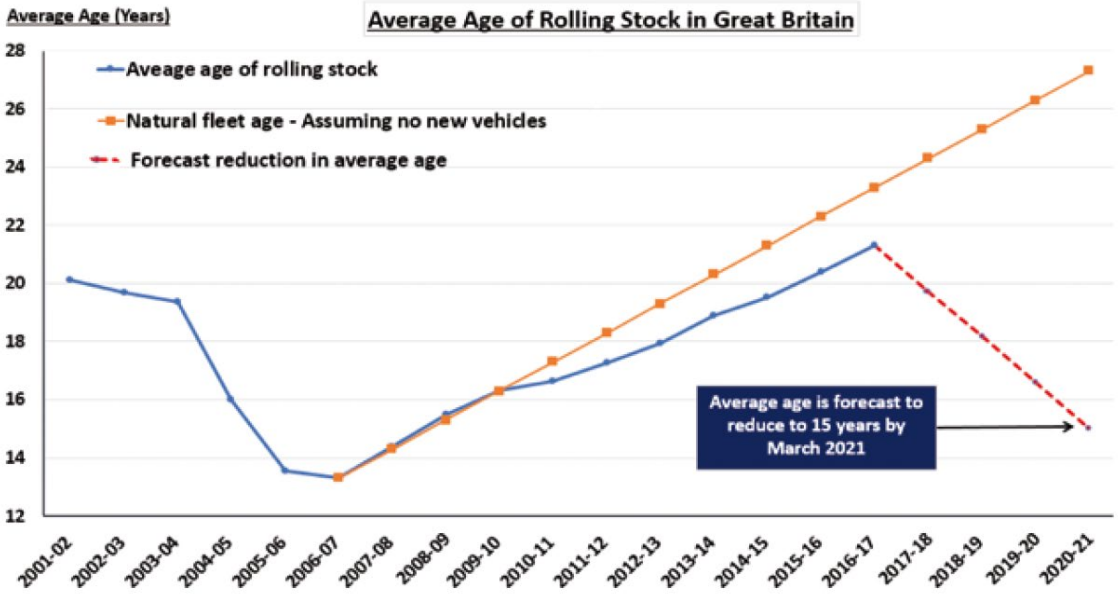
[37] Based on (Le Rail, 2000).

Figure A.2: Example of a detailed breakdown and analysis of rolling stock's life cycle stages



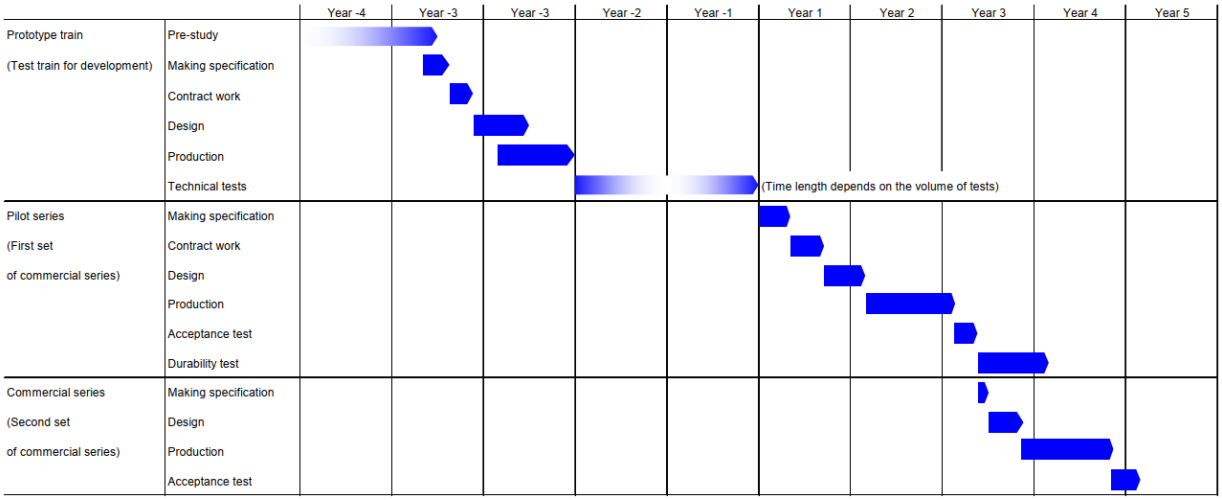
Source: (European Investment Bank, 2022)

Figure A.3: Example of a projection of the average age of the fleet and a forecast to reduce it



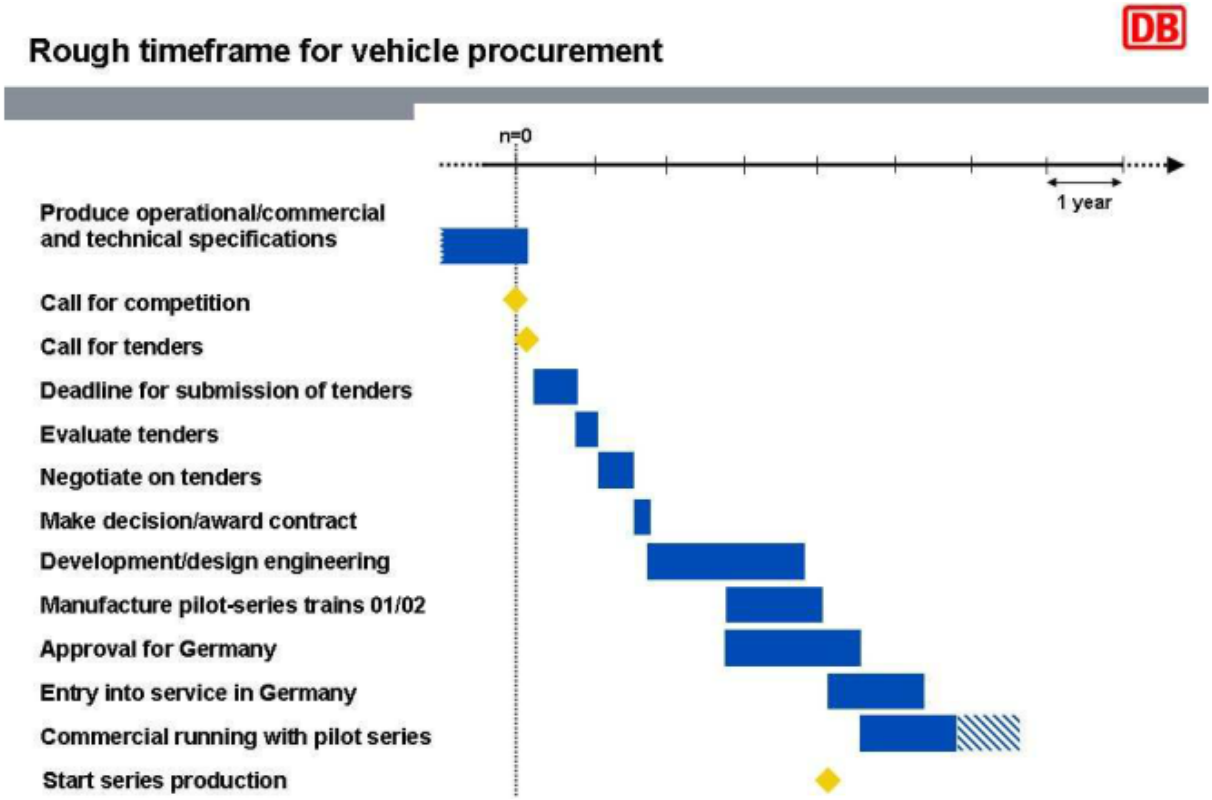
Source: (EVERSHOLT, et al., 2018)

Figure A.4: Example of a schedule for a new high-speed train in Japan



Source: (UIC, 2010)

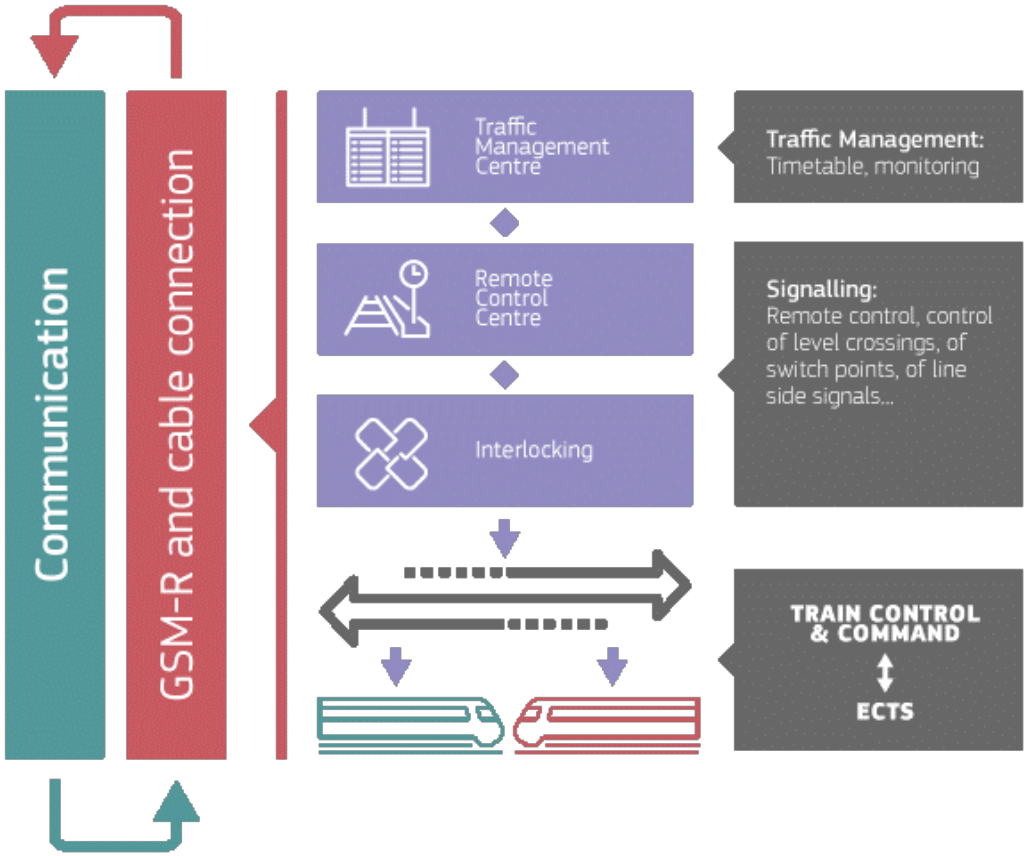
Figure A.5: Example of schedule for vehicle procurement in Germany



