IDEALCAREL

Inclusive Digital Education and Laboratory training by Connecting Academic Rail Educational Laboratories

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ABSTRACT

This study delves into the European railway sector, examining it from three perspectives: the railway sector, the labour market, and the education market. A particular focus is placed on the education and training sector and the potential impact of the IDEALCAREL project on it and vice versa, the sector's requirements.

As the most sustainable mode of transportation, railways will play a crucial role in Europe's Green Deal. There is a high expectation that railways will contribute to and eventually solve the climate crisis, meeting the goals set by the Paris Agreement.

The study also investigates the railway labour market, which faces the challenge of a shortage of skilled workers. Additionally, the European railway education market is analyzed to determine how the STEM Agenda may influence the sector and the relevance of the IDEALCAREL project.

In the first part of the study, the railway sector in Europe was analyzed, including Germany, Austria, Switzerland, Slovakia, the Czech Republic, Poland, Croatia, Slovenia, Serbia, and Denmark.

The second part evaluated the current state of the railway labour force and identified the key challenges for the future, particularly in terms of practical education and laboratories.

The third part analyzed the education market for railway engineers, first examining individual study programs and then comparing them. The study found that although there were similar approaches in the programs, there were challenges in organizing laboratories. Moreover, the quantity of railway studies does not meet the future demands of the railway sector labour force.

Finally, the study concludes with proposed crucial steps for the future development of the railway sector.

1. INTRODUCTION

The railway sector is experiencing a new renaissance in introducing new technologies and new services. This study aims to conduct a comprehensive analysis of the railway sector within the European Union. The sector is undergoing a revival with the introduction of new technologies and services, making the market and technical pillars of the sector critical. However, separating these pillars in real-life operations is challenging. Thus, a common approach to education is needed for future railway engineers.

Task 1 of the study will focus on the examination of the market and technical approaches in the railway sector with case examples. An essential part of the study shall be the liberalisation and interoperability process in railway systems across the European Union, Switzerland and Serbia. Also, the vital part of the study is a functional connection of the railway sector with the European Union Green Deal and the future programming period from 2021 to 2027 with emphasise to strengthen the role of the EU in the decarbonisation process, developing new ideas in technologies, digitalisation, smart transport and competitive research and development. Additionally, the task will incorporate the STEM agenda and EU policies in railway education. Task 1 serves as a foundational step in comprehending the dynamics of the railway sector and arriving at definitive conclusions on the future direction of education for railway engineers.

Task 2 will investigate the current state of the railway sector workforce. Based on the 2018 International Union of Railways study, the average age of employees is 55 and job cuts have caused problems in the engineering field. Lack of knowledge transfer, outdated technology, and negative perception of the railway sector are among the interconnected issues to be addressed. We approached all these interconnected issues with a direct and comprehensive approach. By taking a critical approach, our findings can be applied to the railway sector in the European Union, Switzerland, and Serbia. Our analysis covers the current state and future prospects of the workforce in the railway sector, with a focus on the need for railway engineers. A key component of railway engineering education is hands-on training in laboratories, and it is essential to accurately reflect the sector's future needs in the education of railway engineers.

Task 3 will analyze the educational market for railway engineers in the EU, Switzerland, and Serbia. In the EU, Switzerland and Serbia there are approximately 30 higher education institutions which are providing education in the field of railway engineering, but only 10%, have laboratories that are dealing with railway traffic operation and safety. A survey will be conducted among those education institutions offering railway engineering education, with a focus on their experience in giving lectures and activities during lockdowns. The survey will also evaluate the course structure, including the number of hours and laboratory lectures.

This study will summarize the three essential pillars of the railway sector: policy, labour market, and educational market, each with elements of innovation, expected impact, and transferability potential. The outcome of the study will offer a clear direction for future learning

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outcomes for railway engineers, highlighting the importance of incorporating labs into the curriculum. It is hoped that this study will have a positive impact on the railway sector and inspire other engineering fields to tackle similar challenges.

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2 STUDY WITH CASE EXAMPLES OF THE RAILWAY SECTOR

In this study, the different market and technical approaches in the railway sector will be investigated and analysed. An essential part of the study shall be the liberalisation and interoperability process in railway systems across the European Union. Also, the vital part of the study shall be a functional connection of the railway sector with the European Union Green Deal and future programming period from 2021 to 2027 with emphasise to strengthen the role of the EU in the decarbonisation process, developing new ideas in technologies, digitalisation, smart transport and competitive research and development. Also, on the other hand, we shall include a STEM agenda in connection to EU policies and the railway sector. This first task is a start point for understanding the process in the railway sector and making a concrete finding of possible future development of the railway sector.

2.1 The European Railway Sector

The European Railway system is heterogeneous. As the railways across Europe have grown as national railway systems, almost every European country has its technical systems (signalling, power supply and even track gauge) and operational rules. Furthermore, the operational rule books are a key issue in railway operations, as every Infrastructure Manager in Europe uses their own operating rules. Not only the rulebooks are different, but even the terminology for the same processes and systems could also have different names. These technical issues are a main challenge for the entire sector.

However, railways are a sustainable transport mode with fewer emissions, then every other mode of transport. For this reason, the railways are playing a main part in the European Green Deal. In addition, the European Union declared 2021 as the European year of Rail, to support the image of the Railway system in Europe. The data from 2019 shows, that the European railway transported 1.6 billion tonnes of freight and 9 billion passengers each year [1]. For the railway sector, the labour market is also a crucial issue, as the railway sector in the European Union employs over 1 Million people as Railway Undertakings and Infrastructure Managers. Currently, the lack of skilled workers is a key challenge for the sector. As the entire sector needs qualified workers on every professional level. For employees in the railway sector, an understanding of the railway system is crucial. This knowledge is required on every professional level. System knowledge is a key issue and key qualification for every part of the sector e.g. Infrastructure Managers, Railway Undertakings, Industry, Research and Training.

In the academic sector, the knowledge is taught in traditional lectures and exercises in railway laboratory hands-on sessions. Traditional laboratories are consisting of interlockings that are controlling model railways and the operation can be explored by these model railways. This means that in the laboratories every decision that the participants of the exercise, made can be explored by them.

For a few years, some laboratories are also equipped with locomotive simulators and virtual railway networks for training. This training concept isn´t used only on the academic level, also railway companies traditionally are educating their staff in laboratories.

These teaching facilities are supporting students and railway trainees in the process of system thinking. These training facilities have also a key role to gain practical skills. However, it is also to mention, that railway companies and academic institutions traditionally educate and train the national rules in the exercises. That means that generic teaching approaches are rather the exception, even on the academic level. It is clear, that railway companies have to train their staff by national operating rule books, but it is quite interesting that generic teaching is not more widespread at the present in the academic railway sector, as Interoperability is a main issue for the European railway system.

It has been already mentioned that railways are a sustainable transport mode with all benefits, but the railways in Europe are also facing big challenges. A key issue is an interoperability, which means that trains can operate without barriers between railway systems. This starts with technical issues like different signalling systems, power supply and communication systems. For the signalling systems, interoperability is achieved by replacing the national automatic train protection (ATP) systems with the European Train Control System (ETCS). ETCS enables cross-border operations with the same on-board unit. However, the ETCS does not replace the entire signalling system but just the ATP layer. The underlying interlocking and block systems are not changed. So, ETCS leads to technical interoperability on the ATP level but not to harmonisation of the network control technology. The interoperability of power supply systems is already solved by multi-system locomotives. In modern electric locomotives with three-phase AC traction, the electric power supplied by the catenary has to be transformed to three-phase AC traction power. So, with the need for electronic onboard transformation, the handling of different power supply systems in multi-system locomotives is no longer a problem. So, with a total of just four different power supply systems, multi-system locomotives are a suitable solution for interoperability. For communication, European railways have replaced their national radio systems with GSM-R. Since the GSM standard is outdated in the meantime, it will be replaced by the new Future Rail Mobile Communication Standard (FRMCS), which is based on 5G technology.

But technical issues aren´t the only challenge for interoperability, it is also a matter of national operational rule books, languages and even local terminology, as every Infrastructure Manager uses its own operational rules and regulations. Due to different definitions for essential operating terms, many terms of the national rulebooks have no clear translation into other languages. The first and latest effort to overcome these barriers was Technical Specifications for Interoperability (TSI) OPE. Even with this effort, there is currently not much progress to harmonise the national operational rule books. A first step to overcome that situation would be to establish commonly accepted definitions for essential operating terms.

The last challenge for interoperability is the training of staff. Railway companies must train their staff on the operational rules applied by each infrastructure manager on which they operate. The solution for operational staff (train crew) is, that are trained by every Infrastructure Manager. But interoperability isn´t only a challenge for operational staff, also engineers have to know how to build

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and operate an Infrastructure by applying local rules. It can be seen, that academics could profit from international education in their curricula and the railway sector in general. Table 1 is a try to describe and classify the mentioned issues for Interoperability. In the context of the IDEALCAREL project.

Table 1. Interoperability issues in the railway system

Interoperability issues		
Technical systems	**Organisation**	**Education**
• Signalling • Power supply • ERTMS	• Operational rules • National railway laws • Language	• Generic education models • Curricula of Universities • “Demand of the practice”

However, academic institutions have recognized, that generic teaching is crucial. So first efforts have been done. For example at the TU Braunschweig the Institute of railway systems engineering and traffic safety. The institute has established a generic railway laboratory and offers a lecture for International Railway operations. Furthermore, the University of Applied Sciences in St. Pölten / Austria (FH St. Pölten) teaches in the Bachelor programme “Rail Technology and Mobility” e.g. the subjects Interoperability and International Railway Law [2]. In addition, an international week with lecture series is offered in the international week.

A generic education and the training of skills could be a step to achieving interoperability in the European railway sector.

For a deeper understanding of the challenges of the European railway system, especially the issue of interoperability, it is necessary to give an overview of some European railways. However, this case study doesn´t cover every European country, it is just a selection, done by the authors.

2.1.1 Germany

The German railway network operated by DB Netz AG is the largest in the European Union with 33,400 km [3]. The mentioned Infrastructure Manager DB Netz AG is the biggest in Germany. However, DB Netz isn´t the only IM in Germany. There are various others IMs that are also operating larger networks. These IMs are part of the so-called “NE-Bahnen” which means “Nichtbundeseigene” and could be translated as “Non-Federal- Railways. These NE Railways could be Railway Undertakings and Infrastructure Managers. The latest data from the EBA (Eisenbahnbundesamt = German federal railway authority) is from 2017 and shows that there are 176 active Infrastructure Managers in Germany [4]. This data includes every type of railway in Germany like Light rail, narrow gauge railways and also rack railways.

The latest data for Railway Undertakings from EBA for public Railway Undertakings is from June 2021 and shows that there are 450 in Germany [4]. The latest data for the non-public railways are as well from 2021 and list 146 companies.

The difference between public and non-public railways is defined in the AEG law of Germany:

- *“Pursuant to § 3 AEG, railways serve public transport (public railways) if they are operated as*

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- *RUs are operated on a commercial or business basis and anyone can use them for the carriage of passengers or goods in accordance with their intended purpose (public RUs),*
- *EIUs must provide access to their railway infrastructure (public EIUs),*
- *railway infrastructure managers must grant access to their railway infrastructure (public railway infrastructure managers).*

All other railways and industrial railways are non-public railways." [5]

2.1.1.1 State of the German Railway network:

In Germany, there are several different Signalling systems in use. This can be explained by the history of Germany. In the area of the former DDR, the HI-signalling system is used. While the majority of German interlockings are already computer-based followed by relay interlockings from the late 20th century, part of the network (less than 10%) is still controlled by mechanical and electro-mechanical lever-frame machines from the pre-war era, some of them dating back to the early years of the 20th century. As a result of this historical development and also of the separate development in East and West Germany after WWII, there are today about 90 different types of interlocking systems in use, probably the biggest number of interlocking types in a single country worldwide. This leads to high costs for maintenance and training of the operating staff. That is, why DB developed the strategy to replace all the existing interlockings (except the latest generation of computer-based systems) with a new generation of so-called digital interlockings. The replacement will be done by an industrial roll-out starting this decade. The digital interlockings will be combined with ETCS L2 without trackside signals. This way, after Denmark and Norway, Germany is the third European country that announced to complete replace traditional trackside signalling with ETCS L2 in a nationwide roll-out.

2.1.1.2 Example Havelländische Eisenbahn "HVLE

HVLE is a Railway company based in "Wustermark" nearby Berlin. As Germany has an amount of 450 Railway Undertakings [4], not everyone can be mentioned in this case study. However, the HVLE should be described as an example. This company operates nationally in Germany and international freight trains. Furthermore, the company also does logistics for railway construction sites. However, the companies don´t work only as Railway Undertaking, they are also Infrastructure Managers. This means, that HVLE also operates the largest private shunting yard in Germany and connecting railways. The shunting yard is operated by the subsidiary company Rail & Logistik Wustermark GmbH & Co Kg.

Furthermore, the company has a maintenance facility, which is not only used for engines and waggons that are owned by the company. There is also the possibility that other Railway Undertakings can use these facilities as a customer. Other fields to mention are Consulting and Research and Development [6]. HVLE also owns locomotives and waggons. HVLE is also a shareholder of the BTC Havelland (Bahn Technolgie Campus) [7].

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2.1.2 Austria

The 77 railway companies were active in Austria by the end of 2020, this shows the annual report from 2020 Schienen-Control GmbH [8]. This data covers all types like railway undertakings, infrastructure managers and integrated railway companies. The data from the Austrian Federal Railway (ÖBB) shows, that in 2019, 476.8 million passengers and 105.3 Mio Tonnes were transported by Rail at ÖBB [9]. The passenger numbers are including 266.6 million train passengers and 210.2 million bus passengers in 2019 [9]. These numbers decreased in 2020 to 286.5 (162.8 train and 123.7 bus) million passengers and 95.3 million tonnes in freight traffic.

2.1.2.1 Infrastructure Managers

In 2020 the Austrian railway network had a length of 5,650km, this includes 5,348km standard gauge and 302km narrow gauge (760mm or 1000mm) lines [8].

Table 2. Austrian Railway Network Lenghts [8]

Austrian Railway network	Length in km
Overall length	5,650
Standard gauge	5,348
Narrow gauge	302
Single track	3,457
Double- or multitrack	2,193
Electrified	3,917
15kV / 16.7Hz AC	3,523
25kV 50Hz AC	74
6.5kv 25Hz AC	84
3 kV DC	2
Other DC	234

With a network size of 4,875 km the ÖBB Infrastruktur AG (ÖBB Infra) is the largest Infrastructure Manager, the is controlled by 5 operations centres [9]. However, ÖBB Infra isn´t the only IM in Austria. There are also private railway companies ("Privatbahnen"), that are operating as IM or as integrated railway companies. According to the term private railway, it has to be mentioned, that the federal states of Austria, city governments or the Republic of Austria could be shareholders. The Linzer Lokalbahn railway is a public limited company in which the shares are divided as follows: 54.1% City of Linz, 35,3% Stern&Hafferl Verkehrs-GmBH, 7.0% Neighbouring communities, 2.6% the City of Eferding and 1.0% free float [10].

TEN Corridors

The 5 TEN corridors are part of the Austrian network. This is the corridors 3, 5, 7, 9 and 10.

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Table 3. TEN corridors - part of the Austrian network

Rail Freight Corridor	Member States	Main lines	Start of operation	Corridor website
Scandinavian - Mediterranean	SE, DK, DE, AT, IT	Stockholm/[Oslo] /Trelleborg – Malmö–København– Hamburg–Innsbruck–Verona–La Spezia /Livorno /Ancona /Taranto /Augusta / Palermo	10 November 2015	*www.scanmedfreight.eu*
Baltic-Adriatic	PL, CZ, SK, AT, IT, SI	Swinoujscie /Gdynia–Katowice–Ostrava/Žilina–Bratislava/ Wien/Klagenfurt–Udine–Venezia/ Trieste/ /Bologna/Ravenna Graz–Maribor–Ljubljana– Koper/Trieste	10 November 2015	www.rfc-baltic-adriatic.eu
Orient – East-Med	CZ, AT, SK, HU, RO, BG, EL, DE	— Bucureșt – Constanța Bremerhaven /Wilhelmshaven /Rostock /Hamburg – Praha–Vienna/Bratislava–Budapest — Vidin–Sofia–Burgas /Svilengrad (Bulgarian-Turkish border)/ Promachonas–Thessaloniki– Athína–Patras	10 November 2013	www.rfc-orient-eastmed.eu
Rhine - Danube	FR, DE, AT, SK, HU, RO, CZ	Strasbourg–Mannheim–Frankfurt–Nürnberg–Wels Strasbourg–Stuttgart–München–Salzburg–Wels–Wien–Bratislava–Budapest–Arad–Brașov/Craiova–București–Constanța Čierna nad Tisou (Slovak-Ukrainian border)–Košice–Žilina–Horní Lideč–Praha–München/Nürnberg	by 10 November 2020	http://rfc-rhine-danube.eu/
Alpine-Western Balkan	AT, HR, SI, BG, RS	Salzburg – Villach – Ljubljana -/ Wels / Linz – Graz – Maribor – Zagreb – Vinkovci / Vukovar – Beograd – Sofia Svilengrad (Bulgarian-Turkish border)	March 2020	https://www.rfc-awb.eu

Signalling and train

The ÖBB network is equipped with PZB, LZB and ETCS [11]. Furthermore, some lines of ÖBB are operating in the so-called “Zugleitbetrieb” (Dispatcher controlled operations with verbal authority). Private railway operators are using sometimes the same signalling system as ÖBB infrastructure, this is the case at the Montafonerbahn in Vorarlberg or the Graz Köflacher Bahn in Styria.

In addition, a system for dispatcher-controlled operation with additional cab signalling was developed in Austria, at the University of Applied Sciences Wels [12]. The system started its operation in 2006 on the Stern & Hafferl railways. This train control system uses GPS for positioning. The

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movement authority is sent and received via radio between the dispatching centre and the train. Due to the concept of dispatcher-controlled operation with verbal authority, the infrastructure has to be equipped with spring switches. However, the systems don´t need signals or interlockings.

Railway Undertakings

The mentioned number of 77 railway companies includes every railway company. In 2020 58 Railway Undertakings were active in Austria and 8 integrated railway companies [8]. ÖBB Personenverkehr (hereinafter ÖBB PV AG) is a 100% subsidiary company of ÖBB Holding [8]. The company was founded in 2004 and started operations in 2005, in the business of passenger rail and bus traffic [13]. ÖBB PV AG operates long-distance, regional and night trains. Furthermore, the company holds shares in the City Airport Train (CAT), which operates between Wien Mitte and Vienna International airport [8].

For Intercity services, there are currently two competitors on the Austrian Railway network. This is the WESTBahn Management GmBH (hereinafter Westbahn) and Regio Jet. The Westbahn was founded in 2008 as the first subsidiary of Rail Holding AG [8]. The shares of Rail Holding AG are divided as follows: 49.90% Haselsteiner Familien-Privatstiftung, 32.70% Augusta Holding AG and 17.40% SNCF Voyage Développement SAS [14]. Westbahn operates Intercity services between Salzburg Hbf. and Wien Westbahnhof. The Westbahn does the operational management for the RegioJet trains between Praha and Vienna and Vienna Budapest [8].

Other Railway Undertakings in passenger traffic are operating in regional traffic. Mostly as integrated Railway companies, examples of this are the Salzburger Lokalbahen, Montafonerbahn or the GySEV. It is also mentioned, that the regional Railway Undertaking sometimes is also operating on the network of ÖBB Infrastructure. Examples of this are the Linzer Lokalbahn, this RU is operating on the ÖBB network to reach Linz main station which is also the case at GySev. Most of the Railway Undertakings were active in freight transport [8].

Railway Industry and public authorities

Other important parts to mention are the public authorities and the railway industry. As there is also on demand for skilled railway workers. Two federal authorities to mention are the SCHIG mbH and the Schienen-Control Commission. The Schieneninfrastruktur-Dienstleistungsgesellschaft mbH SCHIG mbH is an authority 100% owned by the Republic of Austria [15]. The company has various tasks in the railway sector. SCHIG acts as Notified Body or organises the contracts for regional rail transport. Another public Authority is the Schienen-Control GmbH is the regulator in Austria, which is owned 100% by the Republic of Austria [8]. Another part of the railway sector to mention is the transport associations.

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Another important part of the railway sector is the railway industry. This includes production and construction works. The railway industry generated sales of 3.1 billion Euros in 2018 and employed 9865 people [16].

The "Klimaticket" Smart Card ("Klimaticket")

On the 26th of October, the new smart card "Klimaticket" (climate ticket) started. This is a new ticket (similar to the Swiss Generalabonement) that is valid on every Austrian public transport mode, which includes railways and every local public transport mode (except touristic transport offers e.g. Schafberg rack railway) [17]. There are different types of tickets, the classic one which costs € 1.095, the youth / senior special for € 821,- and the family ticket for € 1.205 or € 931. In addition, the Klimaticket is researched in the first year, to investigate the impact of the ticket to the public transport sector in Austria.

2.1.3 Switzerland

In Switzerland, the railways are taking a necessary role in the public transport sector. It can be assumed, that the railways in Switzerland are the backbone of public transport. A necessary part plays here is the Generalabonnement (GA). The GA is a ticket that is valid on almost every public transport mode.

Switzerland isn´t a part of the European Union, but the Swiss railway network is a part of the European railway network. The Swiss network has one RFC corridor. Four languages are spoken in Switzerland: Swiss-German, French, Italian and Rhaeto-Romanic. That means for Railway operations, in every language area the local language is used, except for the new Gotthard-base tunnel. As the language border is in the middle of the tunnel, it was decided that Italian is the operational language for the entire tunnel.

SBB CFF FFS

The SBB CFF FFS (hereinafter SBB) group is organised according to the parent company structure and is divided into four operative divisions [18]. The operative divisions are Markt Personenverkehr (market passenger traffic), Produktion Personenverkehr (production passenger traffic), Immobilien (real estate), Infrastruktur (infrastructure) and Segment Güterverkehr (segment freight transport, including the sub-companies SBB Cargo AG, SBB Cargo International AG).

In 2019 the SBB transported 1.32 million passengers per day. This number decreased in 2020 according due to the Covid-19 pandemic to 843,000 passengers per day which means a decrease of -43.7% in long distances service and -32.4% [18].

The infrastructure of the SBB covers 80% of the standard gauge network in Switzerland. The responsible IM for that network is the infrastructure division of SBB. The SBB network borders the French (SNCF), German (DB Netz AG), Italian (RFI) and Austrian (ÖBB) networks. Furthermore the SBB

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network borders on other national standard gauge infrastructures e.g. BLS Netz AG, SOB Südostbahn, Chemins de fer du Jura, etc [18].

The network of SBB is equipped with Signum and ZUB and also with ETCS Level 1 LS.

