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Trans-European Railway High-Speed
Master Plan Study

A general background to support further required studies

Phase 2

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Corrigendum 1

(ECE/TRANS/282)

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Trans-European Railway High-Speed
Master Plan Study -Phase 2
A general background to support further required studies

Corrigendum

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1. **Page 58, 4.2.3, paragraph 3, line 3**

   For table II-20 *read* table II-18

2. **Page 69, 5.3.4, second bullet, line 2**

   For (figure II-23) *read* (figure II-17)

3. **Page 90, Traffic forecast, paragraph 1, line 1**

   For (table II-28) *read* (table II-24)

4. **Page 90, Traffic forecast, last paragraph, line 1**

   For figure II-36 *read* figure II-27

5. **Page 90, Traffic forecast, last paragraph, line 2**

   For figure II-37, *read* figure II-28,

6. **Page 98, paragraph 2, line 2**

   For Figure II-42 *read* Figure II-33

7. **Page 98, last paragraph, last line**

   For figure II-43. *read* figure II-34.

8. **Page 111, last paragraph, at the beginning of line 2**

   For (table II-39) *read* (table II-38)

9. **Page 208, 6., 6.1, paragraph 3, lines 1 and 2**

   For table III-27 and figure III-51 *read* table III-23 and figure III-50

10. **Page 211, paragraph 2, line 4**

    For figure III-50. *read* figure III-51.

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11. Page 255, 2.4, paragraph 1, last line

For table IV-5 and IV-6 *read* table IV-6 and IV-7

12. Page 263, paragraph 1, at the end of line 1

For table IV-8 *read* table IV-9

13. Page 267, last paragraph, last line

For Table IV-9 *read* Table VI-10

14. Page 270, 4.2.3, paragraph 3, line 2

For figures IV-21 and IV-22 *read* figures IV-20 and IV-21

15. Page 272, 2.4, paragraph 3, line 1

For table IV-10. *read* table IV-11.

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Abbreviations and Glossary

ATMF . . . . Uniform Rules concerning the Technical Admission of Railway Material used in International Traffic

ATO . . . . Automatic Train Operation

B/C . . . . Benefit-Cost Ratio, BCR

CBA . . . . Cost-Benefit Analysis

CEN . . . . European Committee for Standardisation

CENELEC . . . . European Committee for Electrotechnical Standardisation

CER . . . . Community of European Railway and Infrastructure Companies

COTIF . . . . Convention concerning International Carriage by Rail

EC . . . . European Commission

ECA . . . . The European Court of Auditors

ECE . . . . Economic Commission for Europe

EIB . . . . European Investment Bank

ERA . . . . European Union Agency for Railways

ERR . . . . Economic Rate of Return

ESI . . . . European and Structural Investment

ETCS . . . . European Train Control System

ETSI . . . . European Telecommunications Standards Institute

EU . . . . European Union

EU States . . . . Members of European Union

FNPV . . . . Financial Net Present Value

FRR . . . . Financial Rate of Return of the Investment

FRMCS . . . . Future Railways Mobile Communication System

GDP . . . . Gross Domestic Product

GOST . . . . GOST (rus: ГОСТ) set of technical standards maintained by the Euro-Asian Council for Standardization, Metrology and Certification (EASC)

GSM-R . . . . GSM for Railways

HRI . . . . Happiness Report Index by The Sustainable Development Solutions Network

IEC . . . . International Electrotechnical Commission

IEF . . . . Index of Economic Freedom by The Heritage Foundation

IMD . . . . International Institute for Management Development

IRS . . . . International Railway Solution, documents issued by UIC

IRR . . . . Internal Rate of Return

ISO . . . . International Organization for Standardization

Italo . . . . The brand name of Europe's first private open access operator of 300 km/h high-speed trains (it: Nuovo Trasporto Viaggiatori)

JR East . . . . East Japan Railway Company operates all of the Shinkansen, high-speed rail lines, north of Tokyo, except the Hokkaido Shinkansen,

LCC . . . . Life Cycle Costs

MCA . . . . Multi-Criteria Analysis

NPV . . . . Net Present Value

THE OSJD. . . . . Organization for Co-operation between Railways (rus: Организация Сотрудничества Железных Дорог, ОСЖД), equivalent of the International Union of Railways (UIC) for East Europe and Asia railway

OTIF . . . . Intergovernmental Organisation for International Carriage by Rail (fr. Organisation intergouvernementale pour les Transports Internationaux Ferroviaires)

PI. . . . . Profitability Index also known as profit investment ratio (PIR) and value investment ratio (VIR)

PPP. . . . . Public-Private Partnership

PSS-MK. . . . . Project-Specific Technical Specifications. Design of the Moscow-Kazan section of the Moscow-Kazan-Yekaterinburg High-Speed Railway with speeds of up to 400 km/h

RAMS . . . . The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

SDR . . . . Social Discount Rate

SNCF . . . . France's national state-owned railway company (fr. Société nationale des chemins de fer)

TEN-T. . . . . Transeuropean Network – Transport

TEN-T BAC . . . . Transeuropean Network – Transport Baltic – Adriatic Corridor

TEN-T NSB . . . . Transeuropean Network – Transport North Sea – Baltic

TER. . . . . Trans-European Railway

TER HSR . . . . TER High-Speed Rail Network

TER States . . . . Armenia (AM), Austria (AT), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia, (CZ), Georgia (GE), Greece (GR), Lithuania (LT), Poland (PL), Romania (RO), Russian Federation (RU), Serbia (RS), Slovakia (SK), Slovenia (SI), Turkey (TR)

TER EU States. . . . . Austria (AT), Bulgaria (BG), Croatia (HR), Czechia, (CZ), Greece (GR), Lithuania (LT), Poland (PL), Romania (RO), Slovakia (SK), Slovenia (SI)

TER non-EU States . . . . Armenia (AM), Bosnia and Herzegovina (BA), Georgia (GE), Russian Federation (RU), Serbia (RS), Turkey (TR)

TER neighbouring States . . . . Belarus (BY), Estonia (EE), Finland (FI), Germany (DE), Hungary (HU), Italy (IT), Iran (IR), Kazakhstan (KZ), Latvia (LV), Moldova (MD), Montenegro (ME), North Macedonia (MK), Switzerland (CH), Syria (SY), Ukraine (UA)

TER region . . . . Region with TER States

TSI . . . . Technical Specification of Interoperability: INF – infrastucture, ENE – energy, CCS – Control Command System, TAP – Telematic Application for passengers, TAF – Telematic Application for freight, NOI – noise, PRM – persons with reduced mobility, SRT – Safety in Railways tunnels, OPE – operation, LOC & PAS – locomotives and passengers carriages, WAG – freight wagons.

UIC. . . . . International Railway of Union (fr. Union Internationale des Chemins des fer)

UIC leaflet . . . . Technical documents issued by UIC

UITP . . . . Association of Public Transport (UITP)

UNECE . . . . United Nations Economic Commission for Europe

UTP . . . . Uniform Technical Prescription issued by OTIF

WEF . . . . World Economic Forum

Executive Summary

1. Introduction

High-speed rail (HSR) has developed rapidly worldwide in recent years. The experience of States implementing these systems shows how they are setting new standards of quality and contributing to the renaissance of railway as a mode of transport. This growth has also facilitated the improved connection of peripheral regions, while strengthening international connections. Currently, railways account for over 50 per cent of the share of total transport services in States with the most developed HSR networks, thanks to HSR offering shorter journeys times and therefore competing more effectively with other modes of transport.

In the TER region, the railway network is heterogeneous with different levels of infrastructure quality with remarkable potential for improvement in some areas. The further development of an HSR network would significantly improve the competitiveness of rail; both for the benefit of the environment and socioeconomic development.

The TER HSR Master Plan Phase 2 is a continuation of the work undertaken in Phase 1, and extends its analysis to the following areas:

- Technical and legislative aspects
- Socioeconomic analysis
- Conditions for the establishment of national and international networks
- Financial and planning elements of HSR.

Currently, there are few railway lines in some TER States that allow train speeds to reach 250 km/h; these are modernised conventional lines and some sections of new lines.

This situation, however, creates a unique opportunity for the development of HSR systems in individual TER States, while ensuring that this development is integrated across the wider TER region through adequate international connections. This study aims to provide decision-makers with the necessary tools to define what, if any, HSR network should be developed in their respective States.

2. The current state of development of high-speed long-distance connections in the TER region

The construction of HSR lines in TER States remains very much in its infancy. The highest rate of development in Central Europe can be observed in Austria, where it is estimated that the planned network will be completed by 2030. This network consists of new lines with a maximum speed of 250 km/h, and existing, modernised, lines with a maximum speed of 230 km/h. In addition to this, significant progress has been made in the construction of the HSR network in the Russian Federation and Turkey.

The analysis in this Master Plan is based on the results of feasibility studies conducted until 31 December 2019. The following research and analyses have been undertaken in the preparation of this Master Plan:

- Desktop analysis and synthesis of relevant documents, studies, and legal acts, including the documents developed during Phase I of this study;
- Surveys to obtain information on HSR construction plans in TER States.

Most HSR projects being implemented or planned in TER States are located in the transport corridors designated in the 1990s – the so-called Cretan, Helsinki, and TINA corridors. The following key corridors have been proposed for the purpose of this study:

1. North to South corridor: from Poland via Czechia, Slovakia, Austria, Hungary, Serbia, Bulgaria and North Macedonia to Greece and Turkey
2. North corridor (East to West): from Germany and Poland to Russian Federation via Belarus and further towards China
3. Middle corridor (the Danube): from Austria and Switzerland, and from Germany and Czechia via Slovakia and Hungary to Romania and Ukraine
4. Southern corridor (East to West): from Italy via Slovenia and Croatia to Hungary with a branch towards Turkey
5. Baltic corridor from Germany, Czechia and Poland (Warsaw) via Lithuania, Latvia and Estonia to Finland
6. Southern East to West corridor from Turkey (Istanbul) to Iran and the Caucasus
7. Carpathian corridor from Poland to Romania via Slovakia and Hungary.

These corridors consist of existing or planned HSR lines, as well as conventional lines, which, after technical upgrades, may supplement the HSR system.

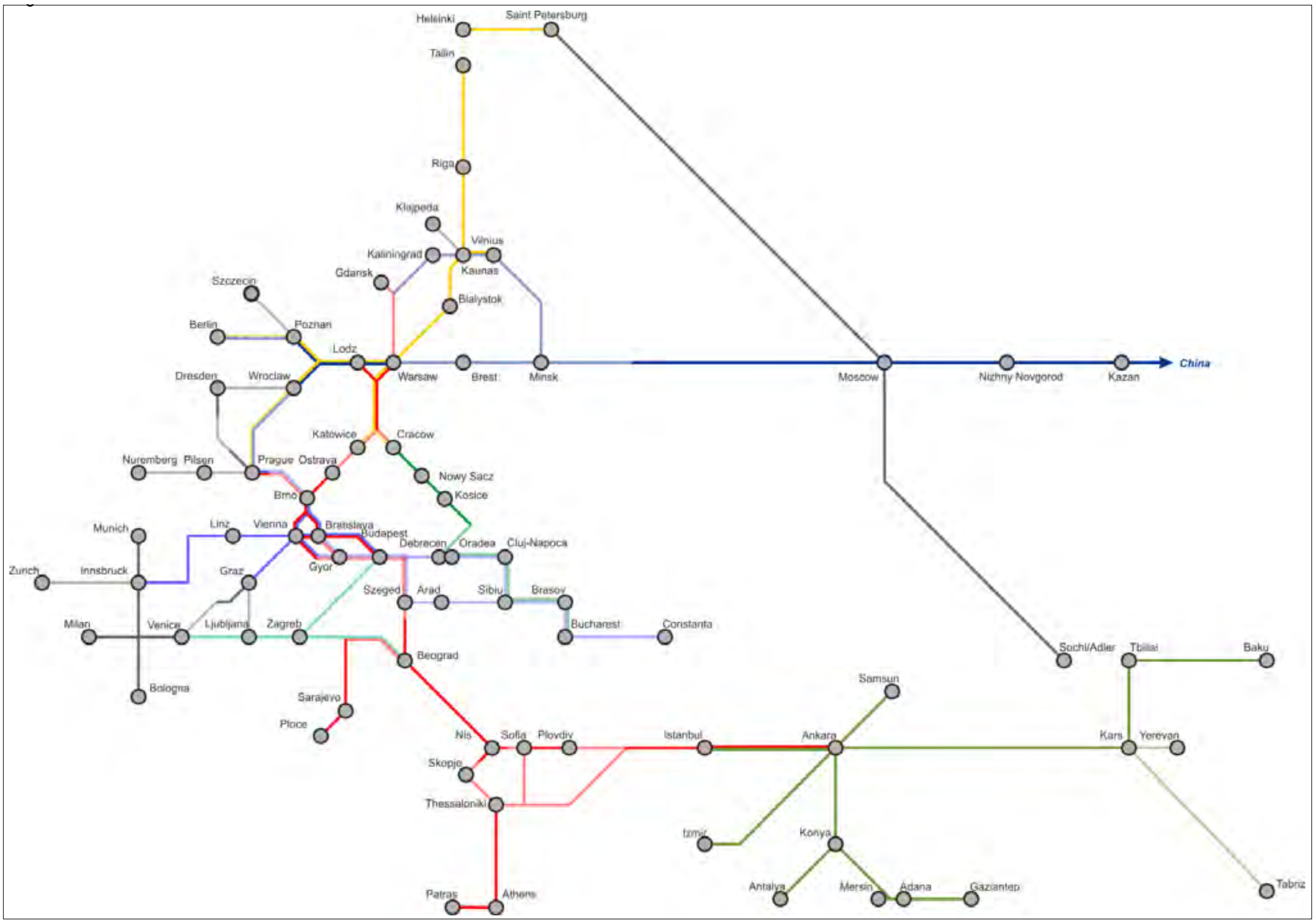
The investment plans have been considered with two milestones: 2030 and 2050 with the final network identified in figure I completed by 2050.

3. Transport potential in the region

The TER network covers a total area of more than 6.4 million km² with varying natural, economic, and social conditions, and has a population of approximately 338 million. The average population density is 50/km². The distribution of population remains highly uneven, covering both large, uninhabited, areas, and highly urbanised ones. Only in a few areas is the urbanisation rate below 50 per cent, and in some States, it is more than 80 per cent. The TER region has 28 cities with populations of more than one million, including 14 capital cities. The TER region is also highly industrialised, with production concentrated in cities and industrial areas.

The existing rail network is relatively dense and is well-integrated into the settlement structure. The core of the network dates back to the nineteenth century. Some gaps exist in the network, and there are some sections that fail to comply with modern technical and construction standards. Nevertheless, the high density of the network allows, in most cases, for the progressive development of HSR networks. Where geographical and environmental conditions allow, partial use of the conventional network for the implementation of HSR connections is possible.

Figure I **Network of TER HSR corridors**



Source: the authors' own research.

4. Technical parameters and standards

The HSR lines planned for construction in the TER region and neighbouring States will be built for maximum speeds of at least 250 km/h. The planned lines in Czechia and Poland will have maximum speeds of 350 km/h, to ensure the maximum possible degree of interoperability. In Austria, new lines are being constructed for maximum speeds of 250 km/h, and existing lines are being modernised to accommodate maximum speeds ranging from 200-230 km/h. In Slovakia, short complementary sections are being upgraded to maximum speeds of 200 km/h. In Hungary, studies are being conducted on the construction of a line from Budapest towards the Austrian border from the HSR line package as part of the target TEN-T network, and one option proposed assumes a maximum speed of 300 km/h. These investments will enable the creation of an attractive international network across Central Europe.

Maximum speeds of 250 km/h in Turkey, and 350 km/h in the Russian Federation are planned. The Rail Baltica line from Warsaw to Tallinn will have a maximum speed of 250 km/h for new sections, and 200 km/h for modernised sections within Poland.

Modernised lines are usually planned to allow maximum speeds of 200 km/h (in Czechia, Serbia, Poland and Slovakia).

The electrification system for new lines will be at 25 kV 50 Hz, with the exception of Austria which will be at 15 kV 16.7 Hz. The modernised lines are also electrified in these systems, except for in Poland, where lines reaching 200-250 km/h are electrified using the 3 kV DC system.

ERTMS Level 2 has been selected for the traffic management system in the European Union, and the same selection has been made by European Union accession candidates and other cooperating States. Future TSI amendments in 2023 will lead to the system being upgraded to ERTMS Level 3.

Simultaneously, important investments have been made in multimodal nodes, alongside new stations, including in Ankara (Turkey) and Lodz (Poland). Similar solutions are planned for other nodes, for example in Brno.

The HSR projects identified above are being implemented according to the standards contained in the relevant TSIs in force in the European Union, but also in other States. For the planned Moscow – Kazan line, the adopted standards are contained in the Specifications for the high-speed line Moscow – Kazan (PSS-MK) document, which assumes use of the 1,520 mm gauge. These requirements are consistent with the Agreement on Main International Railway Lines (AGC). Functionality requirements follow UIC recommendations.

5. Key facts and figures for the TER HSR network

The Master Plan identifies the network of the TER region as:

- Consisting of **23,796** km of new lines with a total cost of €**302.3** billion;
- Supplemented by **2,323** km of lines planned for modernisation to high-speed parameters with a total cost of €**13.8** billion;
- With a total cost of €**316.1** billion;
- with a total average cost in all TER States per year of €**10.5** billion until 2050.

These calculations represent current estimates and are subject to change over time. It should be noted that the costs of some investments might increase during implementation, as demonstrated by experience from the HSR projects previously undertaken in Europe. It should also be noted that investments in the modernisation and upgrading of existing lines to meet HSR parameters represent a relatively small share of total investments (4.1 per cent), in comparison with the construction of new lines. It is understood that often the cost of upgrading existing lines to high-speed parameters would be so high that the construction of new lines is often the only viable option.

This study also shows that the benefits of launching an HSR system are significant. This is demonstrated by the relatively high values (more than 4.5 per cent) of the economic rate of return (ERR) indicators. Benefit/cost ratios in this case are also greater than one. These scenarios also allow for the possibility of some high-speed freight services to operate on some of the HSR lines.

6. Key findings

1) High potential demand for passenger and freight services in the TER region

The construction of a HSR network will significantly improve the mobility of the TER population. This construction, at current socioeconomic development levels, would have a positive impact on the region's sustainable growth, and further draw away traffic from the road and aviation sectors. It is apparent that an efficient transport system in any country is crucial for the whole economy, and the development of HSR networks is increasingly becoming an essential component of such systems.

2) A large number of planned HSR projects

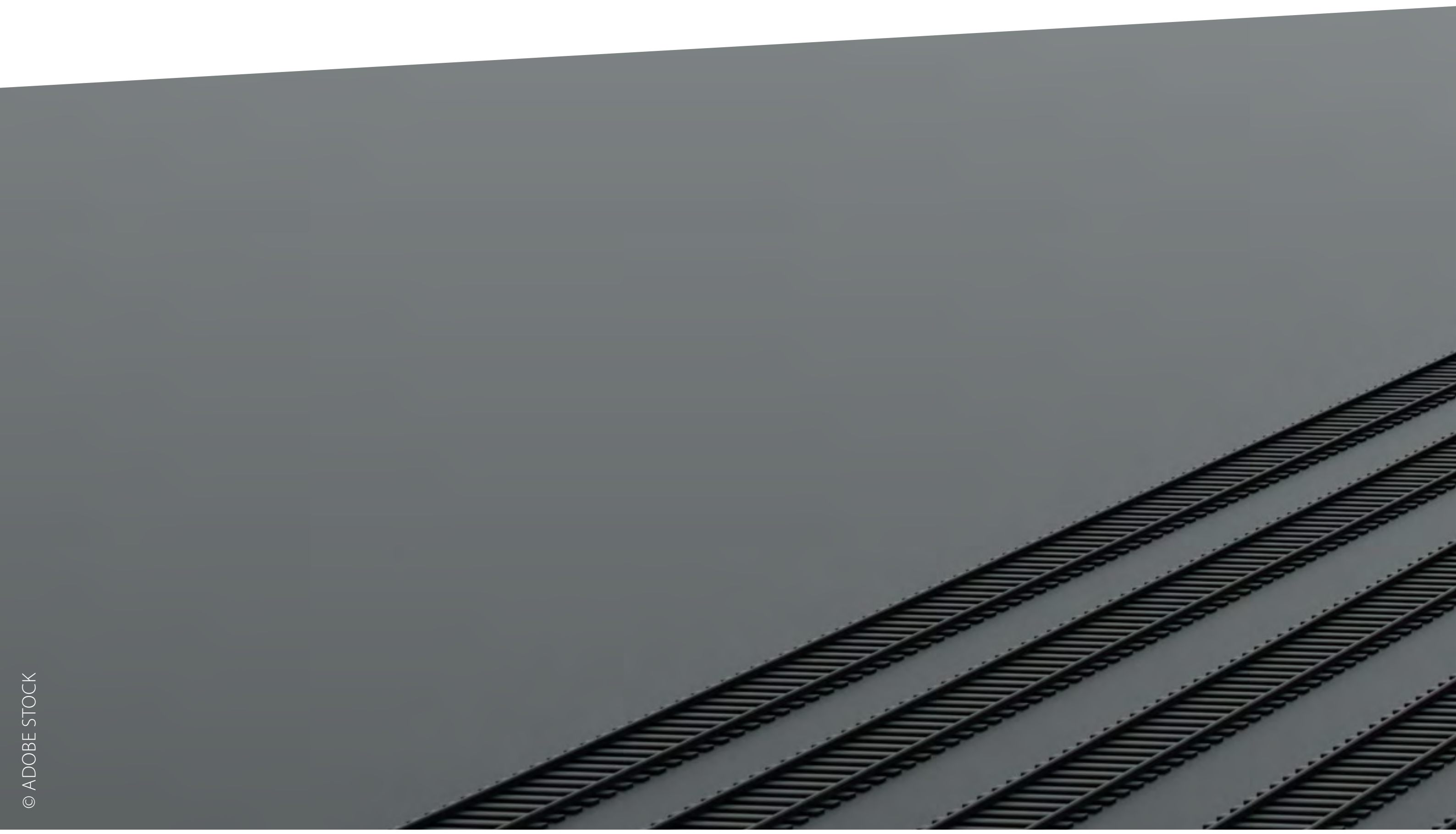
With such a large number of HSR projects under consideration within TER States, it will be possible for those states to close transport gaps across the region, and create effective HSR corridors with a positive impact on the development of the regions. The most significant network gaps exist in the Balkan region, but are also a feature in Central Europe, particularly concerning international connections.

3) Impact on the general competitiveness of rail travel

The analyses conducted in this study demonstrate that HSR significantly improves the competitiveness of rail travel when compared with air and road transport, particularly in relation to journey time and costs for distances up to 800 km, and, in some cases, even up to 1,400 km.

4) Financing of investments in the HSR network

It will be crucial to maximise the financing opportunities available, in particular from the EU and other international institutions, as well as from commercial banks, and from the private sector through PPPs.



7. Recommendations

For TER States to reap the full benefits of the HSR projects outlined in this report, a number of actions should be implemented:

1) International coordination of HSR projects

The coordinated development of HSR projects must occur at international level. This could be achieved through the TER HSR project by the development of an HSR network in the form of a framework investment schedule, which will also ensure that priorities are optimised. This option has to be carefully analysed and agreed among different groups of decision-makers on different levels.

2) Use of high-speed lines for freight transport

HSR lines should be used, at least partially, to establish an express freight network that will improve goods movement and trade turnover and, consequently, competitiveness, especially in international transport. Freight transport options need to be considered at an early stage in the HSR planning process.

3) Development of multimodal nodes/hubs

It is crucial to secure the development of efficient multimodal nodes/hubs, as these will also have a positive impact on the development of the TER region and beyond. The multimodal nodes would provide the opportunity to construct transport interchanges. The respective development plans should consider the position of the HSR network and its nodes as an integrated transport system of the future.

Introduction

The TER high-speed railway Master Plan aims to set the direction of development of a high-speed railway (HSR) network in the region based on global best practices. This Master Plan is a continuation and development of the analysis included in the TER High-Speed Master Plan Phase 1 study.

The rapid development of high-speed railways across the world in recent decades has made it possible to reverse the unfavourable decline in the market share of railways in land passenger transport. Railways have also become competitive with air transport, even over distances up to 1,000 km.

The construction of HSR systems can have a number of positive economic impacts – it stimulates the development of regions not only in terms of investment, but also by providing fast and competitive transport with lower costs and an environmental impact comparable to air and road transport, as well as becoming part of the solution to climate change in Europe and globally.