Source: (UIC, 2010)

Additional information to Chapter 2 – Relevant EU policy framework or regulatory activity

Figure A.6: How the ERTMS works

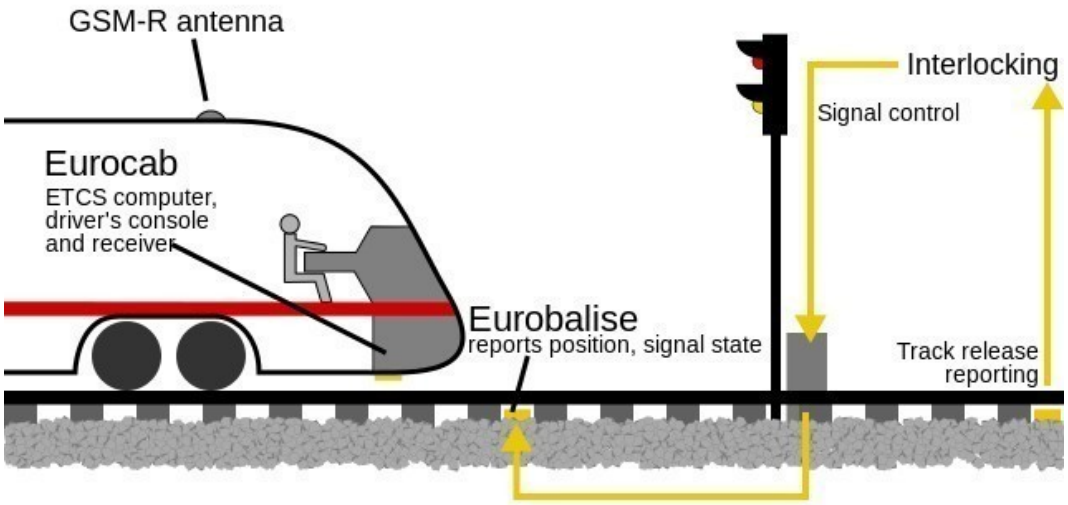


Source: European Commission website[38]

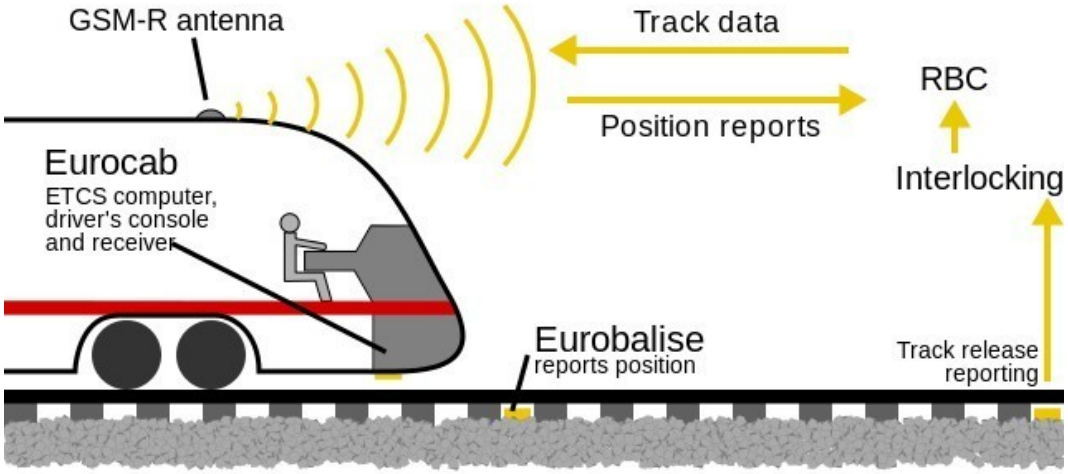
Figure A.7: How ETCS[39] and GSM-R work

Level 1 involves continuous supervision of train movement (i.e. the onboard computer is continuously supervising the maximum permitted speed and calculating the braking curve to the end of movement authority), while non-continuous communication occurs between train and trackside, generally through Eurobalises. Lineside signals are necessary. Train detection and train integrity checks (i.e. the train is complete and has not been accidentally split) are performed by trackside equipment beyond the scope of ERTMS.

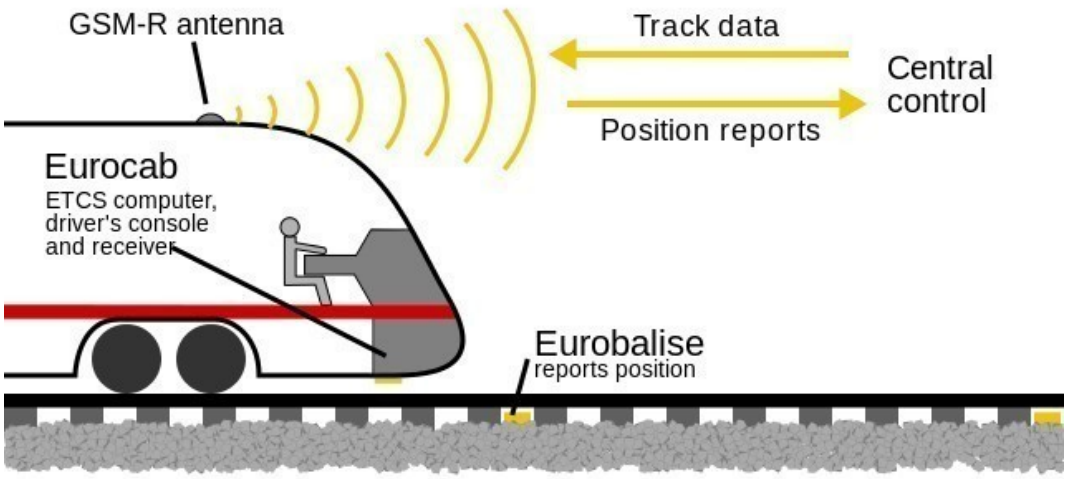
[38] See also https://transport.ec.europa.eu/transport-modes/rail/ertms/how-does-it-work_en.
[39] See also here for more information on ETCS.



Level 2 involves continuous supervision of train movement with constant communication via GSM-R between the train and trackside. Lineside signals are optional in this case and train detection and train integrity checks are performed by the trackside equipment beyond the scope of ERTMS.



Level 3 involves continuous train supervision with continuous communication between the train and trackside. The main difference with Level 2 is that train location and integrity are managed within the scope of the ERTMS system, i.e. there is no need for lineside signals or train detection systems on the trackside other than Eurobalises. Train integrity is supervised by the train.



Source: European Commission website[40]

Box A.1: Automatic Train Operation

As a track-guided transport system, railways are highly suitable for introducing automatic or even autonomous operations while maintaining a high level of safety and increasing infrastructure capacity (Landex, et al., 2019). **ATO is especially suitable for high-speed passenger transport, where certain tasks, such as accelerating and braking, can already be automated today if the infrastructure (both on the track and on the rolling stock) allows for it**. However, a driver still needs to be present and attentive. Four grades of automation (GoA) can be distinguished within the ATO technology and the higher the level, the more automated the train runs. Light rail projects operating in dedicated and small networks (i.e. metro lines) are becoming increasingly automated or even driverless[41], while real-world implementations of ATO technology in conventional railways are still limited.

In some European countries, **pilot projects have been launched to try autonomous train operations where no driver is needed anymore**, but field tests are still being conducted to verify their feasibility and effectiveness (Yin, et al., 2017). These pilot projects mostly focus on passenger trains and operate within a limited geographical scope. For European countries, a more comprehensive review of the developments in ATO technology for rail was elaborated in a report (Poulus, et al., 2018). (Singh, et al., 2017) identified a number of challenges for future development and deployment of autonomous trains, including design, operational, technology-related and human-related aspects. The overview in (IRRB and UIC, 2021) confirmed **ATO over ETCS as a mature solution for GoA 2 and pilot tests up to GoA4 planned at the beginning of 2023**. However, the steps from pilot test through prototype and demonstrator and eventually rollout may take a decade for mature industrial development.

[40] See also https://transport.ec.europa.eu/transport-modes/rail/ertms/how-does-it-work/etcs-levels-and-modes_en.
[41] UITP reported 42 cities operating automated lines, consisting of 7% of the total worldwide (UITP, 2018) and (UITP, 2019).

Box A.2: Digital Automatic Coupling[42]

In the European railway sector, almost all freight trains and their waggons are connected with screw couplers and coupled manually. Due to the manual effort involved, **the process of assembling a train is a time-consuming task**, as a coupler needs to connect all waggons by hand. Other disadvantages of the screw coupling mechanism are safety risks for the couplers and a limited towing capacity compared to other mechanisms. This is especially a burden in single waggon transport, as this requires a lot of shunting operations at yards. Other countries, like the USA and Russia, have implemented automatic coupling as a standard for years. The **advantages of DAC include reduced needs for operational staff on shunting yards, increased train lengths and weights, increased capacity on shunting yards by up to 40%**[43] **and shortened time requirements for brake tests** (estimated 10-40 minutes per train)[44].

According to Shift2Rail's research project FR8RAIL[45], an estimated transition plan for automatic couplers envisages that **all freight waggons in Europe** (i.e. 450 000 to 500 000) **could be coupled automatically within a 12-year period, namely at the latest by 2030**[46]. The research projects identified the price of the technology as the main driver of future developments[47].

42 See also here for more information on DAC.

43 See for example also here.

44 See https://sev-online.ch/de/aktuell/kontakt.sev/2022/der-schienengter-verkehr-hat-zukunft-202205-154230/

45 See D5.6 on the estimated migration plan for automatic couplers.

46 See https://rail-research.europa.eu/european-dac-delivery-programme/.

47 Shift2Rail projects FR8RAIL (see D5.1 on the State of the Art on Automatic Couplers) and estimates the target price for an Automatic Coupler with automation Level I in the range of EUR 1 300 to 1 500. This range price would ensure that the use of Automatic Couplers can be economically justified.