Furthermore, ETCS Level 2 cab signalling is active on the following tracks [18]:

- Bahn-2000-line between Mattstetten (excl.) and Rothrist (excl.)
- Bahn-2000-line between Wanzwil and Solthurn (excl.)
- Brunnen (excl.) – Flüelen – Altdorf – Rynächt – Erstfeld (excl.)
- Gotthard base tunnel
- Bodio (excl.) – Pollegio Nord – Biasca (excl.)
- Biasca (excl.) – Osogna – Claro – Castione (excl.)
- Lausanne (excl.) – Vevey – Vielleneuve – Roche VD (excl.)
- Puidoux (excl.) – Coreseaux-Cornalles (excl.) Vevey-Funi – Vevey
- Bellinzona (excl.) – Giubiasco – Sant´Antonino (excl.) – Cadenazzo (excl.)
- Ardon (excl.) – Sion – Sierre – Salgesch (excl.)
- Bellinzona (excl.) – Giubiasco – Ceneri base tunnel – Vezia – Lugano (excl.).

The SBB also operates as a Railway Undertaking in passenger and Cargo traffic and there are also some RU, in which the SBB is a shareholder. Passenger traffic is operated by SBB Personenverkehr.

In Regional passenger traffic, the SBB Personenverkehr holds a share at the following railway companies [18]:

- SBB GmbH Germany 100%
- Thurbo AG 90%
- ZB Zentralbahn AG 66%
- RegioAlps SA 70%
- Tilo SA 50 %
- Lemanis SA 60%
- Sensetalbahn AG 65.5%

BLS

The standard gauge network of the BLS AG is 420 km long and it is the second largest network in Switzerland [19]. The BLS network does not border international infrastructures. They are the networks of the SBB, ASM, TPF, ZB and MOB. The BLS network is equipped with SIGNUM and ZUB respectively ETCS L1 LS. The "Lötschberg-Basisistrecke" (base route) is equipped with ETCS L2.

The BLS InterRegio, RegioExpress and Regio lines, also the S-Bahn networks of Bern and Luzern. Furthermore, the BLS operates car shuttle trains ("Autoverlad"), buses and boats on the lakes "Thunersee" and "Brienzersee" [19].

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The 3 BLS Interregio lines are:

- IR 17 Bern – Olten
- IR 65 Bern – Biel/Bienne
- IR 66 Bern – Neuchâtel – La Chaux-de-Fonds

The RegioExpres lines are:

- RE Bern – Spiez – Bring (-Domodossola)
- RE (Bern-) – Spiez – Zweisimmen
- RE Bern – Entlebuch – Luzern
- RE (Interlaken Ost) – Spiez – Zweisimmen (GoldenPass line

Rhätische Bahn – RhB

The RhB operates a 384 kilometres long alpine 1,000mm narrow gauge railway [20]. Rhätische Bahn (hereinafter RhB) operates Regio / Regio expresse and S-Bahn trains on their network. On the passenger network, the RhB performed 251,488 passenger kilometres in 2020, in 2019 before the outbreak of the Covid pandemic 377,627. Furthermore also operates freight trains and car shuttle trains. The car shuttle train operates between Prättigau and Engadin and transported 413 cars in 2020 and 529 cars in 2019. In freight traffic, the RhB transported 594 tonnes in 2020 on their network and 563 tonnes in 2019. In 2019 the company had a workforce of 1,380 persons, this number increased in 2020 to 1,434.

Public transport and other Railways

Most major railways are already described, but not all of them. Some other railways should be also mentioned. In the cities, the tram networks are an important part of public transport. Furthermore, the rack railways are also an important part of the public transport system.

The NEAT – "Alpen Transversale"

An important aspect of the Swiss railway sector is the NEAT and the newly built railway tunnels. These are the "Lötschberg", "Ceneri" and the new "Gotthard" base tunnels. In 1963 a commission investigated the railway tunnels and in 1989 the Swiss "Bundesrat" decided on a network variant through the Lötschberg and the Gotthard and Ceneri mountains [21]. In 1992, the Swiss population decided in a referendum to build the NEAT. This was followed by political debates about the financing and redimensioning of the NEAT and another referendum in 1998. The NEAT is also a part of the North-South corridor Rotterdam/Zeebrugge – Genua.

The first tunnel that opened was in 2007 the Lötschberg base tunnel [21]. In 2016 the Gotthard base tunnel opened and in 2020 the NEAT project was finished with the Ceneri base tunnel. It also

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planned to increase the capacity of the Lötschberg base tunnel in 2035 and to research the potential for an expansion of the NEAT to Chiasso.

2.1.4 Slovakia

Železnice Slovenskej republiky (hereinafter referred to as "ŽSR") was established in accordance with the Act of the National Council of the Slovak Republic No. 258/1993 Coll. of 30 September 1993 on Železnice Slovenskej republiky as amended by later regulations, and has a special legal status.

In accordance with Act No. 513/2009 Coll. On Railroads and on amendments of some acts as amended, Železnice Slovenskej republiky as the infrastructure manager primarily provides for activities related to the operation of railways, traffic management and the operability of railways.

Core activities of ŽSR concerning applicants for infrastructure capacity and railway undertakings shall comprise:

a) management and operation of the railway infrastructure,
b) allocation of infrastructure capacity,
c) provision of services to railway undertakings through:
   - minimum access package,
   - track access including access to service facilities (if any),
   - services in service facilities
   - negotiated additional services,
   - negotiated ancillary services.
d) establishment and operation of railway, telecommunication and radio networks,
e) construction, repair and maintenance of railway lines,
f) other business activities as incorporated into the Business Register,
g) levying charges for access to the railway infrastructure.

Railway Corridors in Slovakia

In 2010 the European Parliament and the Council laid down the rules for the establishment of a European railway network for competitive rail freight, consisting of international freight corridors (hereinafter referred to as "RFC") to meet the following goals:

- strengthening cooperation between IMs/ABs on key aspects such as the allocation of paths, deployment of interoperable systems and infrastructure development,
- finding the right balance between freight and passenger traffic along the RFCs, giving adequate capacity for freight in line with market needs and ensuring that common punctuality targets for freight trains are met,
- promoting intermodality between rail and other transport modes by integrating terminals into the corridor management process.

Co-funded by the European Union

To achieve these objectives, the European Union has established eleven international rail freight corridors within its rail network. A general description of each RFC is given in table 4. (More information in the EU Regulation 1315/2013).

Table 4. Rail freight corridors [22]

Rail Freight Corridor	Member States	Main lines	Start of operation	Corridor website
Rhine-Alpine	NL, BE, DE, IT	Zeebrugge–Antwerpen/Amsterdam/Vlissingen /Rotterdam– Duisburg–[Basel]– Milano–Genova	10 November 2013	*www.rfc-rhine-alpine.eu*
North Sea - Mediterranean	NL, BE, LU, FR, UK	Glasgow/Edinburgh /Southampton /Felixstowe – London /Dunkerque / Lille /Liège /Paris /Amsterdam – Rotterdam–Zeebrugge /Antwerpen–Luxembourg–Metz– Dijon–Lyon/[Basel]– Marseille	10 November 2013	*www.rfc-northsea- med.eu*
Scandinavian - Mediterranean	SE, DK, DE, AT, IT	Stockholm/[Oslo] /Trelleborg – Malmö–København– Hamburg– Innsbruck–Verona–La Spezia /Livorno /Ancona /Taranto /Augusta / Palermo	10 November 2015	*www.scanmedfreight.eu*
Atlantic	PT, ES, FR, DE	Sines–Lisbon/Leixões — Madrid–Medina del Campo/ Bilbao/San Sebastian–Irun– Bordeaux–Paris/Le Havre/Metz – Strasbourg /Mannheim - Sines–Elvas/Algeciras	10 November 2013	www.rfc-atlantic.eu
Baltic-Adriatic	PL, CZ, SK, AT, IT, SI	Swinoujscie /Gdynia–Katowice–Ostrava/Žilina–Bratislava/ Wien/Klagenfurt–Udine–Venezia/ Trieste/ /Bologna/Ravenna Graz–Maribor–Ljubljana– Koper/Trieste	10 November 2015	www.rfc-baltic-adriatic.eu
Mediterranean	ES, FR, IT, SI, HU, HR	Almería– Valencia/Algeciras/Madrid–Zaragoza/Barcelona– Marseille– Lyon–Turin–Milan–Verona– Padova/Venezia–Trieste/Koper– Ljubljana–Budapest Ljubljana /Rijeka –Zagreb – Budapest–Zahony (Hungarian- Ukrainian border)	10 November 2013	www.rfc-mediterranean.e u
Orient – East-Med	CZ, AT, SK, HU, RO, BG, EL, DE	— București – Constanța Bremerhaven /Wilhelmshaven /Rostock /Hamburg – Praha–Vienna/Bratislava–Budapest — Vidin–Sofia–Burgas /Svilengrad (Bulgarian-Turkish border)/ Promachonas–Thessaloniki– Athína–Patras	10 November 2013	www.rfc-orient-eastmed.eu

North Sea - Baltic	DE, NL, BE, PL, LT, LV (*), EE (*)	Wilhelmshaven /Bremerhaven/Hamburg / Amsterdam /Rotterdam/Antwerpen– Aachen/Berlin–Warsaw–Terespol (Polish-Belarussian border)/Kaunas–Riga (*)–Tallinn (*)	10 November 2015	www.rfc-northsea-baltic.eu
Rhine - Danube	FR, DE, AT, SK, HU, RO, CZ	Strasbourg–Mannheim–Frankfurt–Nürnberg–Wels Strasbourg–Stuttgart–München– Salzburg–Wels–Wien–Bratislava– Budapest–Arad–Brașov/Craiova– București–Constanța Čierna nad Tisou (Slovak-Ukrainian border)–Košice–Žilina–Horní Lideč–Praha–München/Nürnberg	by 10 November 2020	http://rfc-rhine-danube.eu/
Alpine-Western Balkan	AT, HR, SI, BG, RS	Salzburg – Villach – Ljubljana -/ Wels / Linz – Graz – Maribor – Zagreb – Vinkovci / Vukovar – Beograd – Sofia Svilengrad (Bulgarian-Turkish border)	March 2020	https://www.rfc-awb.eu
Amber	SI, HU, SK, PL	Koper — Ljubljana –/Zalaszentiván — Sopron/Csorna –/(Hungarian- Serbian border) — Kelebia — Budapest –/–Komárom — Leopoldov/Rajka — Bratislava — Žilina — Katowice/Kraków — Warszawa/Łuków — Terespol — (Polish-Belarusian border)	January 2019	https://rfc-amber.eu/

A detailed description of RFCs with ŽSR membership is available on the websites of rail freight corridors [22]:

- RFC "Baltic-Adriatic" – www.rfc5.it
- RFC "Orient/East Mediterranean" – www.rfc7.eu
- RFC "Rhine-Danube" – http://rfc-rhine-danube.eu/
- RFC "Amber" – rfc-amber.eu/.

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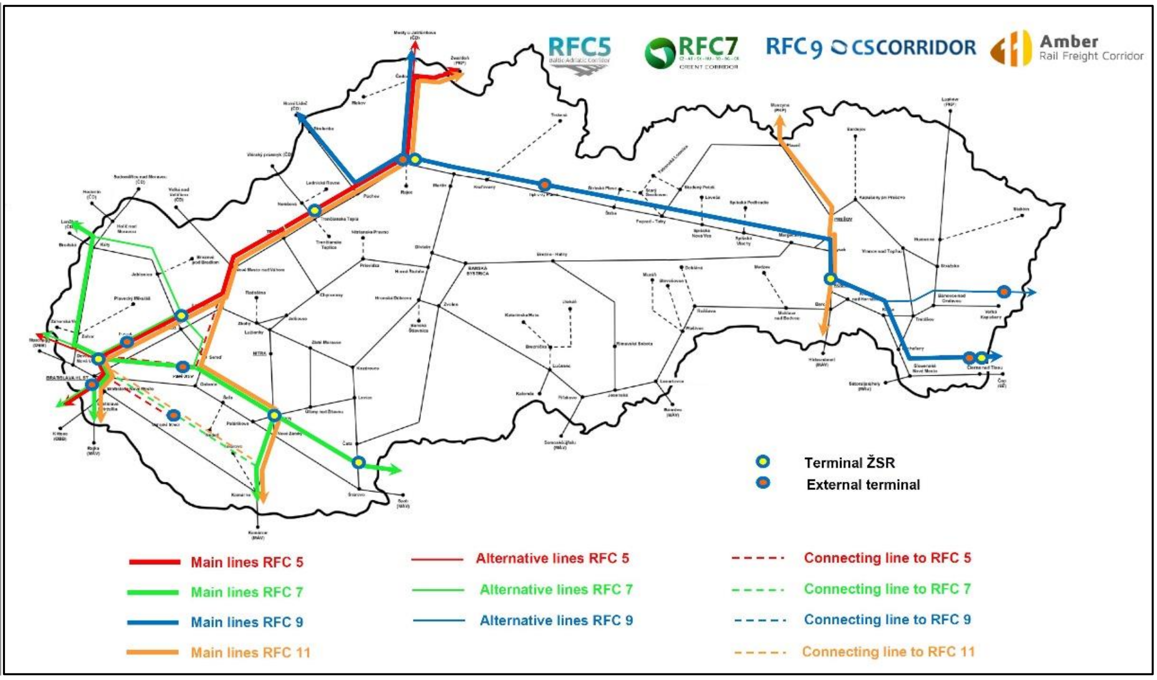

Fig. 1. Rail Freight Corridors situated on ŽSR railway network [22]

Slovak railway infrastructure

Railway lines managed by ŽSR are marked with numbers starting from 101 to 130 (according to the timetable information instruments). Within one track or one numerical designation, there may be included more track sections which are not directly connected.

Track Typologies

Železnice Slovenskej republiky ensures the serviceability of railway infrastructure in railway tracks, structures and buildings.

The railway lines managed by ŽSR comprise the main and the secondary lines in terms of the Act on Railroads and this classification is published on the Ministry website www.mindop.sk in the section "Ministry/Transport/Railway transport/State railway administration department/List of main and secondary lines".

Železnice Slovenskej republiky ensures the serviceability of railway infrastructure in railway tracks, structures and buildings, bridges and tunnels, electrical and power engineering installations and signalling systems. The Company takes care of railway infrastructure maintenance and development under technical progress and requirements for safety and the fluidity of railway traffic. ŽSR ensures these activities through its capacities and also by contracted relationships with suppliers.

ŽSR manages and operates nationwide and regional railway lines and installations as follows:

Table 5. ŽSR Railway infrastructure [22]

RAILWAY TRACKS AND STRUCTURES	unit	31 December 2021

Co-funded by the European Union

Construction length of operated lines	km	**3,580**
Construction length of managed lines	km	**3,627**
Construction length of lines	km	**6,866**
Number of crossings	pc	**2,079**
Number of switches	pc	**8,372**
Number of bridges	pc	**2,326**
The total length of bridges	m	**52,544**
Number of tunnels	pc	**76**
The total length of tunnels	**m**	**45,007**

Track Gauges

The track nominal gauge is 1,435 mm (95.91 % of the tracks) on the railway network managed by ŽSR.

Other track gauges:

Broad-gauge:

1,520 mm line sections: Haniska pri Košiciach ŠRT – Maťovce ŠRT – Uzhorod PSP (UZ)
Výh UZ km 271.0 ŠRT - Čierna nad Tisou ŠRT

Narrow-gauge:

1,000 mm line sections: Poprad-Tatry - Starý Smokovec - Štrbské Pleso (TEŽ)
Starý Smokovec - Tatranská Lomnica (TEŽ) Štrba - Štrbské Pleso (OZ)

760 mm line section: Trenčianska Teplá – Trenčianske Teplice (TREŽ)

Operated: (km) 3 582,462

- narrow gauge track 46,201
- broad gauge tracks 98,718
- normal gauge tracks 3,437,543

Data about lengths of railway tracks are current up to 31.12.2019.

Connecting Railway Networks

Table 6. ŽSR connecting Railway Networks [22]

No.	Border Crossing – ŽSR	Border Crossing - Connected	IM (state)
1	Kúty	Lanžhot	Správa železnic (CZ)
2	Holíč nad Moravou	Hodonín	Správa železnic (CZ)
3	Skalica na Slovensku	Sudoměřice nad Moravou	Správa železnic (CZ)
4	Vrbovce	Velká nad Veličkou	Správa železnic (CZ)
5	Horné Srnie	Vlárský průsmyk	Správa železnic (CZ)
6	Lúky pod Makytou	Horní Lideč	Správa železnic (CZ)
7	Čadca	Mosty u Jablunkova	Správa železnic (CZ)

Co-funded by the European Union

8	Skalité	Zwardoń	PKP-PLK (PL)
9	Plaveč	Muszyna	PKP-PLK (PL)
10	Medzilaborce	Łupków	PKP-PLK (PL)
11	Maťovce	Užgorod	UZ (UA)
12	Čierna nad Tisou	Čop	UZ (UA)
13	Slovenské Nové Mesto	Sátoraljaújhely	MÁV (HU)
14	Čaňa	Hidasnémeti	MÁV (HU)
15	Lenartovce	Bánréve	MÁV (HU)
16	Fiľakovo	Somoskőújfalu	MÁV (HU)
17	Štúrovo	Szob	MÁV (HU)
18	Komárno	Komárom	MÁV (HU)
19	Rusovce	Rajka	GySEV (HU)
20	Lučenec	Ipolytarnóc	MAV (HU)
21	Malé Straciny	Nógrádszakál	MÁV (HU)
22	Bratislava-Petržalka	Kittsee	ÖBB Infrastruktur AG (AT)
23	Devínska Nová Ves	Marchegg	ÖBB Infrastruktur AG (AT)

Note: Concerning the application of the procedures set out in the Commission Implementing Regulation 2019/773 on a technical specification for interoperability relating to the operation and management subsystem 2.1 "(OPE TSI) are border posts identical to the border stations of ŽSR listed in Table 6.

Power Supply

Railway lines managed by ŽSR are divided into electrified and non-electrified and the extent is distinguished in a different colour in the application ŽSR Info Map.

- Electrified lines km 1,585
- Developed length of traction lines km 5,014
- Supply and distributing substations pc 94

Electrified lines are further divided by traction systems as shown in the table:

Table 7. ŽSR electrified railway lines [22]

Traction system	Railway lines
Direct current (600 V)	Trenčianska Teplá – Trenčianske Teplice (TREŽ)
Direct current (1,5 kV)	Poprad-Tatry – Starý Smokovec – Štrbské Pleso (TEŽ)
	Starý Smokovec – Tatranská Lomnica (TEŽ)
	Štrba – Štrbské Pleso (OZ)
Direct current (3 kV)	state border UA/SR - Čierna nad T. – Košice – Žilina – Púchov (outside) – Lúky pod Makytou – state border SR/CZ
	Púchov (outside) – Lúky pod Makytou – state border SR/CZ
	Žilina - Čadca – štátna hranica SR/CZ
	state border UA/SR - ŠRT Maťovce – Haniska pri Košiciach ŠRT
	Maťovce – Bánovce nad Ondavou – Michaľany
	Trebišov – Výh.Slivník
	state border PL/SR – Plaveč – Prešov -– Kysak

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	Košice – Haniska pri Košiciach
	state border HU/SR – Čaňa – Barca
	Čadca – Skalité state border SR/PL
	Vrútky – Martin
	Výh UZ km 271,0 ŠRT - Čierna nad Tisou ŠRT
Alternating current, single-phase (25 kV 50Hz)	Banská Bystrica - Zvolen – Hronská Dúbrava – Šurany – Nové Zámky
	Šurany – Palárikovo
	Nové Zámky – Komárno – state border SR/HU
	state border HU/SR Rusovce – Bratislava
	state border HU/SR - Štúrovo – Bratislava – Kúty – state border SR/CZ
	Bratislava node
	Púchov – Bratislava hl.st.
	Leopoldov – Galanta
	Sereď – Trnava – Kúty
	Kúty – Holíč nad Moravou - state border SR/CZ
Alternating current, single-phase (15 kV 16,7 Hz)	Bratislava-Petržalka – state border SR/AT

Train Control Systems

Information on the train interlocking system at relevant track sections is provided in the track conditions tables (Table 8) and the application ŽSR Info Map. In connection with the deployment of interoperability along railway lines, ETCS (European Train Control System) is rolled out on upgraded track sections under applicable EU and national legislation.

ETCS complemented by the radio-communication GSM-R system is part of the European Rail Traffic Management System (ERTMS).

Railway lines managed by ŽSR equipped with ETCS:

- Bratislava - Rača (outside) – Púchov (ETCS L1)
- Považská Teplá (outside) – Žilina (outside) (ETCS L1)
- Žilina (outside) – Čadca (ETCS L2)

Signalling Systems

Table 8. ŽSR signalling systems [22]

Signalling systems	**unit**	
Track signalling systems		
Automatic block	km	478
Automatic block system	km	370
Semi-automatic block	km	714
Line with telephone communication system	km	1,793
Station signalling system	pc	513
Remote-controlled signalling systems operated by the dispatcher	km	396
Train signalling system	km	753
Crossing signalling system	pc	2,079
of which:		

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Passive crossings - unsecured	pc	1,003
Active crossings - secured	pc	1,076
of which:		
Automatic crossings	pc	1,029
manual crossings	pc	47
Hump signalling systems	pc	218

Operating control points

Table 9. ŽSR operating control points [22]

Operating control points total	pc	**1,024**
Operating control points manned/unmanned	pc	**364 / 660**
of which:		
Railway stations	pc	**294**
Border stations	pc	**22**
Other operating control points (blocks, branching-off, turn-out, stops, transhipment yards, gatekeeper post, operating control points under Regulation ŽSR Z1 and others)	pc	**708**

Railway Undertakings performance

From the year-on-year perspective, a decrease of 4.087 million train-km was recorded in transport performance, which was caused by the impact of COVID-19 measures. The decrease in total performance was largely on the side of passenger transport, where we record a year-on-year decrease of 2.998 million train-km. The decrease in rail passenger services was caused by a change in the Timetable – suspension of international passenger services, and a significant decrease in domestic transport due to mobility restrictions. The largest decrease in transport performance by 2.169 million train-km reported Železničná spoločnosť Slovensko, a. s., while the carrier RegioJet recorded a decrease of 0.454 million train-km and, Leo Express s. r. o. reported a decrease of 0.252 million train-km.

In freight transport, we record a year-on-year decrease in transport performance by 1,089 thousand train-km. The largest decrease of 0.996 million train-km reported Železničná spoločnosť Cargo Slovakia. For other railway undertakings, there was a year-on-year decrease in transport performance by 0.93 million train-km.

Table 10. ŽSR performance [22]

Performance	Unit	31 December 2020	Year-on-year change in %
Passenger transport	(million train-km)	34.146	-8.07
	(million grtkm)	9.002	-13.70
Freight transport	(million train-km)	14.079	-7.18
	(million grtkm)	16.447	-8.13

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Total	**(million train-km)**	**48.225**	**-7.81**
	(million grtkm)	**25,449**	**-10.18**

2.1.5 Czech Republic

Správa železnic, státní organizace (hereafter „Správa železnic“), is a state organization under public law. Správa železnic wishes to contribute to sustainable mobility within the European rail network to boost economic and social development in the Czech Republic.