In Central, Eastern and South-East Europe, along with Turkey – the area covered by the TER network – the number of HSR systems is currently low, and covers only a handful of sections in Austria, Greece, Poland, Russian Federation and Turkey. The rapid and comprehensive development of high-speed rail in this region, which enjoys high development rates, and covers an area of 6.4 million km² and a population of approximately 338 million, is desirable due to the growing importance of the region in the European economy. The region is also characterised by a relatively well-developed railway network, but with low technical parameters due to the fact that it was built primarily in the nineteenth century. Due to political changes in the last century, there are a large number of gaps in the region's existing rail network that prevent the creation of an efficient continental high-speed passenger network. Therefore, building an efficient international passenger railway network using high-speed lines is necessary for the future development of the region.

The following aspects were considered, reviewed and analysed during the preparation of this study:

- Relevant documents, studies, and legal acts, including of the documents developed during Phase I of this study;
- Additional literature;
- Statistical data of the socioeconomic and transport infrastructure diversity of TER States;
- Survey results containing information on HSR construction plans within TER States.

All existing and planned high-speed lines in the European Union within the TEN-T network (considered under EU Regulation 1315/2013 with subsequent additions) have been included in the proposed network.

The TER HSR Master Plan is divided into four sections. The first section identifies the project methodology as well as a review of definitions for high-speed railway systems and the technical standards based on UIC leaflets and the legislative systems of the Russian Federation and the European Union.

The second section starts with a review of the socioeconomic characteristics and an economic growth analysis of the TER region. The fundamental principles of the TER HSR system design, prepared on the basis of global best practice, are also analysed in this section including the existing settlement location and population density influencing the adoption of models for the development of high-speed systems. To complement this analysis, this section also reviews seven sample blueprints for HSR systems that are currently in construction or at an advanced design stage. In addition, five examples of existing high-speed rail systems are described, most of them using conventional lines following modernisation. This section also provides a technical review of solutions in the field of operation and maintenance of HSR systems, communications and signalling systems. A dedicated part of the section offers an overview of the applied and recommended HSR technical requirements by UIC within the Russian Federation, the European Union and other non-European States.

The third section identifies HSR projects in the TER region and in neighbouring States. A tabular summary of projects has been constructed for individual States, including a map of the lines planned and already in operation. This is supplemented by a gap analysis identifying key missing lines and other inefficiencies. Furthermore, this section identifies a network of high-speed lines are arranged in eight separate corridors including recommended connections with other regions of Europe and Asia. Finally, a separate section examines the requirements for the intermodality of transport systems in TER States, with a leading role for HSR systems.

The fourth section is devoted to issues related to the implementation of the recommended TER HSR network identified in the third section including aspects related to project implementation costs until 2050, along with potential sources of revenues for the new systems, and the estimated economic efficiency indicators of the investments planned. This section also identifies the suggested implementation schedule for the TER HSR network following the corridor approach, highlighting also an organizational chart for the implementation of these projects, which ensures international coordination of investments. Finally, this section indicates potential sources of financing for the investments identified earlier.

Throughout this study, particular attention has been paid to the need to link the future HSR system with other modes of transport. An approach based on the urban node system is suggested, in which multifunctional and multimodal centres should be created as a condition for achieving optimal economic efficiency of the future transport system. It is also assumed that in certain cases, sections of conventional lines would be used, which after modernisation could complement the HSR systems. A dedicated section indicates the conditions for using high-speed lines for express freight, in accordance with the latest trends.

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I. Methodology, definitions and rules for the identification of high-speed railway projects

1. Methodology

As set out in the introduction, this report is a continuation of the analysis included in the *TER High-Speed Master Plan Phase 1 study*[1] and, in particular, provides more details on:

- The description and assessment of high-speed line construction projects and modernisation of existing lines to achieve high-speed line parameters;
- An estimation of the demand for high-speed rail between major agglomerations in the TER area and in neighbouring States;
- The legal background on high-speed line construction and operating standards.

In order to define the planned HSR network in the TER States, the analysis is based on the results of the feasibility studies carried out until 31 December 2019.

2. Definitions

2.1 Source documents

Rail transport is subject to national legislation in individual States which defines the basic elements of the railway system and specifies the minimum requirements in terms of safety and interoperability for infrastructure and rolling stock. In addition, European Union (EU) legislation also apply to those TER States within the EU and is also being implemented in pre-accession States.

The legal systems of other States in the TER region may be subject to the provisions of the COTIF Convention and/or the Organisation for Cooperation of Railways (THE OSJD) regulation. These legislative systems often overlap. For example, the coherence of the EU system with the OSJD program is the subject of joint work within the ERA- OSJD Contact Group. Furthermore, the parameters set out in EU legislation are consistent with the UN Agreement on Main International Railway Lines (AGC) but have evolved further and are therefore more detailed. The main agreements are set out below.

2.1.1 European Agreement on Main International Railway Lines (AGC)

For the railway lines covered by the AGC, the basic definitions and parameters of the main components of the railway system are set out in annex 2 to the Agreement (table 1). The following lines have been distinguished:

- A, existing lines that meet the infrastructure requirements and lines to be improved or reconstructed
- B, new lines.

[1] UNECE, *TER High-Speed Master Plan Study – Phase 1*, Geneva 2017.

High-speed lines are classified in B-Category:

- B1, for passenger traffic only – maximum speed 350 km/h
- B2, for passenger and freight traffic – maximum speed 350 km/h
- B3, high-speed lines – 350 km/h.

The regulations and key technical parameters of the infrastructure, as laid down in annex 2, date from 1985 and have been updated over the years to reflect the evolution of the railway system with the most recent revision (revision 4) having been published in 2019.

2.1.2 UIC technical parameters

The UIC documents concerning high-speed rail system have been developed within the framework of the joint multiannual cooperation of the railways (UIC members) and have a global coverage. They are publicly available through the UIC website to all interested parties.[2]

The concepts and strategies for the construction and operation of high-speed rail systems outlined in the UIC documents and leaflets have also been considered in drafting the EU legislative acts, including the TSIs. The UIC standards – International Railway Solutions (IRS) – are set out in the table below.

Table I–1 The list of International Railway Solutions (IRS UIC) relating to the design of high-speed rail systems

Number	Name	Scope
IRS 60670	Implementation of a High-Speed Railway	Definition and Features
IRS 60671	Implementation of a High-Speed Railway	Emerging Phase
IRS 60672	Implementation of a High-Speed Railway	Feasibility Analysis Phase
IRS 60673	Implementation of a High-Speed Railway	Design Phase
IRS 60674	Implementation of a High-Speed Railway	Construction Phase
IRS 60675	Implementation of a High-Speed Railway	Operation Phase

Source: UIC Database www.UIC.org.

2.1.3 Directive (EU) 797/2016 and related Technical Specifications for Interoperability (TSI)

The legal system for rail interoperability in the EU is based on the following legislation and requirements:

- Directive (EU) 797/2016 – The Interoperability Directive – sets out general principles to ensure interoperability within the EU (and cooperating States), including legal measures, essential requirements and bodies responsible for implementing the system and supervision of its functioning.
- A detailed description of the essential requirements is the subject of 11 Technical Specifications of Interoperability (TSIs) referring to individual subsystems of the EU rail system. They define the basic parameters for this subsystem and the principles for assessing their compliance with the essential requirements and the principles for implementing each specification (table I-2).

[2] www.UIC.org.

- TSIs refer to the detailed requirements specified in European Norms (ENs) or other documents and specifications – the list of referenced standards is the subject of annexes J to the TSIs.
- Other ENs have a status of harmonised (non-mandatory) standards, a list of these standards is periodically published by the European Commission.

This system is obligatory for all EU States and EEA States. It is also accepted in the pre-accession States and States cooperating with the EU.

Table I–2 Technical Specifications for Interoperability

Name	Regulation scope	Current legal status (31 May 2019)
INF	Infrastructure	European Commission Regulation 1299/2014 and Commission Implementing Regulation (EU) 2019/776 of 16 May 2019
ENE	Energy	European Commission Regulation 1301/2014 and Commission Implementing Regulation (EU) 2019/776 of 16 May 2019
CCS	Control Command and Signalling	European Commission Regulation 2016/919 and Commission Implementing Regulation (EU) 2019/776 of 16 May 2019
SRT	Safety in Railway Tunnels	European Commission Regulation 1303/2014 and Commission Implementing Regulation (EU) 2019/776 of 16 May 2019
PRM	Persons with Disability and Reduced Mobility	European Commission Regulation 1300/2014 and Commission Implementing Regulation (EU) 2019/772 of 16 May 2019 as regards inventory of assets with a view to identifying barriers to accessibility, providing information to users and monitoring and evaluating progress on accessibility
OPE	Railway operations	Commission Implementing Regulation (EU) 2019/773 of 16 May 2019 on the technical specification for interoperability relating to the operation and traffic management subsystem of the rail system within the European Union
LOC&PAS	Rolling Stock – Locomotives and Passenger Rolling Stock	European Commission Regulation 1302/2014 and Commission Implementing Regulation (EU) 2019/776 of 16 May 2019
WAG	Rolling stock – Freight Wagons	European Commission Regulation 321/2013 and Commission Implementing Regulation (EU) 2019/776 of 16 May 2019
NOI	Permissible levels of noise emission by rolling stock	European Commission Regulation 1304/2014 and Commission Implementing Regulation (EU) 2019/774 of 16 May 2019 as regards application of the technical specification for interoperability relating to the subsystem "rolling stock – noise" to the existing freight wagons
TAP	Telematics applications for passenger service	European Commission Regulation 454/2011 and Commission Implementing Regulation (EU) 2019/775 of 16 May 2019 as regards Change Control Management
TAF	Telematics applications for freight service	European Commission Regulation 1305/2014 and Commission Implementing Regulation (EU) 2019/778 of 16 May 2019 as regards Change Control Management

Source: Own work with the use of information available on www.eur-lex.europa.eu.

2.1.4 Worldwide and regional standards

International standards for general application and specifically for rail applications are set by the following organizations:

1. Worldwide:
   (a) International Organization for Standardization (ISO) – a global non-governmental organization associating national standardisation organizations, founded in 1946, headquarters in Geneva.
   (b) The International Electrotechnical Commission (IEC) is the international standards' and conformity assessment body for all fields of electrotechnology. IEC is the world's leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies.
   (c) International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies – ICTs; founded in 1865, headquarter in Geneva.

2. EU and associated States:
   (a) European Committee for Standardisation (CEN)[3] – an association that brings together the National Standardisation Bodies of 34 European States; CEN provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes.
   (b) European Committee for Electrotechnical Standardisation (CENELEC)[4] is responsible for standardisation in the electrotechnical engineering field. CENELEC prepares voluntary standards, which help facilitate trade between States, create new markets, cut compliance costs and support the development of a Single European Market.
   (c) European Telecommunications Standards Institute (ETSI)[5] – an independent, not-for-profit, standardisation organization in the telecommunications industry (equipment makers and network operators) in Europe, headquartered in Sophia-Antipolis, France, with worldwide projection.

The close collaboration between CEN and CENELEC (CEN-CENELEC)[6] was consolidated at the start of 2010 by the creation of a common CEN-CENELEC Management Centre (CCMC) in Brussels.

The standardisation system in the EU is the subject of Regulation (EU) 1025/2012, which sets out the rules for the organization of this system and the responsibility of individual entities for its implementation.

3. GOST (Russian Federation: ГОСТ)[7] refers to a set of technical standards maintained by the *Euro-Asian Council for Standardisation, Metrology and Certification (EASC)*, a regional standard organization operating under the auspices of the Commonwealth of Independent States (CIS). Part of GOST-R standards is identical to the EN standards. GOST standards are the standardisation system referred to in OSJD documents.

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3 www.cen.eu
4 www.cenelec.eu
5 www.etsi.org
6 www.cencenelec.eu
7 www.gostrussia.com

2.1.5 OTIF documents

As part of its core activities OTIF also prepares key documents that are the basis for technical railway definitions. These are documents adopted pursuant to the Convention on International Carriage by Rail (COTIF) in particular (table I-3):

- Uniform Technical Prescriptions (UTP) and related *Guide for the application of the UTP*
- Uniform Rules concerning the Technical Admission of Railway Material used in International Traffic (ATMF).

The geographical scope of the OTIF Regulation is the Eurasian Railway Area, and in part, Africa. Regulations concerning the construction and operation of railway systems are in accordance with EU regulations and are agreed on a contractual basis. The typical UTP specification and its structure contains the EU legal requirements and additionally requirements for the OTIF area.

Table I–3 Uniform Technical Prescriptions

Name	Regulation scope	Current legal status (31 May 2019)
UTP INF	Infrastructure	Awaiting approval
UTP PRM	Persons with Disabilities and with Reduced Mobility	Since 1 January 2015
UTP LOC&PAS	Locomotives and passenger rolling stock	Since 1 January 2015
UTP WAG	Freight wagons	Since 1 December 2016
UTP NOI	Permissible levels of noise emission by rolling stock	Since 1 December 2015
UTP TAF	Telematics applications for freight traffic	Since 1 December 2017

Source: OTIF www.otif.org.

2.1.6 OSJD documents

For the 1,520 mm system the OSJD issues a set of OSJD leaflets. The harmonised standards for OSJD leaflets are the Russian technical standards GOST.[8] The role of the OSJD leaflets is the same as that of UIC leaflets. As a result of many years of collaboration between UIC and OSJD, common UIC/OSJD leaflets on issues relating to rail traffic between the two systems have been developed. This cooperation, in accordance with the Memorandum of Cooperation between the two organizations of 2016, has been extended to include issues related to the implementation of the new generation of documents – the IRS mentioned above.

The European Union Agency for Railways (ERA) also cooperates with the OSJD on the analysis of the relationship between the 1,435 mm and the 1,520/1,524 mm railway systems in terms of technical and operational aspects, together with a strategic assessment of possible convergence between the two systems (keeping the gauge differences) in the future.

The cooperation started in 2007 with the establishment of a dedicated ERA – OSJD Contact Group with a comparative analysis of the technical specifications for interoperability and the requirements of the 1,520/1,524 mm railway area of the OSJD member States. The results of this joint work have contributed to the revision of the TSIs. This activity is ongoing in order to cover all subsystems and to

[8] *Russian technical standards GOST.*, n.d., www.russiangost.com.

update the analysis or parts thereof, where applicable. In addition, cooperation allows for the exchange of experience in the coordination of measures to maintain and improve technical and operational compatibility on the CIS-EU border.

Requirements for the construction of the Moscow – Kazan line have been developed for higher speeds in the "Specification for the high-speed line Moscow – Kazan (PSS-MK)".[9]

2.2 High-speed railway definitions

High-speed railways have been defined in different ways around the globe and by different entities. This section seeks to identify these definitions and then propose a definitive one to be used in the TER context and in the remainder of the study.

The UIC definition

In *IRS 60670 Terms and definitions High-Speed Railway (HSR)*, the HSR system is defined as "a railway system with an operating speed of at least 250 km/h" but is qualified by the statement: "the definition of HSR may vary from country to country".

The EU definition

EU Directive 797/2016[10] and EU Regulation 1315/2013[11] define railway network elements according to the classification included in their annexes. The definitions of the three highest categories of lines are as follows:

- **(a)** Specially constructed high-speed lines equipped for speeds equal to or greater than 250 km/h;
- **(b)** Specially upgraded high-speed lines equipped for speeds of 200 km/h;
- **(c)** Specially upgraded high-speed lines with special features as a result of topographical, relief or city-planning constraints, to which the speed must be commensurate. This category includes interconnecting lines between high-speed and conventional networks, lines running through stations, accesses to terminals, depots, etc. operated at standard speed by "high-speed" rolling stock.

This network includes traffic management, monitoring and navigation systems, data processing software, infrastructure and telecommunications services for long-distance passenger services and freight services on the network to maintain a secure and harmonious operation of the network and efficient traffic management.

Such a definition is referred to in the Infrastructure TSI (1299/2014)[12] which contains the categorisation of railway lines. The TSI category of line is a combination of traffic codes. For lines where only one type of traffic is carried (for example, a freight only line), a single code can be used; where there is mixed use, one or more passenger or freight codes is used. For the purpose of TSI categorisation, lines are

[9] Russian Railways, *"Specifications for the high-speed line Moscow — Kazan" (PSS-MK)*, n.d.

[10] *Directive (EU) 2016/797 of the European Parliament and of the Council of 11 May 2016 on the interoperability of the rail system within the European Union (Text with EEA relevance)*, Bruxelles n.d.

[11] *Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 establishing the Connecting Europe Facility, amending Regulation (EU) No 913/2010 and repealing Regulations (EC) No 680/2007 and (EC) No 67/2010*, Bruxelles n.d.

[12] *Commission Regulation (EU) No. 1299/2014 of 18 November 2014 on the technical specifications for interoperability relating to the "infrastructure" subsystem of the rail system in the European Union Text with EEA relevance*, 2014.

classified generically based on the type of traffic (traffic code) identified by the following performance parameters:

- Gauge
- Axle load
- Line speed
- Usable length of platform.

The "gauge" and "axle load" columns are treated as minimum requirements as they directly determine which trains may run. The columns for "line speed", "usable length of platform" are indicative and show the range of values that are typically used for different types of traffic and do not directly impose restrictions on the traffic that may run over the line. These categories of lines are consistent with those in the AGC.

Table I–4 Performance parameters of infrastructure for passenger service

Traffic code	Gauge	Axle load [t]	Line speed [km/h]	Usable length of platform [m]
P1	GC	17	250-350	400
P2	GB	20	200-250	200-400
P3	DE3	22.5	120-200	200-400
P4	GB	22.5	120-200	200-400
P5	GA	20	80-120	50-200
P6	G1	12	N/A	N/A
P1520	S	22.5	80-160	35-400
P1600	IRL1	22.5	80-160	75-240

Source: EU Reg. 1299/2014. Gauge marking defined in EN Standards.

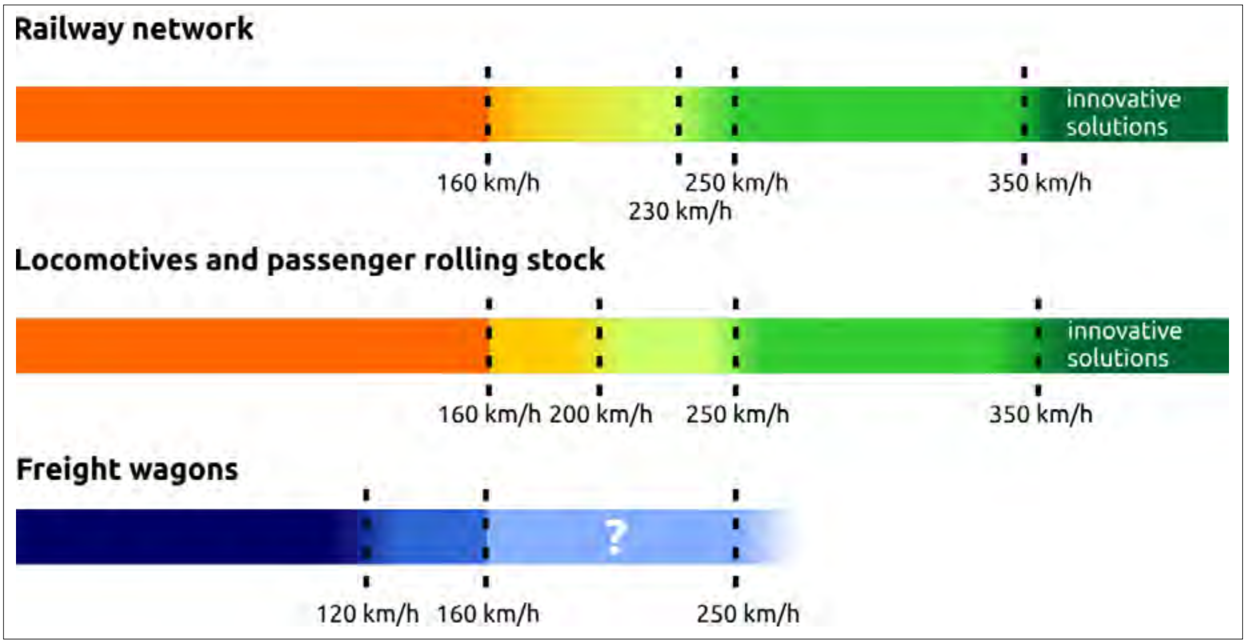
There are no legal restrictions on freight traffic on high-speed lines. The decision to operate freight trains on these lines depends on local conditions (demand, network capacity) while complying with legal requirements in terms of technical performance.

The TSI applies to networks with the following nominal track gauges: 1,435 mm, 1,520 mm, 1,524 mm, 1,600 mm and 1,668 mm within the European Union.

There are currently no separate TSIs for high-speed and conventional rail systems in terms of rolling stock and infrastructure subsystems. Such division existed until 2014 due to the fact that EU legislation on railway interoperability was first developed specifically for high-speed rail systems. In the current TSI specifications, the values of basic parameters are different for various maximum speeds. These values are defined gradually for each successive maximum speed range and some of them are identical across speed ranges. Parameter changes merge at speeds of 160 km/h and 250 km/h as set out in figure I-1 below.

The scope of the current specifications for rolling stock and infrastructure is limited to 350 km/h (currently the highest speed used in normal operation). The procedure for the so-called innovative solutions, in accordance with the rules outlined in the relevant TSIs, should be applied to service speeds over 350 km/h.

Figure I–1 Implementation of technical and operational specifications for the railway system depending on the maximum speeds on railway lines



Source: Own work based on TSIs.

For freight, the limit of TSI application is currently set at 160 km/h. Existing solutions (Mercitalia – Italy) and planned projects beyond that speed are treated as innovative solutions.

Definitions proposed for TER HSR network

For the purposes of the study, the following rules have been adopted:

- Full compliance with the technical solutions of the IRS UIC;
- Full compliance with the OTIF regulations and, in individual cases, with other regulations at the regional level where justified by the need of internal interoperability;
- Full compliance with the EU legal system;
- Full alignment with the AGC.

For the purposes of the TER HSR network, the use of the term high-speed railway shall refer to the entire transport service – associated infrastructure and rolling stock – distinguished by a significantly higher service speed of trains. It applies to both passenger and freight transport. In order to achieve this, the high-speed railway services use:

- New high-speed lines with maximum design speed of at least 250 km/h;
- Upgraded lines with maximum design speed of at least 200 km/h;
- Other lines used to extend the high-speed service;
- High-speed rolling stock with a maximum speed more than 200 km/h.

This will allow the development of HSR systems in a corridor approach where:

- Main line sections are distinguished by the maximum speed that can be achieved under local conditions;
- Additional sections, including those modernised to operate with a speed of 200 km/h (or more);
- Conventional lines with improved technical parameters which constitute links between sections of high-speed lines.

With this approach, the average service speeds should be within the 160-250 km/h range. Higher service speeds require a larger share of high-speed lines of 300-350 km/h or lower proportion of feeder lines. High average service speed is expected to:

- Enable travel times required to achieve the economic efficiency of the HSR network by creating a market that meets social requirements in terms of population mobility;
- Ensure the competitiveness of rail in relation to other means of transport, in particular air transport over a distance of 120-1,200 km or more in specified cases.[13]

3. Rules for the identification of high-speed rail projects

3.1 General rules

The identification of existing and planned lines in TER States is intended to define the possibility of creating international corridors for high-speed trains in accordance with the definitions and parameters set out above and in line with data contained in official feasibility studies and relevant legislation.

3.2 Source documents

The following documents were used to identify HSR projects:

1. Specifications of existing high-speed lines with a maximum speed of more than 200 km/h found in national registers.
2. In the EU, those high-speed lines that are included to the core and comprehensive network referred to in in the Regulation 1315/2013.
3. For the EU neighbouring States which have signed pre-accession agreements, the following legislation was considered as source materials:

   Commission Delegated Regulations (EU) 473/2014 and 2016/758 amending Regulation (EU) No 1315/2013 of the European Parliament and of the Council by adding annex III to this Regulation covering affected States. further modified by Commission Delegated Regulations (EU) 2019/254.
4. Projects identified by the Eastern Partnership (EaP).
5. The UIC studies, in particular:
   (a) High-Speed Rail Atlas. UIC, December 2018;[14]
   (b) Main International Corridors Passing through Middle East. Connecting Asia to Europe. UIC Middle East Regional Office. November 2018.[15]
6. Other information provided by the TER States.

3.3 Surveys

All TER States were requested to provide data in support of the preparation of this Masterplan. The data were provided in survey prepared by the consultant. A template survey is included in annex 1.

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13 *Resolution of UIC "Operating high-speed lines: in search of efficient solutions. Round-table on good practice share and international benchmark"*, Paris, 31 January 2019.

14 UIC, *High-Speed Rail Atlas*, Paris 2018.

15 UIC Middle East Regional Office. *Main International Corridors Passing through Middle East. Connecting Asia to Europe*. Paris 2018.

3.4 Sources of technical and economic data for high-speed railway systems

In order to gather the appropriate level of detail for the analysis, projects with the following type of documentation were reviewed:

- Feasibility studies and construction documentation for advanced projects;
- Preliminary feasibility studies;
- Documentation relating to the inclusion of lines in the TEN-T network in the EU or neighbouring States, in accordance with EU Regulations 1315/2013 amended by 473/2014, 758/2016, 2017/849, 2019/254 and Regulation 1316/2013.