Additional information to Chapter 3 – EU rolling stock production

Table A.1: Overview of global manufacturers in rolling stock supply industry

Company	Consolidated Revenue (Fiscal Year 2020, EUR Million)	Home Jurisdiction	Government Ownership	% of Rail Activities in Consolidated Revenue	Estimated Global Supply Market Share in Supply	Estimated Global Market Share in Rolling Stock	Business Segment		
							Rolling Stock	Services	Signalling and Control
CRRR	31 964	China	> 50%	70	12.7	24.3	Yes	Yes	Yes
Wabtec	6 631	USA	No	99	3.7	8.2	Yes	Yes	Yes
Alstom	8 661	France	No	100	4.9	6.8	Yes	Yes	Yes
Siemens	56 339	Germany	No	16	5.1	6.8	Yes	Yes	Yes
Bombardier	12 576	Canada	No	55	3.9	6.4	Yes	Yes	Yes
Hitachi	66 697	Japan	No	7	2.6	5.1	Yes	Yes	Yes
Transmashholding	3 484	Russia	No	100	2.0	4.2	Yes	Yes	Yes
Stadler	2 951	Switzerland	No	100	1.7	4	Yes	No	Yes
Greenbrier	2 450	USA	No	100	1.4	3.1	Yes	Yes	No
CAF	2 724	Spain	No	74	1.1	1.8	Yes	Yes	Yes
Hyundai Rotem	2 029	Korea	No	52	0.6	1.6	Yes	Yes	Yes
Trinity	1 754	USA	No	100	1.0	1.6	Yes	Yes	No
Kawasaki HI	11 364	Japan	No	9	0.6	1.5	Yes	Yes	No
Nippon Sharyo	777	Japan	No	78	0.3	0.9	Yes	Yes	No
Talgo	480	Spain	No	100	0.3	0.6	Yes	Yes	No
Travagonka	407	Slovakia	No	100	0.2	0.6	Yes	Yes	No
NEWAG	290	Poland	No	91	0.2	0.4	Yes	Yes	No
Titagarh Wagons	174	India	No	99	0.1	0.3	Yes	Yes	No
PT INKA	142	Indonesia	100%	100	0.1	0.2	Yes	Yes	No

Source: Compilation of the authors based on (OECD, 2023)

Box A.3: Focus on the rail supply industry of Australia and the USA

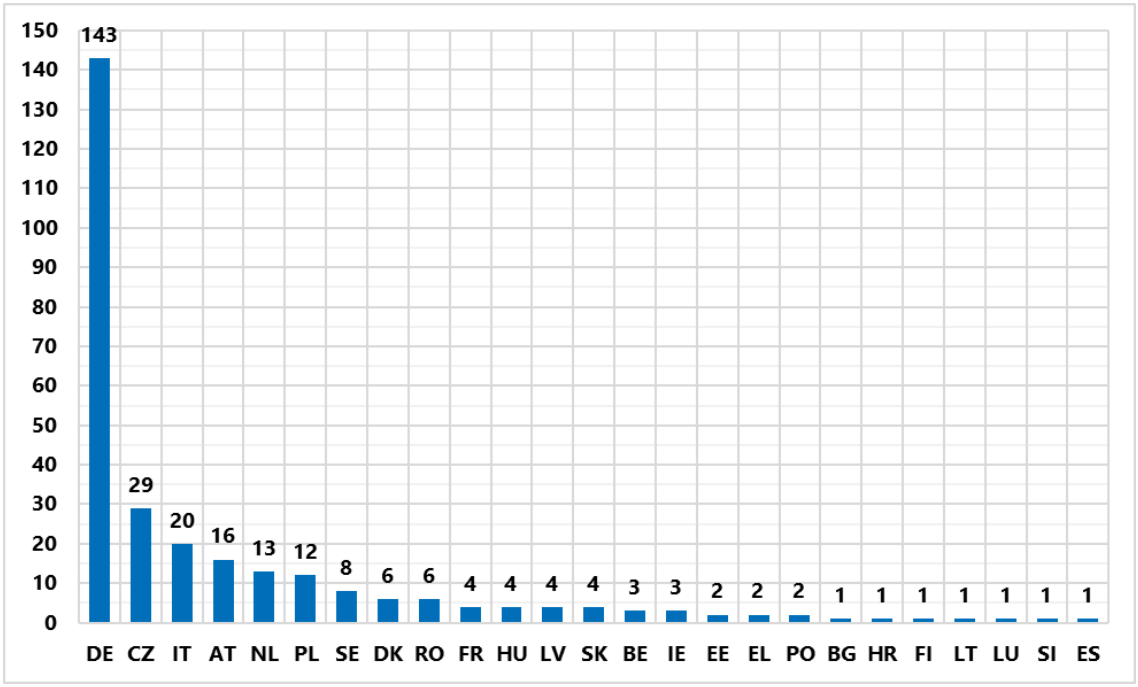
In **Australia,** the rail supply industry generates USD 30 billion (i.e. EUR ~29 billion) on an annual basis and more than 165 000 are employed in this sector. According to (Oxford Economics, 2021), the rail industry supply added 20 000 employees (i.e. +16%) between 2019 and 2021, driven by a number of new projects in passenger and freight rail transport and upgrades to the existing network. Moreover, other investments have been undertaken to replace ageing equipment and systems reaching the end of their life cycle. Many of the suppliers of the railway sector also provide goods and services to other sectors of the economy and more than 1 200 have been identified with at least one connection

to the rail supply industry (see also Table 3.1). Notably, one third of the industry that is active in the supply chain activity focusses on infrastructure construction, one quarter deals with manufacturing of rolling stock and equipment and others provide operations and procurement services. As regards the balance between imports and exports of goods, the majority of the entities in the Australian rail supply industries do not export goods overseas because they are domestically focused or have not assessed their products as suitable for an exporting context.

In 2020, the **rail supply industry of the USA** directly employed approximately 240 000 workers and produced USD 27.7 billion (i.e. EUR ~24.3 billion) of GDP (Oxford Economics, 2023). The indirect and inducted impacts to the economy are estimated to be equal to USD 22.2 billion (i.e. EUR ~19.5 billion) and USD 25.9 billion (i.e. EUR ~22.7 billion), respectively, involving 934 000 workers in total. Rail suppliers enable the rail transport industry to operate by manufacturing railcars and locomotives, and critical rail infrastructure such as signals, rail ties and railway maintenance equipment. The largest share of the American industry consists of new and rebuilt locomotives (i.e. 30%), followed by parts and accessories (i.e. 22%), new freight waggons and passenger railcars (i.e. 20%), railcar maintenance (i.e. 14%) and others non-related railcar equipment (i.e. 14%). The value of products like track signalling is not captured because it could not be identified in government statistics; however, 11% of the rolling stock value sold by the industry was accounted as export in 2020 (i.e. USD 1.3 billion, i.e. EUR ~1.1 billion) (Oxford Economics, 2023).

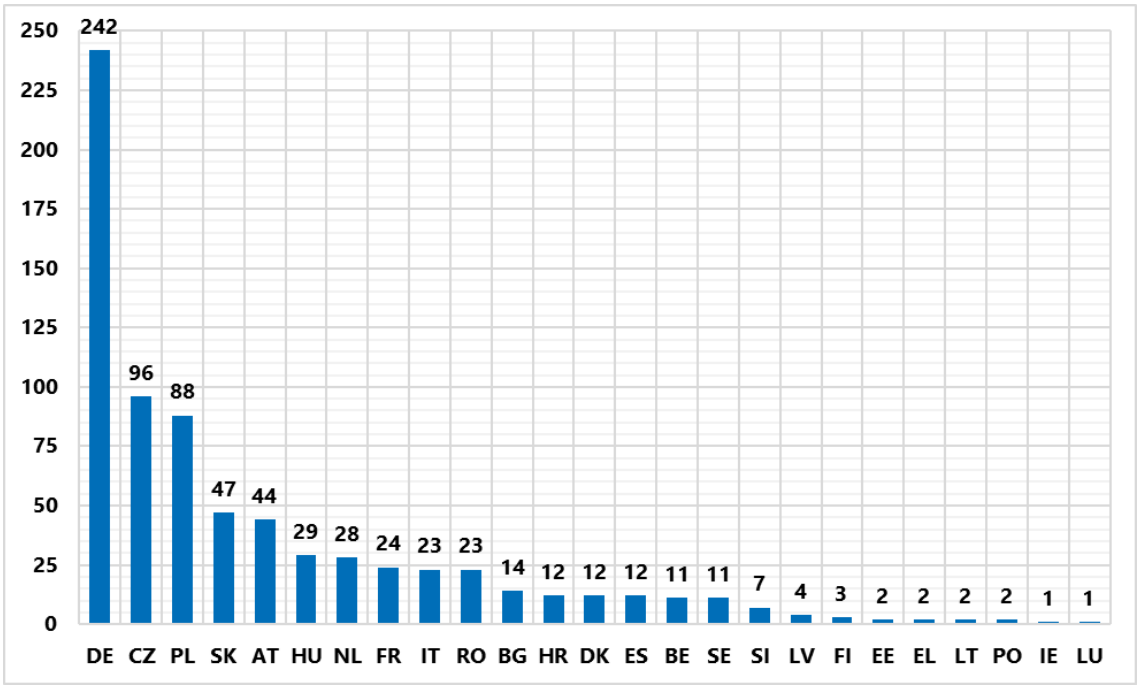
Source: elaboration of the authors based on (Oxford Economics, 2021) and (Oxford Economics, 2023)

Figure A.8 Number of passenger railway undertakings by Member State (2020)