It is responsible for the operation, maintenance and renewal of railway infrastructure, for the control and the safety of all train traffic as well as for participating in the development of the infrastructure.

In the Czech Republic, basic legal conditions for the construction of railways, the conditions for the operation of railways, the operation of railway transport on these railways, as well as rights and obligations of natural and legal persons associated with them are stipulated by the Rail Act and its implementing regulations, as amended, as well as directly effective regulations of the European Union.

International Corridors

Správa železnic is involved in RFC Baltic-Adriatic, RFC Orient/East-Med, RFC North Sea-Baltic and RFC Rhine-Danube.

Link to RFC Baltic-Adriatic, RFC Orient/East-Med, RFC North Sea-Baltic and RFC Rhine-Danube website:

- RFC Baltic-Adriatic – https://www.rfc5.it/,
- RFC Orient/East-Med – www.rfc7.eu,
- RFC North Sea-Baltic – www.rfc8.eu,
- RFC Rhine-Danube– http://rfc-rhine-danube.eu/.

The Czech railway infrastructure

The railways where the Správa železnic is the allocation body, i.e. the national railway and regional railways owned by the state, the national and regional railways, which are not owned by the state, but where the Správa železnic is the railway operator and part of the regional railway owned by the state between the state border of the Czech Republic and the Kraslice railway station where the Správa železnic is authorized by PDV Railways, s.r.o.

The railway lines managed by ŽSR comprise the main and the secondary lines in terms of the Act on Railroads and this classification is published on the Ministry website www.mindop.sk in the section “Ministry/Transport/Railway transport/State railway administration department/List of main and secondary lines“.

Infrastructure Typologies

Table 11. Basic characteristics of the Czech Railway Network [23]

Indicator	Unit of measurement	Amount 2020
Total length of lines	km	**9,377**
Length of electrified lines	km	**217**
– 3 kV DC traction system	km	**796**
– 25 kV AC 50 Hz traction system	km	**1,383**
– 1.5 kV DC traction system	km	**24**
– 15 kV AC traction system	km	**14**
Length of standard-gauge lines	km	**9,354**
Length of narrow-gauge lines	km	**23**
Length of single-track lines	km	**7,337**
Length of double- and more-track lines	km	**2,039**
Total construction length of tracks	km	**15,189**
Number of switch units	s.u.	**22,240**
Bridges	pcs	**6,719**
Tunnels	pcs	**166**
Total bridge length	m	**154,422**
Total tunnel length	m	**54,072**
Level crossings	pcs	**7,784**

Track Gauges

Nationwide and regional railways consist of tracks with standard gauge, defined under UIC Decree No. 510, i.e. 1,435mm (except for the Třemešná ve Slezsku – Osoblaha regional railway with a narrow track gauge of 760mm).

Connecting Railway networks

Table 12. Contact points of nationwide and regional railways with railways in neighbouring countries [23]

Border point	Connected IM
Aš st.hr. (km 29,585)	DB Netz AG (DB Netz)
Bohumín st.hr. (km 279,628)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Bohumín-Vrbice st.hr. (km 4,275)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Břeclav st.hr. (km 77,992)	ÖBB Infrastruktur AG (ÖBB Infra)
Česká Kubice st.hr. (km 184,102)	DB Netz AG (DB Netz)
České Velenice st.hr. (km 163,100)	ÖBB Infrastruktur AG (ÖBB Infra)
Český Těšín st.hr. (km 139,112)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Děčín st.hr. (km 11,860)	DB Netz AG (DB Netz)
Dolní Poustevna st.hr. (km 26,271)	DB Netz AG (DB Netz)
Frýdlant v Čechách st.hr. (km 200,107)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Harrachov st.hr. (km 40,111)	Dolnośląska Służba Dróg i kolei (DSDiK)
Hodonín st.hr. (km 3,009)	Železnice Slovenské republiky (ŽSR)
Horní Dvořiště st.hr. (km 61,097)	ÖBB Infrastruktur AG (ÖBB Infra)
Horní Lideč st.hr. (km 21,110)	Železnice Slovenské republiky (ŽSR)

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Hrádek nad Nisou st.hr. (km 21,769)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Cheb st.hr. (km 140,587)	DB Netz AG (DB Netz)
Jindřichov ve Slezsku st.hr. (km 25,694)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Královec st.hr. (km 62,089)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Kraslice st.hr. (km 27,452)	DB Netz AG (DB Netz)
Lanžhot st.hr. (km 11,395)	Železnice Slovenské republiky (ŽSR)
Lichkov st.hr. (km 113,251)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Meziměstí st.hr. (km 92,774)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Mikulovice st.hr. (km 51,500)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Mosty u Jablunkova st.hr. (km 286,534)	Železnice Slovenské republiky (ŽSR)
Petrovice u Karviné st.hr. (km 292,602)	PKP Polskie Linie Kolejowe S.A. (PKP-PLK)
Potůčky st.hr. (km 46,199)	DB RegioNetz Infrastruktur GmbH
Rumburk st.hr. (km 97,690)	DB Netz AG (DB Netz)
Sudoměřice nad Moravou st.hr. (km 14,950)	Železnice Slovenské republiky (ŽSR)
Varnsdorf st.hr. (km 11,459)	DB Netz AG (DB Netz)
Varnsdorf staré nádr. st.hr. (km 13,706)	Deutsche Regionaleisenbahn GmbH (DRE)
Vejprty st.hr. (km 35,391)	DB RegioNetz Infrastruktur GmbH
Velká nad Veličkou st.hr. (km 44,685)	Železnice Slovenské republiky (ŽSR)
Vlárský průsmyk st.hr. (km 163,500)	Železnice Slovenské republiky (ŽSR)
Vojtanov st.hr. (km 51,897)	DB Netz AG (DB Netz)
Znojmo st.hr. (km 87,660)	ÖBB Infrastruktur AG (ÖBB Infra)
Železná Ruda st.hr. (0,000)	DB Netz AG (DB Netz)

Power Supply

On nationwide and regional railways, the following traction systems are used:

a) DC 3 kV,
b) AC 25 kV / 50 Hz,
c) AC 15 kV / 16,7 Hz,
d) DC 1,5 kV.

Table 13. Contact points of traction systems DC 3 kV and AC 25 kV / 50 Hz [23]

Line	Contact point of traction systems
Přerov–Břeclav[2]	Nedakonice – km 132,103
Přerov–Brno	Nezamyslice – Ivanovice na Hané – km 60,558
Česká Třebová–Brno	Svitavy – Březová nad Svitavou – km 228,109
Kolín–Havlíčkův Brod	Kutná Hora hl.n. (koleje 1 – 6, 11) – km 287,580 – 287,310
Praha–České Budějovice	Benešov u Prahy – Olbramovice – km 132,000
Praha–Plzeň	Beroun – Zdice – km 41,080
Chomutov–Cheb	Kadaň-Prunéřov – Klášterec nad Ohří – km 138,870

Table 14. Contact points of traction systems DC 1.5 kV and AC 25 kV / 50 Hz [23]

Line	Contact point of traction systems
Tábor–Bechyně	ŽST Tábor (průjezd elektrických hnacích vozidel vlastní silou mezi částmi kolejiště elektrizovanými soustavou AC 25 kV a DC 1,5 kV není možný)

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Table 15. Contact point of traction systems at the state border [23]

Foreign IM	Contact point of traction systems	Note
DB Netz	Dolní Žleb st.hr. – Bad Schandau km 11,853	DC 3 kV/AC 15 kV
ÖBB	Sumerrau – Horní Dvořiště km 61,097	AC 15 kV/AC 25 kV
ÖBB	žst. České Velenice km 163,134	AC 15 kV/AC 25 kV
ÖBB	Břeclav st. hr. – Břeclav km 78,000	AC 15 kV/AC 25 kV

Table 16. Basic interface parameters of the pantograph – TV [23]

Parameter	25 kV, 15 kV	3 kV, 1,5 kV
Material of pantograph skid	pure carbon carbon filled copper max. 35%	pure carbon carbon filled copper max. 40%
Length of the collector's head	1950 mm	1950 mm
Width of the collector head	max. 65 cm	max. 65 cm
The static contact force of the pantograph	75 ±15 N	105 ±15 N
The aerodynamic contact force of the pantograph	According to EN 50367 Ed. 2, picture. A.8	According to EN 50367 Ed. 2, picture A.10
Number and distance of pantographs	1-4 pantographs, distance according to Table 4.2.13 TSI ENE, Type A For 3 and more pantographs valid also EN 50367 ed. 2, paragraph. A.1.5, arrangement I.is used too. Longer distances are always used.	1-4 pantographs, distance according to Table 4.2.13 TSI ENE, Type A
Maximal contact wire height	6,300 mm	6,300 mm
Basic contact wire height	5,500 mm	5,500 mm
Minimal contact wire height	5,000 mm 5,100 mm for rail lines with Z-GC clearance profile	4,950 mm 5,100 mm for rail lines with Z-GC clearance profile
Sections for phase separation	the short neutral section according to EN 50367 divided neutral section of arrangement I according to EN 50367 special solution	N/A

Recovery on SZDC electrified lines is permitted at locations marked with appropriate signal devices for electrical operation. Detailed conditions and requirements are given in the directions of SPRÁVA ŽELEZNIC Managing Director, No. 11/2009 (DC 3 kV) and No. 14/2008 (AC 25 kV/50 Hz).

In the years 2021-2024 the Týniště n. O. (off) – Častolovice – Solnice railway will be electrified with AC 25 kV, 50 Hz. For this route, the construction of an FCD (filter-compensating device) that compensates for a power factor of less than 1 in the case of older electrical traction vehicles is not considered. For this reason, only four-quadrant converters with power factor 1 will be allowed to operate on this route.

Train Control Systems

On nationwide and regional railways, the national LS train system and the ERTMS/ETCS system are used as ATP (Automatic Train Protection) systems.

The National LS train control system is a low-capacity line train control system using a frequency-impulse code for the transmission of information between the station or trackside signalling block systems and the mobile part of the national train protection system on the rail vehicle. Circuits designated for code transmission from the train control system on railways where this equipment is used are considered parts of the station and trackside signalling block devices. Station and trackside signalling block devices provide via the national LS train control system simplified signalling information on the next main or distant signal at a longer distance than 1,000 m as if there was a Free Sign.

These are Class B equipment according to the Technical specifications for interoperability in terms of security and management within a subsystem Transeuropean railway system (TSI CCS) for the Czech Republic.

The ERTMS/ETCS system is a European train control system. This is Class A according to the TSI CCS. A detailed description of the ERTMS / ETCS system, its functions and requirements are to be found in documents referenced in the TSI CCS.

The use of ERTMS/ETCS system of Level 2 requires the use of encryption keys to encrypt user data for radio transmission between the radio block central (RBC) and the ETCS mobile part. Encryption keys for ETCS mobile parts are issued at the request of Správa železnic for RBC under its administration. The requirement for the application and detailed procedure are to be found in a separate Správa železnic document published on the Infrastructure Operation Portal.

On the Kolín – Česká Třebová – Brno – Břeclav state border Austria/Slovakia track section, a trackside part of the ERTMS/ETCS system of Level 2 in the version according to the set of specifications No. 1 of the TSI CCS (2.3.0d). The conditions for operating locomotives, control wagons and special traction vehicles with the enabled ETCS mobile part and controlled by this system are specified in the internal regulations of the railway operator.

On the sections Petrovice u Karviné st.hr. PL – Přerov – Břeclav (outside), Brodek u Přerova - Česká Třebová (outside), Český Brod - Praha-Běchovice - Praha-Malešice - Praha-Uhříněves a trackside part of the ERTMS/ETCS system of Level 2 in the version according to the set of specifications No. 3 of the TSI CCS (3.6.0) in system version 1.1 (allows operation of vehicles with the ETCS mobile part version according to the specification set No. 1 [2.3.0d], No. 2 [3.4.0] and No. 3 [3.6.0] according to TSI CCS)

Furthermore, the construction of the line part of the ERTMS / ETCS system is underway with commissioning before the entry into force of the 2022 timetable in the sections Hrušovany u Brna

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(outside) - Židlochovice and Hustopeče u Brna - Šakvice (outside), within which the ERTMS / ETCS level 2 system is implemented. in the version according to the specification set No. 1 (2.3.0d) according to the TSI CCS.

Furthermore, the construction of the line part of the ERTMS / ETCS system is underway and is being prepared with the expected commissioning before the entry into force of the 2022 timetable or during its validity in the sections Plzeň hlavní nádraží (outside) - Cheb (outside), Cheb - Cheb st. hr. DE, Beroun - Plzeň main railway station, České Budějovice - Votice (outside), Votice - Prague-Uhříněves (outside), Prague-Hostivař (outside) - Prague-Vršovice, Prague-Libeň - Prague-Malešice (outside), Prague-Malešice (outside) - Prague-Garden City, Kolín (outside) - Český Brod (outside), Prague-Běchovice (outside) - Prague-Libeň - Prague- Holešovice - Kralupy nad Vltavou (outside), Ústí nad Orlicí (outside) - Lichkov st. hr. PL, Přerov (outside) - Brodek u Přerova (outside), Prosenice - Dluhonice, Mosty u Jablunkova st. hr. SK - Dětmarovice (outside) / branch Závada (outside), Uničov - Olomouc main railway station (outside), within which the ERTMS / ETCS level 2 system is implemented in the version according to the set of specifications No. 3 according to TSI CCS (3.6.0) in system version 1.1.

A condition for activating the encryption keys by RBC for ETCS mobile parts of individual vehicles is to demonstrate the mutual compatibility of the used type of ETCS mobile part (including the SW version) with the trackside part of the ETCS (type and SW version).

Compatibility is demonstrated by:

- submitting a copy of the ES declaration of verification of the onboard subsystem “control command and signalling” for a specific vehicle;
- submitting a copy of the ES certificate of verification of the onboard subsystem “control command and signalling”;
- submitting a copy of the protocol of successful completion of compatibility testing of the used part of the mobile part (according to Chapter 6.5 of the Annex to Commission Regulation (EU) 2016/919). The extent and conditions for compatibility testing are set out in a separate Správa železnic document published on the Infrastructure Operation Portal.

Signalling Systems

The signalling system consists of a uniform system of visible signals in a specified design, shape and colour and audible acoustic signals in a specified design. The signalling system enables easy, fast and unambiguous expression and apprehension of signals and ensures the safe operation of rail transport. The basic signals of the signalling system are listed in Annex 1, Part I, of Decree No. 173/1995 Coll. of the Ministry of Transport from 22 June 1995 by means of which the Railway Transport Rules are issued. Other signals used, are listed in the internal regulations of the railway operator.

Signals are expressed by signal aids (e.g. signalling flag, light, signal board), by hand (visible hand signals), sound (acoustic signals), using signal signs of mechanical or light signal devices and permanent signal devices (visible signals) or by verbal instructions.

Automatic Train Operation

On selected railways of the nationwide and regional network, the automatic train control system (AVV) system is used as the ATO (Automatic Train Operation) system.

For the Automated train control system (AVV), a positioning device, so-called magnetic information points, are located on the track. Magnetic information points are mainly located on rails designed for passenger (stopping) trains. On some tracks, it is also necessary to use GPS (Global Position System) for the AVV mobile (vehicle) parts to identify the location.

The AVV mobile (vehicle) part must include the route map. Based on the local identification of the train, track description and information transmitted via the train control system and/or inserted by the engine driver, the AVV mobile (vehicle) section ensures smooth and economical train movements.

Railway Operators

In 2020, the total number of carriers that have concluded a contract with Správa železnic for the operation of rail transport using state-owned national and regional railways increased to 122.

The total volume of outputs in passenger transport [24] decreased in 2020. Compared to 2019, train kilometres (trkm) decreased by 3 %, and gross tonne-kilometres (gtkm) by 10 %, with České dráhy, a.s. accounting for the majority of total outputs.

ARRIVA vlaky s.r.o., RegioJet ÚK a.s., and Die Ländebahn CZ s.r.o. reported a significant increase in the volume of passenger transport outputs.

Since 13 December 2020, supporting data are used for the calculation of the fee for the use of access roads for passenger transport.

In freight transport [24], total outputs reported a year-on-year decline, with trkm decreasing by 8 % compared to 2019 in the Správy železnic’s network. ČD Cargo, a.s. (ČD Cargo) has retained the majority share in the outputs.

Rail Cargo Carrier – Czech Republic, s. r. o. and LTE Logistik a Transport Czechia s. r. o. also reported a significant increase in the volume of freight transport outputs.

Table 17. Number of carriers (as of 31 December of each respective year) [24]

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number	75	79	84	89	94	96	99	103	107	122

Table 18. Percentage share of carriers on passenger transport output in 2020 [24]

Carrier/Indicator	% of trkm	% of gtkm
České dráhy, a.s.	85.93	86.41
RegioJet, a.s.	4.30	9.23
ARRIVA vlaky, s.r.o.	3.89	1.71

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GW Train Regio a. s.	1.98	0.67
Leo Express, s.r.o.	1.11	1.01
Die Länderbahn CZ, s.r.o.	0.86	0.19
RegioJet ÚK, a.s.		
Leo Express Tenders, s.r.o.	0,47	0.24
Die Länderbahn GmbH DLB	0.31	0.11
Other	0.40	0.12

Table 19. Percentage share of carriers on freight transport output in 2020 [24]

Carrier/Indicator	% of trkm	% of gtkm
ČD Cargo, a.s.	58.53	58.59
PKP CARGO INTERNATIONAL, a.s.	6.31	7.33
METRANS Rail s.r.o.	5.95	8.90
UNIPETROL DOPRAVA, s.r.o.	3.33	4.13
IDS CARGO, a.s.	3.23	3.61
Rail Cargo Carrier – Czech Republic, s.r.o.	3.08	4.28
CER Slovakia, a.s.	1.46	1.75
Cargo Motion, s.r.o.	1.27	1.22
LTE Logistik a Transport Czechia, s.r.o.	1.17	1.38
Other	15.67	8.81

Table 20. Number of line sections in timetables according to category (irrespective of carrier) [24]

Indicator	2019	2020
Ordinary passenger train (Os)	8,723	8,842
Regional fast passenger train (Sp)	541	591
Express trains (R)	538	507
Higher-quality trains (EC, EN, Ex, IC, LE, SC, railjet)	298	264
Express freight trains (Nex)	449	471
Continual freight train (Pn)	826	766
Handling train and work-siding trains (Mn, Vleč)	1,292	1,278
Train sets (Sv)	1,306	1,269
Locomotive trains (Lv)	646	626
Správa železnic catalogue (offer) paths	873	865

2.1.6 Poland

An infrastructure manager is an entity responsible for managing railway infrastructure or when it concerns the construction of new infrastructure, an entity which acts as an investor. The tasks of an infrastructure manager can be performed by other entities.

An infrastructure manager that grants access to its infrastructure to other entities is not allowed to run other rail transport services than these which it performs for its technical purposes. This restriction does not apply to infrastructure managers who grant access only to railway infrastructure belonging to a service facility.

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This restriction does not apply to a situation when an entity performs both the functions of an infrastructure manager and those of a railway undertaking and operates only urban, suburban or regional rail transport services on local or regional stand-alone railway infrastructure.

Currently, the entities performing both the functions of an infrastructure manager and those of a railway undertaking are the following:

- PKP Szybka Kolej Miejska Sp. z o.o.
- PKP Linia Hutnicza Szerokotorowa Sp. z o.o.
- Warszawska Kolej Dojazdowa Sp. z o.o.
- Narrow gauge rail operators.

The managers of standard gauge infrastructure (1435 mm) are obliged to grant access to their infrastructure on a non-discriminatory basis.

International corridors

Three international Rail Freight Corridors (RFCs) cross the rail network managed by PLK. The RFCs were established according to Regulation (EU) No. 913/2010 of the European Parliament and of the Council of 22 September 2010 concerning a European rail network for competitive freight [25]:

a) **Baltic-Adriatic Rail Freight Corridor 5 (RFC5):**
Świnoujście/Gdynia – Katowice – Ostrava/Zilina-Bratislava/Vienna –/Klagenfurt – Udine – (Venice – Bologna/Ravenna) / Trieste/ – Graz –Maribor –Ljubljana – Koper/Trieste,

b) **North Sea-Baltic Rail Freight Corridor 8 (RFC8):**
Wilhelmshaven / Bremerhaven / Hamburg / Amsterdam / Rotterdam / Antwerp – Aachen – Hannover / Berlin – Warsaw – Terespol (Polish- Belarussian border) / Kaunas - Riga – Tallinn / Falkenberg – Prague / Wrocław – Katowice – Medyka (Polish-Ukrainian border)2,

c) **Amber Rail Freight Corridor (RFC11):**
Koper – Ljubljana – / Zalaszentiván – Sopron/Csorna – / (Hungarian-Serbian border) – Kelebia – Budapest – / – Komárom – Leopoldov / Rajka – Bratislava – Žilina – Katowice / Kraków – Warsaw / Łuków – Terespol – (Polish-Belarussian border).

Polish Railway Infrastructure

The National Infrastructure Register (RINF) managed by the President of UTK in an electronic form is available to registered users on the website https://rinf.utk.gov.pl.

Infrastructure typologies

The PLK-managed railway network includes single-track and double-track railway lines, both electrified and non-electrified.

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Table 21. Railway lenghts [25]

Overview of the PLK-managed railway infrastructure in operation (as on 31 December 2019)	**Track gauge 1435 mm [km]**	**Track gauge 1520 mm [km]**	**TOTAL [km]**
Railway line length (total):	18,538,600	141,290	18,679,890
Of which single-track lines:	9,990,200	141,290	10,131,490
Of which double-track lines:	8,689,690	0	8,689,690
Railway track length:	35,688,762	262,049	35,950,811
Of which 27,120 km are open-line tracks and mainline tracks within railway stations:	27,103,010	141,290	27,244,300
Of which train station tracks:	8,585,752	120,759	8,706,511
Length of electrified railway lines:	11,909,040	14,329	23,369

2.1.6.1.1

1.1.1.1.1. Track gauges

PLK manages railway lines with the following track gauges: 1,435 mm (normal gauge standard) and 1,520 mm (wide gauge standard).

Power Supply

For the operation of rail vehicles on its electrified railway lines, PLK provides a contact system power supply rated at 3 kV DC.

PKP Energetyka S.A. Is the operator of the electrical power distribution network connected to the 3 kV DC contact system.

RUs which collect electrical power for traction vehicle propulsion are required to conclude contracts for electrical power purchase and electrical power distribution services or umbrella contracts for electrical power distribution and purchase with the competent power utilities.

Each RU that does not hold a concluded agreement referred to in section 3, may render the electrified operation of the RU on the railway infrastructure infeasible.