For projects with completed feasibility studies, the study has taken into consideration the results of those cost and benefit assessments. For other projects, estimations have been provided.

The following UIC documents have been used as a basis for the development of TER HS network:

1. IRS 60671 Implementation of a High-Speed Railway – Emerging Phase.
2. Resolution of the UIC "Operating high-speed lines: in search of efficient solutions. Round-table on good practice share and international benchmark" which state the following factors as fundamental in considering how to procced with high-speed railways:
    (a) The full Life-Cycle cost;
    (b) Appropriate modelling should be used to evaluate projects;

(c) Rolling stock should meet international standards and be maintained to maximise operational efficiency;

(d) Performance management should be introduced to improve accessibility and customer focus and adapt to changing demand patterns;

(e) High-speed rail is a driving force for innovation, the use of innovative solutions should go beyond ever higher speed on the tracks and into customer services as well as the full journey;

(f) The development of low-cost services with strict rules and some restrictions for customers could be one of the ways to increase efficiency;

(g) Door-to-door transport is a must, as part of rail services, underestimation of that part of services may lead to insufficient financial and economic results, as customers prefer other services with "last mile" proposals;

(h) Planning HSR must be coordinated at international level in order to establish a comprehensive seamless network.

3.5 The need for a corridor approach

In identifying the appropriate high-speed network, it is important to ensure that the corridor approach is considered in order to coordinate different projects on a transnational basis and maximise the benefits to, and efficiency of, the network.

II. Socioeconomic, technical and operational aspects of HSR system design

1. Socioeconomic characteristics and economic growth analysis in the TER region

1.1 Geographical location

The TER network area spans Central and Eastern Europe, as well as a fragment of the western part of Asia, including the Caucasus and the Asia Minor peninsula. It is an area of more than 10 million km² of diverse natural, economic and social conditions. The topographic and historical development of the region have shaped the distribution of the population in the region and hence where the railways lie in this region.

1.2 Population

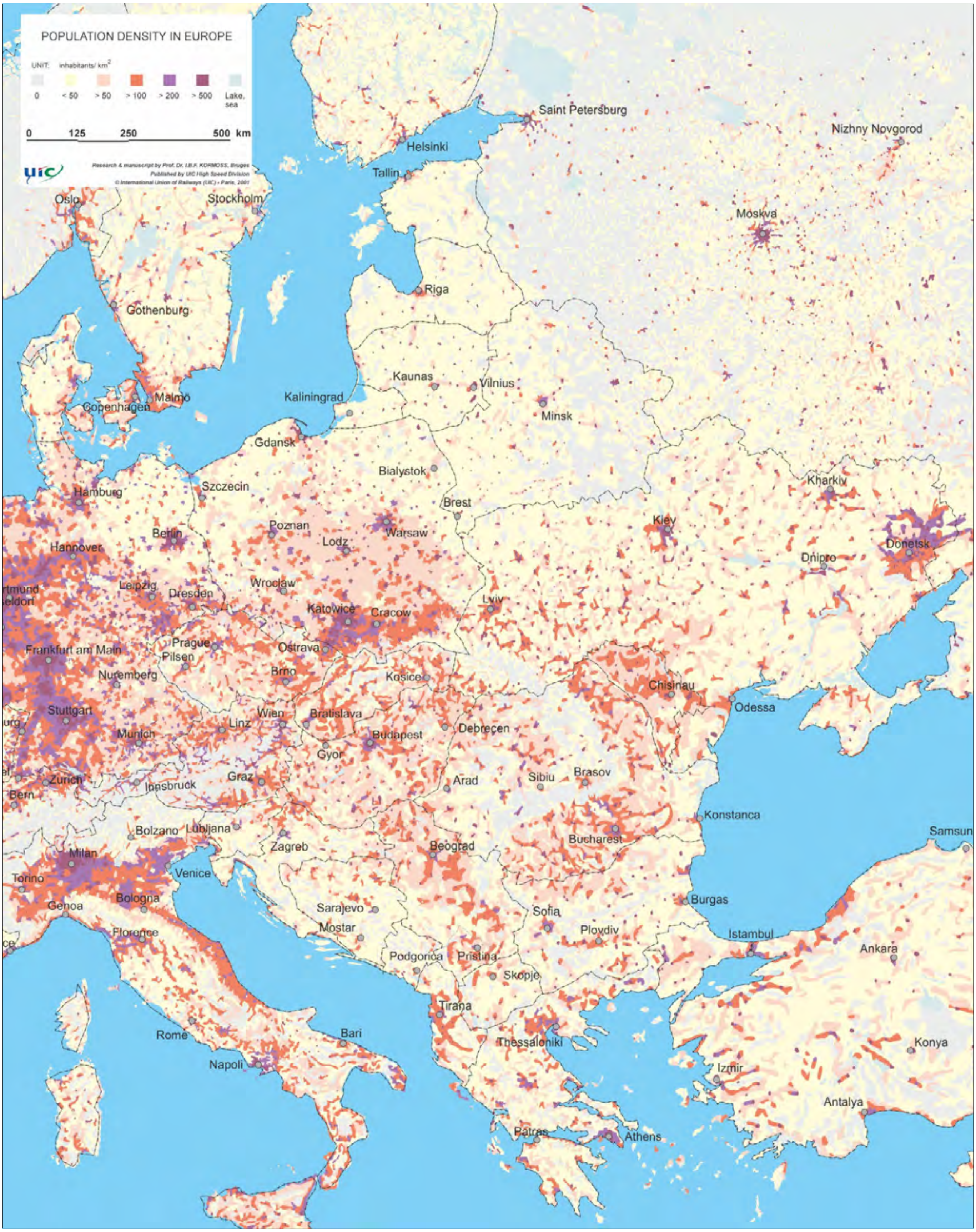
The TER area is occupied by approximatively 500 million inhabitants, which gives an average population density of 50 people per km². The distribution of population in the area remains very uneven, with large uninhabited areas and population areas of less than one person per km². In the Carpathians and in the Alpine valleys, the population density is on the contrary one of the highest in the TER region. Figure II-1 shows the density in more detail.

Apart from the Russian Federation (143 million inhabitants) and Turkey (83 million) the remaining States of the region are either small or medium sized. A large number of States with a small population make up this natural polycentric system. Such a distribution of population occurs both in Central Europe and the Balkans. The complexity of the settlement system in the area is mirrored in the transport system and in particular the railway network which is extensive and restricted only by natural geographical barriers.

The region as a whole is also characterised by a declining population with, however, some States showing a slight increase in population (e.g. in Austria, Czechia, Slovakia, Slovenia and Turkey – see table II-1). This trend may have a negative impact on the development of demand for transport services. Statistics on changes in the TER population over the last 10 years are included in table II-1.

The TER region is also characterised by high levels of urbanisation, at levels usually above 50 per cent, and in some States, above 80 per cent. The TER region has more than 23 cities with a population of more than one million, including 14 capital cities. The largest urban centres are the metropolitan areas of Moscow, Istanbul, St. Petersburg and Ankara. The distribution of the largest cities does not directly relate to the distribution of inhabitants in individual areas – the largest centres are surrounded by low density population areas.

Figure II–1 Population density in the TER region



Source: UIC.

The TER region is also highly industrialised, concentrated in cities and industrial basins, many of which were created in the nineteenth century and the first half of the twentieth century around a resource base or a political (capital) function. Historically, these cities have also been the target of population migration and a source of concentration, which explains the convergence of industrialization and high population density. The largest industrial districts in TER States are the Central Industrial District in Russian Federation and the Upper Silesian Industrial District in Czechia and Poland.

Key considerations for the analysis

Population size and, above all, population density is crucial for the planning of HSR systems. In terms of size the TER region is smaller than the most developed regions in Europe. The first high-speed lines built in Western Europe linked the most populated areas and the major administrative centres. An analysis of figure II-1 shows, however, that population density in the TER region is relatively high, especially in the central part of the Austria, Czechia, Hungary, Poland and Slovakia. There are also relatively densely populated settlements in the Balkan region. The specific nature of the settlements in the Russian Federation facilitate the development of HSRs where the main administrative centres in the region are relatively evenly distributed over a distance of several hundred kilometres.

1.3 Economy

Gross Domestic Product (GDP) in the TER region is lower than for Western Europe, as set out in table II-2, with Central European States having the highest GDP. Annual GDP growth for the TER States over the last few years is relatively high. This is due to the global economic prosperity and the inflow of EU funds. As many as nine States have growth rates of 4-6 per cent (table II-3).

The value of GDP is of particular importance in the study of transport demand. It can be observed that the higher the GDP, the higher the demand for transport. In addition, the increase in demand for passenger transport is typically proportional to the growth rate of GDP.[16]

Table II–1 Population in TER and TER neighbouring States between 2008 and 2017

Country / year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Armenia	3 087 119	306 6045	3 044 868	3 027 938	3 024 127	3 021 979	3 013 839	3 004 588	2 992 364	2 979 442
Austria	8 321 496	8 343 323	8 363 403	8 391 642	8 429 990	8 479 823	8 546 356	8 642 698	8 736 668	8 797 566
Belarus	9 527 985	9 506 765	9 490 583	9 473 172	9 464 495	9 465 997	9 474 511	9 489 616	9 501 534	9 498 264
Bosnia and Herzegovina	3 940 398	3 942 701	3 843 126	3 839 737	3 836 377	3 531 159	3 482 104*	3 429 361*	3 386 267*	3 351 527*
Bulgaria	7 492 560	7 444 442	7 395 598	7 348 327	7 305 888	7 265 114	7 223 937	7 177 991	7 127 821	7 075 946
Croatia	4 310 881	4 306 321	4 296 352	4 282 920	4 269 062	4 254 474	4 236 062	4 207 992	4 172 441	4 129 853
Czechia	10 384 602	10 443 935	10 474 409	10 496 088	10 510 785	10 514 272	10 525 347	10 546 059	10 566 331	10 594 437
Estonia	1 337 090	1 334 515	1 331 475	1 327 438	1 322 695	1 317 996	1 315 344	1 315 407	1 315 789	1 317 384
Georgia	3 848 449	3 814 419	3 786 695	3 756 441	3 728 874	3 717 668	3 719 414	3 725 276	3 727 505	3 728 004
Greece	11 077 841	11 107 017	11 121 340	11 104 899	11 045 010	10 965 211	10 892 412	10 820 883	10 775 970	10 754 679
Hungary	10 038 188	10 022 649	10 000 023	9 958 823	9 920 361	9 893 081	9 866 468	9 843 028	9 814 023	9 787 966
Latvia	2 177 322	2 141 669	2 097 554	2 059 709	2 034 319	2 012 646	1 993 782	1 977 526	1 959 536	1 942 247

16 *EU Transport in figures*. Statistical Pocketbook, Brussels 2018.

Table II–1 Population in TER and TER neighbouring States between 2008 and 2017 (continued)

Country / year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Lithuania	3 198 230	3 162 916	3 097 282	3 028 114	2 987 773	2 957 688	2 932 367	2 904 910	2 868 231	2 828 402
North Macedonia	2 046 898	2 050 670	2 055 003	2 058 539	2 061 044	2 064 031	2 067 471	2 070 226	2 072 490	2 074 502
Poland	38 125 758	38 079 372	38 042 793	38 063 255	38 063 163	38 040 195	38 011 735	37 986 411	37 970 086	37 974 825
Romania	20 537 875	20 367 486	20 246 871	20 147 527	20 058 035	19 983 692	19 908 979	19 815 616	19 702 467	19 587 490
Russian Federation	142 742 366	142 785 349	142 849 468	142 960 908	143 201 721	143 506 995	143 819 666*	144 096 870*	144 342 396*	144 496 740*
Serbia	7 350 222	7 320 807	7 291 436	7 236 519	7 201 497	7 166 552	7 131 787	7 095 383	7 058 322	7 020 858
Slovakia	5 379 232	5 386 405	5 391 428	5 398 384	5 407 579	5 413 392	5 418 649	5 423 800	5 430 797	5 439 231
Slovenia	2 021 315	2 039 669	2 048 582	2 052 842	2 057 158	2 059 953	2 061 979	2 063 531	2 065 041	2 066 387
Turkey	71 051 678	72 039 206	73 142 150	74 223 628	75 175 826	76 147 624	77 181 884	78 218 478	79 277 962	80 312 698

Source: UNECE Statistical Database[17] [access 12 October 2019]; World Bank Database https://data.worldbank.org[18] [access 5 February 2020].
* World Bank Database.

Table II–2 GDP per capita [US$, in prices and PPPs of 2010]

Country/year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Armenia	8 103	7 004	7 209	7 587	8 140	8 412	8 741	9 052	9 105	9 833	10 384
Austria	41 139	39 496	40 127	41 165	41 259	41 022	40 971	40 976	41 301	42 058	42 838
Belarus	24 642	24 734	26 688	28 182	28 664	28 917	29 413	28 330	27 649	28 388	29 301
Bosnia and Herzegovina	9 332	9 058	9 142	9 236	9 170	9 397	9 520	10 595	10 988	11 368	15 914*
Bulgaria	16 832	16 310	16 637	17 385	17 491	17 676	18 104	18 852	19 732	20 634	21 353
Croatia	20 420	18 951	18 715	18 710	18 339	18 311	18 375	18 941	19 778	20 566	27 579*
Czechia	26 796	25 359	25 872	26 383	26 141	26 011	26 682	28 050	28 676	29 856	30 632
Estonia	25 106	21 525	22 148	23 860	24 686	25 113	25 950	26 479	27 122	28 688	29 974
Georgia	8 285	8 032	8 597	9 292	9 955	10 323	10 795	11 089	11 398	11 947	12 516
Greece	31 816	30 368	28 667	26 087	24 314	23 697	24 032	24 085	24 139	24 551	25 089
Hungary	22 091	20 643	20 827	21 266	21 062	21 534	22 498	23 419	24 005	25 109	26 434
Latvia	22 961	20 021	19 533	21 148	22 295	23 050	23 710	24 693	25 362	26 569	28 020
Lithuania	23 235	20 014	20 741	22 493	23 671	24 762	25 852	26 627	27 657	29 301	30 610
North Macedonia	10 752	10 693	11 029	11 268	11 203	11 514	11 912	12 355	12 693	12 716	13 483*
Poland	19 059	19 410	20 092	21 095	21 430	21 746	22 478	23 359	24 092	25 285	26 593
Romania	20 216	19 260	18 619	19 086	19 568	20 328	21 097	22 021	23 211	25 007	26 077
Russian Federation	28 639	26 408	27 501	28 565	29 568	30 022	25 285*	24 516*	24 416*	24 790*	27 143*
Serbia	16 697	16 306	16 491	16 955	16 921	17 496	17 301	17 699	18 386	18 863	19 746
Slovakia	22 316	21 052	22 206	22 977	23 378	23 505	24 127	25 273	25 769	26 516	27 547

17 *UNECE Statistical Database*, http://www.unece.org/stats/econ.html.

18 *World Bank Database*, n.d., https://data.worldbank.org/country/.

Table II–2 GDP per capita [US$, in prices and PPPs of 2010] (continued)

Country/year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Slovenia	31 472	28 805	29 090	29 283	28 456	28 125	28 872	29 488	30 389	31 840	33 061
Turkey	18 922	17 785	19 003	20 807	21 528	23 058	23 924	25 044	25 496	27 047	27 438

Source: UNECE Statistical Database [access 12 October 2019]; World Bank Database https://data.worldbank.org [access 5 February 2020].
* World Bank Database.

Table II–3 Growth rate in prices and PPPs of 2010

Country/year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Armenia	7.7	-13.6	2.9	5.2	7.3	3.3	3.9	3.6	0.6	8.0	5.6
Austria	1.1	-4.0	1.6	2.6	0.2	-0.6	-0.1	0.0	0.8	1.8	1.9
Belarus	10.6	0.4	7.9	5.6	1.7	0.9	1.7	-3.7	-2.4	2.7	3.2
Bosnia and Herzegovina	5.4	-2.9	0.9	1.0	-0.7	2.5	1.3	11.3	3.7	3.5	3.6*
Bulgaria	6.5	-3.1	2.0	4.5	0.6	1.1	2.4	4.1	4.7	4.6	3.5
Croatia	2.1	-7.2	-1.2	0.0	-2.0	-0.2	0.3	3.1	4.4	4.0	2.6*
Czechia	1.6	-5.4	2.0	2.0	-0.9	-0.5	2.6	5.1	2.2	4.1	2.6
Estonia	-4.8	-14.3	2.9	7.7	3.5	1.7	3.3	2.0	2.4	5.8	4.5
Georgia	3.0	-3.0	7.0	8.1	7.1	3.7	4.6	2.7	2.8	4.8	4.8
Greece	-0.6	-4.6	-5.6	-9.0	-6.8	-2.5	1.4	0.2	0.2	1.7	2.2
Hungary	1.2	-6.6	0.9	2.1	-1.0	2.2	4.5	4.1	2.5	4.6	5.3
Latvia	-2.3	-12.8	-2.4	8.3	5.4	3.4	2.9	4.1	2.7	4.8	5.5
Lithuania	3.7	-13.9	3.6	8.4	5.2	4.6	4.4	3.0	3.9	5.9	4.5
North Macedonia	5.3	-0.5	3.1	2.2	-0.6	2.8	3.5	3.7	2.7	0.2	2.7*
Poland	4.2	1.8	3.5	5.0	1.6	1.5	3.4	3.9	3.1	5.0	5.2
Romania	11.1	-4.7	-3.3	2.5	2.5	3.9	3.8	4.4	5.4	7.7	4.3
Russian Federation	5.4	-7.8	4.1	3.9	3.5	1.5	0.7*	-2.3*	0.33*	1.63*	2.26*
Serbia	6.1	-2.3	1.1	2.8	-0.2	3.4	-1.1	2.3	3.9	2.6	4.7
Slovakia	5.4	-5.7	5.5	3.5	1.7	0.5	2.6	4.7	2.0	2.9	3.9
Slovenia	3.4	-8.5	1.0	0.7	-2.8	-1.2	2.7	2.1	3.1	4.8	3.8
Turkey	-0.4	-6.0	6.9	9.5	3.5	7.1	3.8	4.7	1.8	6.1	1.4

Source: UNECE Statistical Database [access 12 October 2019] World Bank Database https://data.worldbank.org [access 5 February 2020].
* World Bank Database.

Table II-4 below sets out the rankings for TER States and neighbouring States according to the calculations of the following:

- **IMD** – International Institute for Management Development (World Competitiveness Ranking Yearbook 2018),[19] ranking of 63 States

[19] International Institute for Management Development, *World Competitiveness Ranking Yearbook 2018*, https://worldcompetitiveness.imd.org.

- **WEF** – World Economic Forum (The Global Competitiveness Report 2018),[20] ranking of 140 States
- **HDI** – UN Human Development Index 2018,[21] ranking of 189 States
- **IEF** – Index of Economic Freedom 2019 by The Heritage Foundation,[22] ranking of 180 States
- **HR** – The Sustainable Development Solutions Network (SDSN) Happiness Report 2019,[23] ranking of 156 States.

According to the data gathered by IMD, Austria (19) is highest ranked TER States with the highest potential for development with Lithuania (29), Czechia (33), Slovenia (37) and Poland (38) in close proximity.

According to the WEF ranking, Austria is ranked highest (22) followed by Estonia (31), Czechia (32), Slovenia (35), Poland (37), Slovakia (42).

The UN Human Development Index measures the degree of socioeconomic development considering life expectancy, education and income. This index shows broadly similar results as set out in the table below.

Index of Economic Freedom by the Heritage Foundation (IEF) focuses on assessing the extent to which the basic principles of economic freedom are implemented and overall improvement of the conditions for the growth of democracy and peaceful cooperation between neighbours, assessing the potential for progress toward prosperity. Among the evaluated TER States, Estonia (15), Georgia (16), Lithuania (21) and Czechia (23) are rated highest.

The Sustainable Development Solutions Network (SDSN) HR Index (Happiness Report 2019) looking at "Wellbeing and Happiness: Defining a New Economic Paradigm" assesses States in terms of the quality of life of people determined by emerging science of happiness, showing that the quality of people's lives can be coherently, accurately and validly assessed by a range of subjective well-being indicators, collectively referred to as "happiness". The Ranking of Happiness 2016-2018 indicates that the highest level of happiness among the TER States is found among the inhabitants of Austria (10) and the Czechia (20).

Table II–4 TER and TER neighbouring States ranking

Country/ranking	IMD	WEF	HDI	IEF	HR
Armenia	na	70 (59.9)	83 (0.755)	47 (67.7)	116 (4.559)
Austria	18 (87.302)	22 (76.3)	20 (0.908)	31 (72.0)	10 (7.246)
Belarus	N/A	N/A	53 (0.808)	104 (57.9)	79 (5.323)
Bosnia and Herzegovina	N/A	91 (54.2)	77 (0.768)	83 (61.9)	78 (5.386)
Bulgaria	48 (65.679	51 (63.6)	51 (0.813)	37 (69.0)	97 (5.011)
Croatia	61 (55.344)	68 (60.1)	46 (0.831)	86 (61.4)	75 (5.432)
Czechia	29 (79.507)	29 (71.2)	27 (0.888)	23 (73.7)	20 (6.852)

20 World Economic Forum, *The Global Competitiveness Report 2017-2018*, 2018, vol. 5.

21 UN, *UN Human Development Index 2018*, 2018, http://hdr.undp.org/en.

22 The Heritage Foundation, *Index of Economic Freedom*, 2019, www.heritage.org.

23 The Sustainable Development Solutions Network, *Happiness Report 2019*, www.unsdsn.org.

Table II–4 TER and TER neighbouring States ranking (continued)

Country/ranking	IMD	WEF	HDI	IEF	HR
Estonia	31 (78.475)	32 (70.8)	30 (0.871)	15 (76.6)	55 (5.893)
Georgia	N/A	66 (60.9)	70 (0.780)	16 (75.9)	119 (4.519)
Greece	57 (57.375)	57 (62.1)	31 (0.870)	106 (57.7)	82 (5.287)
Hungary	47 (65.981)	48 (64.3)	45 (0.838)	64 (65.0)	62 (5.758)
Lithuania	32 (76.889)	40 (67.1)	35 (0.858)	21 (74.2)	42 (6.149)
North Macedonia	N/A	84 (56.6)	80 (0.757)	33 (71.1)	84 (5.274)
Poland	34 (75.434)	37 (68.2)	33 (0.865)	46 (67.8)	40 (6.182)
Romania	49 (64.924)	52 (63.5)	52 (0.811)	42 (68.6)	48 (6.070)
Slovakia	55 (60.037)	41 (66.8)	38 (0.855)	65 (65.0)	38 (6.198)
Slovenia	37 (73.346)	35 (69.6)	25 (0.896)	58 (65.5)	44 (6.118)
Russian Federation	45 (67.179)	43 (65.6)	49 (0.816)	98 (58.9)	68 (5.648)
Serbia	N/A	65 (60.9)	67 (0.787)	69 (63.9)	70 (5.603)
Turkey	46 (66.607)	61 (61.6)	64 (0.791)	68 (64.6)	79 (5.373)

Source: Own study based on International Institute for Management Development *World Competitiveness Ranking Yearbook 2018*, World Economic Forum. *The Global Competitiveness Report 2018*, UN *Human Development Index 2018*, The Heritage Foundation *Index of Economic Freedom 2019*, The Sustainable Development Solutions Network *Happiness Report 2019*.

Summary

These very different indices show that the TER region is very diverse in economic terms. This may affect the development of high-speed rail transport in the area as well as creating promising environment for further developments in each State of the TER region.

1.4 Passenger transport in TER States

The density of the rail network in the TER region varies significantly among States. The highest values are recorded in Central Europe – between 61 and 121 km/1,000 km². Values between 20 and 60 km per 1,000 km² are recorded in the Balkan States. Eastern Europe has the lowest network density (table II-5). The Russian Federation has the longest railway network (84.4 thousand km). In Central Europe, Poland has the longest network (18.5 thousand km).

Only 5 States in the TER region have high-speed railway sections (following the definitions set out in the previous chapter): Austria, Poland, Russian Federation, Greece and Turkey. These sections are short in length and, except for Austria and Turkey, the percentage of these lines in the overall length of the network is low and some of these lines are not yet completely built.

The volume of passenger transport measured in passenger-kilometres per inhabitant as well as freight transport measured in tonnes-kilometres per inhabitant also varies by country. Nevertheless, there is no close link between the volume of transport and the length and density of the rail network.

The highest number of kilometres of annual trips per capita – 1,439 km (2016) occurs in Austria. In most of the other TER States, this value is in the range of several hundred kilometres per capita a year. Its value depends on local transport policy. The lowest values appear in some Balkan States – below 100 passenger-kilometre per inhabitant.

The number of trips per person per year is even more diverse. The highest number of rail journeys per person is 33 in Austria, however, in 10 States, the average citizen travels less than one rail journey per year.