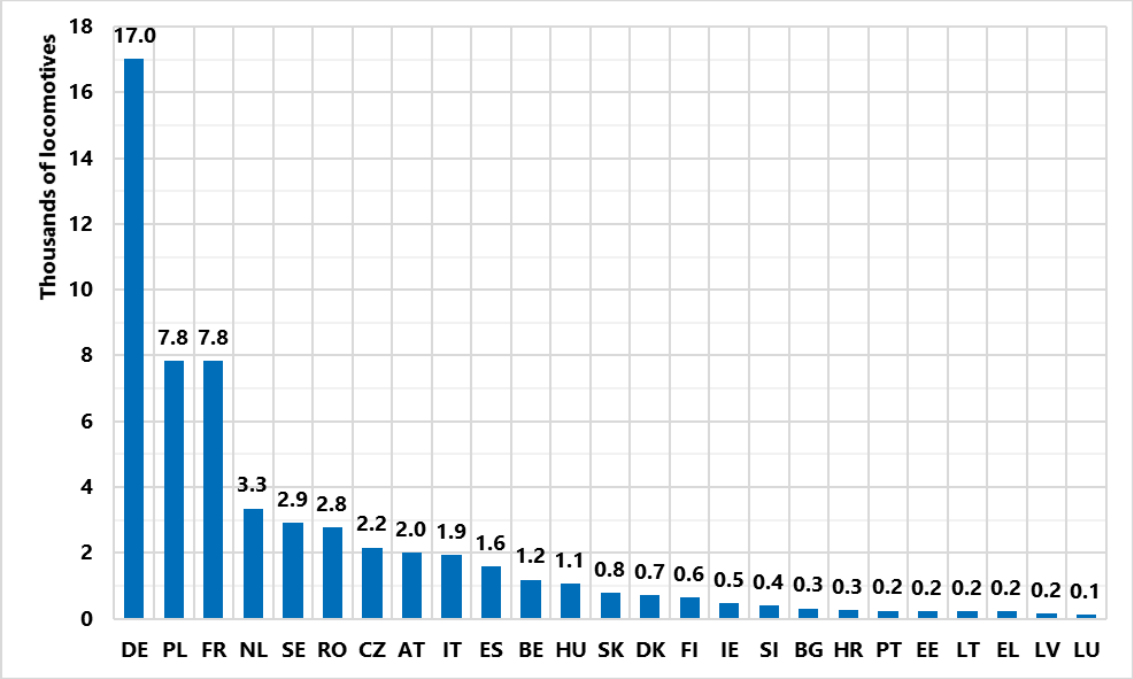
Source: Elaboration of the authors based on (European Commission, 2022c)

Figure A.9 Number of freight railway undertakings by Member State (2020)



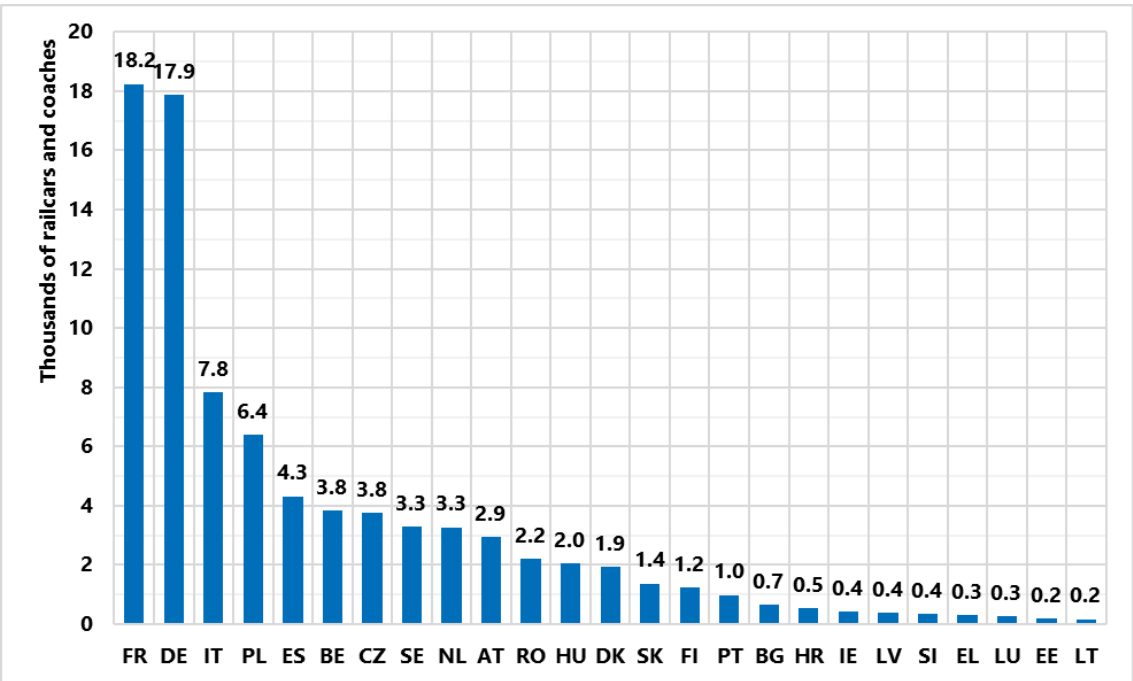
Source: Elaboration of the authors based on (European Commission, 2022c)

Figure A.10: Number of locomotives by Member State (2020)



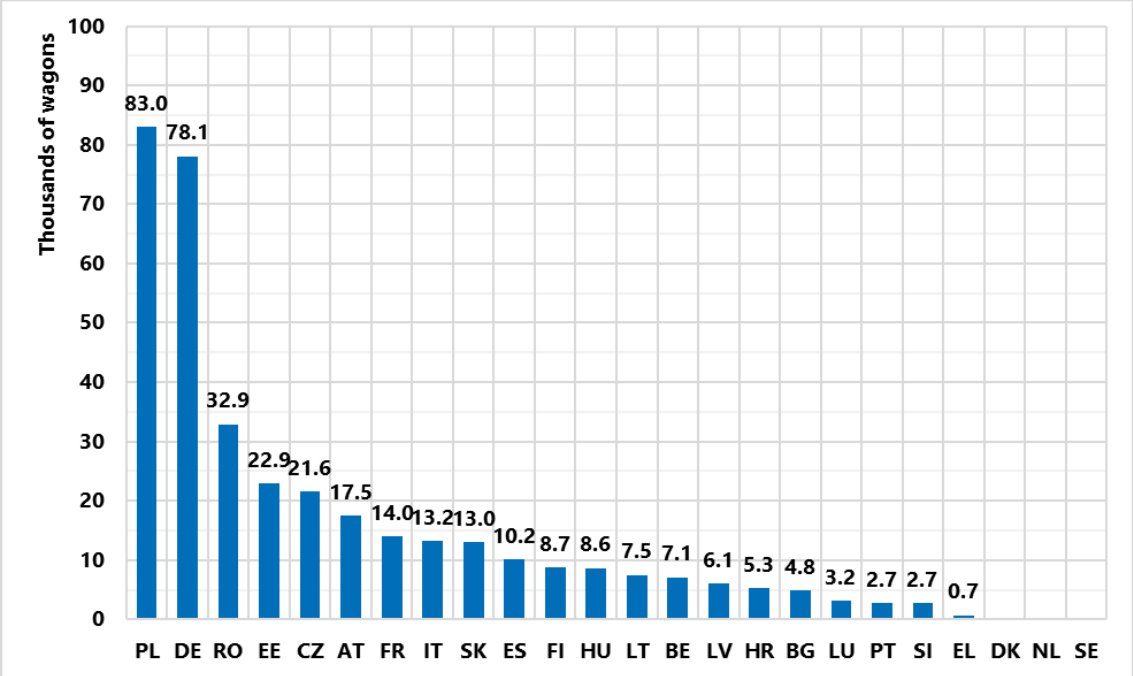
Source: Elaboration of the authors based on (European Commission, 2022c)

Figure A.11: Number of railcars and coaches by Member State (2020)



Source: Elaboration of the authors based on (European Commission, 2022c)

Figure A.12: Number of waggons by Member State (2020)[48]



Source: Elaboration of the authors based on (European Commission, 2022c)

Box A.4: Focus on high-speed rolling stock

High-speed rolling stock is a specific segment of passenger rail transport. The global development of the high-speed network was relatively steady until 2008, but afterwards it rapidly expanded for the construction of new lines in China. **At global level, in 2020,** (UIC, 2023) **reported 56 157 km of high-speed lines in commercial operation of which 44 428 km are in the Asia-Pacific region** (i.e. 79.1% of the total reported). The **EU's high-speed network, in 2020, extended to 11 526 km** (i.e. 19.5% of the total) and increased by almost 1 500 km between 2015 and 2020. Spain is the Member State with the largest high-speed network with almost 3 500 line-kilometres in 2020. No new lines were added to the relatively small networks in Poland, Belgium and the Netherlands between 2015 and 2020. The largest developments since 2015 were in France and Spain, with 676 and 485 additional km of lines respectively. According to European Commission's TEN-T development plan, when considering also the length of the high-speed lines currently reported under construction, the estimated EU's high-speed network will increase to 13 630 km in 2040[49].

Before COVID-19, **global high-speed transport grew regularly between 2010 and 2019** (transport activities measured in pax-km). According to UIC's figures (UIC, 2023), **China was by far the country with the largest high-speed transport activities** (i.e. 74%), followed by Japan (10%) and France, Germany, Italy and Spain (i.e. 13% together) (see also Figure A.13)[50]. When it comes to the **rolling stock, at global level the high-speed fleet consists of approximately 6 500 trains**. Not surprisingly, **the largest share is operated in China** (i.e. 54.7% or 3 556 trains), **followed by EU**

[48] Data not available for Denmark, the Netherlands and Sweden.

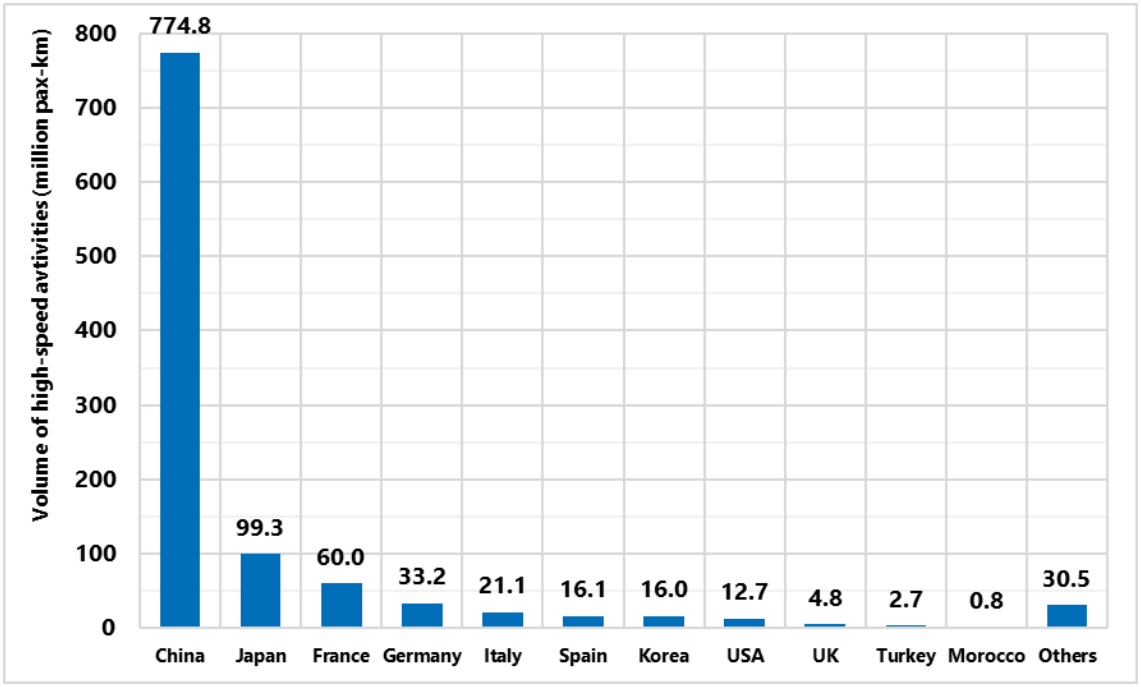
[49] It is worth observing that the extension of additional high-speed lines might be underreported because they operate high-speed services on a mixed operating model (e.g., Germany). France and Spain, as well as Italy, have developed dedicated high-speed lines, where these services are not mixed with others.