Detailed regulations for the operation of the railway infrastructure with overhead contact systems are stated in the Allocation or Usage Agreements.

Table 22. Railway power supply [25]

Specification	**Unit of measure**	**Year 2019**
Traction network equipment:		
length of electrified railway lines	km	11,998
length of traction network	tkm	24,991
catenary disconnectors	pcs.	20,093
including controlled	pcs.	13,483
Direct current equipment 3 kV (leased by PKP Energetyka S.A.):		
traction substations/sectional cabins	pcs.	11
modernised traction substations/sectional cabins	pcs.	26

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Electric points heating system (EOR):		
single turnouts, including locking equipment	pcs.	33,587
External lighting and power systems in buildings:		
points of external lighting	pcs.	205,826
installation points and internal lighting	pcs.	198,571
MV distribution lines:		
non-traction lines (NTL)	km	757
Electric power delivery points:		
number of electric power delivery points	pcs.	16,647
contracted capacity	kW	379,494

Train Control Systems

On selected railway lines managed by PLK, ETCS (European Train Control System) is in operation. ETCS enables train control by locomotive drivers and is a component of ERTMS (European Rail Traffic Management System).

ETCS ensures safe control of train traffic up to line speeds above 160 km/h and complies with the European Railway Interoperability requirements.

The primary functions carried out by ERTMS/ETCS include:

1. Definition of precise MAs (Movement Authorities), which include:
    a) The maximum driving distance defined by the MA limit;
    b) Specification of the driving way, which includes a static line speed profile, a track gradient, locations to avoid stopping the train, and other information;
    c) Line speed limit warnings;
2. Continuous monitoring of run parameters for the trains with onboard ERTMS/ETCS equipment; the monitored parameters include:
    a) The permissible (maximum) driving speed imposed by the train technical parameters and the MA transmitted by the ERTMS/ETCS trackside equipment units;
    b) EoA (End of Authorization)
    c) Operating mode for the ERTMS/ETCS onboard equipment;
3. Monitoring of the actions and reactions taken or neglected by the locomotive drivers in response to the commands and information transmitted via ERTMS/ETCS.

ERTMS/ETCS makes the locomotive driver responsible for correct train control based on the data relayed to the driver by the onboard equipment and the applicable national regulations. The detailed information required for locomotive drivers to discharge their professional duties while driving trains under the guidance of ERTMS/ETCS is specified in the regulations from respective RUs.

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The trains operating on ERTMS/ETCS railway lines are not required to feature ERTMS/ETCS onboard devices. If a train does not feature ERTMS/ETCS onboard equipment, it shall be operated on a non-ERTMS/ETCS railway line, with the control of trackside signals and signs.

Signalling Systems

All topics related to the signalling systems and the list of signals operated in the PLK-managed railway network are regulated in Signalling Manual, listed in Annex 3.1 in the Network Statement of PLK [25].

Operating systems

The primary system used at the Railway Traffic Management Centre is the Operating Performance Registration System (SEPE). It cooperates with approx. 30 systems used by the Company, systems owned by railway operators and neighbouring infrastructure managers.

The information included in the SEPE system comes from the following sources:

1. The Dispatcher Support System (SWDR), in which traffic controllers record the time that a train passes through a station on average up to 3 minutes after the train has passed. After the completion of work on the implementation of a new system called Electronic Traffic Log (EDR), it takes over all functionalities currently supported by SWDR;
2. GPS transmitters installed on traction vehicles of railway operators;
3. data from Local Control Command and Signalling Centres (LCS, the so-called “track signal”);
4. data registered in SEPE by line dispatchers based on information from train dispatchers.

Apart from data on the current location of trains, SEPE also registers data on reasons for delays along with an indication of the entity responsible for the delay, events occurring on the network managed by the Company, and planned and emergency track closures.

Information on the current location of trains, delays and reasons for such delays as well as events occurring on the railway network are presented in the Crisis Management Centre Map (CZK Map) application constituting the primary tool in crises. The CZK Map application is also used in the operation process on an ongoing basis.

At the request of railway undertakings, a dedicated version of the application CZK-P Map was developed, which enables presenting information about the current location of a train of a given undertaking, which uses the application, and other railway undertakings, which agreed to have access to data about their trains. The described functionality of the CZK-P Map application is used by passenger carriers, and since 2018 also freight carriers.

The application used to monitor international train traffic is the Train Information System (TIS) which collects and presents data on trains running on the railway networks in most EU Member States.

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Applications described above (apart from TIS) have been developed by PKP Polskie Linie Kolejowe S.A. using their own means, which significantly facilitated the software development and implementation process.

Implementation work is being carried out for the project entitled: "Development of a design, performance and implementation of an IT solution titled SEPE II – Operating Performance Registration System v. II" has been continued; the new system is planned to replace the SEPE system currently in use. The implementation of the project is planned for 2020.

Groups of railway traffic control equipment in numbers

Table 23. Railway traffic control equipment [25]

Station equipment	**As at 31/12/2019**		
	Signalling centre control area	**Points**	**Signalling device**
mechanical key	595	3,800	2,009
mechanical centralised	957	12,408	10,109
electrical slide	85	2,808	1,895
Relay	749	17,635	21,351
relay-computer	107	1,543	2,297
Computer	336	7,090	9,178
In total	2,829	45,284	46,839

Traffic control systems

The PLK-managed railway network features three general functional groups of traffic control equipment:

- Signal box (station) equipment;
- Open line signalling equipment which controls traffic on train lines;
- Traffic safety equipment at railway crossings.

The line traffic control is managed as follows:

- By signalling traffic via telephone communication equipment, and in the event of telephone communication interruption, via radiotelephone communication equipment;
- With manual block system equipment;
- With automatic block system equipment;
- With remote traffic control equipment;
- By radiotelephone communication between line section traffic operators and drivers of motive units, without the mediation of remote traffic control equipment and passing track manning;
- Without train signalling a single-traction vehicle serves all trains;
- With ERTMS/ETCS Level 1 and 2.

Railway Operators

Business activities based on the provision of passenger or freight transport services by rail or the provision of traction services are subject to licensing.

Rail transport licensing is designed to ensure that the rights of access to the rail transport market are applied on a uniform basis and in a non-discriminatory manner to businesses that wish to provide passenger, freight or traction services on the market.

Actual list of railways operators can see in below link: https://www.utk.gov.pl/pl/rejestry/licencjonowani-przewozn/17781,Wykaz-przedsiebiorcow-posiadajacych-licencje-przewoznika-kolejowego-wydana-przez.html#page for Province Marshals, and for the Mayor of Warsaw. The scope and duration of such contracts are individually determined by the respective organisers.

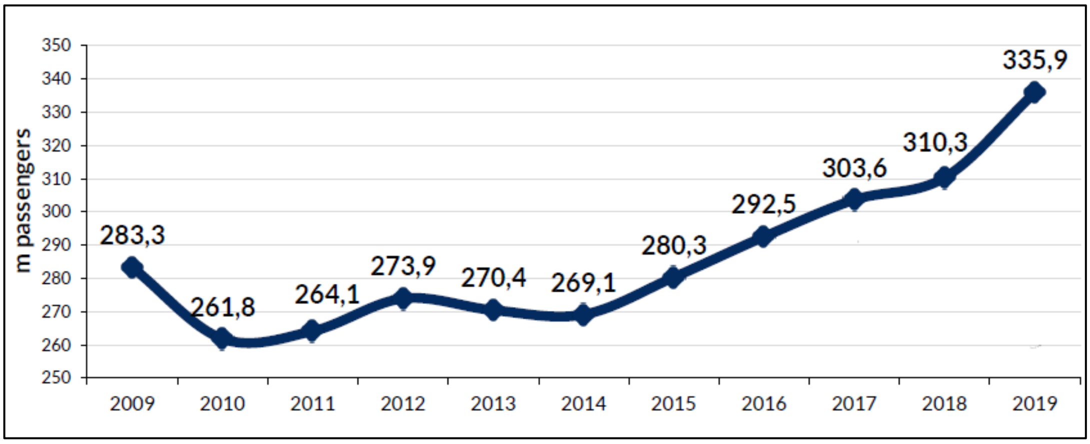

Fig. 2. Number of passengers in Poland from 2009 – 2019 [26]

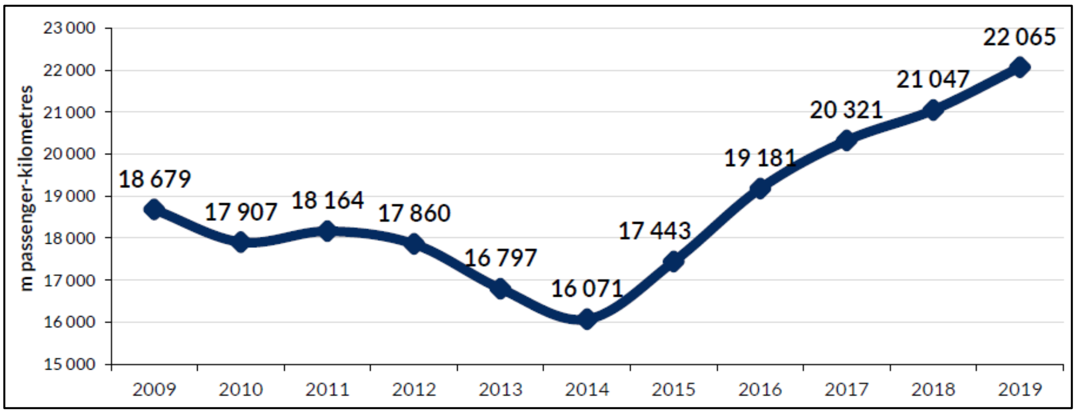

Fig. 3. Number of passengers-kilometres in Poland from 2009 – 2019 [26]

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Freight Transport

In 2019 railways in Poland transported nearly 236.4 m tonnes of cargo. A year before this figure was 250.3 m tonnes. This meant a decrease of 5.5% (13.9 m tonnes). The months with the lowest freight transport performance were December (17.5 m tonnes) and June (18.6 m tonnes).

The decline in 2019 followed two consecutive years of growth in the weight of transported goods. The result for 2019 most closely resembles the one for 2010.

In 2019 entities which had been on the market for a relatively short time engaged in intensive transport activities. The data for 2019 also indicate a rising interest in entering the market among new railway undertakings. Freight rail transport services were provided, i.a., by logistics operators and railway undertakings being part of international rail enterprises, as well as manufacturing companies.

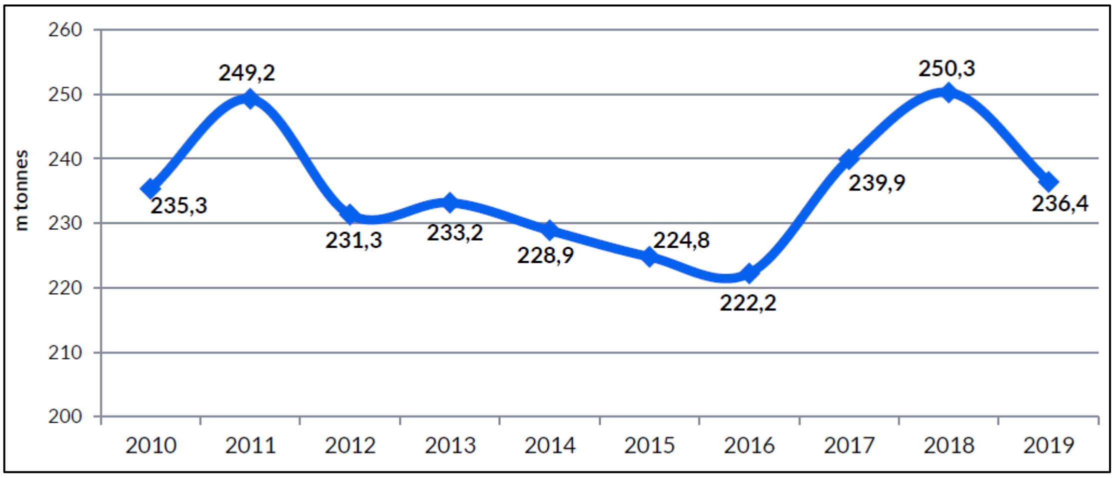

Fig. 4. Amount of freight transport in tonnes in Poland from 2010 – 2019 [26]

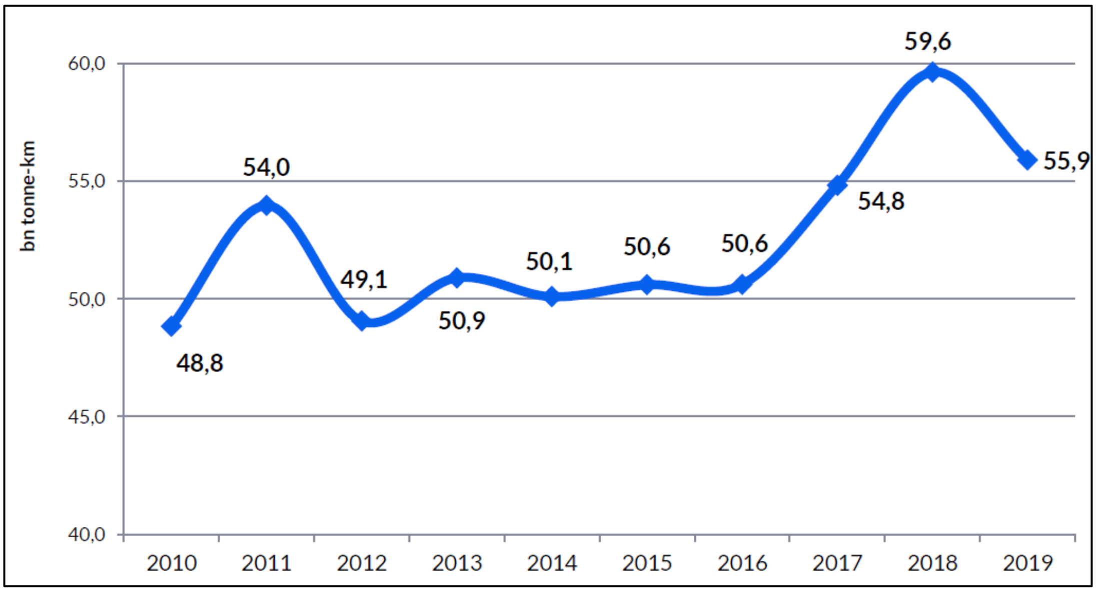

Fig. 5. Amount of freight transport in tonne-kilometres in Poland from 2010 – 2019 [26]

Table 24. List of freight railway undertakings in Poland [27]

Railway undertaking	hard coal, lignite, crude oil and natural gas	metal ores and other mining and quarrying products	coke and refined petroleum products	chemicals, chemical products, and man-made fibres; rubber and plastic products; nuclear fuel	basic metals, fabricated metal products, except machinery and equipment
Alza Cargo	✔	✔	✔		✔
Barter	✔	✔			
B.R.S.		✔			
Bartex	✔	✔			
Bartex Plus		✔			
Captrain Polska	✔		✔	✔	✔
Cargo Master		✔			
Cargo PTT	✔				
CD Cargo Poland	✔	✔	✔	✔	✔
CL Łosośna	✔	✔			
Ciech Cargo	✔	✔		✔	
Colas Rail	✔	✔			
CTL Logistics	✔	✔	✔	✔	✔
CTL Północ	✔	✔	✔		✔
DB Cargo Polska	✔	✔	✔	✔	✔
DB Cargo Spedkol				✔	
Depol		✔			
Ecco Rail	✔	✔	✔	✔	✔
EP Cargo	✔	✔	✔		
Eurotrans	✔	✔	✔	✔	✔
Freightliner PL	✔	✔			✔
HSL Polska	✔	✔	✔	✔	✔
Grupa Azoty „Koltar”	✔	✔		✔	
Inter Cargo	✔	✔	✔		✔
IRT	✔	✔	✔	✔	✔
JSW Logistics	✔		✔		
Karpiel					✔
Kolej Bałtycka	✔	✔	✔	✔	✔
KP Kotlarnia	✔	✔			
LTC	✔	✔			
Lotos Kolej	✔	✔	✔	✔	✔
LTE Polska		✔		✔	✔
LW Bogdanka	✔				
Majkoltrans		✔		✔	
Moris					✔
Olavion	✔	✔	✔	✔	✔
ORLEN KolTrans	✔		✔	✔	

PKP Cargo	✔	✔	✔	✔	✔
PKP Cargo International	✔				
PKP Cargo Service	✔	✔			✔
PKP LHS	✔	✔	✔	✔	✔
Pol-Miedź Trans	✔	✔	✔	✔	✔
POZ BRUK		✔			
PPMT		✔			
PUK Kolprem	✔	✔	✔		✔
Rail Cargo			✔	✔	✔
Rail Polska	✔	✔	✔	✔	
Rail STM	✔	✔			✔
Railpolonia		✔			
Silva LS				✔	
SKPL Cargo		✔			
STK	✔	✔	✔		✔
Swietelsky Rail Polska		✔			
Tabor Rail	✔	✔			
Torpol		✔			✔
Trakcja PRKiI		✔			✔
Transchem			✔	✔	✔
Wiskol		✔			✔
ZIK Sandomierz		✔		✔	
ZUE		✔			
Agnieszka Dolata		✔			

Passenger transport

Passenger rail transport in Poland is performed by licensed railway undertakings. It can be provided as:

- public services;
- commercial transport;
- occasional transport.

Passenger rail transport services are currently performed as public services for 18 organisers of public collective transport under public service contracts, i.e. for the minister in charge of transport,

2.1.7 Croatia

HŽ Infrastruktura d.o.o. (short: HŽI) is a limited liability company, 100% owned by the Republic of Croatia. HŽI wants to contribute to sustainable mobility within the European rail network to boost economic and social development in the Republic of Croatia [28].

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HŽ Infrastruktura is the railway infrastructure manager which consists of the railway lines classified according to the Regulation on the Classification of Railway Tracks (NN 3/2014). This railway infrastructure is owned by the Republic of Croatia, and it is public property for general use, which cannot be alienated from the Republic of Croatia. Exceptionally, real property rights to it may be acquired in the way laid down in the Railway Act (NN 32/19, 20/21) [28].

Based on the Act on the Division of HŽ Hrvatske željeznice d.o.o., upon the day of its entry into the court registry HŽ Infrastruktura took over the possession, use and management of railway infrastructure which is a public good in general use.

International Freight Corridors (RFC)

Croatia and HŽ Infrastruktura is involved in two RFC corridors (Regulation 913/2010/EU), the Mediterranean Corridor - RFC 6 and Alpine Western Balkan RFC 10. Links to RFC Mediterian and RFC Alpine Western Balkan corridor:

- Mediterian- https://www.railfreightcorridor6.eu/RFC6/web.nsf/OnePager/index.html
- Alpine-Western Balkan - https://www.rfc-awb.eu/

The Croatia railway infrastructure

All railway lines in Croatia managed by HŽI comprise the main international second international lines, regional and local railway lines. HŽ Infrastruktura manages the 2,617 km long railway network [29].

Competent for railway in Croatia are the Ministry of Maritime Affairs, Transport and Infrastructure [30], Regulatory body – Croatian Regulatory Authority for Network Industries – (HAKOM www.hakom.hr), Safety Authority – Croatian Railway Safety Agency (ASŽ www.asz.hr), and Air, Maritime and Railway Traffic Accident Investigation Agency (http://www.ain.hr/).

The infrastructure topologies

Table 25. Characteristic of the Railway Network [29]

Indicator	**Unit of measure.**	**Amount 2020**
The total length of the lines	Km	2,617
Length of electrified lines	Km	980
– 3 kV DC traction system	Km	3
– 25 kV AC 50 Hz traction system	Km	977
Length of standard-gauge lines	Km	2,617
Length of single-track lines	Km	2,341
Length of double-track lines	Km	276
Number of stations and stops	Pcs	546
Bridges	Pcs	544
Tunnels	Pcs	109
Level crossings	Pcs	1,499

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Track Gauges

Nationwide and regional railways consist of tracks with standard gauges, defined under UIC Decree No. 510, i.e., 1.435 mm [29].

Connecting Railway Networks

Table 26. The contact points of nationwide and regional railways with railways in neighbouring countries [29]

Border Station	Line	Neighbouring country and Infrastructure manager
Buzet	State border - Buzet – Pula	Slovenia - SŽ
Lupoglav	State border - Buzet – Pula	Slovenia - SŽ
Šapjane	Rijeka - Šapjane - State border	Slovenia - SŽ
Kamanje	Karlovac - Kamanje - State border	Slovenia - SŽ
Savski Marof	State border - Savski Marof - Zagreb GK	Slovenia - SŽ
Kumrovec	Savski Marof - Kumrovec - State border	Slovenia - SŽ
Đurmanec	Zabok - Đurmanec - State border	Slovenia - SŽ
Čakovec	State border – Čakovec Kotoriba – State border	Slovenia - SŽ
	Čakovec - Mursko Središće - State border	Slovenia - SŽ
Kotoriba	State border - Čakovec - Kotoriba - State border	Hungary - MAV
Koprivnica	State border - Botovo - Dugo Selo	Hungary - MAV
Beli Manastir	State border - Beli Manastir – Osijek	Hungary - MAV
Erdut	Vukovar/B. Naselje - Erdut - State border	Serbia - ŽS
Tovarnik	Novska - Tovarnik - State border	Serbia - ŽS
Drenovci	Vinkovci - Drenovci - State border	Bosnia and Herzegovina - ŽRS
Slavonski Šamac	Striz.-Vrpolje – Sl. Šamac – State border	Bosnia and Herzegovina - ŽRS
Volinja	Sunja -Volinja - State border	Bosnia and Herzegovina - ŽRS
Ličko Dugo Polje	State border - Ličko Dugo Polje – Knin	Bosnia and Herzegovina - ŽFBH
Metković	State border - Metković – Ploče	Bosnia and Herzegovina - ŽFBH

Power supply

On nationwide and regional railways, the following traction systems are used [29]:

a) DC 3 kV,
b) AC 25 kV / 50 Hz,

977 km with 25 kV, 50 Hz AC and 3 km with 3 kV DC. This 3 kV DC power supply is only on one section near Croatia – Slovenia state border on section Šapjane – State border.