Table II–5 Railway infrastructure and passenger traffic performance in TER and TER neighbouring States

Country/Factor	Rail network density (2016)	Rail line length in km (2016)	Rail lines length V ≥ 200 km/h	Pkm / inhabitant (2016)	Passenger / inhabitant (2016)
Armenia	24	N/A	0	16.709197	0.117633
Austria	65	5 193*	204	1439.679292	33.055165
Belarus	26	5 447**	0	677.153815	8.608610
Bosnia and Herzegovina	20	601*	0	6.513442	0.115826
Bulgaria	36	3 904*	0	204.550591	3.007090
Croatia	46	2 604*	0	200.362330	4.971190
Czechia	121	9 464*	0	836.903557	16.956879
Estonia	26	1 161**	0	240.160086	5.263762
Georgia	23	N/A	0	146.210401	0.000804
Greece	17	1 809*	471	110.616492	1.445995
Hungary	84	7 438* + 37**	0	779.802534	14.936077
Latvia	29	1 826**	0	298.029738	8.791877
Lithuania	29	115* + 1 796**	0	97.621147	1.365301
North Macedonia	27	683*	0	40.048444	0.319905
Poland	61	18 595* + 537**	224	505.002807	7.689764
Romania	45	10 635* + 134**	0	253.166266	3.271468
Russian Federation	5	84 401** (2013)	807	965.228211	0.007523
Serbia	43	3 764*	0	53.412128	0.000887
Slovakia	74	3 481* + 99**	0	661.965454	0.012802
Slovenia	60	1 209*	0	329.291283	0.006783
Turkey	13	10 131*	588	54.554884	0.001123

*1,435 mm gauge; **1,520/1,524 mm gauge
Bosnia and Herzegovina: population 2013;
Russian Federation: density 2013; pkm of 2013; population 2013;
Serbia: pkm of 2017; passenger 2015.
Source: Own compilation based on UNECE Statistical Database [12 October 2019] and national coordinator questionnaires.

Summary

The rail share of passenger transport in the TER region is significantly lower compared to Western European States, except for Austria, where the volume and share of rail transport is among the highest in Europe. It is important to note though that long-distance HSR services play an important role in Western European States. Their transportation service, measured in passenger-kilometres, currently accounts for almost 30 per cent of passenger transport. In some States, such as France and Spain, high-speed rail travel accounts for more than 50 per cent of the total rail transport services. In TER States, the share of HSR is small and in most States, there is no such service at all.

High-speed freight transport in Europe is still in the testing phase (Italy). Also, the operation of conventional freight trains on high-speed lines is marginal (practically mainly in Germany on selected sections). Studies on the conditions for the implementation of freight on HSRs on a larger scale have been started by UIC. This is reviewed further in later parts of the study.

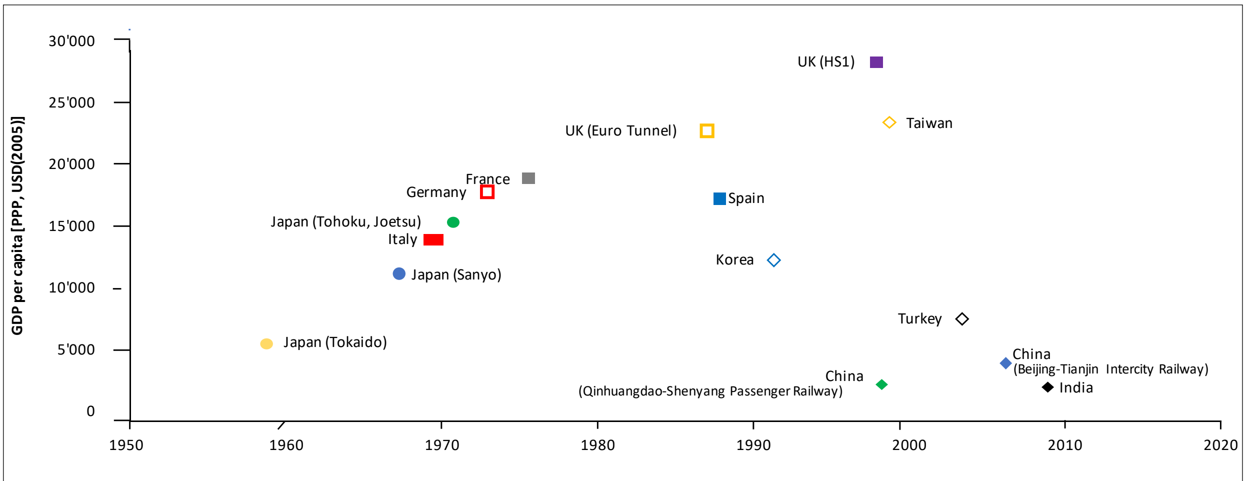
1.5 Affordability for TER States to build high-speed lines

The construction of high-speed lines or even the modernisation of existing lines to high-speed parameters requires considerable financial resources. Conseration should therefore be given as to whether this investment should begin at the current level of socioeconomic development or later in the development cycle. There is a widespread view that high-speed rail is a means of transport for highly developed States, however current studies are looking at things differently.[24] In addition to the developed States such as France, Germany, Italy, the United Kingdom of Great Britain and Northern Ireland, other States have also invested in high-speed lines when their level of GDP per capita was at a level comparable to the majority of TER States today.

Figure II-2 shows GDP per capita (PPP, 2005 US$) at the time the construction of high-speed railways started in a number of States. The construction start date is chosen as the time the final decision to start was taken and implementation began.

In many European States, construction of the high-speed rail began, when the GDP per capita reached between US$15,000 and 20,000. In Asia, construction began in South Korea and Taiwan, when their GDP per capita rose to levels similar to those of European States. On the other hand, in Japan and China construction started before the GDP per capita rose to such levels. In the case of Japan, when construction of the Tokaido Shinkansen began in 1959, the GDP per capita was about US$5,000. Therefore, there is no clear-cut answer to this question.

Figure II–2 GDP per capita in the year in which the construction of high-speed lines started



Source: Criteria for high-speed railway introduction and application in India Hiroyuki TAKESHITA, Institution for Transport Policy Studies, Japan.

[24] H. Takeshita, *Criteria for high speed railway introduction and application in India*, "Institution for Transport Policy Studies, Japan", n.d.

When deciding to start investing in high-speed railways, account should be taken not only of the immediate financial impact but also of the country's long-term economic growth policy. An analysis of historic data on high-speed rail projects completed across the world shows that many socioeconomic factors underline the decision-making processes of States. The most frequently considered factors are economic stimulation of regions resulting from improved accessibility and interregional economic connectivity; the need to adjust modal split, the development of tourism, supporting industry and services related to transport construction; and the establishment of research and development facilities.

The construction of HSR systems can lead to direct, indirect, and induced effects:

1. Direct effects (during construction and following the launch of transport services):
   - Creation of jobs;
   - Shorter journey times;
   - Improvements in safety;
   - Improved reliability and comfort.

2. Indirect effects:
   - Changes in mobility;
   - Improved capacity and safety of other means of transport.

3. Induced (wider) effects:
   - Relocation of enterprises;
   - Accelerating the transformation of cities;
   - Increased property values in the vicinity of the HSR;
   - Development of ancillary infrastructure for the HSR;
   - Network benefits for other modes of transport;
   - Reduced environmental impact of transport;
   - Impact on tourism;
   - Influence on economic growth of the country and regions within it.

The factors identified above outline the potential socioeconomic effects of HSR investments, which can apply to all States with railway networks. The construction of HSRs is widely viewed not only as a way of improving the overall performance of rail services, but also of stimulating a country's economic growth.

2. Demand and geographical drivers for the design of HSR systems

2.1 Background

The main building block in the planning of HSR projects is to assess the population catchment area of the network and to plan the route to maximise population coverage. This issue is important from an economic point of view as, in order to ensure the viability of investments in the HSR system, a minimum number of passengers is required to generate sufficient revenues from transport services. In practice, there is no one size fits all for HSR systems also because the size of the cities that are connected to HS lines can vary significantly. However, the size and mobility of the overall population covered by the system is fundamental as well as the connections between individual regions (current and future).

This section analyses the size and location of cities within TER States, which are the key drivers of traffic, while considering the best practice solutions already adopted in Europe and Asia.

2.2 The size of connected cities and agglomeration

In terms of the size of agglomerations, the following factors need to be considered:

- High-speed lines connect major cities, in particular national and regional capital cities;
- Interchange nodes provide the feeder traffic for the high-speed lines;
- There is no rule as to the minimum size of a city that should have a stop on a high-speed line; what is important, is its socioeconomic function and the role of a node;
- Smaller cities can be added to the network later on if they provide an overall increase in the economic performance of the line;
- Level and degree of businesses developments including potentials for their prospects and their structure – new technologies concentrations;
- Locations of business-parks and their accessibility.

The decision on which cities should be served by the HSR systems should be preceded by a detailed feasibility study learning from previous experiences which should consider the size of the cities, with UIC[25] identifying the best economic results when the cities have a population of more than 5 million inhabitants.

The European Court of Auditors, in its report "A European high-speed rail network: not a reality but an ineffective patchwork, 2018"[26] indicates that a high-speed line should ideally have nine million passengers, or at least six million in the opening year, in order to be successful whilst acknowledging that systems can also work with fewer passengers in some special cases.[27, 28]

The possibilities for launching freight on high-speed lines should also be assessed based on individual feasibility studies, generally considering the above-mentioned factors identified for passenger transport.

25 *Resolution of UIC "Operating high-speed lines: in search of efficient solutions. Round-table on good practice share and international benchmark"* ..., op. cit.

26 The European Court of Auditors, *A European high-speed rail network: not a reality but an ineffective patchwork*, 2018.

27 G. De Rus and C. Nash, I*n what circumstances is investment in HSR worthwhile?*, "Munich Personal RePEc Archive (MPRA)", December 2007.

28 European Commission, *"Guide to Cost Benefit Analysis of Investment Projects"*, 2008.

2.3 Distance between cities

High-speed line stations can be located in city centres, on the outskirts or in the vicinity of important nodes (air, road). The distances between stations vary from a dozen to several hundred kilometres depending on the local conditions and the assumptions made about the system. The most important include:

- Population density (discussed above) and the closeness of urban centres;
- The system of interchange nodes;
- The planned use of the line, together with types of trains that use the network;
- The planned and available capacity of the system.

The way HSR stations are served depends on the traffic model adopted. The most common solution is based on a different category of trains, starting with trains stopping at the largest agglomerations and finishing with trains serving smaller stations as set out in chapter II, section 4.3.2 below.

Other options may also be available and should also depend on the technology used in trains as high maximum speeds require longer acceleration and deceleration distance thus cancelling out any benefit from any higher speed if stops are too close. It is worth noticing, however, that the technology of high-speed trains has been developing over the years and the distance required for acceleration to the maximum speed has been cut nearly a half when comparing current trainsets to the older models.

The acceleration of high-speed trains up to 300 km/h due to their traction characteristics was relatively low in older generations of the rolling stock and required a distance of more than 10 km (even up to 20 km), a comparable distance is required for a train to stop. The new generation of trains will require shorter distances.

Generally, there are no universal rules for the location of stops on high-speed lines. The location of stops may, however, be limited depending on the capacity of the line and the volume of demand for transport and therefore also on commercial decisions. States in the TER region that choose to implement a HSR systems will need to weigh up the benefits of connecting more towns with the cost of doing so.

2.4 The layout types of settlements nationally

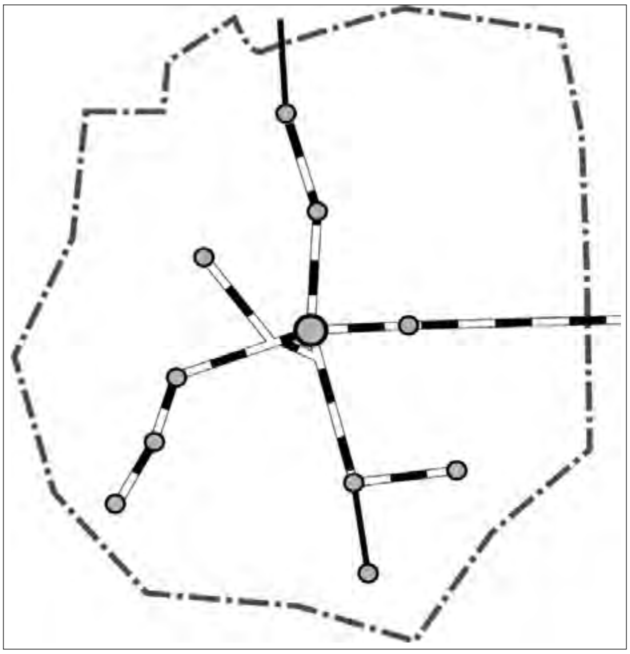
Having considered the distance between the main towns and cities to be put on the network it is also important to consider the settlement structure in the region as a key factor determining how to build a network. To maximise the benefits identified previously it is important to:

- Make sure the largest possible number of cities and agglomerations are included in the network;
- Where a continuous network is not possible because of the layout of the country then different branches should be considered (models shown as letters Y and T);
- The focus of the network should be along primary settlement corridors.

When considering the above it is important to understand the three main settlement types: monocentric, polycentric and linear described in more detail below.

1. Monocentric settlement model

Figure II–3 Monocentric model



Source: Own work.

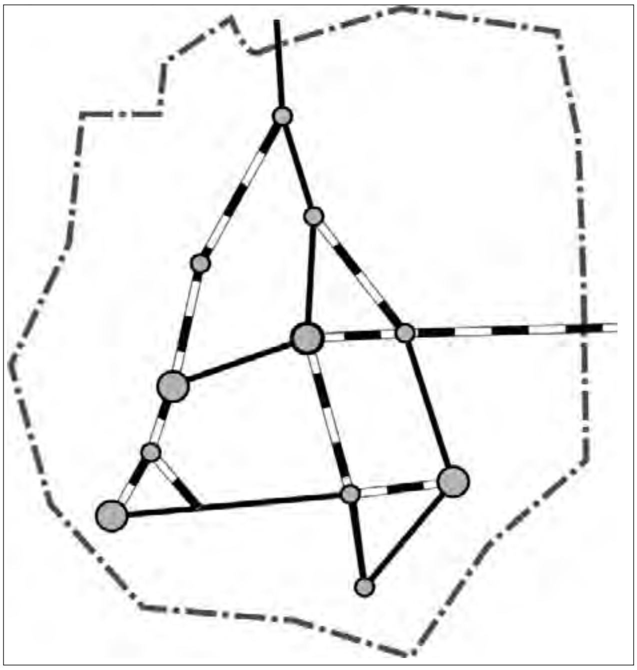
The monocentric model (figure II-3) is typical of States whose capital is the dominant city, distinctly outnumbering other cities in terms of population and economic potential. In this model, high-speed lines extend out from the capital city of the country with even several hundred daily services on the main routes with infrequent stops at intermediate stations. This model guarantees high frequency and quality of connections between major cities and the country's capital. Due to the high-speed, a large number of connections and the low development of the routes, travel times from the capital are very competitive when compared to air transport.

At the same time, the number of connections other than to the capital is small and/or limited to mainly crossing through the metropolitan area of the capital (or through the use of an orbital line). Where they exist the journey time is relatively long, which results from a substantial lengthening of the route in comparison to a straight section. This type of structure is exemplified in France and Spain as explained in more detail in Phase I of the Master Plan.

Among the States in Central Europe, the monocentric structure can be observed in Hungary, where Budapest plays a visibly dominant role. The Russian Federation networks have a similar character, with a very strong dominance of Moscow, while in Belarus, the prominent role is played by Minsk. The Serbian network should also be considered monocentric, although it will be a part of linear structure when considered with the wider international network of the region.

2. Polycentric settlement model

Figure II–4 Polycentric model



Source: Own work.

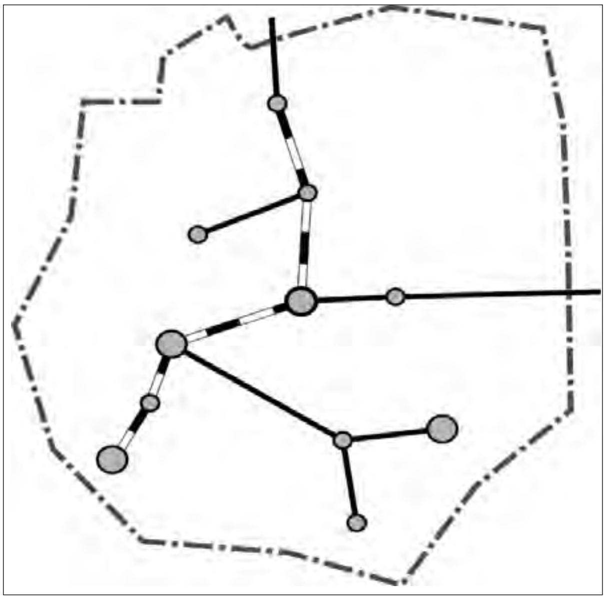
The polycentric model (figure II-4) is common in States where the dominance of one centre is not apparent and individual cities and agglomerations have their own specialisation or are similar in terms of importance. In this case, high-speed lines create a mosaic of new and modernised sections supported by the conventional network.

The polycentric model provides a significant network of connections between the largest centres. Route layout is limited, and the average speed may be lower than that in the monocentric model if there are different parameters of the line, including conventional lines. For some connections a change of train or lower-category train is necessary. A typical polycentric model is the HS network in Germany as explained in more detail in Phase I of the Master Plan.

Among TER States, the classical polycentric model can be seen in Poland and Turkey where a number of large cities exist, although the transport system had developed from an initial monocentric model. The Czech network can be considered as polycentric although concentrated around two main centres – Prague in the West and Brno in the East.

3. Linear settlement model

Figure II–5 Linear model



Source: Own work.

The linear model (figure II-5) is typical for settlement networks where the layout is determined by natural topography. There is one main high-speed line in this pattern that connects a number of agglomerations of similar size. The core main line is usually supported by conventional feeder lines. High-speed services implemented on this type of model are usually highly competitive with low journey times, however towns off the network can suffer significantly compared to those on the network. Linear models can be found in Italy or Japan as explained in more detail in Phase I of the Master Plan.

The linear structure is also typical in many TER States as a result of their topographical structure. This is the case in Slovakia, where the major cities and routes are situated in the valleys of Hornád and Váh that in turn flow along the Carpathian arch. The linear structure is also exemplified in the rail networks of Croatia, Bosnia and Herzegovina and, partially, Serbia, as well as Bulgaria. The main line connecting these States runs parallel to the ranges of the Dinar Alps. The same is also true with the network in Azerbaijan, Georgia and, also, for a large part of the Greek and Romanian network.

2.5 Settlement structure in TER and TER neighbouring States

2.5.1 General

The settlement structure of TER States is very heterogeneous. Its development has been driven by the size and density of population, origin and shape of settlements, and finally by economic progress. In terms of average population density, TER States can be divided into three groups. The States with the highest population density located in the central and western part of Europe make up the first group. In the central part there are eastern Austria, Czechia, Hungary, Poland and Slovakia. In all the States population density amounts to more than 100 people per km². These are mostly lowland States, easily accessible and with no uninhabited areas.

The second group includes mountainous States in eastern and southern Europe, where population density is less than 100, but more than 70 people per km². This group includes western Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, North Macedonia, Romania, Slovenia and as well as Armenia, Georgia and Turkey with slightly higher density levels. These are States where the development of transport infrastructure is more demanding mainly due to the natural topography.

The third group includes the States of Northern and Eastern Europe. They have the lowest population density of about 20-60 people per km². These are Belarus, Estonia, Latvia, Lithuania and the biggest country of the TER network – Russian Federation. In these States the distribution of population is fairly uneven with a mix of differently densely populated centres. This is the case in the Russian Federation, where population density falls below one person per km² in the north of the country while in the European part of Russian Federation it is around 26 people per km². Although there is low population density, the agglomeration of Moscow is the most populous agglomeration in the Russian Federation and Europe, has the highest number of inhabitants of all TER States.

2.5.2 Cities

The TER region is composed of 28 cities and urban areas with a population exceeding one million inhabitants; Poland, Russian Federation and Turkey alone have more than one. In cases where there is just one city of this size it is always the capital of the country. There are 35 cities and urban agglomerations within the range of 0.5 up to one million inhabitants, and there are 276 towns with 100-500 thousand inhabitants. Detailed information about the largest cities is set out in table II-6 below.

Table II–6 City/agglomeration statistics in TER and TER neighbouring States

Name and system type	Cities with population > 1 million	Cities with 1 million > population > 500,000	Cities/agglomerations with 500,000 > population > 100,000	Comments
Armenia (AM)	1: Yerevan	0	2:* Gyumri, Vanadzor	60% urbanisation and 37% in Yerevan. Monocentric system
Austria (AT)	1: Vienna	0	4: Graz, Innsbruck, Linz, Salzburg	65% urbanisation, 20% in Vienna. Linear system within national boundaries
Bosnia and Herzegovina (BiH)	0	0	3: Banja Luka, Mostar, Sarajevo	40% urbanisation, 10% in Sarajevo. Linear system

Table II–6 City/agglomeration statistics in TER and TER neighbouring States (continued)

Name and system type	Cities with population > 1 million	Cities with 1 million > population > 500,000	Cities/agglomerations with 500,000 > population > 100,000	Comments
Bulgaria (BG)	1: Sofia	0	5: Burgas, Plovdiv, Ruse, Stara, Varna, Zagora	75% urbanisation, 17% in Sofia. Linear system divided into two parallel sections
Croatia (HR)	0	1: Zagreb	3: Osijek, Rijeka, Split	60% urbanisation, 17% in Zagreb. Linear system
Czechia (CZ)	1: Prague	0	5: Brno, Liberec, Olomouc, Ostrava, Pilsen	73% urbanisation, 12% in Prague. Polycentric model with some Linear elements
Estonia (EE)	0	0	1: Tallinn	68% urbanisation, 33% in Tallinn, Linear system connecting to neighbouring States
Georgia (GE)	1: Tbilisi	0	3: Batumi, Kutaisi, Rustavi	> 50% urbanisation and about 33% in Tbilisi. Linear system
Greece (EL)	1: Athens (greater city)	1: Athens	4: Iraklion, Larisa, Patra, Thessaloniki	80% urbanisation, 30% in Athens. Linear system
Hungary (HU)	1: Budapest	0	7: Debrecen, Győr, Kecskemét, Miskolc, Nyíregyháza, Pécs, Szeged	73% urbanisation, 18% in Budapest. Monocentric system
Latvia (LV)	0	1: Riga	0	68% urbanisation, 33% in Riga. Strong dominance of capital. Monocentric system
Lithuania (LT)	0	1: Vilnius	3: Kaunas, Klaipeda, Siauliai	66% urbanisation, 18% in Vilnius. System unclear
North Macedonia (MK)	0	1: Greater Skopje,	0	57% urbanisation, 25% in Skopje. System unclear
Poland (PL) (based on data for agglomerations)	4: Conurbation of Upper Cracow, Lodz, Silesia, Warsaw	4: Tri-city: Gdansk, Gdynia, Poznan, Sopot, Szczecin, Wroclaw	21: Bialystok, Bydgoszcz Kalisz-Ostrów Wlkp, Czestochowa, Elblag, Gorzow, Jelenia Gora, Kielce, Koszalin, Lublin, Olsztyn, Plock, Radom Opole, Rzeszow, Słupsk, Tarnow, Torun, Walbrzych, Wloclawek, Zielona Gora	60% urbanisation, 5% in Warsaw. A number of large cities leading to a polycentric structure

Table II–6 City/agglomeration statistics in TER and TER neighbouring States (continued)

Name and system type	Cities with population > 1 million	Cities with 1 million > population > 500,000	Cities/agglomerations with 500,000 > population > 100,000	Comments
Romania (RO),	1: Bucharest	0	23: Arad, Bacau, Baia Mare, Botosani, Buzau, Braila, Brasov, Cluj-Napoca, Constanta, Craiova, Drobeta-Turnu Severin, Galati, Lasi, Oradea, Piatra Neamt, Sibiu, Târgu Mures, Timisoara, Pitesti, Ploiesti, Râmnicu Vâlcea, Satu Mare, Suceava	55% urbanisation, 10% in Bucharest. Linear system
Russian Federation – *2006	7: Kazan Rostov on Don, Moscow, Nizhny Novgorod, Samara, St. Petersburg, Ufa	15: Izewsk, Jaroslav, Krasnodar, Lipetsk, Naberezhnye Chelny, Orenburg, Penza, Perm, Riazan, Saratov, Togliatti, Tula, Uljanowsk, Volgograd, Worone	96: Aczynsk, Arkhangelsk, Armavir, Arzamas, Astrakhan, Balakovo, Balasykha, Batajsk, Belgorod, Bieriezniki, Briansk, Chasaviurt Sierpuchov, Cheboksary, Cherepovec, Cherkiesk, Chimki, Derbent, Dimitrowgrad, Dzerzhynsk, Elektrostal Almetjevsk, Elista, Engels, Glazow Grozny, Ivanovo, Joskar-Ola, Kaliningrad, Kaluga, Kamyshyn, Kirov, Kislovodsk, Kolomna, Korolov, Kostroma, Kovrov, Kurgan, Kursk, Lubiercy, Luki, Magnitogorsk, Majkop, Makhachkala, Murom, Mytiszczi, Nalchyk, Nazran, Nieftiekamsk, Nievinnomyssk, Nizniekhamsk, Noginsk, Novocherkavsk, Novomoskovsk Novocheboksarsk, Novokujbyszevsk, Novoshakhtinsk, Novorosyjsk, Nowvotroick, Obninsk, Odincovo, Oktiabrskij, Oriechovo-Zujevo, Orsk, Orzel, Oskol, Petrozavodsk, Piatigorsk, Podolsk, Pskov, Rybinsk, Sakhty, Salavat, Saransk, Scholkovo, Siergijev Posad, Sievierodvinsk, Smolensk, Sochi, Stary Veliky Novgorod, Stavropol, Sterlitamak, Syktyvkar, Syzran, Taganrog, Tambow, Tver, Uchta, Vielkie Zukovskij, Vladykaukaz, Volgodonsk, Vologda, Wlodzimierz, Wolzski, Yeletz, Zeleznodoroznyj	74% urbanisation, 9% in Moscow. Monocentric system
Serbia (RS)	1: Belgrade	0	10: Čačak, Kragujevac, Kraljevo, Nis, Novi Pazar, Novi Sad, Pančevo, Smederevo, Subotica, Zrenjanin	> 52% urbanisation, 23% population in Belgrade. Linear system
Slovakia (SK)	0	0	2: Bratislava, Kosice	52% urbanisation, 8% in Bratislava. Linear system

Table II–6 City/agglomeration statistics in TER and TER neighbouring States (continued)

Name and system type	Cities with population > 1 million	Cities with 1 million > population > 500,000	Cities/agglomerations with 500,000 > population > 100,000	Comments
Slovenia (SI)	0	0	2: Ljubljana, Maribor	>3 9% urbanisation, 14% in Ljubljana. Linear system
Turkey (TR)	23: Istanbul Ankara, Izmir, Bursa, Antalya, Adana, Konya, Şanlıurfa, Gaziantep, Kocaeli, Mersin, Diyarbakır, Hatay, Manisa, Kayseri, Samsun, Balıkesir, Kahramanmaraş, Van, Aydın, Tekirdağ, Denizli, Sakarya	12: Muğla, Eskişehir, Mardin, Trabzon, Malatya, Erzurum, Ordu, Afyonkarahisar Sivas, Adıyaman, Tokat, Batman, Zonguldak, Elazığ, Kütahya, Çanakkale, Osmaniye, Ağrı, Çorum, Şırnak	65: Giresun, Isparta, Yozgat, Aksaray, Edirne, Muş, Düzce, Kastamonu, Uşak, Niğde, Kırklareli, Bitlis, Rize, Amasya, Siirt, Bolu, Nevşehir, Kars, Kırıkkale, Hakkari, Bingöl, Yalova, Burdur, Karaman, Karabük, Kırşehir, Erzincan, Bilecik, Sinop, Iğdır, Bartın, Çankırı, Artvin, Gümüşhane, Kilis, Ardahan, Bayburt, Tunceli	> 77% urbanisation rate, 6% in Ankara, 18% in Istanbul. Polycentric system

Source: TER country questionnaires compilation.