[50] (UIC, 2023) reports also that, in 2020, in China 1.6 billion passenger were transported on high-speed trains, whereas 154 million in Japan, 64.4 million in France, 55.0 million in Germany, 40.3 million in the Republic of Korea and 14.9 in Spain.

Member States (i.e. 26.5% or 1 723 trains) (see also Figure A.14).

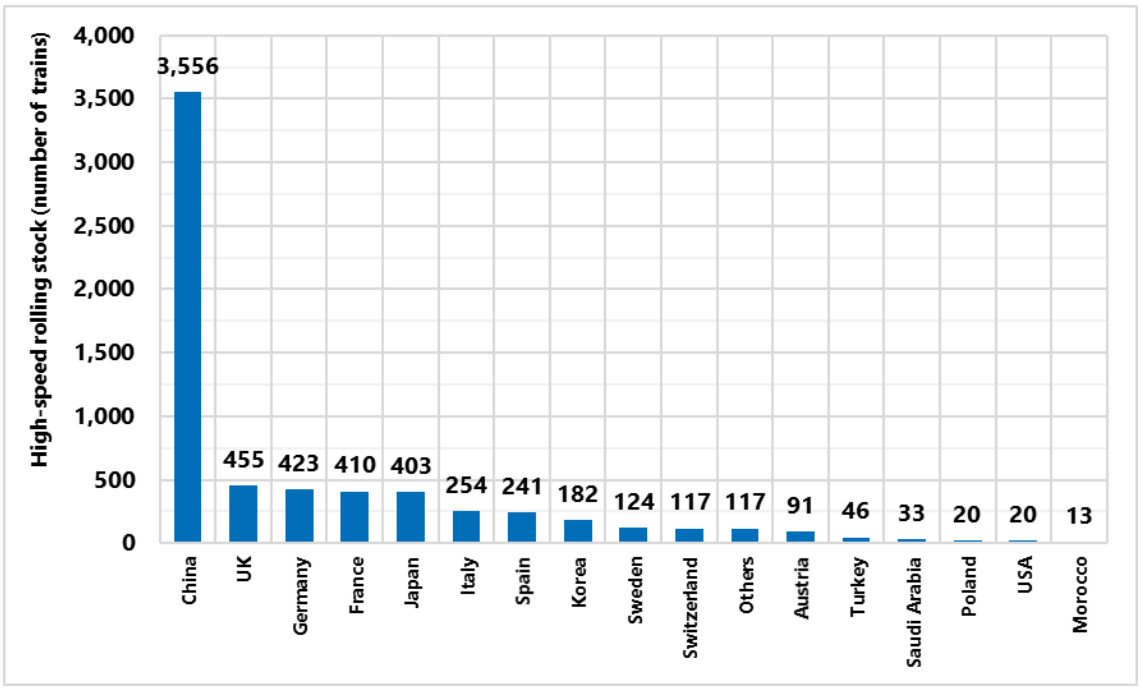
Source: elaboration of the authors based on (European Commission, 2022c) and (UIC, 2023)

Figure A.13: Global high-speed transport activities (2020)



Source: Elaboration of the authors based on (UIC, 2023)

Figure A.14: Global high-speed rolling stock (2020)



Source: Elaboration of the authors based on (UIC, 2023)

Table A.2: Number of enterprises manufacturing locomotives and rolling stock

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	10	7	9	10	8	9	9	7	10	11
Belgium	9	9	9	9	9	9	9	8	7	7
Bulgaria	13	13	12	12	13	12	10	9	11	10
Croatia	14	13	11	12	12	13	12	11	9	9
Cyprus	0	0	0	0	0	0	0	0	0	0
Czechia	48	50	47	49	52	57	60	59	60	65
Denmark	4	5	4	5	5	6	7	7	5	4
Estonia	3	1	0	0	0	1	1	1	2	1
Finland	3	3	2	2	2	1	3	3	3	3
France	41	72	28	39	42	39	32	29	26	22
Germany	75	82	81	68	100	102	91	111	107	134
Greece	6	6	6	6	4	5	4	6	4	4
Hungary	44	42	38	37	37	37	37	38	41	41
Ireland	0	0	0	0	0	0	0	0	0	0
Italy	122	119	139	132	134	149	138	131	119	110
Latvia	4	5	5	7	10	8	8	7	7	4
Lithuania	1	1	1	1	2	2	2	1	3	2
Luxembourg	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0
Netherlands	17	15	16	15	18	15	18	22	18	15
Poland	137	114	82	106	93	100	97	149	183	192
Portugal	3	4	4	4	4	4	4	4	3	4
Romania	54	50	48	49	42	44	42	38	40	39
Slovakia	15	14	13	13	11	8	9	9	8	7
Slovenia	4	4	3	3	2	2	2	3	3	3
Spain	82	80	55	81	70	77	78	66	64	67
Sweden	32	34	37	39	40	37	36	24	22	25
EU27[51]	**741**	**743**	**650**	**699**	**710**	**737**	**711**	**743**	**763**	**783**

Source: compilation of the authors based on Eurostat

[51] In the Eurostat database the value at EU27 level might not correspond to the total value of the Member States. Missing values in the original source of the information are indicated as n. a. (i.e. not available).

Table A.3: Number of employees in manufacturing locomotives and rolling stock

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Belgium	n. a.	n. a.	n. a.	766	689	626	562	472	552	552
Bulgaria	2 135	2 311	2 156	2 057	1 954	2 028	1 948	2 100	2 386	2 488
Croatia	1 126	618		571	650	1 088	1 080	1 221	1 060	926
Cyprus	0	0	0	0	0	0	0	0	0	0
Czechia	10 234	10 543	10 486	10 410	10 393	10 356	10 146	10 306	10 044	10 009
Denmark	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	57	n. a.	n. a.	n. a.
Estonia	n. a.	n. a.	0	0	0	n. a.	n. a.	n. a.	n. a.	n. a.
Finland	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
France	n. a.	14 857	14 990	14 768	14 068	13 047	13 018	n. a.	n. a.	n. a.
Germany	19 400	20 198	21 034	21 780	22 124	20 620	19 785	28 796	20 531	17 655
Greece	9	n. a.	n. a.	n. a.	9	11	6	7	4	4
Hungary	3 633	3 259	2 960	3 372	n. a.	n. a.	n. a.	3 711	4 908	n. a.
Ireland	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Italy	n. a.	n. a.	n. a.	10 745	n. a.	n. a.	10 366	n. a.	10 999	10 617
Latvia	1 090	1 165	1 176	1 201	1 043	749	582	687	686	634
Lithuania	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Luxembourg	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0
Netherlands	351	305	306	317	256	253	248	255	317	314
Poland	10 078	10 135	11 271	11 182	11 207	10 814	10 657	n. a.	12 293	13 675
Portugal				79	73	76	85	86	87	100
Romania	7 756	7 265	6 351	6 534	5 981	5 531	5 511	5 507	5 551	5 624
Slovakia	3 207	3 305	3 160	3 439	3 346	2 918	2 873	3 056	3 269	3 455
Slovenia	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Spain	11 148	11 078	11 089	10 852	10 832	11 302	11 639	12 348	12 004	12 572
Sweden	n. a.	n. a.	n. a.	2 203	2 806	2 685	2 515	2 506	2 225	2 338
EU27[52]	**101 307**	**102 702**	**103 130**	**104 221**	**102 474**	**99 209**	**98 237**	**113 617**	**107 726**	**108 878**

Source: compilation of the authors based on Eurostat

[52] In Eurostat database the value at EU27 level might not correspond to the total value of the Member States. Missing values in the original source of the information are indicated as n. a. (i.e., not available).

Table A.4: Number of enterprises in repairing and maintaining other transport equipment

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	7	11	16	16	16	16	33	39	62	78
Belgium	20	14	11	27	23	32	35	32	52	56
Bulgaria	132	158	176	188	214	218	234	257	267	249
Croatia	13	12	16	13	14	14	15	14	21	21
Cyprus	0	0	0	0	0	0	0	0	0	0
Czechia	234	234	234	234	234	264	338	394	450	507
Denmark	20	27	19	19	17	13	15	18	19	16
Estonia	22	27	22	25	23	20	21	21	28	28
Finland	10	10	14	12	13	16	22	24	31	39
France	79	73	131	120	99	113	94	86	89	88
Germany	469	510	527	458	898	849	975	1,039	1,139	1,233
Greece	9	9	11	13	9	10	86	109	19	12
Hungary	62	68	66	73	89	83	79	80	82	81
Ireland	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Italy	132	126	123	122	129	133	127	139	132	140
Latvia	37	51	61	71	71	78	82	82	78	79
Lithuania	27	29	32	37	45	53	56	60	84	106
Luxembourg	1	1	1	1	1	1	1	1	1	1
Malta	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	6	14
Netherlands	23	48	100	115	138	143	147	155	158	163
Poland	248	259	288	276	256	299	289	338	340	348
Portugal	85	89	96	99	104	100	102	101	102	72
Romania	81	83	83	90	81	77	76	67	67	65
Slovakia	10	11	12	10	12	11	12	12	14	10
Slovenia	9	10	16	20	20	20	19	17	18	19
Spain	46	42	39	76	48	48	109	207	216	195
Sweden	47	49	54	55	60	68	74	58	58	59
EU27[53]	**1 714**	**1 873**	**2 098**	**2 142**	**2 600**	**2 700**	**3 000**	**3 400**	**3 500**	**3 700**

Source: compilation of the authors based on Eurostat

[53] In the Eurostat database the value at EU27 level might not correspond to the total value of the Member States. Missing values in the original source of the information are indicated as n. a. (i.e. not available).