The power supply system AC 25 kV / 50 Hz is on all other electrified railway tracks in Croatia. The list of these tracks is [29]:

- M101 State Border - S. Marof - Zagreb Gk

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- M102 Zagreb Gk - Dugo Selo
- M103 Dugo Selo – Novska
- M104 Novska - Tovarnik - State Border
- M201 State Border - Botovo - Dugo Selo
- M202 Zagreb Gk – Rijeka
- M203 Rijeka – Šapjane
- M303 Strizivona-Vrpolje - Slavoski Šamac - State Border
- M304 State Border – Metković – Ploče
- M401-M410 Zagreb railway joncion
- M502-1 Zagreb Gk - Velika Gorica
- M502-2 V. Gorica - Sisak - Novska
- M602-M604 Port Rijeka junction
- R102 Sunja - Volinja - State Border
- L102 S. Marof - Kumrovec - State Border (to Harmica)

Table 27. Contact point of traction systems at the state border [29]

Border Station	Line	Neighbouring country and Infrastructure manager	Power Supply
Šapjane	Rijeka - Šapjane - State border	Slovenia - SŽ	3 KV
Savski Marof	State border - Savski Marof - Zagreb GK	Slovenia - SŽ	3 KV
Koprivnica	State border - Botovo - Dugo Selo	Hungary - MAV	25 KV
Tovarnik	Novska - Tovarnik - State border	Serbia - ŽS	25 KV
Slavonski Šamac	Strizivojna-Vrpolje – Slavonski Šamac – State	Bosnia and Herzegovina - ŽRS	25 KV
Volinja	Sunja -Volinja - State border	Bosnia and Herzegovina - ŽRS	25 KV
Metković	State border - Metković - Ploče	Bosnia and Herzegovina - ŽFBH	25 KV

Train Control Systems

On international, regional, and local railway lines the national train system is INDUSI I60 and the ERTMS/ETCS L1 system is used as ATP (Automatic Train Protection) system [29].

Signalling and safety devices represent a basic safety system for controlling the movements of trains which must provide timely transmission of information on the state of track and driving mode on locomotive devices. The German Indusi (germ. Induktive Signalsicherung) is a national automatic Train protection system. That safety system works in the same way by using tuned circuits trackside and onboard. That close coupling between both circuits takes place only at discrete points, so the information is spot transmitted.

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According to system functions and the type of transmission, the Indusi system belongs to the group of systems with intermittent transmission at low data volume and with braking supervision. That means they provide for an attentiveness check at the signals which can show „Caution“, train stop functions and more or less complex supervision functions, but without calculating a dynamic speed profile.

The basic characteristics of the previous system variants as of I60 stayed the same. There is an onboard and trackside part of the equipment. The trackside equipment consists of three types of passive trackside magnets in the form of resonant circuits.

Trackside magnets are mounted to the right rail to communicate signal aspects to trains. Each trackside magnet is adjusted to the specific frequency (500, 1,000 and 2,000 Hz) with the frequency coding the information from the precisely known trackside signal. Depending on signal aspects, the trackside resonant circuits can be switched effectively or ineffective.

The Locomotive's magnet is configured to receive information from the trackside magnet and therefore is placed above the right rail to distinguish the direction of movement. The resonant circuits of vehicle magnets permanently swing in mentioned frequencies. If the switch is effective when the train passes over a trackside magnet, loss of energy happens and the onboard equipment registers and processes that. Its executive part triggers the activation of the pneumatic part of the device and affects immediate emergency braking. In the case of an ineffective switch (e.g. all signals are clear), the Indusi magnets are disabled and the resonant circuit on the vehicle is not influenced. Since the trackside magnet gets its energy from the vehicle's magnet by induction, the system does not need a local power supply.

Main tracks are also equipped with a modern combination train protection system which increases railway line capacity.

Many combinations of these safety devices and main groups are [29]:

- **RC+AB+TWT (Remote Control + Automatic Blocks + Two-way working track)** Those types of safety devices enable a two-way working track and use automatic block protection interstation distances. On this railway line are also included devices for remote control of this section. Those type of safety devices is installed only in one section in Croatia. This section is on the main international track M104 Vinkovci – Tovarnik section.
- **AB (Automatic Blocks)** These types of safety devices enable the use of automatic block protection interstation distance and splitting intersection distance into blocks. All main international and corridor railway lines in Croatia are equipped with this type of safety device.
- **AB+TWT (Automatic Blocks + Two-way working track)** These types of safety devices enable the use of automatic block protection interstation distance and splitting intersection distance into blocks. Those types of safety devices enable two-way working tracks and use automatic block protection interstation distances. Those type of safety devices is installed only in two small sections in Croatia on M104 main railway track.

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- **SI (Station interdependence)** This type of safety device enable interstation distance to protect without blocks but is connected with station interlocking and it is installed only in two small sections in Croatia on regional railway lines.
- **SI+TWT (Station interdependence + Two-way working track)** Those types of safety devices enable interstation distance to protect without blocks but are connected with station interlocking. Two-way working track safety devices enable two-way working tracks. This type of safety device is installed only in small sections in Croatia on railway track M101 between Savski Marof state border and Dobova state border (Slovenia).
- **Other types of safety devices and interlocking** (Those types of safety devices are simple devices mostly relay type or a mechanical simple interlocking. Those devices are used for small stations. Those types of devices are with or without light signals. With this type of interlocking is not possible interstation distance protect. Some stations on local railway tracks are without any type of simple interlocking and for traffic control use telecommunication only. These types of safety devices are mostly on a regional and local railway line with small traffic intensity.
- **The ERTMS/ETCS system** is a European train control system. This is Class A according to the TSI CCS. A detailed description of the ERTMS / ETCS system, its functions and requirements are to be found in documents referenced in the TSI CCS.

  The ERTMS/ETCS system is in the testing period of use and isn't an official automatic train protection system in Croatia. ETCS L1 is installed only in one section in Croatia. This section is on the main international track M104 Vinkovci – Tovarnik section.

Railway operators

In 2020, the total number of carriers that have concluded a contract for the operation of rail transport using state-owned national and regional railways [31]:

- HŽ Putnički prijevoz
- HŽ Cargo
- ENNA Transport
- Rail & Sea
- Rail Cargo Carrier – Croatia
- Slovenske železnice – Tovorni promet
- Train Hungary Magánvasút Kft Branch office Zagreb
- Transagent Špedicija
- CER Cargo
- Eurorail logistics

The number of passengers in 2019 is 19.854 mil., 2020 is 13.103 mil. Passenger train kilometre in 2019 is 734 mil. The total volume of outputs in passenger transport decreased in 2020. Passenger train kilometre in 2020 is 449 mil. Compared to 2019, train kilometres (trkm) decreased by 38 % [31].

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In freight transport, the total goods carried in 2019 is 14.449 mil tons and in 2020 14.992 mil. tones.

The total tonne kilometre in 2019 is 2.911 mil. and in 2020 is 3.279 mil. Compared to 2019, train kilometres (trkm) increased by 12.6 % [31].

2.1.8 Slovenia

The Republic of Slovenia is the founder of Sovenske železnice Group with nine Companies. The Public Railway Infrastructure (PRI) consists of the facilities and equipment necessary for undisturbed public rail service, as well as the associated land, which is used for predetermined functional purposes. The PRI is established for the public good, is owned by the state and is used in a way and under the conditions, defined in the ZZelP, as well as regulations issued on the basis thereof. Slovenske železnice Infrastruktura d.o.o. (SŽI) is the railway infrastructure manager of all public railway infrastructure in Slovenia. The rail network in the Republic of Slovenia is defined in the Decree on the categorisation of railway lines. Depending on traffic volume, economic importance and role in connecting the railway traffic, rail lines are divided into main and regional lines [32].

International Railway Freight Corridors (RFC)

Slovenia is involved in four RFC corridors (Regulation 913/2010/EU), Baltic – Adriatic, Mediterranean, Alpine – Western Balkan and Amber [32]. Links to more information about those corridors:

- Baltic – Adriatic - https://www.rfc5.eu/
- Mediterranean https://www.railfreightcorridor6.eu/RFC6/web.nsf/OnePager/index.html
- Alpine – Western Balkan - https://www.rfc-awb.eu/
- Amber - https://rfc-amber.eu/

The Slovenian Railway Infrastructure

All railway lines in Slovenia managed by SŽI comprise the main international and other regional railway lines. SŽ Infrastruktura manages the 1,207.7 km long railway network [33].

Competent for railway in Slovenia is the Ministry of Infrastructure (https://www.gov.si/en/state-authorities/ministries/ministry-of-infrastructure/), Public Agency of the Republic of Slovenia for Railway Transport (www.azp.si).

The infrastructure topologies

Table 28. The basic Characteristics of the Railway Network (31st December 2019) [33]

Indicator	Unit of measure	Amount 2020
The total length of the lines	km	1.207,7

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Length of electrified lines – 3 kV DC	km	610
Length of standard-gauge lines	km	1.207,7
Length of single-track lines	km	874,2
Length of double-track lines	km	333
Number of stations and stops	pcs	209
Bridges	pcs	435
Tunnels	pcs	87
Level crossings	pcs	972

Track Gauges

Nationwide and regional railways consist of tracks with standard gauges, defined in accordance with UIC Decree No. 510, i.e., 1,435 mm [33].

Connecting Railway Networks

The Republic of Slovenia shares borders with the IMs of the following countries:

- Italy – RFI - Rete Ferroviaria Italiana
- Austria – ÖBB Infrastruktur Betrieb AG
- Hungary – MÁV Gépésze Zrt Magyar Államvasutak
- Croatia – HŽ Infrastruktura

Table 29. The contact points of nationwide and regional railways with railways in neighbouring countries [33]

Border Stations	Line	Neighbouring country and Infrastructure manager
Lendava / Čakovec	Lendava – Lendava d.m.* / Čakovec d.m. - Čakovec	Croatia - HŽI
Središče / Čakovec	Središče – Središče d.m. / Čakovec d.m. – Čakovec	Croatia - HŽI
Rogatec / Đurmanec	Rogatec – Rogatec d.m./ Đurmanec d.m. – Đurmanec	Croatia - HŽI
Imeno / Kumrovec	Imeno – Imeno d.m. / Kumrovec d.m. – Kumrovec	Croatia - HŽI
Dobova / Savski Marof	Dobova– Dobova d.m. / Savski Marof d.m. – Savski Marof	Croatia - HŽI
Metlika / Kamanje	Metlika – Metlika d.m. / Kamanje d.m. – Kamanje	Croatia - HŽI
Ilirska Bistrica / Šapjane	Ilirska Bistrica – Ilirska Bistrica d.m. / Šapjane d.m. – Šapjane	Croatia - HŽI
Rakitovec / Buzet	Rakitovec – Rakitovec d.m. / Buzet d.m. – Buzet	Croatia - HŽI
Jesenice / Rosenbach	Jesenice - Jesenice d.m. / Rosenbach d.m. – Rosenbach	Austria - ÖBBI
Prevalje / Bleiburg	Prevalje – Prevalje d.m. / Bleiburg d.m. – Bleiburg	Austria - ÖBBI

Co-funded by the European Union

Šentilj / Spielfeld Strass	Šentilj – Šentilj d.m. / Spielfeld Strass d.m. – Spielfeld Strass	Austria - ÖBBI
Nova Gorica / Gorizia Cle.	Nova Gorica – Nova Gorica d.m. / Gorizia d.m. – Gorizia Cle.	Italy – RFI
Sežana / Villa Opicina	Sežana – Sežana d.m. / Villa Opicina d.m. / Villa Opicina	Italy – RFI
Hodoš / Oriszentpeter	Hodoš – Hodoš d.m. / Oriszentpeter d.m. – Oriszentpeter	Hungary - MAV/GYSEV

Power supply

On nationwide and regional railways, the following traction systems are used DC 3 kV electrical power supply system.

The power supply system DC 3 kV / 50 Hz is on all other electrified railway tracks in Slovenia. A list of these tracks is [33]:

- M10 d.m. – Dobova – Ljubljana
- M20 Ljubljana – Jesenice – d.m.
- M30 Zidani Most – Šentilj – d.m.
- M40 Pragersko – Ormož
- M41 Ormož – Hodoš – d.m.
- M50 Ljubljana – Sežana – d.m.
- M60 Divača – branching Prešnica
- M62 branching Prešnica – Koper
- M64 Pivka – Ilirska Bistrica – d.m.
- M 14 bend Zidani Most
- M45 bend Pragersko
- 51 bend Divača
- R11 Ljubljana Zalog – bran. Kajuhova (P3)
- R12 Ljubljana Zalog – Ljubljana (P4)
- R13 Ljubljana Zalog – Ljubljana (P5)

Table 30. Contact point of traction systems at the state border [33]

Border Stations	Line	Neighbouring country and Infrastructure manager	Power Supply
Dobova	Dobova– Dobova d.m. / Savski Marof d.m. – Savski Marof	Croatia - HŽI	25 KV
Ilirska Bistrica	Ilirska Bistrica – Ilirska Bistrica d.m. / Šapjane d.m. – Šapjane	Croatia - HŽI	25 KV
Jesenice	Jesenice - Jesenice d.m. / Rosenbach d.m. – Rosenbach	Austria - ÖBBI	15 kV
Šentilj	Šentilj – Šentilj d.m. / Spielfeld Strass d.m. – Spielfeld Strass	Austria - ÖBBI	15 kV
Sežana	Sežana – Sežana d.m. / Villa Opicina d.m. / Villa Opicina	Italy – RFI	3 kV

Co-funded by the European Union

Hodoš	Hodoš – Hodoš d.m. / Oriszentpeter d.m. – Oriszentpeter	Hungary - MAV/GYSEV	25 kV

Train Control Systems

Signalling systems are intended for traffic control and safety purposes. They are light or graphic signals, located along the rail line, interconnected and connected via the central device to point switches and other equipment located along the train routes. Signalling systems are used to show signals for permitting or prohibiting train movement and signs for permitted train movement with a regular or reduced speed, depending on the location and geometry of the line, shape of the route (straight line or turn), the situation with the traffic and other factors.

The signalling systems are classified in accordance with the purpose of their use: Station safety equipment (electronic signalling equipment, electronic relay signalling equipment, electro-mechanical signalling equipment, mechanical signalling equipment, combined equipment)

- **Automatic rail Block equipment – APB** Ensures complete security of successive trains on an open line between two stations.
- **Block Systems (MO)** – Simplified APB to control availability and security on the entire network between the station sections.
- **Bi-directional running (OP)** – Complete security and signalisation of the train movements on double-track lines in both directions.
- **Remote Traffic Control (DVP)** – Active remote control and traffic management on a definite line or junction station from the central part
- **Auto Stop Devices (ASN)** – Automatic train stop in case of an uncontrolled conveying of the main signals.
- **Shunting technique** – Performing technological work procedure; Speed control of the wagons when disassembling, sorting out trains or wagons through humps, flat wheel detection devices, hot axle detection devices, axle load exceedance detection devices, hazard detectors.

There are different Traffic Control Systems on the PRI, intended for traffic management.

- Remote control
- Local control

The European Railway Safety System ETCS Level 1, version 2.3.0d, which is one of the systems for ensuring the interoperability of the railway signalling system, is under construction on the PRI lines. The following lines are equipped with the ETCS Level 1 [33]:

- 10 Zidani Most – Ljubljana
- 10 Zidani Most – Dobova
- 30 Zidani Most – Pragersko
- 40 Pragersko – Ormož
- 41 Ormož – Hodoš – d.m.

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- 50 Ljubljana – Sežana – d.m.
- 60 Divača – cepišče Prešnica
- 62 cepišče Prešnica – Koper
- 11 Ljubljana Zalog – cepišče Kajuhova (P3)
- 12 Ljubljana Zalog – Ljubljana (P4)
- 13 Ljubljana Zalog – Ljubljana (P5)
- 14 lok Zidani Most
- 45 lok Pragersko
- 51 lok Divača

Railway operators

In 2020, the total number of carriers that have concluded a contract for the operation of rail transport using state-owned national and regional railways [34]:

- Slovenske železnice – Tovorni promet, d.o.o.
- Slovenske železnice – Potniški promet, d.o.o.
- Adria transport d.o.o.
- Luka Koper, d.d., pristaniški in logistični sistem
- Rail Cargo Carrier, družba za železniški tovorni promet, d.o.o.
- Primol-Rail d.o.o.
- Ten Rail, železniški tovorni promet, d.o.o.
- Train Hungary Maganvasut Kft. Branch office Ljubljana
- InRail S.p.A.
- Metrans Adria kontejnerski promet, d.o.o.
- PKP Cargo International SI d.o.o. (Primol-Rail d.o.o.)

The number of passengers in 2019 is 13.9 mil., 2020 is 8.2 mil. Passenger train kilometre in 2019 is 698 mil. The total volume of outputs in passenger transport decreased in 2020. Passenger train kilometre in 2020 is 397 mil. Compared to 2019, train kilometres (trkm) decreased by 41 % [34].

In freight transport, the total goods carried in 2019 is 21.9 mil tons and in 2020 19.4 mil. tones.

The total tonne-kilometre in 2019 is 5.292 bil. and in 2020 is 4.7 bil. Compared to 2019, train kilometres (trkm) decreased by 11 % [34].

2.1.9 Serbia

The infrastructure of Serbian Railways (IZS) is a joint stock company for the management of public railway infrastructure founded by the Republic of Serbia. Railway infrastructure is a good intended for use by the general public, owned by the Republic of Serbia that can be used by railway undertakings, on equal terms, in accordance with the Law on Railways. Depending on traffic volume, economic importance and role in connecting the railway traffic, rail lines are divided into main and other lines [35].

International Railway Freight Corridors (RFC)

The Republic of Serbia is involved in one RFC corridor (Regulation 913/2010/EU), Alpine – Western Balkan. Link to more information about this corridor [36]:

- Alpine – Western Balkan - https://www.rfc-awb.eu/

On the territory of the Republic of Serbia, the network of Alpine – Western Balkan Corridor includes the following railway lines from Sid to Presevo: Belgrade – Sid – State border, Belgrade – Mladenovac – Nis, (Belgrade) – Rakovica – Jajinci – Mala Krsna - Velika Plana, Nis – Presevo – State border. The following branches connect to the primary route of the Corridor: Xb, (Budapest) – Novi Sad – Belgrade (the railway line (Belgrade) - Stara Pazova – Subotica), and Xc, Nis – Dimitrovgrad – (Sofia – Istanbul) (the railway line Nis – Dimitrovgrad – State border [36].

The Serbian Railway Infrastructure

All railway lines in Serbia managed by IZS comprise the main international and other railway lines. Infrastruktura ZS manages the 3.735,8 kilometre-long railway network [36].

Competent for railway in Serbia is the Ministry of construction, transport and infrastructure (https://www.mgsi.gov.rs/), Direkcija za Železnice (http://www.raildir.gov.rs/latinica/index.php,)Centar za istraživanje nesreća u saobraćaju (http://cins.gov.rs/latinica/index.php).

The infrastructure topologies

Table 31. The basic Characteristics of the Railway Network (31st December 2019) [36]

Indicator	**Unit of measure.**	**Amount 2020**
The total length of lines	km	3,735.8
Length of electrified lines – 25 kV AC	km	1,278.4
Length of standard-gauge lines	km	3,735.8
Length of narrow-gauge lines	km	22.5
Length of single-track lines	km	3,441.1
Length of double-track lines	km	294.7
Number of stations and stops	pcs	690
Bridges	pcs	956
Tunnels	pcs	334
Level crossings	pcs	2,138

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Track Gauges

All the above data relate to standard-gauge 1,435 mm tracks. The infrastructure of Serbian Railways is also managed with a museum-tourist railway line - "Shargan Eight" - which is 22, 5 km long and whereof track gauge is 760 mm [36].

Connecting Railway Networks

The Republic of Serbia shares borders with the IMs of the following countries [36]:

- Croatia – HŽI
- Hungary - MAV
- Romania – CFR SA
- Bulgaria – BDZ
- Montenegro – ZCG
- North Macedonia – MZ
- Bosnia & Herzegovina – ZRS

Table 32. Border lines [36]

Border Stations	Line	Neighbouring country and Infrastructure manager
Šid/Tovarnik	Sid (IZS)-Tovarnik (HŽ)	Croatia - HŽI
Bogojevo/Erdut	Bogojevo (IZS)-Erdut (HŽI)	Croatia - HŽI
Subotica/Kelebia	Subotica (IZS)- Kelebia (MAV Zrt)	Hungary - MAV
Horgos/Roszke	Horgos (IZS)- Roszke (MAV Zrt)	Hungary - MAV
Vrsac/Stamora Moravita	Vrsac (IZS)-Stamora Moravita (CFR SA)	Romania – CFR SA
Kikinda/Jimbolia	Kikinda (IZS)- Jimbolia (CFR SA)	Romania – CFR SA
Dimitrovgrad / Dragoman	Dimitrovrad (IZS)- Dragoman (BDZ)	Bulgaria - BDZ
Presevo / Ristovac Tabanovci	Presevo (IZS)- Tabanovci (MZ)	North Macedonia - MZ
Vrbnica/Prije polje ter. Bijelo Polje	Vrbnica (IZS) -Bijelo Polje(ZCG)	Montenegro - ZCG
Brasina/Zvornik Novi	Brasina (IZS)-Zvornik Novi (ZRS)	Bosnia & Herzegovina - ZRS

Signalling systems

There are eleven types of station tracks interlocking on the IZS network. On the IZS network, all main arterial routes are equipped with fully centralized electrical relay signalling & interlocking equipment, as follows [36]:

- Belgrade-Nis-Presevo: Siemens SpDrS-64/JZ track circuit system
- Belgrade Resnik-Vrbnica: Siemens SpDrS-64/JZ axle counter system
- Belgrade-Sid: Siemens SpDrS-64/JZ track circuit system
- Indjija-Subotica: Westinghouse track circuit system

The main arterial routes Sid-Belgrade-Nis-Presevo and Belgrade-Vrbnica are included in the system of remote traffic control and supervision – remote control centre (manufactured by

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Westinghouse). There are three remote control centres - in Belgrade, Pozega and Nis. Based on this device 3 remote control centres were built in Belgrade, Nis and Pozega with a total of 140 controlled stations. Dimitrovgrad Station (the railway line Nis-Dimitrovgrad-State border) is equipped with electronic signalling & interlocking device Simis-W with an Iltis control & supervision system manufactured by Siemens. Stations Belgrade Centre, Pancevo Glavna and Cuprija are equipped with electronic signalling & interlocking devices. Other lines are equipped with the above-stated interlocking types, but there is no continuity as regards one system of interlocking.

Traffic control systems

The movement of trains running in opposite directions and consecutive train movements are controlled by requesting and giving permission i.e. announcement of arrival and departure. Consecutive trains can follow one another only in particular time intervals. For control of the trains following one another in particular time intervals, railway lines can be divided into [36]:

- Block sections between stations - when two neighbouring stations control the sequence of trains in the station interspace,
- Train-recording points - when two neighbouring train-recording points or a station and a neighbouring train-recording point control the sequence of trains in announcement intervals,
- Block sections – when the traffic of consecutive trains is controlled by automatic positioning of automatic block signals in the position of permitted or forbidden train ride. In addition to space distance, in the case of consecutive trains in train reporting and block intervals, there should be a time interval to avoid train stopping before automatic block signals due to different train journey times over block sections (time spacing).