The existing urban structure of the TER region as a whole shows that there is, in many States, an optimal structure to facilitate the development of a high-speed network. Although the average population density is not the highest in Europe, it is still on the level of some States with a well-developed HSR (e.g. Spain – 78 people per km^2). Frequent concentrations of the population spread out over, in some cases, long distances are also conducive to the development of HSRs. This is complemented by the fact that population concentration in cities is high in most States (more than 80 per cent in some States). This may mean that international connections between neighbouring capital cities can play a leading role in the development of the TER HS network.

2.6 Conclusion and recommendations

The settlement structure of the TER region is very heterogeneous, with varying population density and settlement structure. Nonetheless, some common features can be defined for the entire TER region, which is useful from the point of view of planning the HSR network. The most important of these is the high degree of urbanisation in the area, reaching 80 per cent in some States. In addition, there is a network of cities which have been historically linked even if they are now separated by borders. The existing rail network is relatively dense and well-integrated into the settlement structure. Where gaps exist, they are most often of a qualitative nature – some sections of the network remain underutilized or even impassable, many of which do not meet modern technological and construction specifications. Nonetheless, the high density of the railway network enables, in most situations, the construction of HSR networks as an evolution of the current system, in which it is possible to partly use the conventional network for the implementation of HS connections during the transitional phases. Nevertheless, geographical conditions and associated obstacles, such as mountain ranges or surface waters, remain very complex.

In Central Europe, a monocentric structure dominates at the level of individual States (with the exception of Poland). However, considered as an integrated region, the settlement structure is a typical polycentric structure. It is therefore possible to create an efficient rail network based on high-speed lines that integrate most cities in the entire region directly without the need to concentrate international traffic in the capitals of those States. A multidirectional rail link approach can be highly efficient and more appealing than air transport. The existing rail network in this area requires major changes in order to achieve this goal, as well in Czechia, Poland and the Baltic States. Nevertheless, there are systemic limitations in some areas with lower population density where the rail network is not complete (e.g. the belt which starts from southern Poland through Slovakia to eastern Hungary and Romania and further to Bulgaria). There is a very good opportunity to develop a HSR network along old traditional trade paths from the Baltic Sea (Gdynia/Gdańsk) through Poland, Czechia/Slovakia, Hungary – with 2 lines: to the Black Sea (Romania, Bulgaria, Greece and Turkey and to the Adriatic Sea (Austria, Slovenia, Italy and Serbia, Croatia, Bosnia and Hercegovina).

The Balkan region, if considered as an integrated region, also has a polycentric structure with a large number of medium-sized cities. However, due to topographical conditions, the rail network does not connect these cities in a satisfactory, direct, way. Overcoming obstacles in the form of high mountain ranges requires the construction of expensive new lines with tunnels. Importantly, this region is characterized by a relatively low population and therefore does not generate large transport flows.

In Eastern Europe, the monocentric system dominates with Moscow as the centre of the region. Despite the network's orientation towards the capital of the country a linear pattern can be seen along the railroads leading to Moscow. The proposed network of high-speed lines will handle these bands to a large and wide degree, especially towards the Urals and towards Poland via Belarus. Nonetheless, due to the very large distances, these lines could have a maximum speed of up to 400 km/h.

In Turkey, despite the fact that Istanbul and Ankara dominate over other cities in terms of population, and both of these cities are connected by the main transport axis to the high-speed line, the remaining large and medium-sized cities are relatively evenly distributed across the country. The key objective seems to be to extend the high-speed line network eastwards to the border with Iran and other States which can be done with high-speed lines. However, it is important to note that long distances are a barrier to the dominance of rail transport in this region and that some passenger traffic will be served more efficiently by air transport. However, since high-speed lines can also be used for fast freight traffic, new opportunities for freight traffic on the Asia – Europe axis may also emerge.

For the TER region, as a whole, the design of a HSR system based on a polycentric model appears to be the most desirable option where possible and considering existing topography and the historical development of settlements.

3. Technical parameters for new and modernised lines

3.1 Performance parameters

3.1.1 Classification of parameters

The choice of performance parameters for a planned high-speed line depends on the categorisation of the line which, as mentioned in previous sections can be:

- Maximum speeds 250 km/h and above; or
- Speeds lower than 250 km/h but higher than 200 km/h.

The first category of lines concerns newly constructed lines, where the choice of performance parameters is not limited by the existing railway infrastructure or difficult topographical conditions. This category also usually excludes freight traffic, which may potentially result in capacity limitations. HSL Rail Baltica is an example of this.

The second category of lines typically involves lines modernised to high-speed line parameters. The current alignment or topography mean that the potential increase in maximum speed is limited. Frequently, these lines also have intensive freight and regional passenger traffic.

For practical and economic reasons, high-speed trains are offered as system platforms covering the entire speed range up to 350 km/h and more. The choice of speed is directly related to the traction parameters. This is due to the small size of the equipment and rolling stock market in terms of speeds of 200-250 km/h compared to the 250-350 km/h. In addition, the market for high-speed rolling stock and equipment is much smaller than the market for conventional rail. Table II-7 shows this as there are currently less than 5,000 high-speed vehicles in operation across the world, while single orders for regional trains are counted in hundreds of vehicles.

Table II–7 Number of high-speed trains worldwide (maximum speed of more than 200 km/h)

Area	Number of trainsets
Europe	1 789
Asia	2 987
Other	40
Total	**4 816**

Source: UIC, 2019.

It should also be noted that in many States the P2 category lines complement the networks based on P1 category lines. The alignment of the parameters and the subsequent use of the same technical solutions are critical for achieving consistency, both in operational and technical terms, throughout the system, as well as for the improvement of economic efficiency.

3.1.2 Maximum speed

From a technical point of view, the choice of the maximum speed depends only on the geometrical parameters of the track. There are no variations in technical requirements for the line in the speed range from 250 to 350 km/h (category P1). Such differences are also minimal if the speed is less than 250 km/h. Several of the TSI line parameters change their value at 230 km/h. The maximum speeds selected for HSR systems are usually 230 km/h, 250 km/h, 280 km/h, 300 km/h, 310 km/h, 320 km/h, 350 km/h, 360 km/h; this depends mainly on local topographical conditions.

It is important to ensure that performance parameters are equal or better than the minimum chosen for the entire transport corridor. It helps to avoid bottlenecks (reduced speed, reduced capacity, too low axle loads). In some cases, the marginal cost of opting for a higher speed when building a new line can be very small. It is therefore recommended that minimum performance parameters for the TER network are:

- For modernised lines speeds of 200-230 km/h;
- For new lines with topographical restrictions 250 km/h, and for other lines 300-350 km/h.

In order to achieve internal interoperability of the system within a given area (country, region) and within a single national or international corridor (TER HSR), it is advisable to select the rolling stock for long-distance trains with the maximum speed equal to the highest attainable value in that corridor.

3.1.3 Structure gauge

For high-speed lines with a maximum speed of more than 250 km/h, the GC structure gauge has been adopted, i.e. the largest of those specified in the EN 15273-3 standard. The adoption of such high values, i.e. the space between the vehicle and surrounding structures, is to account for strong aerodynamic interactions caused by a vehicle traveling at high-speed and also to allow for larger trains. For the maximum speed of 200-250 km/h, a smaller structure gauge – GB is allowed. In practice, if possible, a higher value or GC gauge as well as larger spaces between track axes are allowed. For example, for the currently modernized Belgrade – RS/HU border in Serbia line, the GC gauge was adopted. As indicated in the previous section on maximum speeds the additional cost of upgrading to GC gauge instead of upgrading to GB standard is usually minimal.

The choice of the structure gauge should also be considered from the point of view of interoperability and consistency within transport corridors (national and international) and networks in a given region. Decisions on the structure gauge should be evaluated in appropriate feasibility studies before commencing the investment considering also the impact on the wider international corridor.

3.1.4 Axle load

Permissible axle load is a parameter related to the need to minimise the excessive dynamic effect on railway tracks and structures (viaducts, bridges). The standard axle load on conventional lines in Europe is 22.5 tonnes. This is the value adopted for the TEN-T core network, for lower category lines smaller values are permitted. In practice, a weight of up to 22.5 tonnes is expected in order to achieve good system interoperability on lines across transport corridors. The OSJD standard for 1,520 mm lines is 25 tonnes.

For high-speed lines above 250 km/h, axle load values are much lower due to the high dynamic effect of the vehicle on the track at high-speed. In Europe, the TSI INF axle load value, based on many years of experience, reflected in UIC leaflets, is 17 tonnes per axle. Lower values can be found in Asia (e.g. 16 tonnes in Shinkansen, Japan). For the speed range of 200-250 km/h, axle load values are higher – 20 tonnes.

If freight traffic is planned on the high-speed line, it is possible to increase the axle load. This, however, involves higher construction costs for the line and increased maintenance. Within the EU, the TSI INF allows this for example on the HSL Rail Baltica where the permissible axle load for freight trains up to

120 km/h is 25 tonnes. According to the previously mentioned report of the European Union Court of Auditors, the cost of adapting the high-speed line to freight traffic increases the cost of its construction for the same maximum speed parameter by about 5 per cent. The decision to adopt higher axle load values should therefore be considered in economic terms.

3.1.5 The length of platforms or station tracks

Choosing the length of platforms at stations determines permissible length of the passenger trains. In the EU, platform lengths are subject to regulation in the TSI INF. For the P1 line category, the minimum platform length should be 400 m, and for the P2 line category between 200 and 400 m. Platform design should also allow for future growth in requirements.

Similar parameters have also been introduced in non-EU TER States. The introduction of common values was based on the modular design of the first high-speed trains. The basic length of the train, however, remained at 200 m. This corresponds to 350-400 passengers in the 2 + 2 configuration in second class, and 1 + 2 in first class. In Asian States, the standard 2 + 3 and 2 + 2 has been adopted, giving a higher number of passenger seats.

If two units are coupled together for higher capacity, the length of train can be increased to 400 m. The demand for high-speed transport has meant a greater interest in longer trains. Examples of train lengths over 200 m include:

- ICE 1 (DB) in the longest arrangement is 358 m;
- TGV Atlantique (SNCF) – 237.5 m;
- ETR.500 (Trenitalia) – 327.6 m;
- Eurostar e300 (Eurostar) – 378 m and e320 – 400 m.

In the newer generation of trains, lengths of more than 200 m are seen in:

- Sapsan (RŻD) – 250 m;
- ICE 4 (DB) – in the longest version 288 m.

In China and Japan, the standard length of high-speed trains is 200 m and they operate in coupled formation to reach 400 m. Longer single trains – 400 m in length – are also used to operate on some selected high-traffic lines. The platform lengths of a subset of countries are set out in table II-8.

Table II–8 Lengths of platforms in selected high-speed systems

Country	Length of platform
Germany	Minimum 400 m
France	Minimum 405 m
China	450 m for trains with 16 cars, 230 m for trains with 8 cars
Japan	Minimum 410 m

Source: UIC IRS 60680.

For freight trains running on high-speed lines, the minimum length of station tracks should also be assumed. For the highest category of freight line, F1, the minimum length is 740 m. Adopting longer station tracks recommended in the TSI INF – 1,050 m – enables longer trains to operate on such lines. This is very important with regard to capacity limits, which is a concern when trains run at varying maximum speeds. HSL Rail Baltica has assumed a station length of 1,050 m to avoid such problems.

3.2 Track geometry parameters

3.2.1 Legislation

In EU States, track parameter requirements are covered by TSI INF. The values of parameters included in the TSIs, the so-called basic parameters, are minimum values that must be achieved to ensure interoperability within the European Railway Area. And relate to the 1,435- and 1,520-mm track gauges. The requirements for the 1,520 system in EU are generally set at a maximum speed of 250 km/h.

In the OTIF system, a draft UTP INF specification is being prepared, but it will be consistent and compatible with the TSI INF. In the non-EU States with a 1,520 mm gauge, the technical and operational requirements follow TSI INF but considering the relevant OSJD leaflets and the relevant harmonised GOST standards. Requirements for the construction of the Moscow – Kazan line have been developed for higher speeds in the Moscow – Kazan High-Speed Line Specification (PSS-MK).

3.2.2 Recommended parameters

The TSI INF lists 42 basic parameters. The main ones are summarized in table II-9 with a list of mandatory requirements and recommendations from the UIC and others.

Table II–9 Track geometry parameters

Basic parameter	Interoperability requirements within EU TSI INF	UIC and other recommendations
	Line layout	
Structure gauge	According to 4.2.1 and EN 15273-3 200-250 km/h: GB 250-350 km/h: GC For the 1 520 mm track gauge system, all traffic codes selected according to point 1.1 (tables 1 and 2) are applied with the uniform structure gauge “S” as defined in appendix H to this TSI.	For 1 520 system recommended standards PSS-MK
Distance between track centres	For track 1 435 mm 160 < v ≤ 200: 3,80 m 200 < v ≤ 250: 4,00 m 250 < v ≤ 300: 4,20 m v > 300: 4,50 m For track 1 520 mm 160 < v ≤ 200: 4,30 m 200 < v ≤ 250: 4,50 m v > 250: 4,70 m	UIC, for track 1 435 mm - 350 km/h: 4,7-5,0 m - 300 km/h: 4,5-4,8 m - 250 km/h: 4,2-4,6 m

Table II–9 Track geometry parameters (continued)

Basic parameter	Interoperability requirements within EU TSI INF	UIC and other recommendations
	Line layout	
Maximum gradients	Gradients as steep as 35 mm/m are allowed for main tracks on new P1 lines dedicated to passenger traffic at the design phase provided the following "envelope" requirements are observed (a) the slope of the moving average profile over 10 km is less than or equal to 25 mm/m (b) the maximum length of continuous 35 mm/m gradient does not exceed 6 km Gradients of tracks through passenger platforms of new lines and of new stabling tracks intended for parking rolling stock (made to prevent the rolling stock from running away) shall not be more than 2,5 mm/m.	For other cases the maximum gradient shall be determined according to the terrain, design speed, transport demand, type and mass of train and economic analyses. Within DB experiences with mixed traffic on two HSL in Germany: from Hanover to Würzburg and from Mannheim to Stuttgart it should be no higher than 12.5‰ to run heavy freight trains. According to UIC IRS 60680 a maximum gradient of 25‰~35‰ is recommended according to the experience of different States. For the 1520 system the recommended standards are PSS-MK
Minimum radius of horizontal curve	The minimum design radius of horizontal curve shall be selected with regard to the local design speed of the curve. (1) The minimum horizontal design curve radius for new lines shall not be less than 150 m.	The curve radius shall meet the requirements of train speed, adapt to the terrain and geological conditions, reduce work volume, and facilitate maintenance. Factors influencing the minimum curve radius: - Train running safety and stability, guaranteeing that the train does not overturn on curves. - Adaptation to terrain, reduce the impact on buildings and structures, reduce work volume and construction cost. - Small curve radius can reduce the volume of work and construction cost, but may increase track maintenance work, because of this the curve radius needs to be determined in consideration of the whole life cycle cost. Recommended value of the minimum curve radius (IRS 60680 – project): - 350 km/h: 5 500 – 7 250 m - 300 km/h: 3 600 – 5 000 m - 250 km/h: 2 500 – 3 500 m For 1520 system recommended standards PSS-MK

Table II–9 Track geometry parameters (continued)

<table>
<tr><th>Basic parameter</th><th>Interoperability requirements within EU TSI INF</th><th>UIC and other recommendations</th></tr>
<tr><td colspan="3">Line layout</td></tr>
<tr><td>Minimum radius of vertical curve</td><td>(1) The radius of vertical curves (except for humps in marshalling yards) shall be at least 500 m on a crest or 900 m in a hollow

For the 1 520 mm track gauge system the radius of vertical curves (except the marshalling yards) shall be at least 5 000 m both on a crest and in a hollow</td><td>According to UIC IRS 60680

Calculation of the radius of vertical curve:

$R_v = \frac{V^2}{3.6^2[a_v]}$

$[a_v]$ – vertical centrifugal acceleration allowed by the requirements of riding comfort (m/s^2), recommended value
$0.3\ m/s^2$~$0.6\ m/s^2$</td></tr>
<tr><td colspan="3">Track parameters</td></tr>
<tr><td>Nominal track gauge</td><td>(1) European standard nominal track gauge shall be 1 435 mm.

(2) For the 1 520 mm track gauge system the nominal track gauge shall be 1 520 mm.</td><td>No other recommendation</td></tr>
<tr><td>Cant</td><td>(1) The design cant for lines shall be limited as defined

Ballasted track

- Freight and mixed traffic: 160 mm

- Passenger traffic: 180 mm

Non ballasted track

- Freight and mixed traffic: 170 mm

- Passenger traffic: 180 mm

(2) The design cant on tracks adjacent to station platforms where trains are intended to stop in normal service shall not exceed 110 mm.

For the 1 520 mm track gauge system the design cant shall not exceed 150 mm.</td><td>No other recommendation</td></tr>
<tr><td>Cant deficiency</td><td>(1) The maximum values for cant deficiency:

For operation of rolling stock conforming to the Locomotives and Passenger TSI

- v ≤ 300: 153 mm

- v > 300: 100

For operation of rolling stock conforming to Freight Wagons TSI

- v ≤ 160: 130 mm

For all types of rolling stock of the 1 520 mm track gauge system the cant deficiency shall not exceed 115 mm. This is valid for speeds up to 200 km/h.</td><td>No other recommendation</td></tr>
</table>

Table II–9 Track geometry parameters (continued)

Basic parameter	Interoperability requirements within EU TSI INF	UIC and other recommendations
Track parameters		
Abrupt change of cant deficiency	The maximum values of abrupt change of cant deficiency shall be: - 130 mm for v ≤ 60 km/h, - 125 mm for 60 km/h < v ≤ 200 km/h - 85 mm for 200 km/h < v ≤ 230 km/h - 25 mm for v > 230 km/h. For the 1 520 mm track gauge system the maximum values of abrupt change of cant deficiency shall be: - 115 mm for v ≤ 200 km/h, - 85 mm for 200 km/h < v ≤ 230 km/h, 25 mm for v > 230 km/h.	No other recommendation
Equivalent conicity	Design limit values (wheel profile S1002, GV1/40): - 60 < v ≤ 200: 025 - 200 < v ≤ 280: 0,20 - v > 280: 0,10	No other recommendation
Railhead profile for plain line	The design of railhead profiles for plain line shall comprise: - A lateral slope on the side of the railhead angled to between vertical and 1/16 with reference to the vertical axis of the railhead; - The vertical distance between the top of this lateral slope and the top of the rail shall be less than 20 mm; - A radius of at least 12 mm at the gauge corner; - The horizontal distance between the crown of the rail and the tangent point shall be between 31 and 37.5 mm.	No other recommendation
Rail inclination	For tracks intended to be operated at speeds greater than 60 km/h, the rail inclination for a given route shall be selected from the range 1/20 to 1/40. For sections of not more than 100 m between switches and crossings without inclination where the running speed is no more than 200 km/h, the laying of rails without inclination is allowed.	No other recommendation

Source: Own study on UIC data.

3.3 Catenary and power supply

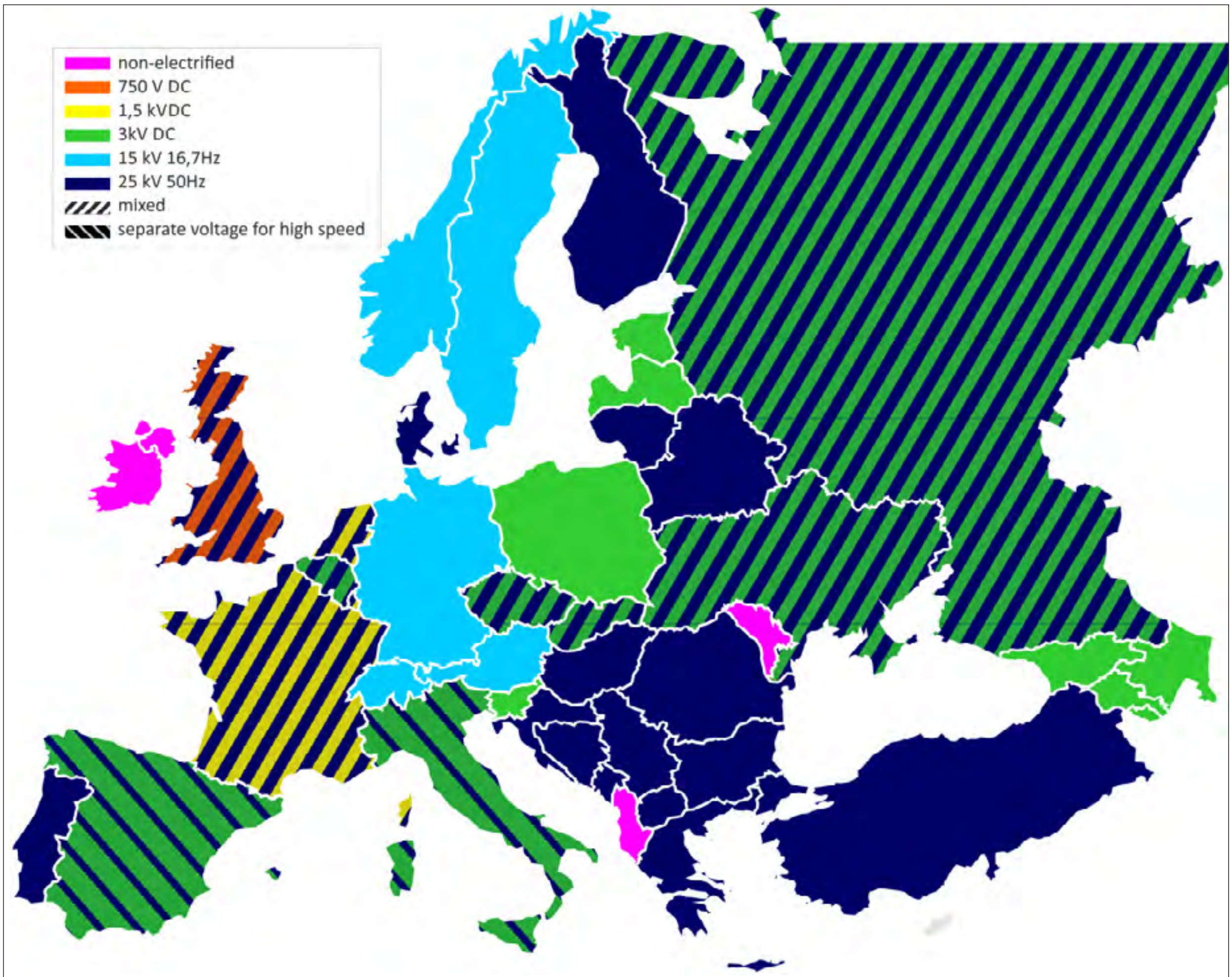
3.3.1 Catenary power supply systems

Currently, there are 4 basic catenary power supply systems used in Europe (table II-10):

1) The 25 kV 50 or 60 Hz system and its more energy-efficient 2 x 25 kV 50 or 60 Hz variant. This system is used in many European and Asian States, especially in those States where railway electrification started in the 1950s and 1960s.
2) The 15 kV 16.7 Hz system. This system is equally efficient but requires separate power supply from the national power grids (including its own power plant or converter system from national 50 Hz power supply systems). The system is used in Germany, Austria, Switzerland and Sweden (also 2 x 15 kV variant).
3) The 3 kV DC system used in many European States, including in the Belgium, Czechia, Italy, Poland, Slovakia, Spain from the early stages of rail electrification. This system is characterised by low energy efficiency and low efficiency, especially at speeds above 200 km/h.
4) The 1.5 kV DC system used in the southern regions of France and the Netherlands. This system is no longer being developed due to its limitations.