Table A.5: Number of employees in repairing and maintaining other transport equipment

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	3 510	3 473	3 429	3 415	3 415	3 479	3 562	122	152	187
Belgium	147	193	225	204	227	191	198	195	232	246
Bulgaria	463	572	578	570	453	547	407	464	470	504
Croatia	2 832	2 661	2 378	2 012	1 724	1 626	1 565	1 572	1 355	1 096
Cyprus	0	0	0	0	0	0	0	0	0	0
Czechia	n. a.	n. a.	n. a.	n. a.	2 158	2 576	2 744	2 809	3 849	3 758
Denmark	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Estonia	n. a.	n. a.	337	360	n. a.	266	241	n. a.	n. a.	n. a.
Finland	84	83	42	47	44	564	52	65	73	65
France	2 061	1 544	1 724	n. a.	n. a.	1 778	1 207	2 031	1 539	915
Germany	14 314	14 632	14 777	14 261	14 980	13 814	14 788	14 325	8 414	7 844
Greece	38	15	17	634	540	624	636	660	16	17
Hungary	5 750	6 001	5 824	1 343	1 334	1 721	2 136	1 919	2 071	2 183
Ireland	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Italy	2 928	2 442	2 794	2 595	2 888	3 001	3 079	3 355	3 926	4 510
Latvia	1 844	1 976	2 019	2 051	1 680	1 532	1 444	174	177	160
Lithuania	589	611	613	620	586	528	1 104	97	138	154
Luxembourg	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Malta	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	14	21
Netherlands	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Poland	9 214	9 583	7 925	8 772	8 440	7 994	8 829	5 780	5 582	4 252
Portugal	1 570	1 338	1 285	1 285	1 236	1 271	1 303	1 559	1 699	735
Romania	7 078	7 232	7 565	7 162	6 425	5 919	5 907	5 967	6 042	6 136
Slovakia	1 995	2 075	2 058	2 131	2 114	2 016	1 858	1 798	1 813	1 626
Slovenia	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Spain	2 985	2 746	2 622	6 094	6 199	6 279	6 464	6 704	7 212	7 489
Sweden	3 127	3 121	2 991	3 000	2 850	2 841	3 060	2 313	2 537	2 460
EU27[54]	**70 245**	**71 083**	**69 313**	**110 783**	**87 272**	**65 911**	**67 453**	**56 776**	**52 228**	**49 007**

Source: compilation of the authors based on Eurostat

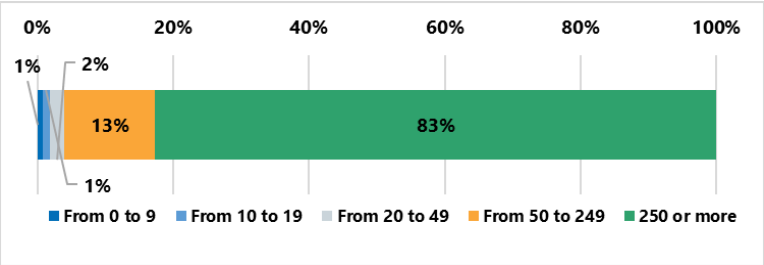
[54] In the Eurostat database the value at EU27 level might not correspond to the total value of the Member States. Missing values in the original source of the information are indicated as n. a. (i.e. not available).

Box A.5: SME[55] in the rail supply industry

SMEs are economic entities relevant to the objectives of the Europe 2020 Strategy, because they are deemed engines for growth and job creation. However, their competitiveness is affected by a limited exploitation of international opportunities and innovation prospects in the Single Market and beyond. **The European Commission promotes and supports SMEs' economic activities outside the EU,** as part of the Industrial policy strategy and Market Access Strategy. By applying the SME's definition, the share of this type of economic entities is found relatively small in the Commission's report of the expert group on the competitiveness of the rail supply industry (European Commission, 2019d) and elaborating on Eurostat data.

As Figure 3. shows, the share of **SMEs involved in manufacturing locomotives and rolling stock is in the range 16-18% for the time period between 2019 and 2020**. For rail infrastructure, given the high degree of specialisation and intensity of capital needed, only 17% of them were SMEs. Compared to the other two sectors, **the segment of signalling and electrification shows a slightly higher share of SMEs, equal to 21%** (UNIFE, 2021).

Figure 3.6: Share of companies manufacturing locomotives and rolling stock by number of employees (average value for the years 2019 and 2020)

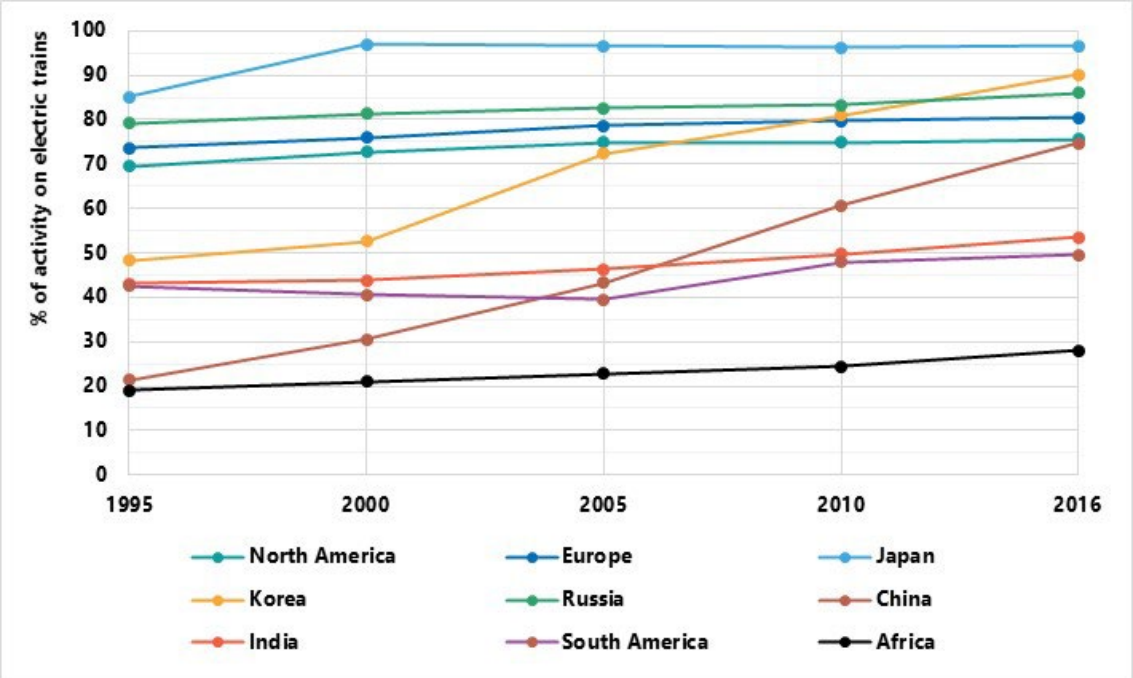


Source: elaboration of the authors based on the Eurostat data and (European Commission, 2019d)

[55] According to Article 2 of the Commission Recommendation of 6 May 2003 (Official Journal of the European Union, 2003), an SME is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million. Within the SME category, a small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 10 million. Within the SME category, a micro-enterprise is defined as an enterprise which employs fewer than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million.

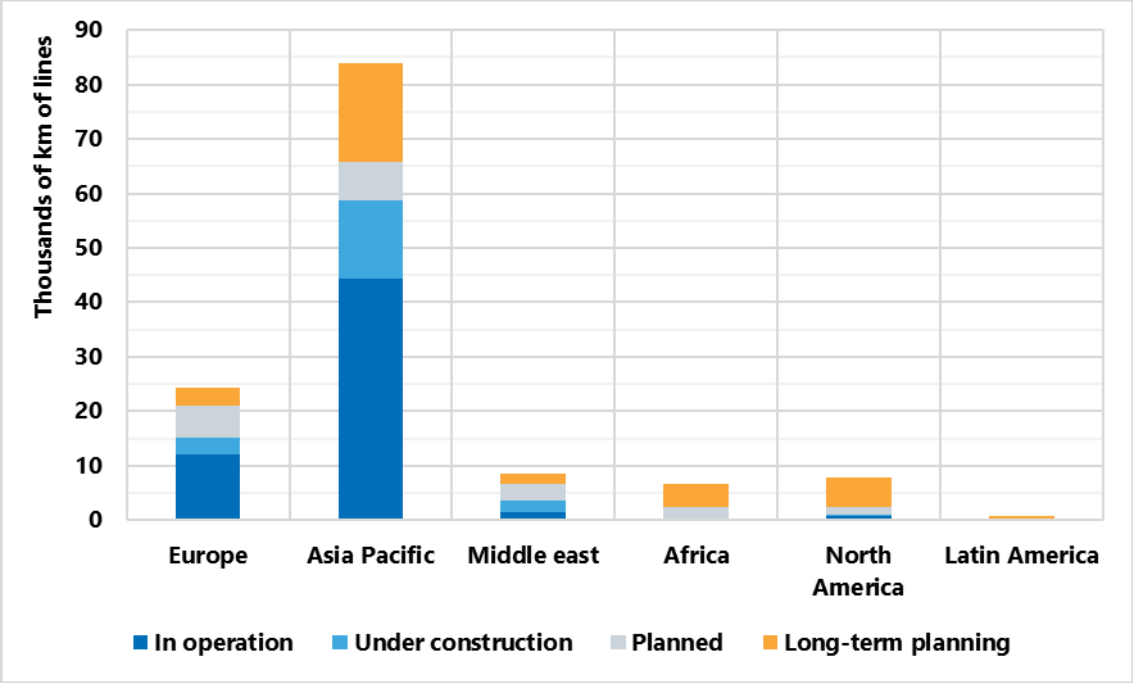
Additional information to Chapter 4 – Demand for rolling stock based on EU policy

Figure A.15: Share of activity on electric trains by region of the world (1995-2016)