On the railway lines of JSC "Serbian Railways Infrastructure," there are also interstation interlocking devices (MZ) which regulate train traffic at distances between stations, where an interstation track occupation is reported using axle counters. There can only be one train in one block section on the same track and at the same time. Train operation is regulated by movements inspectors who use the station signal boxes and along railway lines through remote control – by the remote control dispatcher from the central signal box, except at the stations that are not included in the remote control system. The traffic of trains running in opposite directions and consecutive trains is regulated by movements inspectors at manned stations and along the railway lines included in the remote control system, it is regulated by remote control dispatchers. "Infrastructure of Serbian Railways" JSC uses "Flexi code 560" remote control system on its territory, manufactured by Westinghouse. It uses semiconductor technology and a code system and controls instruction completeness at the stages of forwarding and acceptance. It was developed as a standard format and it consists of a remote control centre, which can control 32 stations on one railway line and one or more lines for data transfer, as well as the remote control equipment at stations (satellites). Based on this device, 3 remote control centres were constructed in Belgrade, Nis and Pozega, with 140 controlled stations. The train control system is governed by the Traffic Regulations (Regulations No 2 published in the “Official Gazette of the Community of Yugoslav Railways (ZJZ)” No. 3/94) and Traffic

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Instructions (Instructions No. 40, published in the "Official Gazette of the Community of Yugoslav Railways (ZJZ)" No. 6/80-47), with all appurtenant amendments, corrections and interpretations [36].

Automatic train control system-ATC systems

For the time being, there is no automatic train control system on the railway lines of JSC "Serbian Railways Infrastructure". 31 Intermittent transmission AS device (automatic train control) with resonant frequencies of 1000Hz and 2000Hz, type Indusi (I 60), is used for the control of train movements [36]. It is comprised of a track magnet (stationary trackside part of the device) transmission system (the inductive link between the track magnet and locomotive auto-stop device), and locomotive part installed on the traction unit. Track magnets are installed on the right-hand side of the track, in the direction of train movement. Functioning and operating of AS devices have been stipulated under the Operator's Manual for inductive I60 AS devices (Instructions No 425), Instructions for installation, testing and putting into operation and maintenance of the locomotive part of I-60 AS device (Instructions No 426), and Instructions for use, installation, testing and maintenance of trackside AS devices on the lines of Yugoslav Railways (Instructions No 427).

Operators in Serbia Railway transport:

- Srbija voz Beograd A.D. železnički prevoz putnika
- Srbija Kargo Beograd železnički prevoz robe A.D.
- SI – Cargo Logistics d.o.o. Beograd
- Privredno društvo za građenje, remont i održavanje pruga ZGOP a.d. Novi Sad
- STANDARD LOGISTIC d.o.o.
- DOO ZA PROIZVODNJU, PROMET I USLUGE ELIXIR GROUP ŠABAC
- KOMBINOVANI PREVOZ"
- A.B. Prevoz d.o.o. Beograd
- TRANS CARGO LOGISTIC d.o.o
- Rail Transport Logistic d.o.o. Novi Beograd
- EURORAIL LOGISTIC d.o.o. Smederevo
- DESPOTIJA doo Beograd
- Panon Rail Doo Subotica
- NCL NEO CARGO LOGISTIC DOO
- NIS A.D. NOVI SAD
- OBL LOGISTIC DOO BEOGRAD – Novi Beograd"
- LOKOTRANS DOO SUBOTICA
- ELEKTROPRIVREDA SRBIJE JP BEOGRAD-OGRANAK TENT
- TRANSAGENT OPERATOR DOO BEOGRAD"
- ATM BG DOO NOVI BEOGRAD
- Global Neologistics d.o.o. Beograd-Stari grad"

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The number of passengers in 2019 is 4.2 mil., 2020 is 2.6 mil. Passenger train kilometre in 2019 is 285 mil. The total volume of outputs in passenger transport decreased in 2020. Passenger train kilometre in 2020 is 157 mil. Compared to 2019, train kilometres (trkm) decreased by 44,9 % [37].

In freight transport, the total goods carried in 2019 is 11,5 mil tons and in 2020 10,5 mil. tones.

The total tonne kilometre in 2019 is 2.8 mil. and in 2020 is 2.74 mil. Compared to 2019, train kilometres (trkm) decreased by 8,7 % [37].

2.1.10 Denmark

The railway System in Denmark is mostly liberalized, which means that there is a clear split between Infrastructure and Railway Undertakings. The state-owned infrastructure is managed by Banedanmark [38].

Infrastructure Manager

The entire railway network has a size of 2,508km [39]. The largest Infrastructure Manager is Banedanmark. The Danish Infrastructure borders international and national Infrastructure [38]. The network borders Germany and Oresond Bridge Consortium Partnership infrastructure as international borders. Banedanmark Infrastructure borders with two German IM, DB Netz AG I Padborg and NEG Niebüll in Tonder. The banedanmark network borders national to: Nordyske Railways, Midtjyske Railways, Vestbanen, Aarhus Light Rail, Lokaltog (region H) and Lokaltog (region S). The network is equipped with ATC, ATC train stop and ETCS L2. The operational rulebook is published in the English language, whereas the language of operations is Danish. A part of the network also belongs to the European rail freight corridor 3 (Scandinavian – Mediterranean).

Railway Undertakings

14 Railway Undertakings were operating in 2020 in Denmark [39]. One of them is DSB, which transports more than 195 passengers every year [40]. This RU is organized as an independent public corporation, which is owned by the Danish Ministry of Transport. The turnover is approx. over 10 billion DKK per year and the company has a workforce of around 7,400 people.

2.2 Impact of Railway on the European Green Deal and the Climate Crisis

The biggest global challenge is currently climate change. An international effort to tackle the climate crisis is the Paris climate pack from 2016. The Paris climate pact aims to hold the increase of the global average temperature under 1.5°C / 2°C [41]. Cop 26 was the last conference about climate change, which was held in Glasgow in 2021. The result of the conference was the Glasgow climate pact.

The European Union started with the European Green deal an initiative to tackle climate change. The main aim of the European Green Deal is to achieve a climate-neutral European Union by 2050 [42]. The entire transport sector accounts for a quarter of the greenhouse gas emissions in the European Union and this number is still growing. So it is mentioned in the Green Deal, that a reduction of 90% of these emissions is needed by 2050 to achieve climate neutrality. Furthermore, all transport modes have to contribute to the reduction of emissions. The European Commission aims to adopt a strategy for sustainable smart mobility. In addition, the Green Deal is targeting a strong boost for multimodal transport.

For achieving this target it is mentioned in the Green Deal, that 75% of today's inland freight that is carried today by road should be shifted onto rail and inland waterways. This leads to the conclusion, that the European railways are needing an increase in capacity. However, the European Green Deal doesn´t focus only on technical issues and research, it is also focussing on schools, training institutions and universities, as the commission wants to develop and support the knowledge, skills and attitudes on climate change and sustainable development on this educational level [1].

Railways can take a key role in supporting the European Green Deal and in achieving the goals of the Paris climate pact, as railways are a sustainable transport mode. So it makes sense, to take a look at different transport modes in their emissions. The first following graphic is taken from "Allianz pro Schiene" (Alliance pro-Rail), a German non-profit, independent association for the promotion of environmentally friendly and safe rail transport and shows the nitrogen emissions of different transport modes. In every column, the gram per passenger kilometres is compared. The data for comparison is taken from 2019 and is based on the data of the German Federal Agency.

The left diagram is a comparison of long-distance passenger services. It can be seen that the railways are producing 0,03 g/pkm, buses 0.05g/pkm, cars 0,39 g/pkm and aeroplanes 0.98. In the middle local transport is compared, and it shows, that trams and metros are emitting 0.05 g/pkm, railways 0.19 g/pkm, busses 0.29 g/pkm and cars 0.39 / pkm. The last right diagram is focusing on freight transport, which shows that freight trains are emitting 0.03 g/pkm, lorries 0.24 g/pkm and inland vessels 0.38 g/pkm. From the Allianz pro Schiene data it can be concluded, that the railway has an advantage over all modes of transport.

According due the data from Allianz pro Schiene railways are having benefits over all other modes of transport.

Figure 7 is taken from the report on the Austrian railway industry and is focusing on the issue of freight transport.

With all the mentioned benefits of railway transport, it is also mentioned, that the Railway sector is currently facing a big challenge. This is the lack of skilled workers on every level. This starts with the operating personnel like train drivers, traffic controllers and train crew. Furthermore, also

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railways and traffic and transport engineers are missing. In May 2019 the German Union of Railway Engineers analysed the demand for Engineers only in Germany. A result of this investigation was, that till 2030 almost 50% of the Engineers in the public transport sector will be retired. VDEI estimated in 2019 that in the upcoming 11 years, 33,000 railways engineers should be trained, which means around 3,000 Engineers per year.

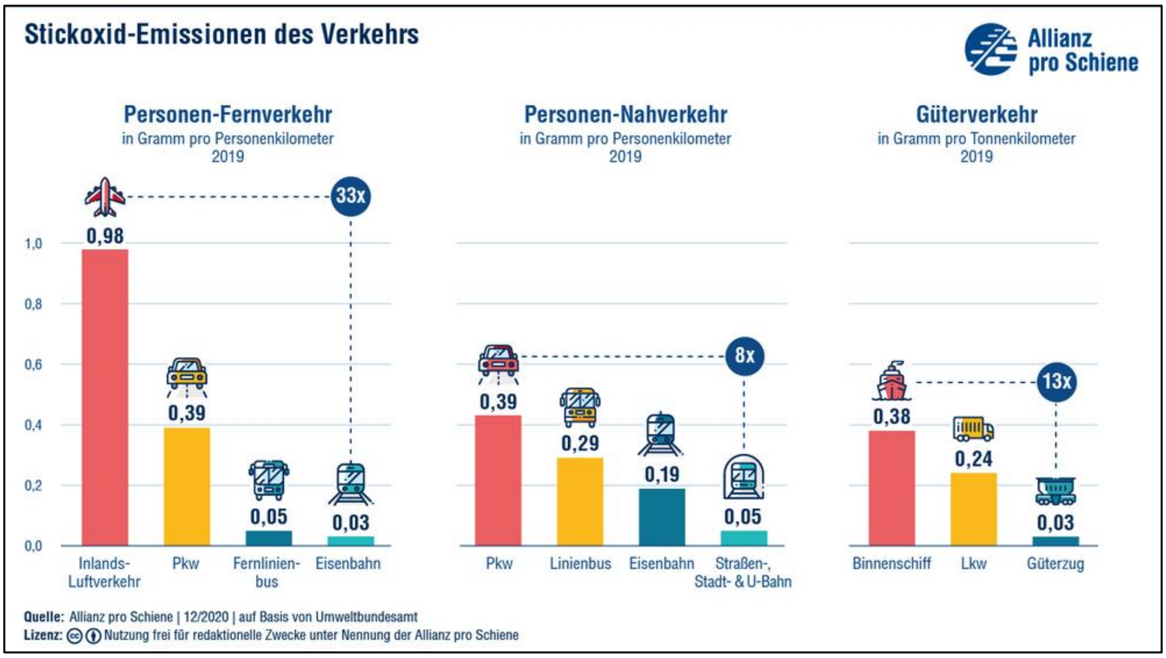

Fig. 6. Nitrogen oxide emissions [43]

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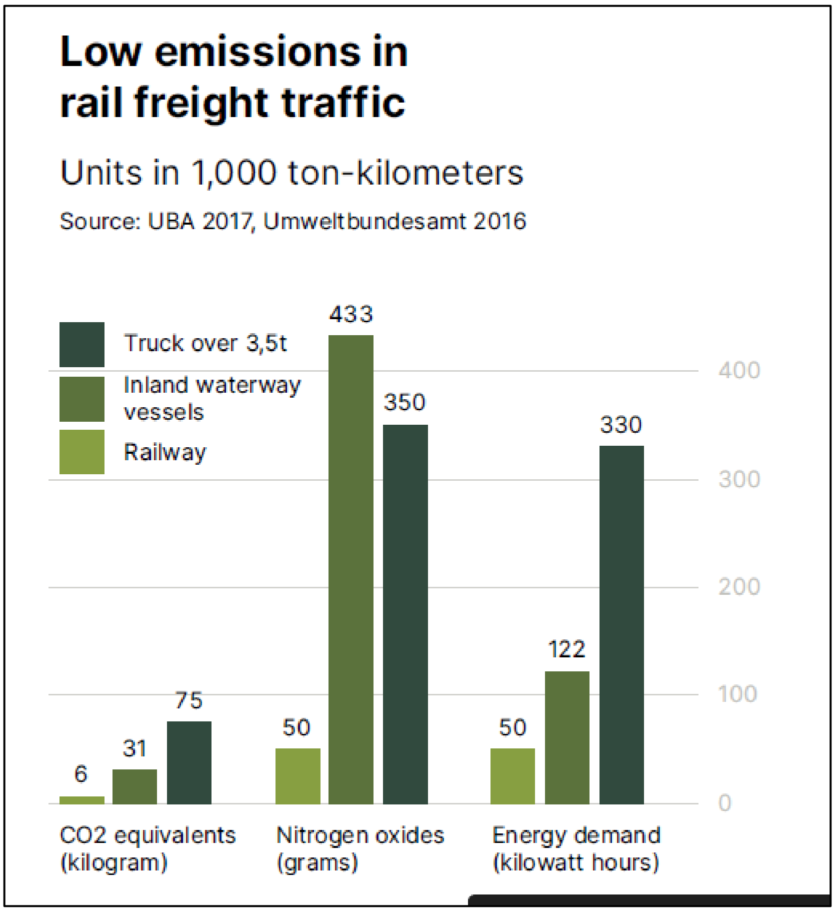

Fig. 7. Figure 1. Emissions in freight transport

2.3 STEM Agenda and the Railway sector

The STEM Agenda is an Agenda to bring students into the STEM field. STEM stands for Science, Technical, Engineering and Mathematics. The railway sector offers jobs for every part of the STEM Agenda. A problem for the STEM field is also finding skilled workers. The interest of students in the STEM field is on a decreasing trend [44].

For that reason various initiatives have been started, to make the STEM sector more attractive.

The STEM Agenda could be also a chance for the railway sector as the railway sector offers various jobs in the sector. But the entire sector isn´t focussed only on the field of Engineering,

As the railway sector offers various jobs and requires Engineers, the STEM Agenda could be a chance for the younger generation. However, the railway sector is not only a field of Engineering, it offers also academic positions and Research and Development with new research questions. With the rise of the use of computer support, there is also room for math positions.

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2.4 Short Summary

Railways are a sustainable transport mode with low emissions. However, the railway sector is facing also many challenges in Europe. Technical issues are a main challenge as mentioned in this chapter. According to the complexity of the railway systems across Europe, system knowledge is crucial for employees in the Railway sector.

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3 INVESTIGATION OF THE CURRENT STATUS OF LABOUR FORCES IN THE RAILWAY SECTOR

The railway sector and the many activities linked to the sector are important sources of employment for European citizens. In the past decade, the sector has not only continued to provide secure jobs for existing employees but has also initiated an ongoing revitalisation process that will offer opportunities for younger generations. This is particularly relevant at a time when the European Union is facing a significant challenge in the area of youth unemployment. The objective of the analysis is to assess the current employment and skills situation for different categories of railway staff, from workers to engineers, railway managers and researchers. The analysis presents the employment situation in different European regions.

3.1 Current situation

According to the Eurostat Labour Force Survey (LFS) [42], in 2016. level of employment is 817,752 persons working in the following four NACE (Nomenclature of Economic Activities) sectors:

- 7% Manufacture of railway locomotives and rolling stock (30.20)
- 48% Construction of railways (NACE-3: 421 Construction of roads and railways) (42.12)
- 35% Passenger rail transport, interurban (49.10)
- 9% Freight rail transport (49.20)

The report [45] provides overviews of employment in four major railway companies in Europe: SNCF (Société Nationale des Chemins de Fer Français), DB (Deutsche Bahn), NS (Nederlandse Spoorwegen) and Network Rail. Further differentiation of the Eurostat figures to regions in Europe was done: Germany, Netherlands, France and UK (the so-called core countries) were compared to all the other countries in Europe. This comparison reveals that the core countries show stable employment levels and a higher level of employment in managerial, engineering and technical jobs compared to other countries.

In the analysis, the ISCO (International Standard Classification of Occupations) distribution for occupations has been used. The classification is relatively abstract. To make the distribution somewhat more understandable, the following jobs should be associated with the occupational titles:

- Senior managers (rail operations manager)
- Professional engineers (mechanical engineers)
- Technicians and associate professionals (dispatcher)
- Clerical support workers (railway sales agents)
- Service workers and sales workers (train attendants)
- Craft and related trades workers (rail switch person)
- Plant, machine operators (train drivers)
- Elementary occupations (cleaning personnel)

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Current skills distribution according to the occupational category is shown in table 33.

Table 33. Overview of the current skills distribution according to occupational category [45]

2012-2016: trend	ISCED 0-2	ISCED 3-4	ISCED 5-6
Senior managers	-10%	5%	5%
Professional engineers	0%	-1%	2%
Technicians and associate professionals	-1%	-3%	4%
Clerical support workers	-1%	-4%	5%
Service workers and sales workers	-5%	5%	-3%
Craft and related trades workers	-4%	2%	2%
Plant, machine operators and train drivers	-3%	1%	1%
Elementary occupations	-3%	-4%	6%

The following results are of importance in analysing skills distribution and development [45]:

- A clear upskilling tendency is visible in all railway jobs towards ISCED (International Standard Classification of Education) 5-6 (academic level), but mainly in higher jobs such as professionals, technicians, and clerical support workers. In more basic jobs, job requirements also appear to have shifted upwards, but more to middle educational levels
- Most of the employees need at least a middle level of educational degree to get recruited and to perform their jobs
- The CEDEFOP ESJS (The European Centre for the Development of Vocational training European skills and jobs survey) survey adds to this picture that educational requirements may be on the rise in these higher jobs, but that employees experience those requirements in work itself may not be rising. Rising recruitment levels seem not connected to changes in job content. The figures do not allow us to say if future changes may require higher job levels. The OECD PIAAC (Organisation for Economic Co-operation and Development The Programme for the International Assessment of Adult Competencies) survey confirms this result in the sense that current requirements to work in a job have risen over time. Most employees find that these requirements are needed for the jobs, but an important group of railway employees also find they are overqualified for their jobs
- Both surveys PIAAC and ESJS, allow overviews of different types of skills needed for occupations (technical, communicative, social, and organisational skills). The ESJS results do not show major distinctions in skills profiles between occupational groups, which would mean that all jobs require a considerable amount of skills. The PIAAC results show more differences between jobs, with more technical and organisational skill requirements for management and top-professional categories.

To assess the skills, it is important to assess the general level of employment and its distribution according to the job title in the railway sector. It is challenging to get precise figures on employment in the railway sector. The ERRAC-Rail 2050 report [46] says that the railway sector provides direct employment to 2.3 million persons. Indirectly the sector contributes to some 4 million jobs. The RMMS (Rail Market Monitoring) data indicate that only 900,000 people work in the sector

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[47]. The figures are quite divergent. Assessment of the general level of employment is given based on several sources: RMMS data, Labour Force Survey, and the situation in several major railway organisations. The current situation is described, and where possible, the development of employment over the past years. We enhance the statistical information for the four countries with more detailed information coming from national data and data from the major railway transport organisations [45].

The RMMS 2016 Fourth report [48] gives the following estimate: "According to the RMMS, at the end of 2014 rail operators and infrastructure managers employed about 900,000 people. The number of employees decreased by 4% between 2009 and 2014. The workforce is predominantly male, and the proportion of workers over 40 is more than 50% in many companies. Ageing is a particular concern in Spain, Greece, Finland and Italy. On the positive side, after long recruitment freezes, rail companies in the many Member States have recently begun to recruit again. Today, the most common elements referred to in the Member States where the sector is considered attractive, have secure employment, good salaries, and career opportunities under a positive corporate climate. This figure of 900,000 people employed by railways does not include NACE 30.2, manufacture of rolling stock. This report for the railway sector refers to railway undertakings and rail infrastructure managers.

Table 34. Self-employed in incumbent railway undertaking (2011, 2014) [45]

	2011	2014	Variation (%)
FR	110,000	96,200	-14%
DE	58,000	61,000	5%
NL	24,069	28,348	15%
IT	36,700	31,802	-15%
CZ	33,566	24,163	-39%
AT	26,282	13,181	-99%
PL	25,222	29,555	15%
RO	22,149	20,273	-9%
BE	20,011	20,585	3%
HU	16,085	17,522	8%
ES	13,955	14,429	3%
SK	12,846	12,042	-7%
BG	11,137	10,125	-10%
FI	8,390	7,592	-11%
DK	8,052	8,131	1%
LT	6,733	6,496	-4%
SE	5,265	4,878	-8%
SI	4,562	4,028	-13%
LV	3,944	3,734	-6%
LU	3,753	3,943	5%
PT	3,643	3,484	-5%
IE	1,912	2,280	16%
EL	852	858	1%

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HR	-	4,176
EE	-	1,472

Notes: CZ 2014: whole CD group, DK 2014: Includes DSB, Oresund, Private lines and Metro (Freight N/A). DE 2011: not including the number's IM and rail-related facilities staff. EE 2014: includes Estonian Railways, GoRail, ELRON Edelaraudtee. NL 2014: includes NS staff outside NL. SE 2014: SJ and AB and Greeen Cargo AB

For estimating any figures about employment size in the railway sector, all surveys use the LFS as a reference point. Only the LFS can therefore be used as an estimate of the size of employment.

Table 35. Estimation of the number of employed persons (including self-employment) in the railway sector split by occupation in the EU-28 [49]

	2012	**2013**	**2014**	**2015**	**2016**
Senior managers	6%	6%	6%	6%	6%
Professional engineers	9%	9%	10%	10%	10%
Technicians and associate professionals	15%	15%	14%	15%	15%
Clerical support workers	10%	11%	11%	11%	11%
Service workers and sales workers	6%	5%	5%	5%	5%
Craft and related trees workers [service personnel]	19%	18%	19%	19%	19%
Plant, machine operators and train drivers [train drivers]	26%	25%	25%	25%	25%
Elementary occupations	10%	10%	10%	10%	10%
Total	100%	100%	100%	100%	100%
N =	876,023	853,240	846,544	837,718	817,752

Notes: Due to Eurostat regulations: values of cells with a flag "a" were not publishable because of low reliability, cell values with a flag "b" can be published but with a warning concerning their reliability.

For the four selected railway sectors, the current employment is shown. Employment seems to have declined over five years with more than 60,000 persons, a drop of nearly 7%. Development in employment over the past years is shown in table 36.

Table 36. LFS: general trend in employment over the period 2012-2016 [45]

Major occupations	**2012-2016**	**2016**
Senior managers	0%	6%
Professional engineers	1%	10%
Technicians and associate professionals	0%	15%
Clerical support workers	1%	11%
Service workers and sales workers	-1%	5%
Craft and related trades workers [service personnel]	0%	19%
Plant, machine operators and train drivers [train drivers)	-1%	25%
Elementary occupations	0%	10%
Total	100%	100%
The overall change in employment level / N=	-7%	817,752

The overall distribution of personnel over the different occupational groups seems to have remained quite stable over time. The major job categories are (1) train drivers, (2) service personnel on trains and (3) in stations and more technical professionals. The proportions of the different job categories in the total employment only change marginally. The development over time does not show the tendency predicted by other studies that administrative personnel would decline strongly. Also, the expectation that employment in the railway sector would grow does not seem to be fulfilled [45].