The figure II-6 below sets out the various systems in Europe.

Figure II–6 Electrification of Railway System in Europe



Source: UIC data.

Table II–10 Power supply on high-speed lines

Speed range	Line category	
	P1	P2
≤ 250 km/h		a.c. 25 000 V 50 Hz a.c. 15 000 V 16,7 Hz d.c. 3 000 V d.c. 1 500 V
> 250 km/h	a.c. 25 000 V 50 Hz; a.c. 15 000 V 16,7 Hz d.c. 3 000 V (with limits to 250 km/h)	

Source: EN 50388.[29]

3.3.2 Characteristics of high-speed line power supply

The key criterion for choosing a high-speed line power supply system is its efficiency. For a train speed of more than 300 km/h, the active power consumption is 8-10 MW for a single unit with a length of up to 200 m (approximately 350-400 passengers) and up to 20 MW for a double traction unit. For units with lower speeds of up to 250 km/h, the level of power consumption is up to 6 MW, which is equivalent to the maximum power for a 3 kV DC system. For the 1.5 kV DC system, the power limit is even lower and the maximum train speeds achievable is at the level of 200 km/h (figure II-11).

High-speed trains, with their technical specifications, have higher power supply requirements making the 25 kV AC system the most efficient for this type of traffic with the lowest unit costs of construction and maintenance due to the possibility of using power substations located at distances of up to 100 km (compared to 6-12 km for the 3 kV DC system).

Table II–11 Parameters of various power supply systems

Parameter	Category of line	
	P1	P2
Typical source power available power of the source [MW]	20-60	15-45
Typical source power available power of the source [MW]	8-20	5-15
Length of the route supplied by one source under normal operating conditions [km]		
Distance from source to sectioning point		
25 000 V – 50 Hz	15-30	20-30
2 × 25 000 V – 50 Hz	20-45	20-50
15 000 V – 16,7 Hz	15-30	20-35
2 x 15 000 V – 16,7 Hz	30-60	30-60
3 000 V	6-12	7,5-12,5
1 500 V	-	2-8

Source: EN 50388.

29 *EN 50388 Railway Applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability*, n.d.

3.3.3 Interoperability issues

The patchwork of systems set out in figure II-6 above create interoperability concerns which can be overcome by:

- The unification of power supply systems in the region or corridor, which in practice means conversion of the electrification system to the most efficient 25 kV 50 Hz system or, in specific locations, to 15 kV 16.7 Hz in bordering regions of this system;
- The use of multi-system rolling stock that allows power supply from various systems.

Interoperability of high-speed lines is facilitated in the EU with the requirement that new lines for maximum speed above 250 km/h on the Trans-European network are constructed to use the 25 kV or 15 kV traction power systems. This can create an interoperability constraint with electrification on conventional lines which can be addressed by using multi-system rolling stock.

If an existing electrified line is being modernised consideration should be given to whether to upgrade it to a different power supply system also considering the costs of the various options. In addition, multi system rolling stock is possible and common on some networks. The cost of installing multi-system equipment in a vehicle is currently c.a. €0.5 million per vehicle and thus a low-cost option to facilitate interoperability.

3.4 Technical standards identified in the AGC

Since its signing in 1985, the AGC has been updated on a number of occasions to reflect more recent parameters and to keep it in line with practices across the region. The key technical parameters identified in the AGC are set out in table II-12 below.

Table II–12 Infrastructure parameters for main AGC lines

Parameters	Category A*	Category B**		
		B1 (passenger traffic only)	B2 (passenger and goods traffic)	B3 (high-speed lines)
Number of tracks	-	2	2	
Vehicle loading gauge	UIC B	UIC C1	UIC C1	
Minimum distance between track centres	4.0 m	4.2 m	4.2 m	
Nominal minimum speed Line category P1 P2 P3 P4 P5 P6 P1520 P1600 F1 F2 F3 F4 F1520 F1600	350 km/h 250 km/h 200 km/h 200 km/h 120 km/h N/A 160 km/h 160 km/h 120 km/h 120 km/h 100 km/h N/A 120 km/h 100 km/h	350 km/h 250 km/h 200 km/h 200 km/h 120 km/h N/A 160 km/h 160 km/h	350 km/h 250 km/h 200 km/h 200 km/h 120 km/h N/A 160 km/h 160 km/h 120 km/h 120 km/h 100 km/h N/A 120 km/h 100 km/h	350 km/h 250 km/h 200 km/h 200 km/h 120 km/h N/A 160 km/h 160 km/h

Table II–12 Infrastructure parameters for main AGC lines (continued)

Parameters	Category A*	Category B**		
		B1 (passenger traffic only)	B2 (passenger and goods traffic)	B3 (high-speed lines)
Authorized mass per axle: Locomotives (≤ 200 km/h) Rail cars & rail motor sets (≤ 300) Carriages Wagons ≤ 100 km/h 120 km/h 140 km/h	 22.5 t 17 t 16 t 20 t 20 t 18 t	 - 17 t - - - -	 22.5 t 17 t 16 t 22.5 t 20 t 18 t	 - 17 t - - - -
Authorized mass per linear metre	8 t	-	8 t	
Test train (bridge design)	UIC 71	-	UIC 71	
Maximum gradient	-	35 mm/m	12.5 mm/m	35 mm/m
Minimum platform length in principal stations	400 m	400 m	400 m	
Minimum useful siding length	750 m	-	750 m	
Level crossings	none	none	none	

* A – existing lines which meet the infrastructure reequipments and lines to be improved or reconstructed
** B – new lines
Source: UNECE, European Agreement on Main International Railway Lines (AGC), annex 2, revision 4 (2019).[30]

3.5 Other technical solutions for HSRs

The tables below summarize selected technical solution of high-speed lines with their recommended values according to best practices.

Table II–13 Typical components of the superstructure

Component	Solution
Rail	60 kg/m, welded
Ties	Concrete monobloc or bi-bloc 1 666 per km or slab track
Turnouts	Movable for more than 200 km/h
Signalling system	on-board ERTMS Level 2 (in EU States obligatory) or equivalent

Source: Own study, UIC.

When choosing track type, the choice is between:

- Ballasted track, the oldest and constantly improved solution
- Slab track, the solution designed to last decades.

Both solutions are now widely used worldwide, since they provide the same level of performance. Both solutions have advantages and disadvantages so individual circumstances need to be considered when making the decision on which to choose. Table II-14 sets out both solutions.

[30] UNECE, *European Agreement on Main International Railway Lines (AGC), annex 2, revision 3 (the edition of the 2017 AGC Agreement)*.

Table II–14 Comparison of ballasted track and slab track

Type of track	Ballasted track	Slab track
Advantages	Requires low investment cost Good track elasticity Long-term experience proven	Almost maintenance-free Better availability Gradient up to 4% Great ride performance and stability
Disadvantages	Requires frequent maintenance of the track geometry Requires periodic renewal of ballast Gradient limited to 3.5%	Higher noise level Needs more investment cost

Source: Own study, UIC.

4. Operational solution for high-speed rail

4.1 Recommended maximum design speed

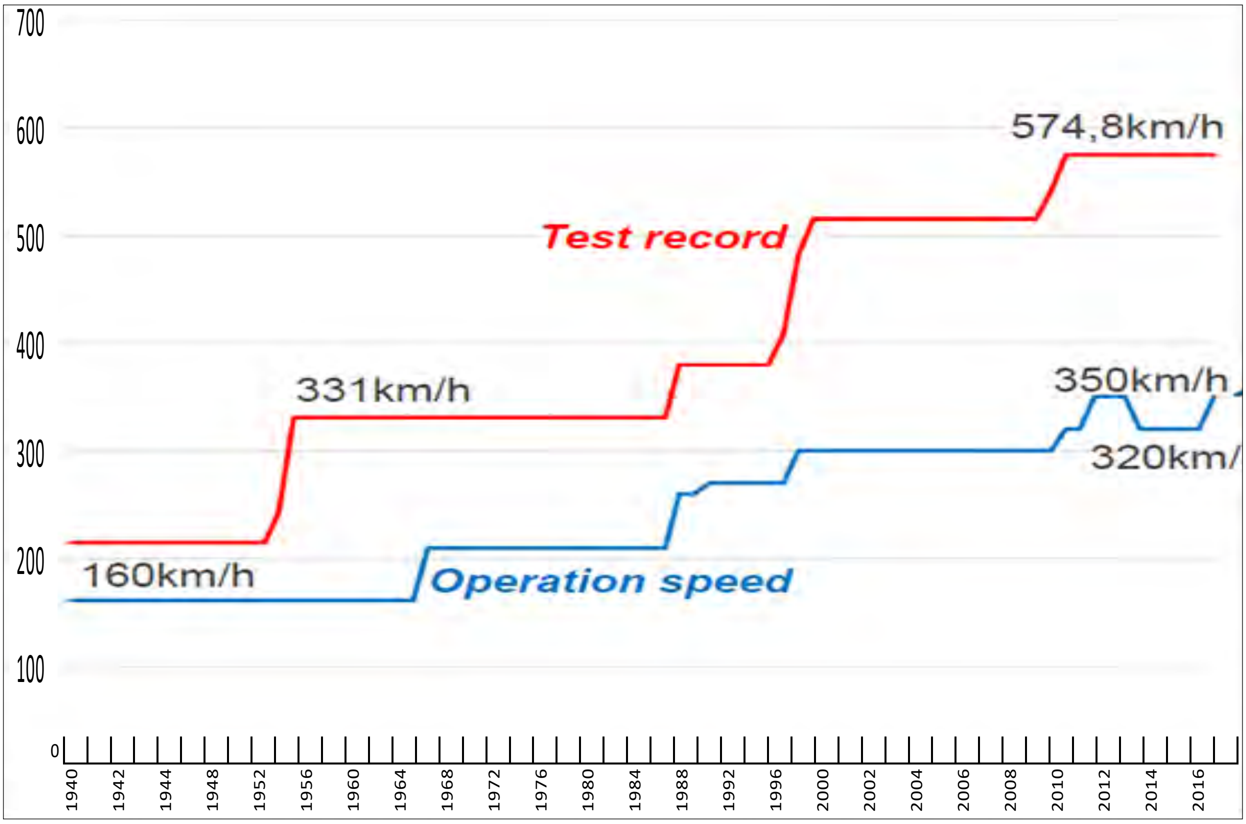
4.1.1 Basic principles for choosing the maximum speed

The choice of the maximum speed identified in the previous section is driven by individual policy decisions that will consider whether:

- Minimising travel time is the primary objective; or
- Maximising capacity is the main goal.

Technical parameters of high-speed lines result from many conditions: operational requirements, design assumptions as well as access to design solutions and technologies. When planning the construction of high-speed lines, it is necessary to make them as future proof as possible. History shows that the technological advancement of rolling stock has often out-paced infrastructure development. As shown in the figure II-7 below.

Figure II–7 High-speed rail maximum speed increase



Source UIC.

4.1.2 The role of travel time

In the design of HSR systems, the possibility to obtain shorter travel times is of particular importance. The optimum value of travel time results in the technical parameters for a given line and, above all, the maximum speed that can be achieved on that line. Therefore, the choice is a compromise between the shortest time possible, the distance between stops and the construction cost. The willingness to travel falls as journeys are longer and take more time.

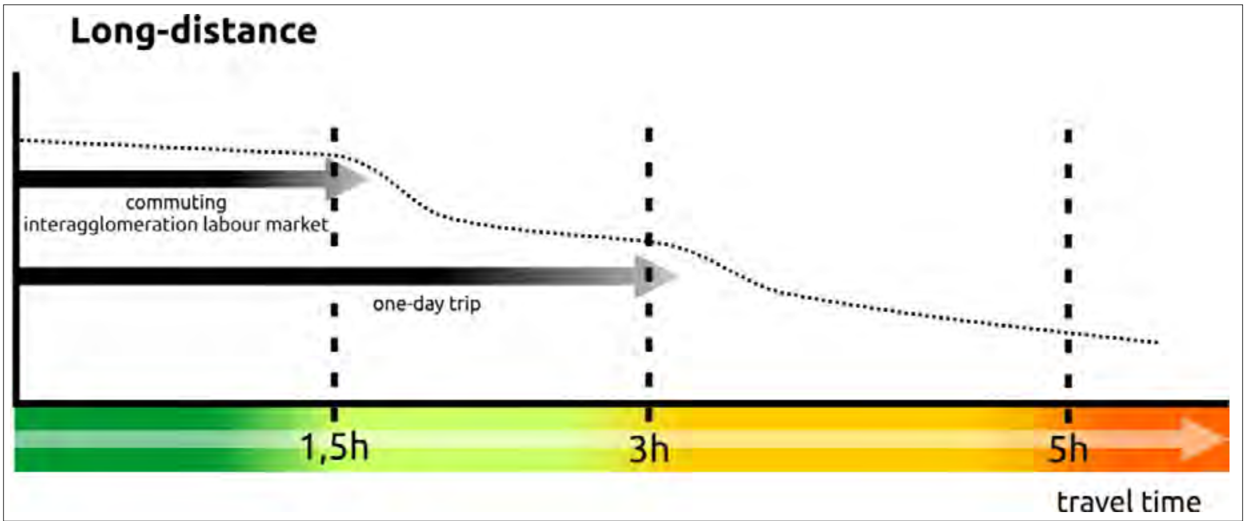
As the distance increases, the strength of economic and social ties decreases. Therefore, shortening travel times brings communities together and allows for journeys that previously were not considered to become ideal. Transport research has shown that generally if travel times are less than 90 minutes, the market share of railway transport is very high and even exceeds 90 per cent. The market share decreases gradually and drops down significantly when exceeding three hours as air transport becomes a significant competitor (table II-15). There are, of course, specific situations where these travel time thresholds are different, for example if a mountain range makes a non-rail distance virtually longer because of potential weather considerations.

Table II–15 Travel time and socioeconomic effects and railway competitiveness

Travel time	Socio-economic effects	Passengers flows	Railway competitiveness
Up to 1.5 hour	An urban labour and services market are developed generating economic growth	Relatively high and even passenger flows during the whole day – possible business travel on different day time	Very high level of competitiveness, in case of some connections unrivalled
1.5 – approximately 3 hours	Active, multilateral economic relations are created	Possible one-day trip particularly important for business	High level of competitiveness
More than 3 hours	Depending on economic and social relations, favourable conditions for strengthening socioeconomic links are created	With travel time exceeding 3 hours, the demand is expected to decline	With travel time exceeding 3 hours the ability to compete and the market share are expected to decrease.

Source: Own work, based on A. Szarata, J. Raczynski: The role of Polish infrastructural projects in creating railway network in Central Europe.[31]

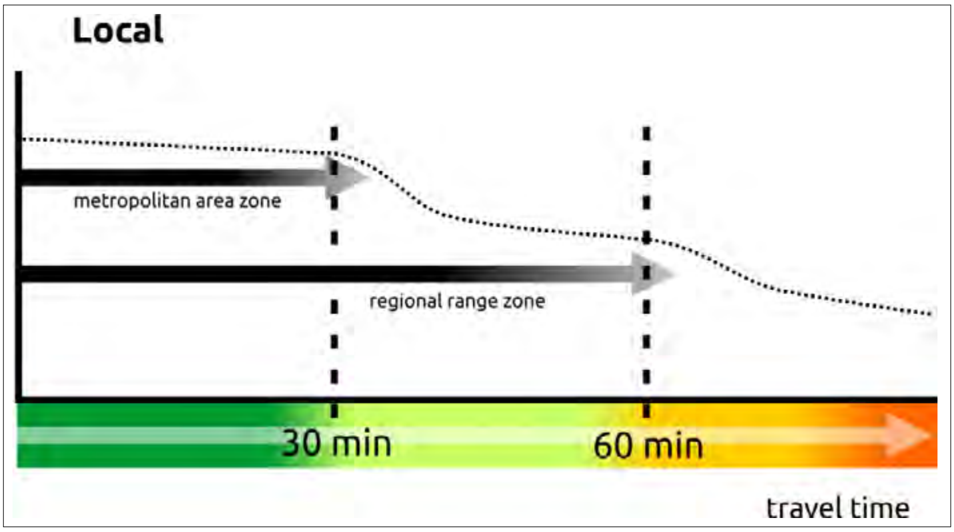
Figure II–8 Market share and passenger traffic volume depend on travel time over long distances



Source: Own work.

[31] Szarata A., Raczynski J.: *The role of Polish infrastructural projects in creating railway network in Central Europe*. Transport Technology Systems, tts 9EN/2018, ISSN 1232-3829.

Figure II–9 **Market share and passenger traffic volume depend on local travel time (regional and metropolitan)**



Source: Own work.

SNCF's experience shows that shortening the time of journeys that take more than 5 hours will have a less noticeable impact on the potential increase in demand than further lowering shorter travel times. The increase in passenger flows is most likely to follow the reduction of travel time in the range of 3-4 hours, tied to the maximum amount possible for a one-day trip.[32]

Furthermore, research carried out by SNCF on the first high-speed lines with stable demand shows that there is also a significant amount of induced, new traffic from people who would not previously travel, showing that new passengers are captured from:

- Air transport – 30 per cent
- Road transport – 20 per cent
- Induced mobility – 50 per cent.

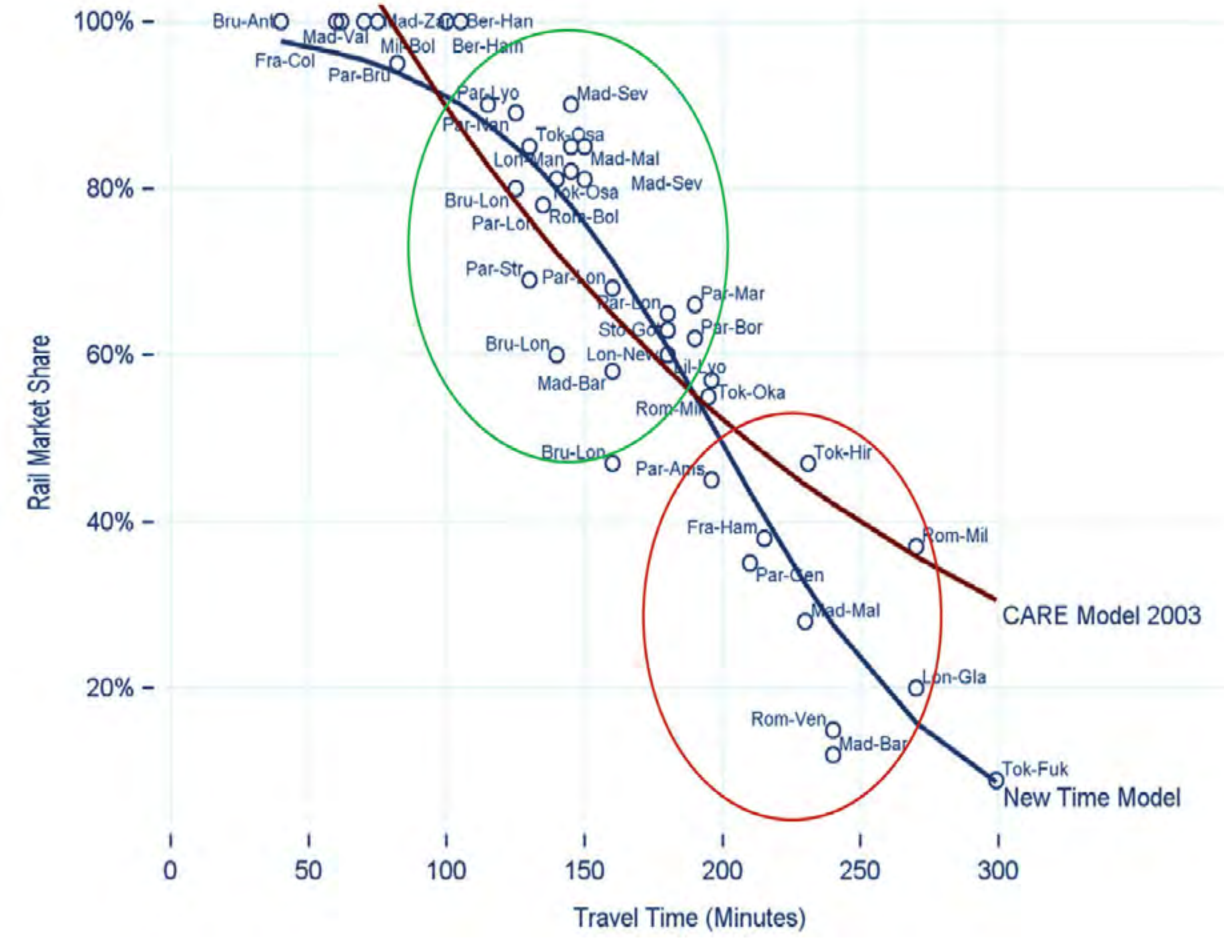
Modal capture of rail is also strongly dependent on local market conditions and pricing policy.

These different local conditions mean that modelling results of potential capture and market share need to be done with some caution to ensure that the competitiveness of different modes of transport is measured correctly. Some of the modelling results are presented in the figure II-10. This provides a comparison of older model (CARE Model 2003) and the newer, more precise model (New Time Model).[33]

[32] M. Lebeuf, *High Speed Rail*., Paris 2014.

[33] P. Martins, *Stat for high-speed train model recalibration*, "Forecasting Air Transport Workshop", Cologne, Germany, 7 November 2015.

Figure II–10 Travel time and market share of rail transport compared to air transport



$$U_{KDP} = \begin{cases} \dfrac{1}{1+e^{-(4{,}4129+0{,}0018d-0{,}0264t)}} & t \geq 80 \\ 1{,}415 - 0{,}006t & t \in (70{,}80) \\ 100 & t \leq 70 \end{cases} \qquad [\%]$$

U_{KDP} – share of high speed railway [%]
t – travel time [min]
d – distance [km]

Source: Martins P., *Stat for high-speed train model recalibration*, Forecasting Air Transport Workshop, 7 October 2015, Cologne, Germany.