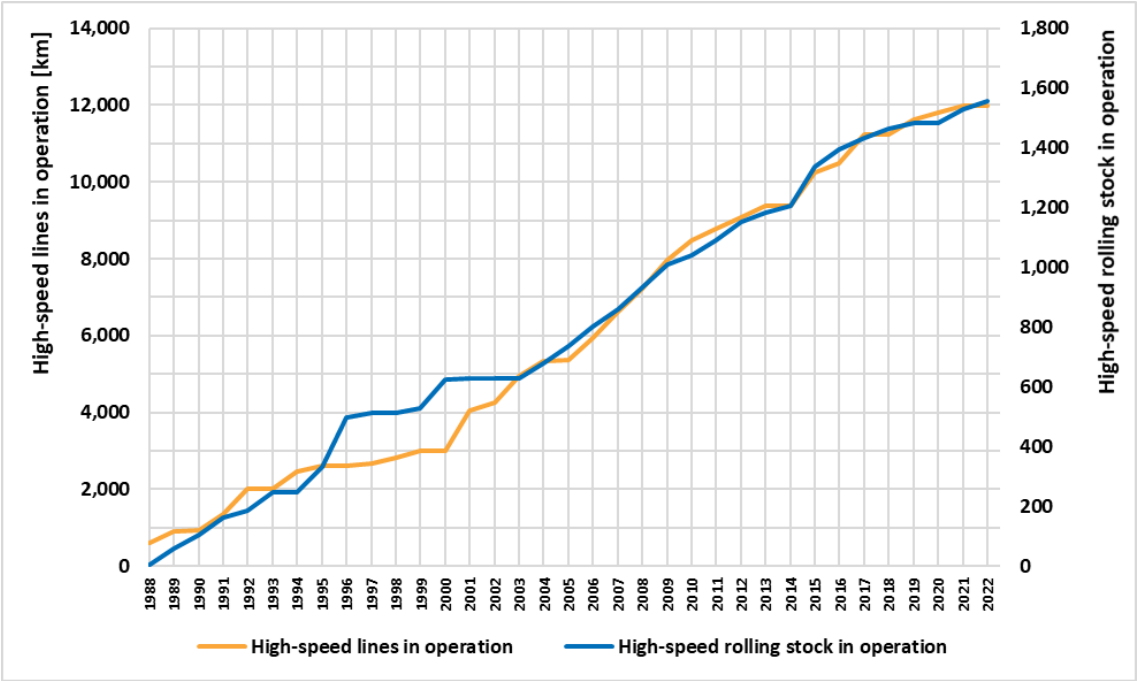
Source: elaboration of the authors based on (IEA, 2019)

Figure A.16: Forecast of global high-speed rail network development



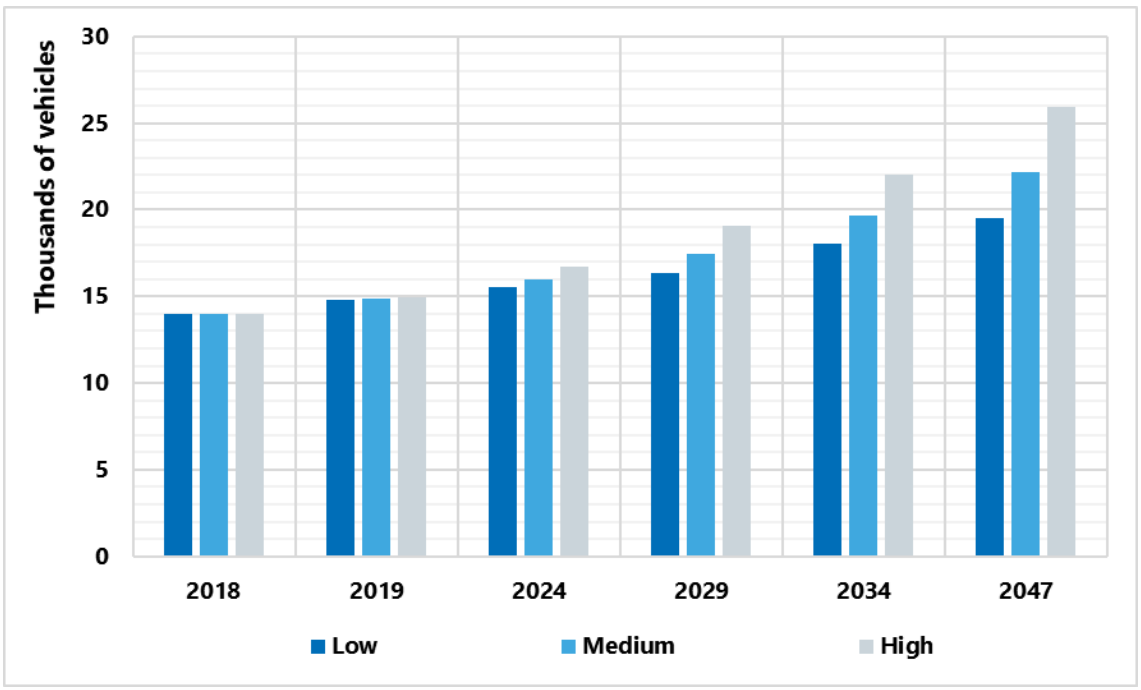
Source: elaboration of the authors based on (UIC, 2021)

Figure A.17: Development of high-speed network and rolling stock in the EU (1998-2022)



Source: elaboration of the authors based on (UIC, 2021)

Figure A.18: Projection of the national passenger fleet in the UK (2018-2047)[56]



Source: elaboration of the authors based on (EVERSHOLT, et al., 2018)

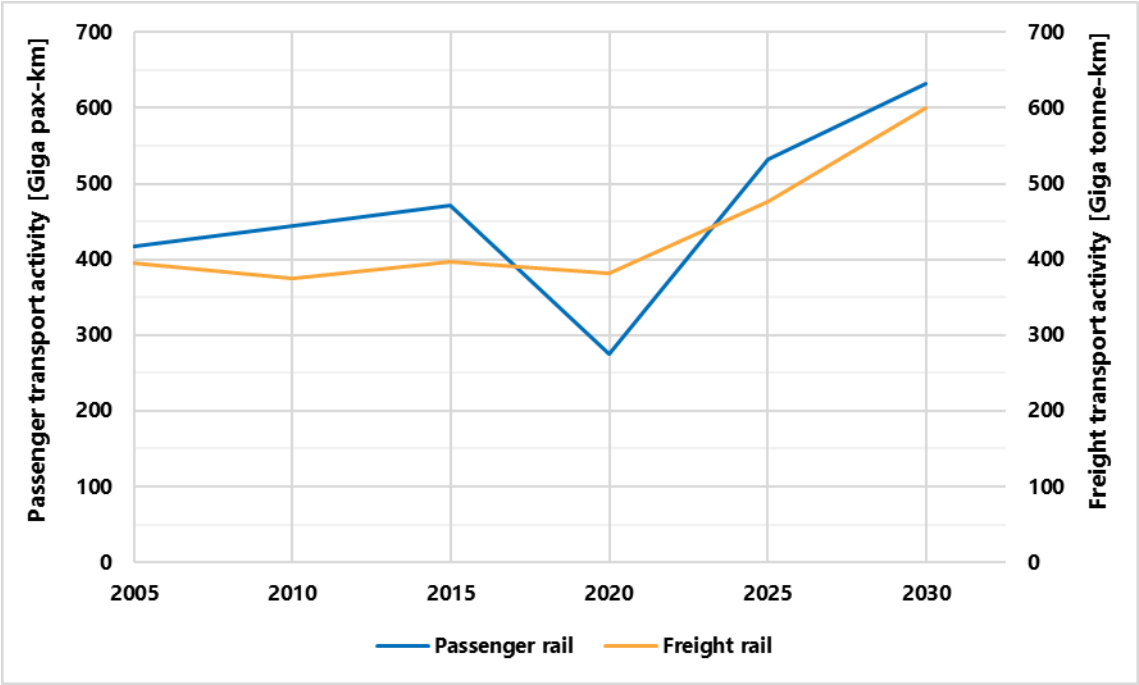
[56] Detailed projections are provided by the type of rolling stock: shorter distance self-powered, middle distance self-powered, long distance self-powered, shorter distance electric, middle distance electric, long distance electric and bi-mode and very high-speed electric.

Table A.6: Existing forecast for freight wagons

Wagon Type	Product Transported	Growth Rate (Average % 2021-2035)	Drivers and Risks
Open	Scrap, wood, solid mineral fuel	• - 2.7% coal and ignite • + 1.5% intermediate goods	**Drivers:** diversified nature of end-markets underpins demand fundamentals **Risks:** Europe committed to phase out coal power plants by 2030 reducing demand for coal.
Hoppers	Fertilisers, grain, cement and sand	• + 1.1% basic chemicals and fertilisers • + 0.5% agriculture • + 2.9% ceramic, clay and refractory products	**Drivers:** chemicals underpinned by solid demand. Diversified profile of goods transported supports the demand for hoppers. **Risks:** Cyclicality of construction industry may result in volatility of some inputs transported by rail. Fertilisers potentially subject to regulatory risks.
Flat	Metal sheet, building materials	• +1.5% construction • + 2.0% general purpose machinery • +1.9 manufacturing	**Drivers:** under EU renovation wave, renovation rates of buildings should double by 2030, supporting the building and construction industry. **Risks:** Cyclicality of construction industry may trigger volatility in demand profile.
Covered	Palletised consumer goods	• + 1.5% packaged food • + 1.8 beverages	**Drivers:** Diversified product base supports demand profile and long-term growth. **Risks:** Competition with road transport, particularly for food segment and in case of new green road transport solutions
Tank	Liquid and gaseous commodities	• - 4.9% oil and natural gas • + 1.8% chemical and pharmaceuticals • + 1.4% rubber and plastics	**Drivers:** Growth of tank waggons expected to be driven by robust chemical demand and partial shift of chemical industry to Asia. **Risks:** Long-term structural decline in oil industry anticipated to cap growth in tank segment.
Intermodal	Large containers	• + 2.2% consumer durables • + 2.1% domestic appliances • + 2.5% computers and office equipment	**Drivers:** Development of large logistics hubs with integrated supply chains support the growth of intermodal waggons. Policy support of multimodal freight transport should drive further growth. **Risks:** Onshoring of finished goods production may cap growth. 3D printing is a long-term risk.
Specialised	Refrigerated food	• + 1.5% food	**Drivers:** Labour supply (e.g. shortage of truck drivers) and fuel price volatility may drive shift from road to rail for refrigerated food. **Risks:** Road remains the main transport solution for refrigerated products, expected to accelerate further with new green road solutions.