The Labour Force Survey was analysed at the EU level. The comparison of major rail organisations shows different developments between the countries. For this reason, an additional analysis of the LFS data was conducted to provide insight into the developments between the four core countries of this report (Germany, France, Netherlands and the UK) to be compared to the rest of the countries in Europe. The main reason for this is to see to what degree the developments within the four countries are comparable to the rest of Europe. The following tables (37a, b; 38a, b) show the change over time in general employment and occupational levels.

Table 37. Estimation of the number of employed persons (including self–employed) in the railway sector split by occupation and regional selection

a: Total GE+FR+NL+UK	2012	2013	2014	2015	2016
Senior managers	8%	10%	8%	7%	7%
Professional engineers	11%	10%	12%	11%	10%
Technicians and associate professionals	21%	19%	18%	18%	19%
Clerical support workers	6%	9%	10%	11%	11%
Service workers and sales workers	6%	5%	4%	7%	5%
Craft and related trees workers [service personnel]	13%	13%	15%	14%	14%
Plant, machine operators and train drivers [train drivers]	24%	23%	23%	22%	21%
Elementary occupations	11%	11%	11%	11%	12%
Total	100%	100%	100%	100%	100%
N =	338,703	335,751	344,760	348,330	339,935

Note: Due to Eurostat regulations: values of cells with a flag „a“ were not publishable because of low reliability; cell values with flag „b“ can be published but with a warning concerning their reliability.

b: EU-28 excl. GE, n, NL, UK	2012	2013	2014	2015	2016
Senior managers	5%	4%	5%	5%	5%
Professional engineers	8%	9%	9%	9%	9%
Technicians and associate professionals	10%	12%	11%	11%	11%
Clerical support workers	12%	12%	12%	11%	10%
Service workers and sales workers	6%	5%	6%	5%	5%
Craft and related trades workers [service personnel)	2%	22%	21%	2%	23%
Plant, machine operators and train drivers [train drivers]	27%	27%	26%	27%	27%
Elementary occupations	9%	10%	10%	10%	9%
Total	100%	100%	100%	100%	100%
N =	537,320	517,489	501,783	489,388	477,817

Note: Due to Eurostat regulations: values of cells with a flag „a“ were not publishable because of low reliability; cell values with flag „b“ can be published but with a warning concerning their reliability.

Table 38. LFS: general trends in employment over the period 2012-2016 and regional selection

a: Major occupations: Total GE+FR+NL+UK	2012-2016	2016
Senior managers	0%	7%
Professional engineers	0%	10%
Technicians and associate professionals	-2%	19%
Clerical support workers	5%	11%
Service workers and sales workers	-1%	5%
Craft and related trees workers (service personnel)	1%	14%
Plant, machine operators and train drivers (train drivers)	-3%	21%
Elementary occupations	1%	12%
Total	100%	100%
An overall change in employment level 1 N =	0%	339,935

b: Major occupations: EU-28 excl. GE, FR, NL, UK	2012-2016	2016
Senior managers	0%	5%
Professional engineers	1%	9%
Technicians and associate professionals	1%	11%
Clerical support workers	-2%	10%
Service workers and sales workers	-1%	5%
Craft and related trades workers [service personnel)	0%	23%
Plant, machine operators and train drivers (train drivers)	0%	27%
Elementary occupations	0%	9%
Total	100%	100%
An overall change in employment level N	-11%	477,817

Quite divergent developments between the two regional selections showed in previous tables. The four core countries for this study show remarkable stability of employment over the total period, even though it seems that there are stronger fluctuations within the selected period.

For the other countries, the decline in employment with -11% is quite strong. When looking at the occupational composition within the regional selections, the general composition of employment shows different developments. In GE+FR+NL+UK (Germany, France, Netherlands and the UK), the major changes are in clerical support workers (+5%) and train drivers (-3%). Where other studies predicted that administrative personnel would decline in the rail companies, mainly the operational jobs on the trains decline in importance. We see the predicted decline in clerical support workers (-2%) and service and sales workers (-1%) in the other regional selection. But overall, the occupational distribution here remains quite stable [45].

The occupational composition is quite different between the regional selections [45]. In the four core countries, the presence of managers, engineers and technical professionals is 30% higher than in the other selection of countries. In this other selection of countries, the weight of personnel is mainly in service personnel and on-board occupations (train drivers). Suppose these developments are compared to the general population of the different selections. In that case, we see that the overall employment in rail organisations is higher in the other selection of countries than would be expected from looking at population levels. This would mean that the core countries have relatively less employment in rail organisations. From Eurostat data, we also know that these four countries have more railways (in length) and more passengers to tend to than the other country's selection. These figures show that the companies in the core countries are probably more efficient in their operations. Possibly, this is achieved by the presence of more managers, engineers and technical experts.

A survey [50] among CER (Community of European Railway and Infrastructure Companies)) member companies) that collected information on the age structure of their employees revealed that more than 50 % of current employees are aged above 45 years.

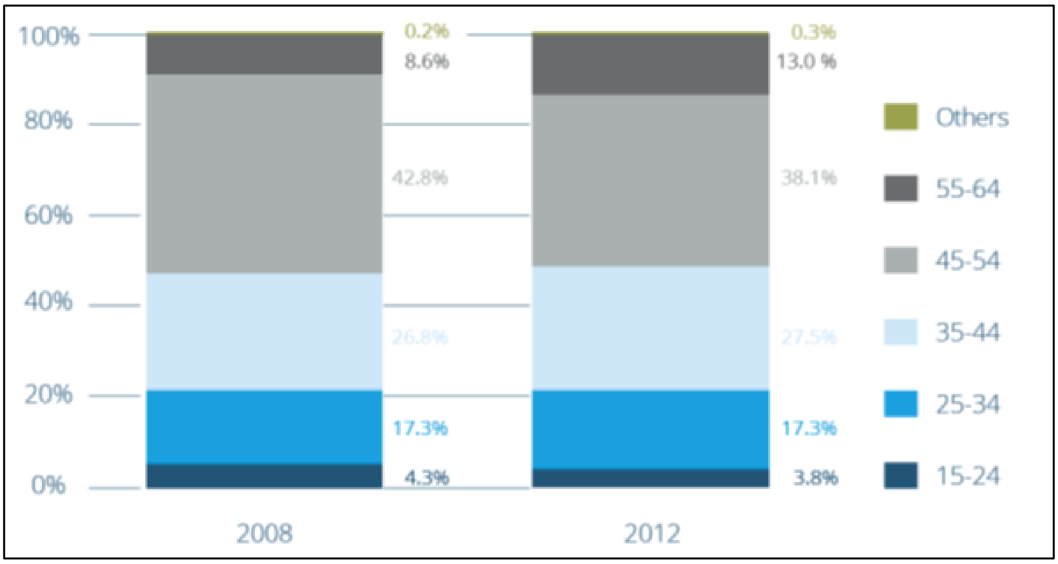

Fig. 8. Age distribution of employees in the railway sector (2008,2012) [45]

The data show that, whereas in 2008 only 8.6 % of railway company employees were close to retirement age, this number had risen to 13 % in 2012. On the one hand, this demonstrates that railway transport continues to provide job security for an older generation of employees. On the other hand, this reveals an emerging necessity for railway transport operators to attract and train young people. As a consequence of this demographic shift, railway transport is expected to contribute positively to the challenge of youth unemployment.

3.2 Future trends

In the report [45] are analysed a great number of foresight and forecasting studies on employment. The main conclusions from these reports are:

1. Employment levels will continue to decline until the end of this decade. After this decade, new growth is foreseen.
2. Skill levels should be rising, mainly because of technological demands. The sector will see great skill discrepancies, mainly caused by an ageing workforce.
3. Solutions to deal with these skill discrepancies are seen in more training and in shifting employment practices.

In the following figure, the main results have been summarised.

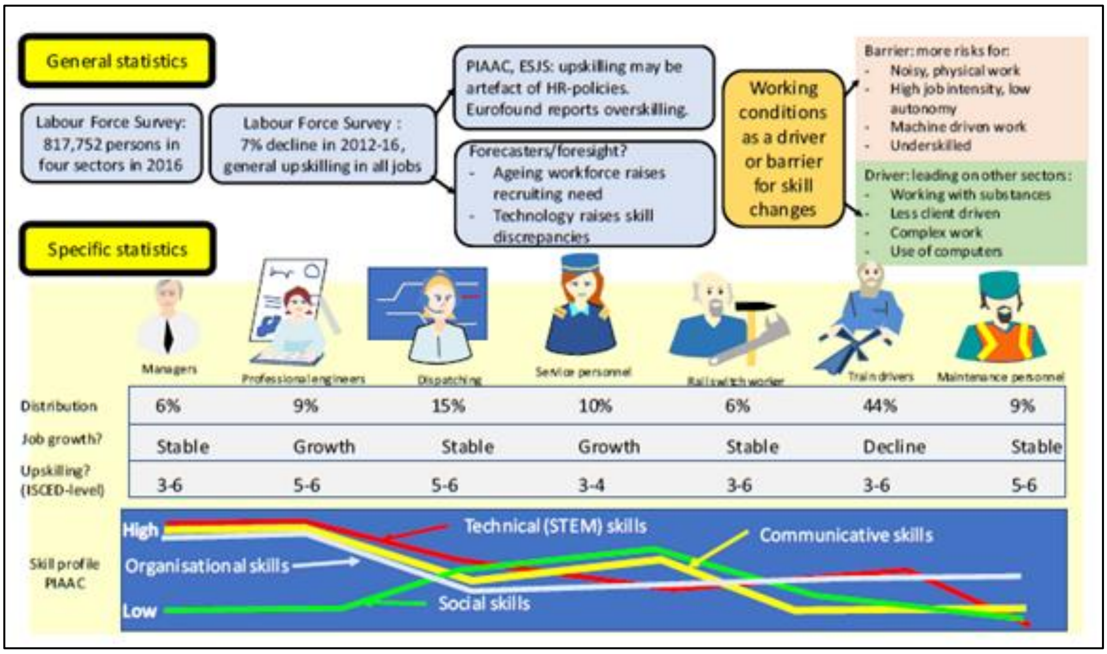

Fig. 9. Summary of main results

The different foresight and forecast studies use different approaches to paint the picture of the future and different technology scenarios. Scenarios for employment and skills are developed with different purposes. The main differences are those using policy changes [51] and those using differences in employment changes (ageing of workers: pensioning scenarios). To understand the employment and skills situation of the future, the studies stress some particularities of the EU railway sector [45] driving the changes in employment and skills demand:

1. The context remains one of deregulation, harmonisation, but also fragmentation of the railway sector. At the EU level, the railways are managed under different models, with different competition regimes. The market liberalisation has not been completed but has been in development since 2007 for freight. There is still a lot to do for passenger transport. Outsourcing is the main strategy, but a lot of legislative rules are blocking change. Employers and trade unions are working on the reduction of risks and insecurity in passenger transport.

2. The need for EU investments is framed in improving, maintaining and using the European innovation advantage. Investments, however, have been on and off: the economic crisis has affected public budgets.
3. The railways are also experiencing growing competition from bus companies and personal car transport. Even though the sector can win on the ecological side, the inefficiencies of the sector and the unreliability of services do not help its position in comparison to other transport sectors.
4. Technology has changed from investing in high-speed train technology into digital technologies for managing all elements of the railway undertaking: (1) new technologies for traffic management, (2) control, (3) ticketing, (4) maintenance and (5) operation of rail services. Investments are in less labour-intensive complete freight trains, automatic shunting (ERTMS-European Rail Traffic Management System), and fewer skill requirements.

The main lessons from these studies are the following:

1. Employment will continue to decline, but there will be a big replacement need. The Christidis study [52] expects employment growth after 2020 when growth in passenger demand is expected to accelerate due to higher penetration of high-speed rail.
2. The skills issue has changed over time. In the 2000s, the stress was on "soft skills" like leadership skills, people management and customer service, which have been named as most important for operating train companies in the future. In the current decade, the skills issue has been framed in the context of engineering and digital skills.

The changes are different for different jobs. In Table 39, some predictions are listed for different occupational jobs.

Table 39. Overview of predictions for occupational jobs [45]

	Davydenko et al., 2009	Crhistidis et al., 2014	Panteia 2015
Managerial	Stability. Managers would require more e-skills because panning and managing will become more computer-based. More understanding of regulation will be needed. Managers will require border skill sets to deal with rising complexity. Entrepreneurship will be required.		Supply, distribution and related managers remained stable.
Business and logistics professionals	An increase in employment is foreseen, because of privation, business restructuring, more need for marketing and service concepts, and the necessity for the implementation of new technologies. Broader skill sets required: teamwork, and higher analytical capabilities.		Transport conductors; number changes from 174000 to 186000
	Davydenko et al., 2009	**Crhistidis et al., 2014**	**Panteia, 2015**

Administrative and back-office workers	Railway companies were quite overstaffed. These job functions will shrink in any scenario. Skill demands will rise for these functions. Some functions will experience tasks.	The number of administrative staff is expected to decrease by a further 23%. Productivity for administrative jobs is expected to almost double (a 92% increase between 2010 and 2030). Recruitment of administrative staff with different profiles and skills than the ones leaving.	
Stewards, mechanics and train drivers	The number will increase due to the converging factors of growing demand for rail transport and the call for safety improvement. Skill requirements will be rising: more e-skills, multi-skilling, language skills, and more creativity. Rail mechanics will experience rising technical knowledge requirements. Interdisciplinary abilities will be important. Train drivers will not all have the same changes in skills: much is dependent on the transport system. Demands will be higher because of the charging levels of personnel.	The numbers of mobile and technical staff, on the otter hand, are expected to grow more steadily, more in line with the growth in demand. Productivity for mobile and technical jobs is expected to grow at comparable rates to those of activity (27% and 11% respectively).	Demand for travel ard travel stewards will rise from 168,000 to 196,000. Locomotive engine drivers 2010=272,000; 2015=280,000; 2020=292,000 Railway brake, signal and switch operators: 66; 68; 70

The studies all foresee rising demands for engineers and more technical personnel on the trains. Administrative personnel should decline quite sharply. The solutions for tackling the skills issues have remained roughly the same over the past ten years: (1) more diversity (more women), (2) more transfer of skills (to deal with the pensioning issue), (3) better working conditions for a better image, (4) more training of the current workforce, (5) more investment into harmonisation of training, and (6) more agreement into better working conditions.

3.3 Recommendation

Railway transport provides access to every European citizen and thereby aims to guarantee mobility for all. This includes providing an alternative to personal car travel together with providing high-capacity solutions for congested areas.

The railway sector upholds job security in times of crisis. Despite the pressures caused by the 2008 crisis, railway companies have retained existing staff members and hired new ones.

Furthermore, the demographic development within railway companies shows an upcoming need to hire young people. Especially in times of strong youth unemployment, railway operators can positively contribute thanks to their large vocational and educational training programmes.

Including both direct and indirect effects generated through supplier relations and infrastructure investments, the railway sector's basic economic footprint is estimated at 2.3 million persons employed and € 142 billion in gross value added. This amounts to about 1.1 % of the EU GDP.

The railway transport sector directly contributes more to EU GDP than air or water transport. Moreover, labour productivity growth within the rail transport sector has outperformed the EU economy.

The railway transport sector functions as a connector of European people and businesses, and its innovative power and sustainable character are of priceless importance to European policymakers. Strong economic advantages that have led to more innovation, combined with building on a strong local market and exploiting well-known environmental benefits, have brought the EU rail sector to a world-leading position.

3.4 Short Summary

According to the Eurostat Labour Force Survey (LFS) 2016, the current level of employment is 817,752 persons working in the four sectors "Manufacture of railway locomotives and rolling stock" (7%), "Construction of railways" (48%), "Passenger rail transport, interurban" (35%), "Freight rail transport" (9%). In the past five years, employment in the sector has declined by nearly 7%. Further differentiation of this employment development according to regions was done, comparing Germany, Netherlands, France and UK (core countries) versus all other countries. This comparison reveals that employment levels remain quite stable in the core countries and that the grunt of employment decline happened in the non-core countries.

Figure 10 is shown the current distribution of employment in the rail sector according to the major occupational categories (ISCO classification).

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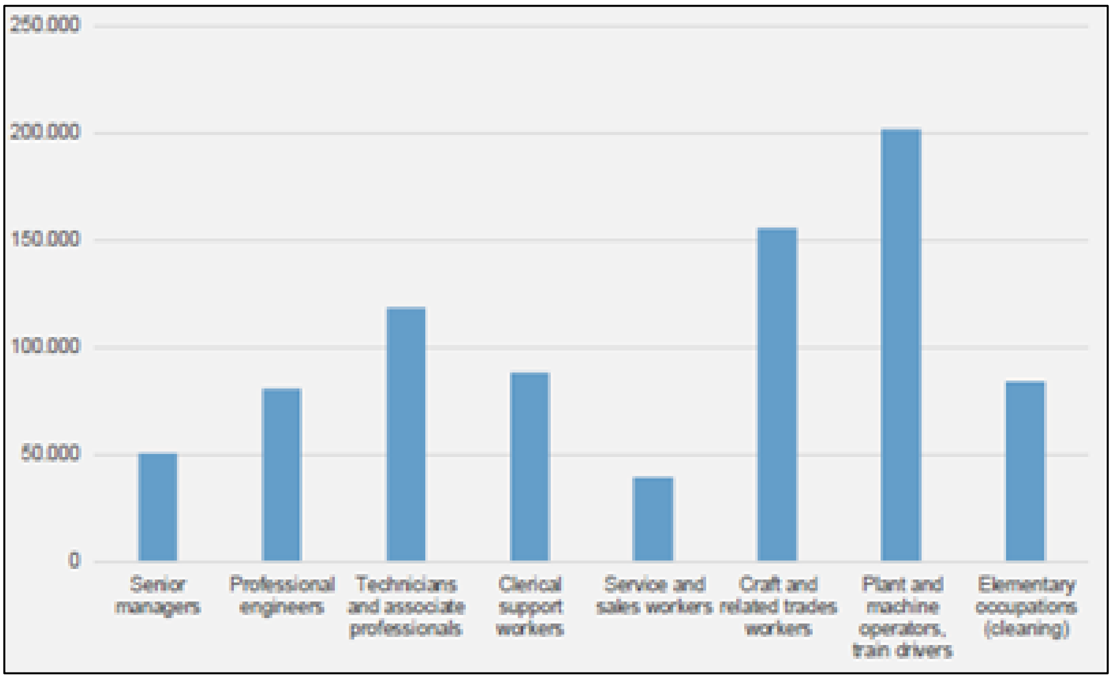

Fig. 10. Distribution of employment in the railway sector according to occupation [45]

For the skill distribution and development, are found the following results:

1. There is a clear upskilling tendency visible in all railway jobs towards academic level (ISCED 5-6), but mainly in higher jobs such as professional engineers, technicians (for example dispatchers) and support workers such as railway sales agents. In more basic jobs such as train drivers, job requirements also appear to have shifted upwards, but more to middle educational levels (professional training).
2. Most of the employees need at least middle-level educational degrees to get recruited and perform their jobs.
3. A further result is that the apparent rise in skills may also be attributed to rising educational requirements used by companies and not so much to a change in work itself. An important number of employees find they are overqualified for the work they are doing.
4. There are differences in skills profiles between railway occupations. Not all occupations have the same technical, communicative, social, and organisational skills. Technical and organisational skills are very important for management and engineering occupations, less so for other categories.
5. Occupational distributions differ between the regions compared in the report. The core countries show more employment in managerial, engineering and technical occupations. The educational level also seems considerably higher in these occupations.

A lot of studies have been conducted over the years to estimate what skills and employment will do in the future. Comparing the predictions from the past about our current employment helps to understand what is changing in practices. This helps us to understand what we may expect in the next decade. These studies generally predict a further decline in employment until the end of this decade. The expectation is that in the 2020s, new employment growth is inevitable because of the ageing workforce (many will leave the sector). Technological change will require a great effort from the rail sector to deal with rising skill discrepancies. Solutions to deal with these skill discrepancies are seen in more training and in shifting employment practices. An important observation in this respect is that these foresight and forecasting studies show clear discrepancies with the actual tendencies in employment and skilling. The forecasters see other things than current statistics show us. This discrepancy is the main starting point for the discussion in workshops with the sector.

Key findings:

- The level of education of employees is increasing, although the complexity of the workplace does not require it,
- The structure of employees changes from administrative to technical jobs,
- In the next few years, there will be a change of generations. A large pool of new employees is needed,
- Within companies, it is necessary to develop additional education for specific jobs.

4 ANALYSIS OF THE EDUCATIONAL MARKET FOR RAILWAY ENGINEERS

Comparative analysis is a research method based on the mutual comparison of selected characteristics of several researched elements (FILIT 3.0, Open Philosophical Encyclopedia, Piaček and Moravčík, 1999). Selected characteristics perform a comparative analysis of the structure and content of individual fields of study in the field of operation and economics of transport.

As part of a comparative analysis of the structure and content of individual fields of study, 27 study fields and programs are compared out of a total of 170 fields of study provided in the field of transport operation and economics.