However, it is important that any analysis that is undertaken ensures that the full picture is taken into consideration, not only travel time.[34]

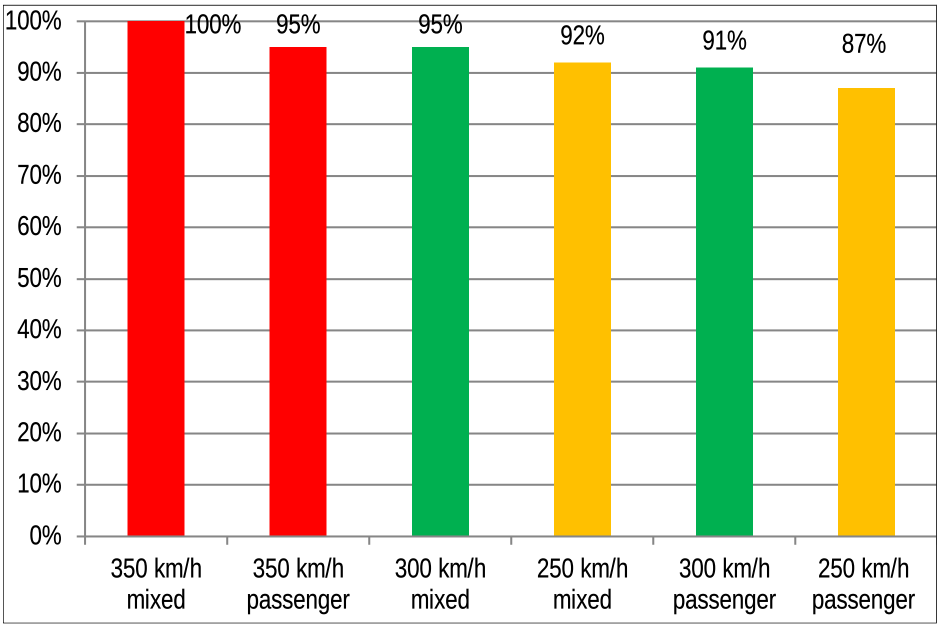
4.1.3 Maximum speed and its influence on costs

Infrastructure investment costs

Net of topographical factors, the difference in construction costs between the line with the maximum speed of 250 km/h or 350 km/h is minor and the same technologies and the same materials are used as set out by the European Court of Auditors (figure II-11).

[34] Helios and SAMI Consulting, Challenges of Growth 2013, Task 7, European Air Traffic in 2050, n.d., http://www.eurocontrol.int/articles/challenges-growth, 13 September 2019.

Figure II–11 **Differences in the cost of constructing high-speed lines**

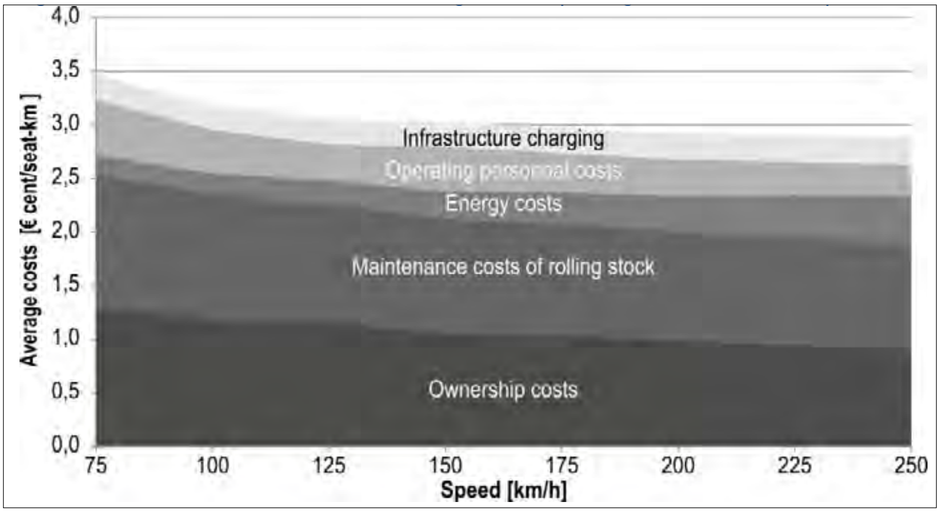


Source: A European high-speed rail network: not a reality but an ineffective patchwork. European Court of Auditors, Special Report No. 19, 2018.

Operating costs

Generally, the shorter the travel time the lower the marginal cost, due to better use of production resources, i.e. rolling stock and personnel. This relationship is shown in figure II-12 where the individual cost categories are identified.

Figure II–12 **The structure of the carrier's average costs depending on the commercial speed of the train**



Source: Dyr T., Ziolkowska K. 2015, Financial effectiveness of high-speed rail in Poland,[35] Garcia A., *Relationship between rail service operating direct costs and speed*.[36]

35 T. Dyr and K. Ziolkowska, *Financial effectiveness of high-speed rail in Poland*, "Transport Technology Systems" (PL:Technika Transportu Szynowego), tts 6/2015.

36 A. Garcia, *Relationship between rail service operating direct costs and speed*, UIC 2010.

The only component of cost that is increasing with train speed is energy consumption which makes up about 5 to 7 per cent of the carrier's operational total cost. This cost is absorbed by the passengers accepting to pay more for shorter travel times and in any case has been falling gradually as a result of technological progression with manufacturers offering its reductions of from 25 to 30 per cent.

It can be seen therefore that an increase in train speed does not significantly increase the unit costs per passenger-kilometre as well as tonne-kilometre. The higher cost of high-speed rolling stock compared to conventional rolling stock is compensated by higher productivity resulting from higher daily mileage and faster turnover of the rolling-stock. The rolling stock production technologies and the technical requirements for rolling stock are similar to the rolling stock running at speeds of lower than 200 km/h. The core requirements and technologies are the same, the difference is that within the operations – high-speed trains are usually longer and have more power units.

4.1.4 Revenues increase as the travel time decreases

The issue of travel time reduction when assessing the effectiveness of investments in high-speed rail appears at the feasibility stage. The time saved is an important element when assessing social and economic benefits of investments. Although the value of the travel time savings varies between different social and freight groups it tends to be generally higher if the country's economic development is high. Its value increases as socioeconomic development progresses.

Social benefits from improved attractiveness of rail travel can include: changes in the transport mode choice giving intermodal solutions and variations (among road, air transport and rail transport) not only to high-speed rail but also to conventional rail, since the majority travellers use more than one transport mode in their journey. The same pattern works within freight transport – even with a greater focus on intermodal. These benefits include reducing the environmental impact of transport and a fall in road accidents.

The direct operational benefits of higher speed and lower travel times for train operators are:

- Increased passenger numbers;
- Potentially higher revenues, since passengers are willing to pay more for a shorter travel time.

Higher revenues will primarily result from induced traffic rather than increased fares as historically the introduction of high-speed services has not increased fares significantly. Furthermore, HSRs are also usually free from operating subsidies (although many had some form of subsidy in the infrastructure construction phase).

4.1.5 Interdependence between maximum speed and travel time

A simplified analysis can be used to assess the impact of the maximum speed increase on travel time. It compares differences in travel time for different maximum speeds on 100, 200 and 300 km line sections without train stops (table II-16).

Table II–16 Travel time as a function of the maximum speed (without stops and time necessary for acceleration and braking)

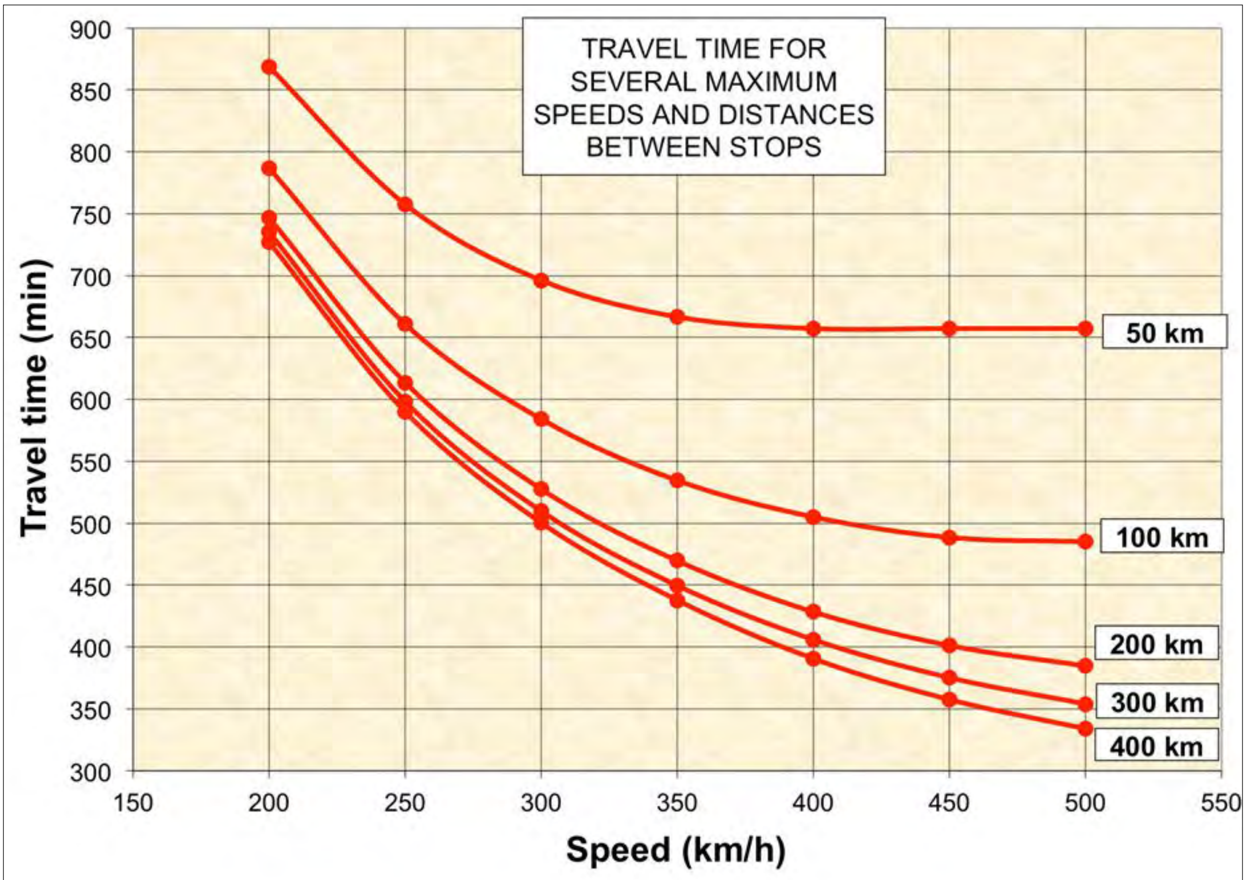
Maximum speed [km/h]	Section length [km]		
	100	200	300
200	30	60	90
250	24	48	72
300	20	40	60
350	17	34	51
400	15	30	45

Source: Own work.

The calculations in the table show that increasing the maximum speed above 300 km/h has fewer and fewer marginal effects on travel time reduction. Furthermore, commercial speed should be used for actual operating conditions being analysed which need to include:

- The number of stops at intermediate stations;
- Time needed for departures from railway junctions, usually at a lower speed.

Figure II–13 Travel time for selected distances between stops



Source: *Clara Zamorano*, 11th Training on High-Speed Systems. UIC – Paris, 20 April 2015.[37]

[37] C. Zamorano, *The conventional network. The potential of conventional lines. Tilting technology*, "11th Training on High-Speed Systems. UIC – Paris", 20 April 2015.

The ratio of commercial speed to the maximum on existing and planned lines can be as high as 0.9, but it is usually lower.

The choice of maximum speed for a line is determined by a number of factors, with the most important being:

- Required travel time;
- Terrain conditions;
- Infrastructure construction cost;
- Availability of technical solutions.

Ultimately, the choice of maximum speeds must be subject to feasibility studies on a case by case basis. The choice of maximum speed is often a compromise between technical possibilities and possible economic effects. However, economic analysis should consider an exceptionally long lifespan for railway investments, even of over 100 years. Excessively compromising solutions and cost-effective infrastructure may turn out to be outdated and have a negative impact on the economic efficiency of the project. The feasibility study should therefore include an in-depth analysis of the technology development scenarios at least in the perspective of several dozen years.

4.2 The choice between building new lines and modernise existing ones

4.2.1 Factors that influence decision making

The choice of whether to build a new HSR line or upgrade an existing one to high-speed parameters depends on a number of factors:

- Will the new travel time along the modernised line be sufficient to create a competitive advantage for rail thus increasing market share (economic efficiency)?
- Will the capacity of the modernised line be sufficient to deliver an appropriate transport service?
- Will the investment be cost effective?
- Will the modernised rail system meet the requirements of the spatial development plans on the level of regions, States and continent keeping in mind ongoing economic and social changes or should the rail system undergo a radical restructuring process?

It should also be considered whether it is appropriate to construct new lines along the entire length of the transport corridor. A lower cost solution aimed at only upgrading the lines where the bottlenecks exist may be a better solution (for example as done for the Vienna – Linz transport corridor in Austria).

The quality of existing infrastructure is another important issue. In many States, especially in the TER region, sections of the railway network were built in the nineteenth century limiting their ability to be upgraded above 120-160 km/h at a reasonable cost in relation to the cost of building a new line with much better technical and functional parameters (higher speed, higher capacity etc.). However, in practice, the increase in speed on lines after modernisation is limited to 200-230 km/h, due to technical and operational conditions resulting from the existing structure and the need to maintain the existing conventional traffic.

The choice of the investment option should be preceded by detailed analyses that go beyond railway issues and include social and spatial concerns, including such things as whether new agglomerations need to be covered by the HSR system, as well as impact on the industry and on the development of the research and development sector.

These considerations are described in more detail in the framework of the feasibility studies set out in appendices 2 and 3, which assess various options movernization versus new construction.

4.2.2 The scope of line modernisation and expected effects

The goal of achieving shorter journey times can be achieved by implementing various technical and organizational modernisation measures, which depend on the local situation in each network, but cover a basic set of actions:

1) Renewal of tracks, power supply and signalling system with a relatively small speed increase without changing geometrical parameters of the line.
2) Removal of line bottlenecks with reduced speed, replacement of switches, improvement of station systems. It is possible to build additional tracks on selected sections, which will allow local and long-distance traffic to be separated, increasing the capacity of the line, which in turn may increase the speed for selected trains.
3) Use of tilting trains to increase speeds on track curves.

In the third case, the introduction of tilting trains allows an increase in maximum speeds of up to 30 per cent. Having said that, tilting trains are more expensive than conventional ones and lead to increased wear and tear on the tracks. Furthermore, the speed increases are subject to external factors such as speed restrictions for lines with level crossing (160 km/h), the presence of people on platforms during a non-stop train passing (160 km/h) or the obligation to use cabin signalling (140 km/h). Some examples of the use of tilting train technology are set out in the table II-17 below.

Table II–17 Technical characteristics of tilting EMUs

Series	Infrastructure manager	Country	Start of operation	Gauge [mm]	Number of units
S220/Sm3	VR	Finland	1995	1 520	25
Sm6	VR+RŻD	Finland, Russian Federation	2010	1 522	4
490 *Alaris*	RENFE	Spain	1998	1 668	24
4000 *Alfa Pendoluso*	CP	Portugal	2000	1 668	10
310	SŽ	Slovenia	2000	1 435	3
390	Virgin	UK	2002-2009	1 435	1 + 52, 4
680	ČD	Czechia	2005	1 435	7
ETR 600	FS	Italy	2008	1 435	12
ETR 610	FS	Italy	2008	1 435	7 + 7
ICE-T	DB	Germany	1999	1 435	57, 11
ICE-T	ÖBB	Austria	2006	1 435	3
Acela Express	Amtrak	USA	2000	1 435	20
Acela Liberty	Amtrak	USA	(2022)	1 435	28
N700	JNR	Japan	2007	1 435	189

Source: Based on Graff M.: Włoskie linie i pociągi dużych prędkości, tts 1-2/2011.[38]

[38] Graff M.: *Włoskie linie i pociągi dużych prędkości*, Transport Technology Systems, tts No 1-2/2011 [PL Technika Transportu Szynowego].

Achieving speeds above 200 km/h usually requires a wide range of upgrades with reconstruction of the accompanying infrastructure, power supply systems and station systems. In general, the modernisation of a conventional line to HSL parameters is possible up to a speed of 230 km/h and in some cases of up to 250 km/h. The limit of 230 km/h was introduced in the EU TSI INF specification, when defining selected critical components of the infrastructure.

4.2.3 The construction of new high-speed lines

As mentioned previously, the resulting time savings for travellers and freight transport when building a new line to higher technical standards (and speeds above 300km/h) can be much higher than if the lines are only modernised (up to 230 km/h) as set out in table II-16 above.

High maximum speeds require increases in track curve radius, this is not difficult to implement in lowlands and areas which are not urbanised where the differences between costs of the 160 to 350 km/h line are minor. In challenging topographical conditions, i.e. in mountainous areas, the costs of speed increase are higher. For this reason, in some countries (Switzerland, the Basque Country in Spain) cases lines are designed for a speed of up to 250 km/h.

Currently in Europe, new lines are being constructed or designed at maximum speeds in the range of 300-350 km/h, less often at 250 km/h. The summary of the maximum speeds for Europe is provided in table II-20. Higher maximum speeds are used or planned to be used in China, mainly due to the large distances between agglomerations.

On the other hand, the construction of new lines is a major financial and organizational challenge:

- Higher costs should be expected than when upgrading existing lines – even several times higher in regions with difficult topographic and geological conditions;
- The long period of line design, including necessary economic and spatial development analyses preceding it – with line construction taking 10 years on average in Europe and sometimes longer;
- The construction of new lines requires the involvement of large financial and human resources, which can be a heavy burden for individual States without external support.

All these conditions limit the length of high-speed lines in Europe as set out in table II-18. Nevertheless, their importance for European railways is significant as they constitute the backbone of the transport network.

Table II–18 Maximum speed for the new lines in Europe

Country	Maximum design speed for the new lines [km/h]	Length of a rail line operated, constructed or planned [km]
Austria	250	266
Czechia	300-350	1 005 (565 km of line design speed 300-350 km/h)
Denmark	250	206
Estonia	250	848
Latvia		
Lithuania		
France	320-350	4 562
Germany	250-300	2 167
Italy	250-350	1 269

Table II–18 Maximum speed for the new lines in Europe (continued)

Country	Maximum design speed for the new lines [km/h]	Length of a rail line operated, constructed or planned [km]
Poland	300-350	1 305
Portugal	300	596
Spain	250-350	4 903
Sweden	320	740
United Kingdom	400	656
Switzerland	250	159
Russian Federation	350-400	2 978

Source: UIC Statistics (2019).

4.2.4 Recommendation

The choice between modernising the existing railway line to high-speed parameters (200 km/h and more) and the constructing of a new line must be preceded by a thorough analysis as there are no universal rules determining the efficacy of both solutions. Local conditions must be considered in each case. The most important issues to be considered as part of analytical work are the following:

1) The political will to invest significantly across the country (to create at least national HSR Network).
2) Economic and trade forecasts at least for the country and its neighbours, as well as national budgetary resources for at least 20 years.
3) Whether the current spatial development of the country/region is sufficiently served by the existing railway system and, if not – are there substantial changes and a new railway system required or only small ones leading to an improvement of the existing system. This analysis should look at likely developments over the next 30 to 50 years based on the likely spatial development strategies of the country/region.
4) Will the modernisation of the existing line to higher speeds and the introduction of fast passenger trains on it and with mixed traffic (including freight trains) not reduce capacity? Will it be necessary to build more tracks and rebuild railway stations to improve capacity? This can lead to increased modernisation costs comparable to the construction of a new high-speed train line.
5) Are there any international conditions, e.g. the need to provide the continuity of international corridors through the country/region.

The analysis of investment programs in TER States (and across the world) indicates that line modernisations make up only a small share of overall HSR investments. The only exception to this is Germany, which has a very dense polycentric system with a large number of lines, where even those built in the ninetheenth century that have been successfully modernised to the speed of 230 km/h at a reasonable cost.

Ultimately, the modernisation of the line to increase its maximum allowed speed is economically viable in so far as the following conditions are met:

- Forecasted rail services are large enough and the introduction of high-speed connections will not disrupt other types of services and they will develop intermodal solutions.
- The cost of modernisation is substantially lower than the cost of new line construction.
- Travel times after the modernisation will be attractive to passengers and will thus generate increased passenger and freight flows, at the same time, the country’s social and economic objectives will be accomplished.

As mentioned above though, all these considerations need to be made in the context of global, regional, national and local requirements.

Table II–19 Comparison of conditions for the construction of a new high-speed line and the modernisation of the existing line to high-speed parameters

Line modernisation	
Advantages	**Disadvantages and reservations**
Less investment in infrastructure	The modernisation of the line may require long-term closure or significant traffic restrictions – this will result in a decrease in carriers' revenues shift of railway operators to other connections/paths and difficulty in the recovery of potential passengers' flows.
	It may turn out that the cost of reducing the travel time is not substantially lower than constructing a new line
	The capacity of the line after modernisation may be reduced as a result of the increase in the speed difference between the slowest (regional passenger and freight) and fastest trains
Shorter investment time	It may turn out that the period of investment is significantly shorter, particularly if there is a need to run traffic on the line simultaneously.
	There may be unforeseen delays and cost increases compared to the plan
New line construction	
Advantages	**Disadvantages and reservations**
The possibility to revolutionise the transport system of the region/country	The need for new land acquisition
	Much higher costs than when upgrading the line
The possibility of having significant economic effects	It is required to develop and implement an efficient national development plan and early booking of financial sources
Substantial shortening of travel times, increasing regional accessibility	Restructuring of the entire rail network is needed at national or at least at regional level, as well as the procurement of rolling stock adapted to the specifications of new lines
Impulse for the development of industry, trade and research facilities	An efficient and large-scale development program must be developed, implemented and adequate large-scale investments must be made

Source: Own study.

4.3 Choosing the type of service

The technical and operational possibilities of using high-speed lines for various type of traffic varies. The choice of HS service also needs to consider how it will interact with other service types and whether or not it will operate on a dedicated line.

From a legal point of view, there are no obstacles to operate different types of trains on the same high-speed line. However, it is required at the design stage of the line to adopt technical solutions that will enable the traffic of freight trains and regional passenger trains on such line. Many high-speed rail systems with mixed traffic solutions are currently operated around the world. Their design solutions are adapted to local needs.

4.3.1 Regional and urban passenger traffic

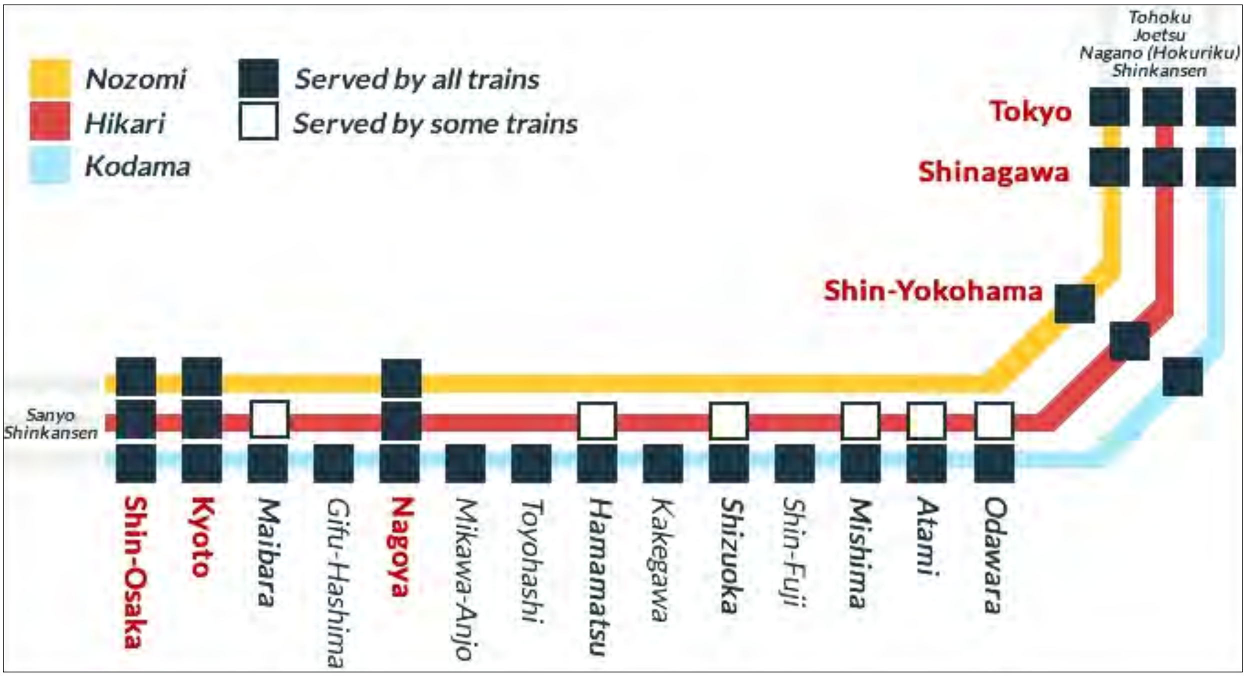
The use of high-speed lines by local or long-distance passenger transport allows conventional rolling stock to be operated in cases where the capacity of the high-speed lines allows the introduction of trains with lower speeds.