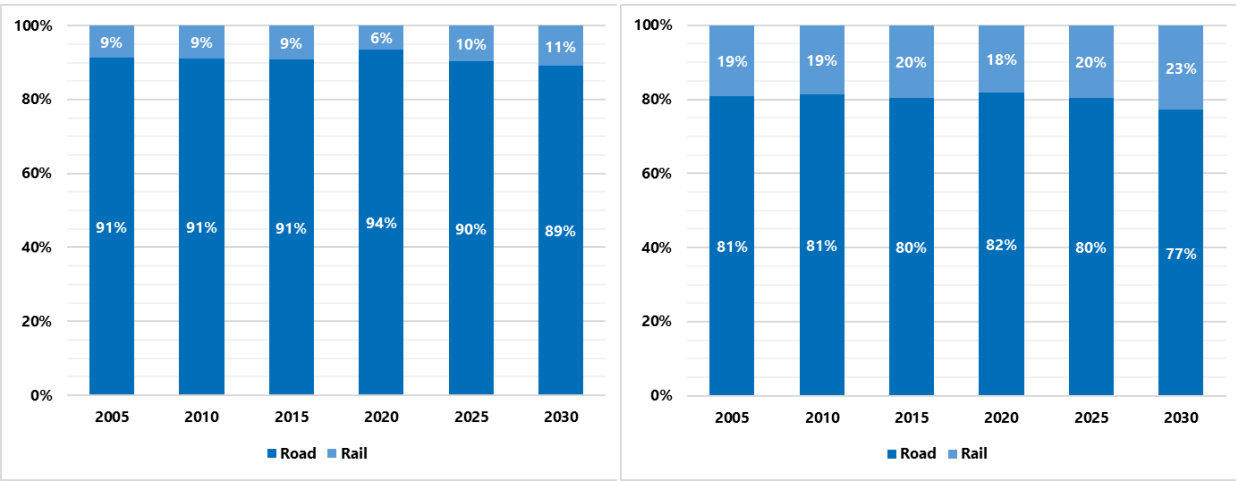
Source: elaboration of the authors based on various sources

Figure A.19: Projections of passenger and freight rail activities in the EU until 2030



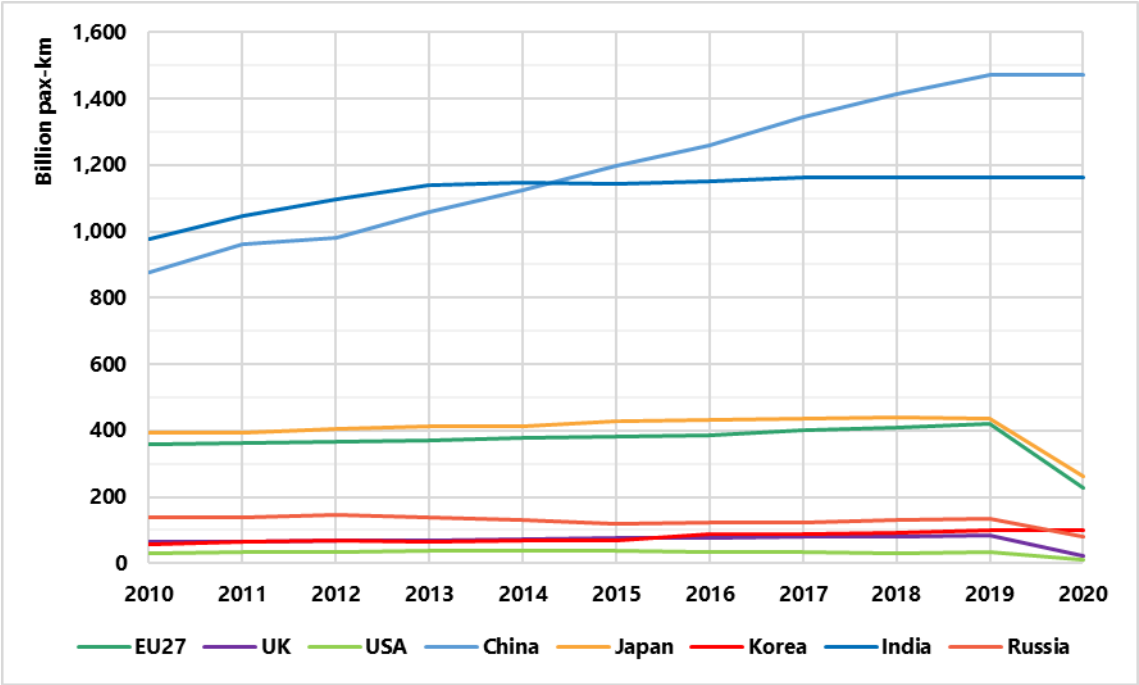
Source: elaboration of the authors based on EU Reference scenario 2020 (MIX Scenario)

Figure A.20: Projections of passenger (left) and freight (right) modal shares of road and rail transport modes in the EU until 2030



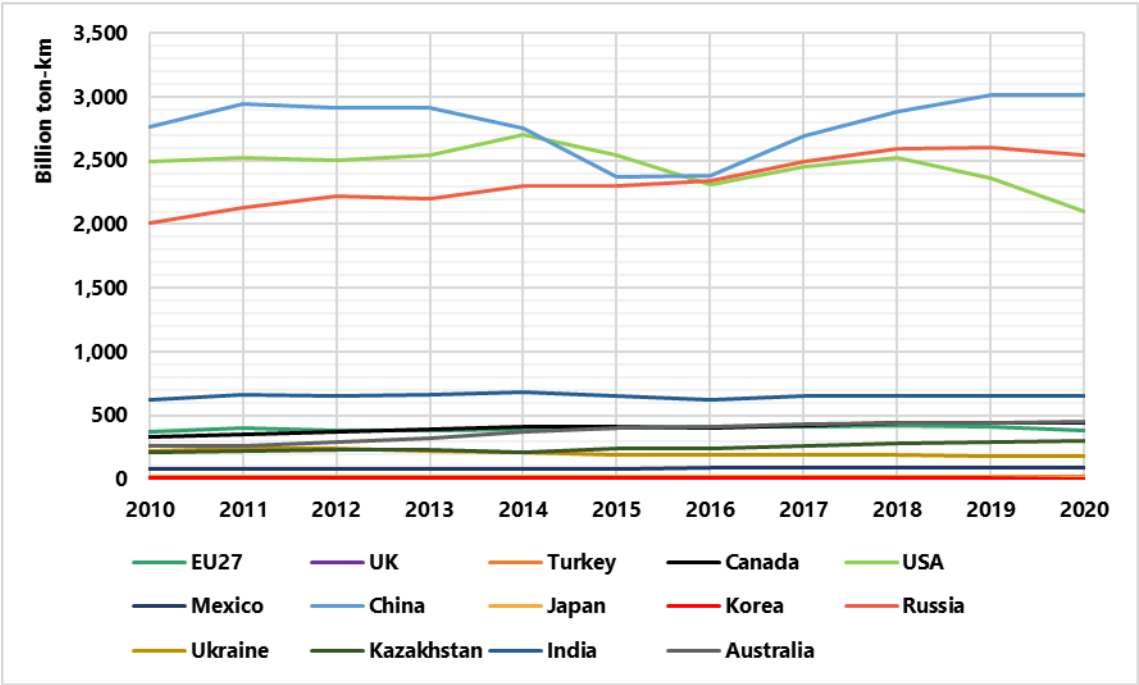
Source: elaboration of the authors based on EU Reference scenario 2020 (MIX Scenario)

Figure A.21: Rail passenger transport activities in countries where rolling stock suppliers are located (2010-2020)



Source: elaboration of the authors based on Eurostat data for EU27 and OECD database for other counties

Figure A.22: Rail freight transport activities in countries where rolling stock suppliers are located (2010-2020)



Source: elaboration of the authors based on Eurostat data for EU27 and OECD database for other counties

Box A.6: Rail industry forecasts for the UK and the USA

Other forecasts have been developed by the industry for the UK and the USA.

The **UK's** Rail Sector deal of 2018 aims to double rail exports by 2025 (OXERA, 2021). Long-term strategy predicts three growth scenarios combined with two electrification scenarios up to 2047 (EVERSHOLT et al., 2018). Key expectations include an increase of 40-85% in the national passenger fleet, rise of electric fleets from 72% to 86% and decrease of self-powered fleets from 28% to 19%. It is estimated that the capital cost of new rolling stock will exceed GBP 13.0 billion, attracting international manufacturers, although around 50% of new vehicles are set to be built in the UK.

The **USA's** short-term forecasts indicate that 40 215 and 36 625 railcar units are expected to be delivered in 2023 and 2024, respectively (Oxford Economics, 2023). These figures follow the general trend of gradually reducing volumes of deliveries from the peak in 2015 (82 296 units).

Source: elaboration of the authors based on (OXERA, 2021) and (Oxford Economics, 2023)

Additional information to Chapter 5 – EU financial instruments

Box A.7: Examples of EIB loans to finance rolling stock in the EU

In 2015, **PKP Intercity (Poland)** received a loan of **EUR 224 million** for the modernisation of its passenger rolling stock. The project involved the purchase of 20 electric locomotives and the modernisation of 118 passenger carriages, among other measures.

In 2018, the EIB provided a **EUR 200 million** loan to Construcciones y Auxiliar de Ferrocarriles **(CAF), a Spanish rail manufacturer** to finance its RDI strategy.

In 2019, **Railpool Leasing Company**, a major European rolling stock leasing company, received a loan of **EUR 200 million** to finance the acquisition of new, primarily electric, locomotives. The loan was backed by the European Fund for Strategic Investments (EFSI).

In 2020, the **Bulgarian State Railways (BDZ)** signed with the EIB a **EUR 160 million loan** agreement to modernise its passenger rolling stock, signalling and catenary systems. The project also received EU grants under the Operational Program "Transport and Transport Infrastructure" 2014-2020 co-financed by the Cohesion Fund.

Source: elaboration of the authors based EIB website

The study provides an assessment of the foreseeable demand and supply of rolling stock up to the year 2030 and highlights the obstacles to the provision of rolling stock that may potentially hinder the attainment of EU goals in rail transport. The study provides the basis to consider whether or not there is a necessity to incentivise rolling stock supply within the EU (including imports and/or domestic production) and provides policy recommendations relevant to EU decision-making. The EU market is mature and expected to grow.

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