To ensure a clear structure and systematicity within the comparative analysis of the structure and content of study programmes in the field of transport operation and economics, individual study programmes are named and marked with a letter and subscript in such a way that only abbreviated labels can be used during the comparative analysis itself. The abbreviated label of individual study programmes is given in the following table:

Table 40. Abbreviated labels of individual study programmes

Label of the study programme	Name of the study programme	Name of the institution of tertiary education providing the study programme
O_1	Transport economics MSc	University of Leeds
O_2	Railway Engineering with Project Management MSc	University of Leeds
O_3	Railway Operations, Management and Policy MSc	University of Leeds
O_4	Transport Planning and Engineering MSc	Newcastle University
O_5	Master of Science in Engineering: Logistics and Traffic	Katholieke Universiteit Leuven (KU Leuven)
O_6	Mobility and Transport/Transport Engineering and Mobility (M.Sc.), specialization: Transportation Logistics	Rheinisch-Westfälische Technische Hochschule Aachen (RWTH Aachen)
O_7	Railway System Engineer (RSE)	Rheinisch-Westfälische Technische Hochschule Aachen (RWTH Aachen)
O_8	Policy: Infrastructure, Planning and Environment	Technische Universiteit Delft (TU Delft)
O_9	Design: Transport Systems & Networks	Technische Universiteit Delft (TU Delft)
O_{10}	Operations: Traffic, Technology & Control	Technische Universiteit Delft (TU Delft)
O_{11}	Engineering: Transport, Logistics & Supply Chains	Technische Universiteit Delft (TU Delft)
O_{12}	Logistics Engineering	Breda University of Applied Sciences
O_{13}	Transport	University of Zagreb
O_{14}	Railway Transport	University of Zagreb
O_{15}	Mobility, Transport and Logistics	Danmarks Tekniske Universitet (DTU)
O_{16}	Railway Transport (BSc)	University of Zilina

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O₁₇	Railway Transport (MSc)	University of Zilina
O₁₈	Forwarding and Logistics (BSc)	University of Zilina
O₁₉	Forwarding and Logistics (MSc)	University of Zilina
O₂₀	Rail Technology and Mobility (BSc)	FH St. Pölten (University of Applied Sciences)
O₂₁	Industrial Engineering Railway, Specialisation Railways and Transport	FH Erfurt
O₂₂	Railway Systems	TU Dresden
O₂₃	Civil Engineering Infrastructure	TU Graz
O₂₄	Transport and Traffic Engineering	TU Braunschweig
O₂₅	Transport and Traffic Engineering	TU Braunschweig
O₂₆	Railway Transport	University of Belgrade
O₂₇	Railway Transport	University of Belgrade

Source: author

4.1 Comparative analysis of the structure of individual study programmes

The comparative analysis of the structure of individual study programmes is based on the characteristics defining the organizational structure of the study programmes in the field of transport operation and economics. The observed characteristics within the specification of the organizational structure of individual study programmes are the degree of study within which the field of study or program is provided, the language of instruction of the field, the basic unit of organizational form of the academic year, duration of full-time study (months), (non) existing possibility of external study, duration of the external study (in months), amount of annual tuition for students from EU / EEA countries for full-time study and amount of annual tuition for students from countries outside the EU / EEA for full-time study. The selected characteristics are compared in the following table:

Table 41. Comparative analysis of the structure of individual study programmes in the field of operation and economics of transport

Study programme	Degree of study	Language of studies	The basic unit of the academic year	Duration of the full-time study (in months)	The (non) existing option of external (part-time) study	Duration of the external (part-time) study (in months)	Annual tuition fee for EU/EEA students at full-time study	Annual tuition fee for non-EU/EEA students at full-time study
O₁	2.	ENG	semester	12	✓	24/36	10,500 £	25,750 £
O₂	2.	ENG	semester	12	✓	24/36	11,500 £	25,750 £
O₃	2.	ENG	semester	12	✓	24	10,500 £	25,750 £
O₄	2.	ENG	trimester	12	✓	24	11,400 £	24,300 £
O₅	2.	ENG	semester	24	✗	–	961.90 €	6,600 €
O₆	2.	GER ENG	semester	24	✗	–	0 €	0 €

O_7	2.	GER ENG	semester	24	✗	–	0 €	0 €
O_8	2.	ENG	semester	24	✗	–	2,168 €	18,750 €
O_9	2.	ENG	semester	24	✗	–	2,168 €	18,750 €
O_{10}	2.	ENG	semester	24	✗	–	2,168 €	18,750 €
O_{11}	2.	ENG	semester	24	✗	–	2,168 €	18,750 €
O_{12}	1.	ENG	trimester semester*	48	✗	–	8,906 €	8,906 €
O_{13}	1.	HRV	semester	36	✓	36	≤ 8,400 kn	8,400 kn
O_{14}	2.	HRV	semester	24	✓	24	≤ 8,400 kn	8,400 kn
O_{15}	2.	ENG	semester	24	✗	–	0 €	15,000 €
O_{16}	1.	SLO	semester	36	✓	48	0 €	0 €
O_{17}	2.	SLO	semester	24	✓	36	0 €	0 €
O_{18}	1.	SLO	semester	36	✗	–	0 €	0 €
O_{19}	2.	SLO	semester	24	✗	–	0 €	0 €
O_{20}	1.	GER ENG	semester	36	✓	36	363.36 € + 20.70 €	1,500 € + 20.70 €
O_{21}	1.	GER	semester	36	✗	–	249.90 € **	–
O_{22}	2.	GER	semester	24	✗	–	289.10 € **	–
O_{23}	2.	GER	semester	24	✗	–	20.70 €	726.72 € + 20.70 €
O_{24}	1.	GER	semester	36	✗	–	391.51 € **	–
O_{25}	2.	GER	semester	24	✗	–	391.51 € **	–
O_{26}	1.	SRP	semester	48	✓	48	1,000 €	1,000 €
O_{27}	2.	SRP	semester	12	✓	12	1,000 €	1,000 €

Source: available information from web portals of universities and colleges, processed by: the author

* 3 years – trimester, 4th year – semesters

** no instuition fee, but semester fee

4.1.1 Synthesis of comparative analysis of the structure of individual study programmes in the field of operation and economics of transport

Table 41 shows that 19 of the 27 characterized study programmes in the field of transport operation and economics are provided only in the second master's (or engineering) degree. Even though the choice of study programmes made by us is influenced by certain subjective criteria, their selection copies the general trend in terms of the organizational structure of study programmes in the field of transport operation and economics. The fact that most study programmes in the field of transport are provided only at the master's (or engineering) level of study is caused in Western European countries by the established interdisciplinary nature of transport as a field of study, which is followed up in masters and engineering studies. engineering, construction and natural science bachelor's study fields and programs, which usually include a study block dedicated to a transport subject. However, in the countries of Central, South-Eastern and Eastern Europe, there are still several

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study programmes in the field of transport operation and economics, which are also provided with the bachelor's degree.

In terms of the division of the academic year into smaller organizational units, the division of the academic year into semesters prevails in 25 of the 27 study fields, i. into 2 large study blocks - these are divided into either autumn and spring or winter and summer semesters. In the case of using the division of the academic year into trimesters, it is a division into 3 basic parts.

As far as the duration of full-time university studies is concerned, the study programmes at the master's (or engineering) level of study are mostly 24 months, i.e. j. 2 academic years. However, there are exceptions in which second-level higher education lasts only 1 academic year - these are most often found at universities and colleges in the United Kingdom and other countries in Western or South-Eastern Europe, respectively. Within the bachelor's degree, four study programmes in the field of transport operation and economics were identified - these study programmes represent a general trend in education in the field of transport in their territory - the study programme of Logistics Engineering is provided at the University of Applied Sciences in Breda. The Netherlands represents a 4-year professionally oriented bachelor's degree program, which is characteristic of Western European countries in structure and duration, while the Railways and Freight and Logistics courses at the University of Zilina and the University of Zagreb study department represent students' theoretical teaching. In the field of operation and economics of transport at the same time, their duration represents the standard length of bachelor's degree education in the countries of Central, South-Eastern and Eastern Europe. The countries of Central, South-Eastern and Eastern Europe are characterized by a bachelor's degree, generally lasting 3 academic years.

Only 6 universities offer the possibility of external study within the identified study programmes. External study is possible in the bachelor's study programmes Transport (University of Zagreb), Railway Transport (University of Zilina), Railway Transport (University of Belgrade) and Rail Technology and Mobility (FH St. Pölten (University of Applied Sciences)) and master's resp. engineering the study programmes Transport Economics (University of Leeds), Railway Operations and Management (University of Leeds), Railway Operations, Management and Policy MSc (University of Leeds), Transport Planning and Transport Engineering (University of Newcastle), Railway Transport (University of Zagreb), Railway Transport (University of Zilina) and Railway Transport (University of Belgrade). The total length of external study within the University of Leeds is adaptable to the needs of the students, but the maximum can be 24 or 36 months. Newcastle University, University of Zagreb, University of Zilina, FH St. Pölten (University of Applied Sciences) and the University of Belgrade have a fixed length of external study.

In terms of tuition fees, it is possible to observe within the identified study programmes that tuition fees are paid by students mainly at universities and colleges within the countries of Western Europe. However, an exception within Western Europe is Germany and the RWTH Aachen University in its territory - free tuition fees are guaranteed at RWTH Aachen for both EU / EEA and non-EU students. Another university at which free tuition is guaranteed for all students is the University of Zilina. Free tuition fees, but only for students from EU / EEA countries, are also guaranteed for students

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at the Danish Technical University. Of all the fields and programmes characterized and analysed, the highest tuition (£ 25,750) is paid by students at the University of Leeds.

4.2 Comparative analysis of the content of individual study programmes

The comparative analysis of the content of individual study programmes is based on the characteristics defining the content of the mentioned study programmes in the field of transport operation and economics. The monitored characteristics within the content of individual study programmes are the types or areas of compulsory and optional subjects (respectively modules - according to the type of field of study or program) taught within individual study programmes.

The thematic areas are intended separately for compulsory and optional subjects based on Table 42, which lists the number of compulsory and optional subjects within the individual study programmes. The numbers of compulsory and optional subjects are expressed in the table by numbers and the mathematical symbol "+", which is used either to separate the numbers of individual thematic blocks of taught groups of modules or subjects within the division guaranteed by the university or university (most often in the case of study programmes with a duration of 1 academic year); or for the separation of compulsory or optional subjects according to individual years within a given study programme (in the case of two-, three- or four-year study programmes). In selected cases, subjects focused only on the elaboration of the final thesis are also defined. From the point of view of determining the total number of compulsory or optional subjects taught within the study programme, the "+" symbol can be considered as an addition mark. Table 42 shows the share of compulsory and optional subjects in the total content of individual analysed study programmes.

The subjects within both groups of subjects are in the next step divided according to their content focus into transport (1), economic (2), technical and general professional (3), general (4) and internship (5) securing subjects. The content structure of individual study programmes in terms of subjects is compared in the following tables - Table 43 is intended for compulsory subjects and Table 44 is intended for optional subjects.

Table 42. Number of compulsory and optional modules (subjects) in individual study programmes

Study programme	Number of compulsory modules/subjects	Number of optional modules/subjects
O_1	7 + 1	5
O_2	9	0
O_3	7	7
O_4	12	0
O_5	13 + 1	56
O_6	7 + 1	51
O_7	10 + 1	30
O_8	6 + 2 + 1 + 7	17 + 11 + 10 + 7 + 6 + 8 + 3
O_9	6 + 2 + 1 + 6	17 + 11 + 10 + 7 + 6 + 8 + 3
O_{10}	6 + 2 + 1 + 6	17 + 11 + 10 + 7 + 6 + 8 + 3
O_{11}	6 + 2 + 1 + 6	17 + 11 + 10 + 7 + 6 + 8 + 3
O_{12}	20 + 20 + 9 + 3 + 1	2 + 4

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O_{13}	10 + 9 + 7 + 1	2 + 4 + 3 + 4 + 4
O_{14}	7 + 3 + 1	3 + 5 + 7
O_{15}	2 + 1 + 4	4 + 6 + 5 + 5
O_{16}	12 + 12 + 11	7 + 9 + 7
O_{17}	11 + 6	11 + 14
O_{18}	12 + 12 + 10	8 + 7 + 4
O_{19}	12 + 10	6 + 4
O_{20}	77	0
O_{21}	22	23
O_{22}	13	22
O_{23}	6	67
O_{24}	20	13
O_{25}	22	20
O_{26}	31	35
O_{27}	0	17

Source: information available from the web portals of universities and colleges, processed by: the author

Table 43. Proportional expression of the number of compulsory and optional modules (subjects) in individual study programmes

Study programme	The percentage share of compulsory modules/subjects (%)	The percentage share of optional modules/subjects (%)
O_1	61	39
O_2	54	46
O_3	50	50
O_4	100	0
O_5	20	80
O_6	14	86
O_7	27	73
O_8	21	79
O_9	19	81
O_{10}	19	81
O_{11}	19	81
O_{12}	90	10
O_{13}	61	39
O_{14}	42	58
O_{15}	26	74
O_{16}	60	40
O_{17}	40	60
O_{18}	64	36
O_{19}	69	31
O_{20}	100	0
O_{21}	49	51
O_{22}	37	63
O_{23}	8	92
O_{24}	61	39
O_{25}	52	48

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O_{26}	47	53
O_{27}	0	100

Source: information available from the web portals of universities and colleges, processed by: the author

According to the information in Table 43, in terms of the percentage of all subjects taught and thus also in terms of the number of electives within all subjects, the most adaptable study programme is considered to be the engineering field of Railway Transport (University of Belgrade), 100% of which consists of electives subjects. We can also pick the study programmes of Civil Engineering Infrastructure (TU Graz) and Mobility and Transport/Transport Engineering and Mobility (M.Sc.), with specialization: Transportation Logistics (Rheinisch-Westfälische Technische Hochschule Aachen (RWTH Aachen)), which have a share of electives subjects up to 92% and 86%.

Other study programmes, which in terms of the percentage of 79-81% of the provided subjects are optional, are engineering study programmes provided within the study programme Transport, Infrastructure and Logistics at TU Delft - these are study programmes Transport Policy and Principles: Infrastructure, Planning and Environment; Design of transportation systems and networks; Operations and Management: Transport, Technology and Control and Engineering: Transport, Logistics and Supply Chains.

On the contrary, the least adaptable study programmes, the departments most involved in the compulsory subjects are the Department of Transport Planning and Transport Engineering (University of Newcastle), the Department of Railway Engineering with Project Management (MSc) and the Bachelor's degree program in Rail Technology and Mobility Bsc. at FH St. Pölten (University of Applied Sciences). The share of compulsory subjects in the total content of the 3 study programmes is 100%.

Tables 44 and 45 show the number of subjects in each thematic group and their percentage shares in the total content of study programmes.

Table 44. Distribution of compulsory subjects within individual study programmes according to their area of focus

Study programme	Transport subjects	Economic subjects	Technical and general professional subjects	General subjects	Practice, Training
O_1	2	5	0	1	0
O_2	3	3	0	1	0
O_3	4	1	1	1	0
O_4	9	3	0	1	0
O_5	9	2	2	1	0
O_6	5	1	1	1	0
O_7	5	0	4	1	1
O_8	5	4	6	1	0
O_9	8	2	4	1	0
O_{10}	6	1	7	1	0
O_{11}	5	4	5	1	0
O_{12}	14	13	10	13	3
O_{13}	9	2	4	12	0

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O_{14}	9	1	0	1	0
O_{15}	3	3	0	1	0
O_{16}	10	5	7	12	1
O_{17}	6	4	3	4	0
O_{18}	11	8	5	10	0
O_{19}	7	3	7	5	0
O_{20}	33	10	18	6	10
O_{21}	9	5	4	1	3
O_{22}	7	2	3	0	1
O_{23}	2	0	3	0	1
O_{24}	9	2	6	1	1
O_{25}	4	0	12	2	4
O_{26}	14	2	5	9	1
O_{27}	0	0	0	0	0

Source: information available from the web portals of universities and colleges, processed by: the author

Table 45. Distribution of optional subjects within individual study programmes according to their area of focus

Study programme	Transport subjects	Economic subjects	Technical and general professional subjects	General subjects	Practice, Training
O_1	2	2	2	0	0
O_2	2	2	2	0	0
O_3	0	0	0	0	0
O_4	0	0	0	0	0
O_5	3	3	21	1	6
O_6	14	12	19	4	2
O_7	9	2	14	4	1
O_8	23	15	21	0	3
O_9	23	15	21	0	3
O_{10}	23	15	21	0	3
O_{11}	23	15	21	0	3
O_{12}	2	1	1	2	0
O_{13}	4	0	4	9	0
O_{14}	9	2	4	0	0
O_{15}	3	10	7	0	0
O_{16}	2	1	0	3	17
O_{17}	6	2	3	9	5
O_{18}	0	1	0	15	3
O_{19}	2	0	0	8	0
O_{20}	0	0	0	0	0
O_{21}	18	1	3	1	0
O_{22}	19	0	2	0	1
O_{23}	15	0	40	10	2
O_{24}	7	0	3	1	2

O_{25}	17	0	2	1	0
O_{26}	17	7	4	7	0
O_{27}	11	4	1	0	1

Source: information available from the web portals of universities and colleges, processed by: the author

4.2.1 Synthesis of comparative analysis of the content of individual study programmes in the field of operation and economics of transport

Based on the division of subjects into individual thematic subgroups, it is possible to determine, thanks to a summary of compulsory and optional subjects, which subjects contribute in what proportion to the total content of characterized study programmes in the field of transport operation and economics. The percentage share of individual groups of subjects in the total number of subjects taught within the characterized study programmes is expressed in the following table:

Table 46. Percentage shares of individual regional subgroups of taught subjects according to individual study programmes

Study programme	Transport subjects (%)	Economic subjects (%)	Technical and general professional subjects (%)	General subjects (%)	Practice, Training (%)
O_1	31	54	8	8	0
O_2	33	33	0	33	0
O_3	50	7	14	29	0
O_4	67	25	0	8	0
O_5	25	10	48	4	13
O_6	32	22	34	8	3
O_7	34	5	44	12	5
O_8	36	24	35	1	4
O_9	40	22	32	1	4
O_{10}	38	21	36	1	4
O_{11}	36	25	34	1	4
O_{12}	27	24	19	25	5
O_{13}	30	5	18	48	0
O_{14}	69	12	15	4	0
O_{15}	22	48	26	4	0
O_{16}	21	10	12	26	31
O_{17}	29	14	14	31	12
O_{18}	21	17	9	47	6
O_{19}	28	9	22	41	0
O_{20}	43	13	23	8	13
O_{21}	60	13	16	4	7
O_{22}	74	6	14	0	6
O_{23}	23	0	59	14	4
O_{24}	50	6	28	6	9

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O_{25}	50	0	33	7	10
O_{26}	47	14	14	24	2
O_{27}	65	24	6	0	6

Source: information available from the web portals of universities and colleges, processed by: the author

In terms of the ratio of transport subjects (74 - 67%) concerning the total content of the subjects of the given study programme, the leading study departments are Railway Systems (TU Dresden), Railway Transport (University of Zagreb) and Transport Planning and Transport Engineering (University of Newcastle).

On the contrary, the smallest share of 21% consists of transport subjects within the bachelor's study programmes of Railway Transport and Freight Forwarding and Logistics at the University of Zilina.

In terms of the share of economic subjects in the total content, the leading departments are the Department of Transport economics MSc (University of Leeds) with a share of economic subjects at 54% and the study department Mobility, Transport and Logistics (Danish Technical University) with a share of economic subjects in the total content 48%.

On the contrary, no subjects of economic orientation occur within the study programmes of Civil Engineering Infrastructure (TU Graz) and Transport and Traffic Engineering (TU Braunschweig).

4.3 Short Summary

The offer of study programmes in the field of transport focusing on railway transport is interesting and varied. The problem is students' preferences because many of them don´t prefer the study of transport science.

Every study programme is different, because of regional-specific needs, but the core of study programmes is very similar. Very important is cooperation between universities and between universities and praxis. One of the very good possibilities how to upgrade the level of education in the field of transport is close cooperation between transport labs and preparing new study materials and using new teaching methods.

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5 CONCLUSION

Railways are a sustainable transport mode with low emissions. The European railway system consists of national railway systems. Characteristics of the systems are different signalling systems, operational rules or power supply systems, etc. The reason for that difference is that the railway systems in Europe have grown and developed as national systems. However, the European Union has started efforts to harmonise the railway system and achieve interoperability, e.g., technical specifications for Interoperability (TSI).

So it is clear that system knowledge for railway engineers is required. This consists of system knowledge and practical skills. The theoretical knowledge is taught with traditional lectures on the academic level, and the skills are gained in academic exercises. Those exercises are held in railway laboratories. However, most of the laboratories focus on education on national railway systems. New laboratory teaching methods and common skills in understanding the railway system could also be supportive steps to achieve interoperability in Europe.

According to the Eurostat Labour Force Survey (LFS) 2016, the level of employment is 817,752 persons working in the four sectors "Manufacture of railway locomotives and rolling stock" (7%), "Construction of railways" (48%), "Passenger rail transport, interurban" (35%), and "Freight rail transport" (9%). In the past five years, employment in the sector has declined by nearly 7%. Further differentiation of this employment development according to regions was done, comparing Germany, Netherlands, France and UK (core countries) versus all other countries. This comparison reveals that employment levels remain quite stable in the core countries and that the grunt of employment decline happened in the non-core countries.

For the skill distribution and development, are found the following results:

1. There is a clear upskilling tendency visible in all railway jobs towards academic level (ISCED 5-6), but mainly in higher jobs such as professional engineers, technicians (for example dispatchers) and support workers such as railway sales agents. In more basic jobs such as train drivers, job requirements also appear to have shifted upwards, but more to middle educational levels (professional training).
2. Most employees need at least middle-level educational degrees to get recruited and perform their jobs.
3. A further result is that the apparent rise in skills may also be attributed to rising educational requirements used by companies and not so much to a change in work itself. An important number of employees find they are overqualified for their work.
4. There are differences in skills profiles between railway occupations. Not all occupations have the same technical, communicative, social, and organisational skills. Technical and organisational skills are very important for management and engineering occupations, less so for other categories.

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5. Occupational distributions differ between the regions compared in the report. The core countries show more employment in managerial, engineering and technical occupations. The educational level also seems considerably higher in these occupations.

According to our research, we can conclude that the key findings in labour forces are the following:

- The level of education of employees is increasing, although the complexity of the workplace does not require it,
- The structure of employees changes from administrative to technical jobs,
- In the next few years, there will be a change of generations. A large pool of new employees is needed, and
- Within companies, it is necessary to develop additional education for specific jobs.

The main findings in Intellectual Output 1 - Impact on the Railway sector can be summarised in the following conclusions:

1. The European railway system is developing in the direction of a single area which means country-specific rules should be spread throughout the European Union area railway community.
2. In the following decade technology level of the railway system is increasing rapidly (for example digital automatic couple, ERTMS, …), so there is a need for advanced engineering knowledge and highly skill-oriented personnel.
3. In the last decade a number of workers in the railway sector was around 800,000. It means that it was quite stable, but we can notice some changes from administrative to engineering jobs.
4. The structure of average age of employees is 50 years old and more. This means that in quite a short period it will be a change in the generation of the railway sector, and now is a crucial time to start recruiting young people for a start to study engineering topics for the railway sector.
5. Also, future engineers need to develop soft skills, so working in teams and obligatory internships are crucial for the future railway system.
6. Railway companies have to make a 5 to 10 years plan for recruiting railway engineers because engineering study is time-consuming.
7. At the European Union level, there are different approaches to high education for railway engineers, so overall, there is a big demand for such study programs in high education. The troubling part is for country-specific study programmes, so there is a need for more generic approaches to learning railway engineering.
8. Quite a lot of high education institutions use different labs in their teaching process. Labs can be from mathematical modelling, statistical tools, simulation software, models laboratories and on-site laboratories.

9. In the future, it is necessary to connect different laboratories to have a broader scope of knowledge students can learn during their studies.
10. In today's digital society, there is a need for cooperation between different laboratories using internet connections. In this way, students can better understand different railway systems at the European Union level and understand the possibility of introducing new technologies in the railway system.
11. There are many interesting study programmes in the field of railway transport in the European Union. But it requires better networking, connection and cooperation to create study programmes more popular and these all need support from European Union programmes.
12. The public and especially potential students need to get information about these study programmes and their future very good career opportunities.

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