Assuming that the maximum speed for high-speed trains will be between 300 and 350 km/h, for regional trains the maximum speeds should be at least 160-200 km/h. Some approaches to using high-speed lines for regional services include:

- Construction of stations directly on the high-speed line in smaller cities, in their vicinity or at large nodes (roads),
- The use of high-speed line sections with sufficient capacity for regional (and even agglomeration) trains in express service. This solution is applicable for high-speed line sections next to large agglomerations. E.g. after about 50-100 km, these trains leave the high-speed lines and continue traveling on existing conventional lines. In this way, the connectivity of towns located far from agglomerations will be substantially improved, in particular, in terms of very long travel times (travel time reduced by ca. 60 minutes and even more in some cases).

Mixed traffic is used on many HSLs worldwide. In Japan, Shinkansen lines are used for various types of trains as shown in the figure below: Kodama trains for regional/local traffic, Hikari to service medium-sized towns, Nozomi serving only large agglomerations (figure 14).

Figure II–14 Train system of various categories illustrated with the example of the Shinknsen line in Japan



Source: JR East.

These models depend on the use of sections of high-speed lines departing from large agglomerations for the purpose of regional connections.

If regional trains are planned to stop at smaller stations, dedicated station tracks with platforms are required.

4.3.2 Freight traffic

High-speed lines may be used for freight traffic according to local needs and capabilities. There are currently no generally applicable legal rules or guidelines for this type of traffic. Freight transport on high-speed lines can be carried out by two types of rolling stock:

- Conventional: hauled by locomotive with the maximum speed of up to 160 km/h (typically 120 km/h);
- High-speed new build or converted passenger trains (currently operated in Italy).

The introduction of freight traffic on high-speed lines has capacity implications on those lines.

The benefits of operating on a high-speed line revolve around shorter delivery times:

1) This is important for very long distances and in conditions where the alternative conventional network has low operating parameters or is overcrowded or overloaded;
2) supports freight shift from road to rail
3) opens new trade opportunities
4) Creates a new market for time sensitive deliveries on rail;
5) supports freight shift from air to rail such as on express parcels.

In the last case, preliminary analyses show that following the construction of a high-speed line from China to Western Europe, rail could effectively compete with air transport on the express delivery market and also contribute to its development, however, this is heavily depending on freight volumes, their weight and size.

Freight traffic on high-speed lines can improve the economic efficacy of investments and can be an important part of the decision-making process for new HSR investment, although being very small compared to passenger traffic on the line. At the same time there are examples demonstrating the legitimacy of mixed traffic in Europe, one of such examples is Hanover – Wurzburg, where the number of freight trains varies by 20-50 per cent of number total number of trains depending on the line section.

Freight traffic on high-speed lines is present in many States around the world. It is most developed in Germany, also on newly constructed lines. In Germany, mixed traffic is generally carried out on high-speed lines at speeds of up to 120-160 km/h. In Spain, it is planned to use high-speed lines for the purpose of freight services which could significantly increase the market share of rail in freight transport.

In Japan, freight trains are also operated on some sections of the Shinkansen line and are planned to be extended to other lines.

In France, there is no freight traffic on newly constructed high-speed lines due to the lack of capacity. Mixed traffic is carried out only on the cross-border line with Spain between Perpignan and Figueras. This line has a maximum speed of 300 km/h for passenger trains. However, the use of this line for both passenger and freight trains are currently below the expected level, which is due to the fact that the key sections in France have not yet been completed and the logistics system has not yet been sufficiently developed.

When Rail Baltica was planned, it was assumed that this would be a line for both passenger and freight traffic. In Poland, the planned HSL also provides for the possibility of freight traffic on selected sections of railway lines. In view of the fact that HSL in Poland was designed to relieve the existing conventional lines and provide greater capacity for freight trains, these trains will run on these lines only to a limited extent. This would apply to cross-border sections, e.g. Wrocław – Prague and Katowice – Ostrava.

In Italy, the national railway company started operating high-speed freight services in November 2018. The rolling stock used is converted ETR 500 high-speed passenger train and uses the high-speed line for most of its journey.

Table II–20 Mercitalia high-speed freight train data

Parameter	Solution
Train type	High-speed train on the basis of ETR 500
Maximum speed	250 km/h (currently 180 km/h)
Connection	Caserta n/Naples – Bologna
Route length	550 km
Travel time	3.5 h.

Source: Mercitalia.

The operation of high-speed freight trains with maximum speeds of 250-300 km/h is also being considered on the Europe-Asia route passing through Germany – Poland – Belarus – Russian Federation.

4.3.3 Operating conditions

The use of high-speed lines both for freight and passenger regional traffic requires a range of organizational measures including:

1) Needs assessment
   - Transport volume forecasts;
   - Determination of the type of freight train (bulk, container transport, etc.) and passenger regional train (length, necessary height of platforms);
   - Forecasted maximum train speeds;
   - Projected train weights and axle loads.

2) Development of an operational plan for the line specifying:
   - Capacity (planning sufficient number of stations for freight and passenger regional trains intermodal nodes and stops during faster overtaking of passenger trains);
   - Timetable framework (e.g. freight trains may be allowed to operate during the whole day or only at night).

When operations begin, focus needs to switch to:

1) Traffic management with trains running with substantially differentiated speeds;
2) The number of stations dedicated especially to freight and passenger regional traffic;
3) Planning maintenance works on the line when there are night train operations;
4) Maintaining high safety and security standards in freight transport (load securing, etc.).

Freight traffic on high-speed lines is therefore not only associated with higher construction costs, but also with higher maintenance costs. The decision to use the high-speed line for freight traffic should therefore be preceded by appropriate technical and economic analyses on case-by-case basis.

4.3.4 Conclusions and recommendation

World experience shows that mixed traffic on high-speed lines where the maximum speed is up to 300 km/h and even more is possible. In considering this, it seems that the implementation of freight traffic on high-speed lines in the TER States is possible on a large scale and may bring substantial benefits. The following potential corridors passing through the TER region could be considered for such transport:

- Western Europe – Asia;
- North-South corridor from the Baltic Sea via Central Europe and Balcans to Turkey and then to Asian States;
- Rail Baltica Corridor from Finland via Central Europe to Western and Southern Europe.

Based on these considerations it will be important to ensure that consider the possibility of efficient freight traffic taken into account when planning the construction of high-speed lines.

The implementation of passenger regional traffic on high-speed lines depends on specific local needs. For example, in Poland, the planned high-speed line also offers the possibility of regional passenger train traffic to use its infrastructure near large agglomerations. The planned high-speed network in Czechia also assumes mixed traffic on a number of sections. Technical barriers for introducing this category of trains on high-speed lines are much lower than for freight traffic due to the higher maximum speed of passenger rolling stock and lower train mass.

5. Communication and signalling systems

5.1 The development of communication and signalling systems

In high-speed railway systems, it is particularly important to ensure a high level of traffic safety and security. Trackside visual signals shall be replaced by systems based on the direct exchange of information between track-side equipment and the vehicle. The first high-speed lines were equipped with their own dedicated command and control systems which supplemented the existing systems necessary for operation on conventional lines. The first international trains (Thalys, Eurostar) had to be equipped with up to 5 different control systems used in different States.

In the early 1990s, the UIC together with European railways began work on unifying traffic control systems and developing new standards using the most advanced digital technology. The results of this work were implemented at the European Union level and in the 2002 TSI for Control Command System (TSI CCS). These solutions were adapted and developed also by China Railways as CTCS.

5.2 Systems overview

This section covers an important element of the structural subsystem of railways focusing on how staff and rolling stock communicate with each other and with the infrastructure. Communication and signalling systems are regarded as complementary technical solutions covering not only primary signalling but also command and control systems as well as technical solutions for mobile communication and fixed equipment ensuring communication between operational stations. As a consequence, communication and signalling have to be seen as a series of technical solutions made up of:[39]

1. **Primary signalling**
   - **1.1.** Station interlocking
   - **1.2.** Block systems
   - **1.3.** Level crossing protection systems
   - **1.4.** Marshalling yard management systems

2. **Operational communication systems**
   - **2.1.** Wired communication systems
   - **2.2.** Mobile communication systems

3. **Control command systems based on track-train data transmission**
   - **3.1.** Automatic warning systems (AWS) warning drivers approaching dangerous locations e.g. in front of signals capable to show stop aspect
   - **3.2.** Automatic train protection systems (ATP) verifying train run over a stop signal without considering train running dynamics
   - **3.3.** Automatic train control systems (ATC) verifying train run over a stop signal fully considering train dynamic behaviour and route inclinations
   - **3.4.** Automatic train operation (ATO) in different variants up to fully driverless solutions and cooperating automatic train supervision systems (ATS) supporting operators supervising driverless operations

[39] Detailed definitions of these components are included in: Pawlik M.: *Reference functional model for supporting safety and security of the railway transport by data transmission systems*. ISBN 978-83-7814-908-8, Oficyna Wydawnicza Politechniki Warszawskiej, Warsaw 2019, p. 186.

4. **Area emergency braking systems**
    4.1. Driver emergency braking systems
    4.2. Automatic emergency braking systems

5. **Railway auxiliary automatics**
    Railway clocks, passenger information systems (local and remote controlled data management as well as visualisation units and announcement systems together with dedicated data transmission systems), video monitoring supporting operational staff (e.g. for rear end checking), autonomic (separate from primary signalling) junction protection systems (e.g. derails), platform door control, platform edge clearance control, etc.

5.3 Systems

5.3.1 Background

Technical solutions used for primary signalling must comply with operational rules and applicable signalling standards including signal aspects which are different in individual TER States. Nevertheless, all contemporary solutions are either based on electronic programmable components or relays and generally based on generic products. Best practice in this area is based on Safety Integrity Levels (SIL) (see chapter 5.3.2. below). In terms of wireless communications, most TER States are already using or are migrating to a unified solution – GSM-R (see section 5.3.3. below).

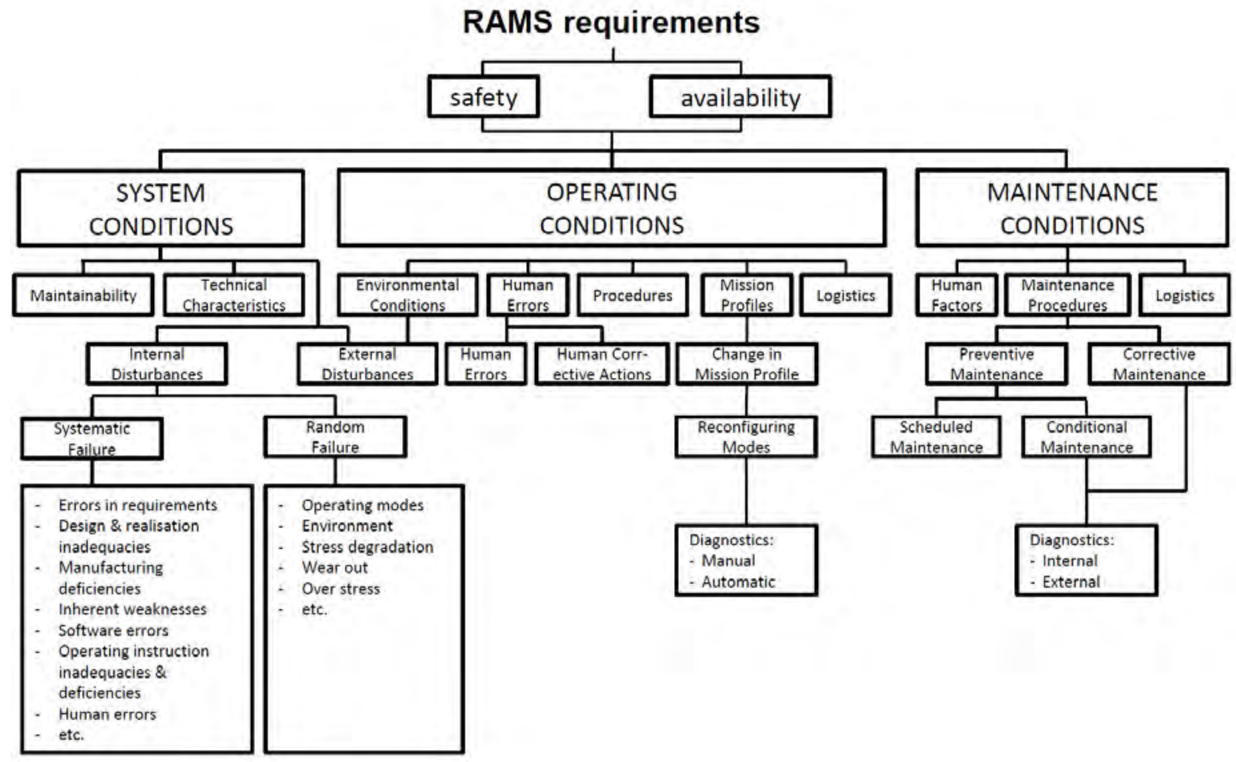
In the past, different technical solutions were developed for command and control systems. Such systems were used on main and high-speed lines operated with a limited number of traction vehicles. Such systems are currently known as class B national solutions and are being replaced by a unified solution – ETCS (see section 5.3.4. below).

Recently, the concept of the railway signalling safety, security and cybersecurity has been integrated into Functional Integrity Levels (FIL), considering the inherent safety of signalling as well as security (see section 5.3.5. below). The remainder of this section looks into detail on each of these areas.

5.3.2 Primary signalling Safety Integrity Level (SIL 4)

A series of CENELEC rail standards define how to demonstrate reliability, availability, maintainability and safety (RAMS) which together form the basis for a safe system. The main standard EN 50126 (Parts 1 and 2) applies to the entire rail transport system. Supplementary standards defining the rules for the specification and demonstration of RAMS are: EN 50128 applicable to software, EN 50129 applicable to signalling systems and EN 50159 applicable to communication systems used for primary signalling and control command technical solutions.

Figure II–15 Reliability, Availability, Maintainability and Safety (RAMS) requirements



Source: CENELEC – EN 50126-1:2017-10 Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) – Part 1: Generic RAMS Process.[40]

RAMS standards apply to generic products used by the industry as the basis for various technical systems operating in different TER States as well as for specific applications for example for customised station interlocking equipment complying with track layouts, occupancy checking organizations, applicable operational rules and signal aspects. Safety cases prepared in accordance with RAMS standards shall cover all cooperating systems and components as well as safety relevant interfaces. Generic safety cases as well as application safety cases are being verified by independent assessors. This approach applies to station interlocking systems, block systems, level crossing protection systems, marshalling yard management systems as well as to command and control, track-side and on-board control systems, based on national requirements and industry practice. ETCS (discussed in more detail below) requires an independent risk assessment bodies accredited under railway safety directive.[41]

5.3.3 Global System for Mobile Communication – Rail (GSM-R)

GSM-R is a unified mobile communication solution for railways based on well-defined public GSM standard modified to meet the specific needs of the rail industry. The overall structure shown in figure II-22 is composed of:

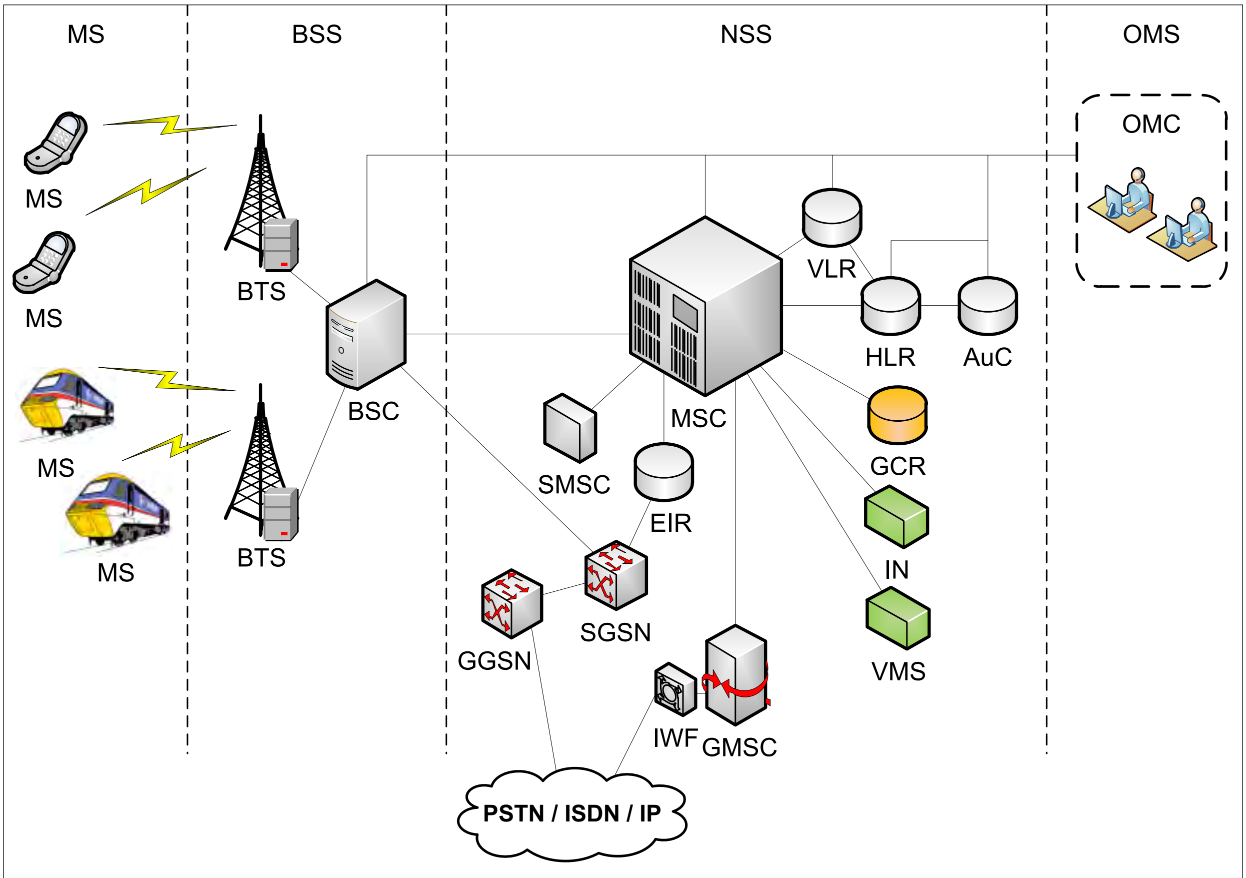
- Mobile Radio Stations (MS) which exchange data over radio signals with trackside installations consisting of three layers: BSS, NSS and OMC;
- Base Station Subsystem (BSS) composed of: Base Transceiver Stations (BTS) and their controllers – Base Station Controllers (BSC);

40 CENELEC – EN 50126-1:2017-10 Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) – Part 1: Generic RAMS Process.

41 Presently – Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety (EU OJ L138/102).

- Network Switching Subsystem (NSS) controlling the entire GSM-R network using Message Switching Centre (MSC), Home Location Register (HLR) and Visitor Location Register (VLR) serving users roaming on the network e.g. international trains, Authentication Centre (AuC) and other supporting components;
- Operation Maintenance Centre (OMC) that is used for configuring, monitoring, and optimising the entire GSM-R as well as for planning and managing disaster recoveries.

Figure II–16 Global System for Mobile Communication – Railways (GSM-R) – Overall structure



Source: European Integrated Railway Radio Enhanced Network GSM-R System Requirements Specification Version 15.4.0, UIC CODE 951-15.4.0, ISBN 2-7461-1832-4.[42]

The rail specific features of GSM-R are:

- Functional Addressing (FA) that allows dispatchers to call train drivers and staff by their train numbers (functional number);
- Location Dependent Addressing (LDA) that allows train drivers to call dispatchers responsible for operation in the train's current location;
- Railway Emergency Calls (REC) are calls with the highest priority that require dispatchers (controllers) and drivers to follow emergency procedures.

42 European Integrated Railway Radio Enhanced Network GSM-R System Requirements Specification Version 15.4.0, UIC CODE 951-15.4.0, ISBN 2-7461-1832-4.

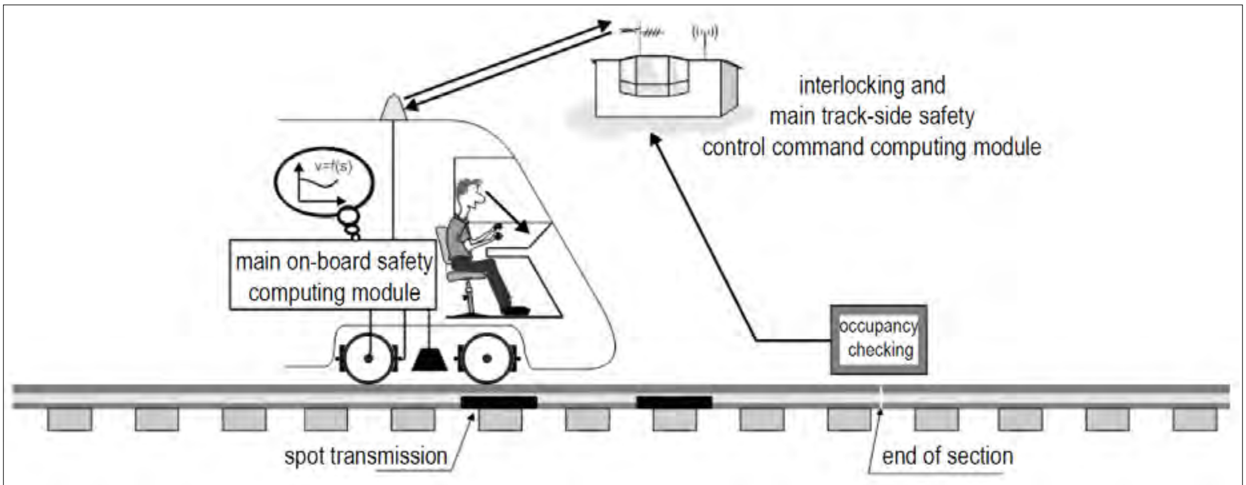
GSM-R is already used significantly across TER States. Implementation projects are also underway. Given that GSM system on which GSM-R is based is 3 generations old and is an outdated system, the railway industry is cooperating to define future radio-communication standard.

5.3.4 European Train Control System (ETCS)

The European Train Control System (ETCS) is an Automatic Train Control (ATC) system. ETCS specifications distinguish three main levels of application:

- Level 1 (L1) based on spot transmission devices (Eurobalises) transmitting electronic movement authorities in accordance with signal aspects displayed by track-side signals;
- Level 2 (L2) is a GSM-R radio-based system for passing through fixed block movement authorities from ETCS radio block centres (RBC) to ETCS on-board units (figure II-23);
- Level 3 (L3) using GSM-R radio data transmission for passing through moving block movement authorities from ETCS radio block centres to ETCS on-board units.

Figure II–17 European Train Control System (ETCS) L2 overall flow chart



Source: TSI CCS Annex A subset 026 – ERTMS/ETCS System Requirements Specification, issue 3.4.0.[43]

Levels 1 and 2 split the tracks into sections on which only one train at a time can transit. Level 3 abandons fixed block sections and the authorisation to proceed is defined by end of the train ahead.

5.3.5 Overall communication and signalling and security measures for safety, security and cybersecurity Functional Integrity Level (FIL 1)

Programmable and electronic solutions are also used in additional signalling related systems and devices. Consequently, the classification described in the section on the Profitability Index also known as profit investment ratio (PIR) and value investment ratio (VIR) above has been extended as follows:

All types of systems, devices and components in the above listed categories contribute to the broadly defined safety of the railway system. It is therefore important to define the overall approach in order to verify completeness of the safety goals. Such approach is defined in a monograph.[44] It is based on

[43] TSI CCS Annex A subset 026 – ERTMS/ETCS System Requirements Specification, issue 3.4.0.

[44] Pawlik M.: *Railway safety and security functional reference model built on data transmission based systems.* ISBN 978-83-7814-908-8, Warsaw University of Technology Publishing House, Warsaw 2019.

the subdivision of functionalities between technical safety systems ensuring operational safety, security supporting systems ensuring protection of life and goods and cybersecurity. The overall approach is based on knock-out and differentiation questions defined for sixteen groups of safety-related functions and sixteen groups of security-related functions. YES/NO answers to questions are valued 1/0. Differentiating questions answers are valued 1/2. As a result, thanks to appropriate number of differentiating questions, products of all answers regarding safety and security equal 0, 1, 2, 4, 8, 16 or 32.

All groups of functions use geographically distributed components that interact with each other. Even when components are used for a single station data transmission, acquisition, processing, receiving, verification and storage, they are exposed to cyber-crime. All transmission systems have to be protected. There is no doubt that transmissions used for signalling and control command are protected, however, the other systems, especially those related to passenger information systems and security, are usually perceived as not requiring protection. Meanwhile, cyber-attracts that have already taken place in the rail industry, have mostly been related to timetabling, ticketing and passenger information systems. Timetabling, ticketing, assets management, project management, contracting and payments are seen as IT systems, and therefore are covered by EU Directive 2016/1148 concerning measures for a high common level of security of network and information systems across the Union. This does not apply to all of the OT systems, mentioned above, for which cyber threats have to be considered. As a result, knock-out and differentiating questions have also been defined for all types of data systems covering entire chains (acquisition, processing, sending, transmission, receiving, verification, use and storage).

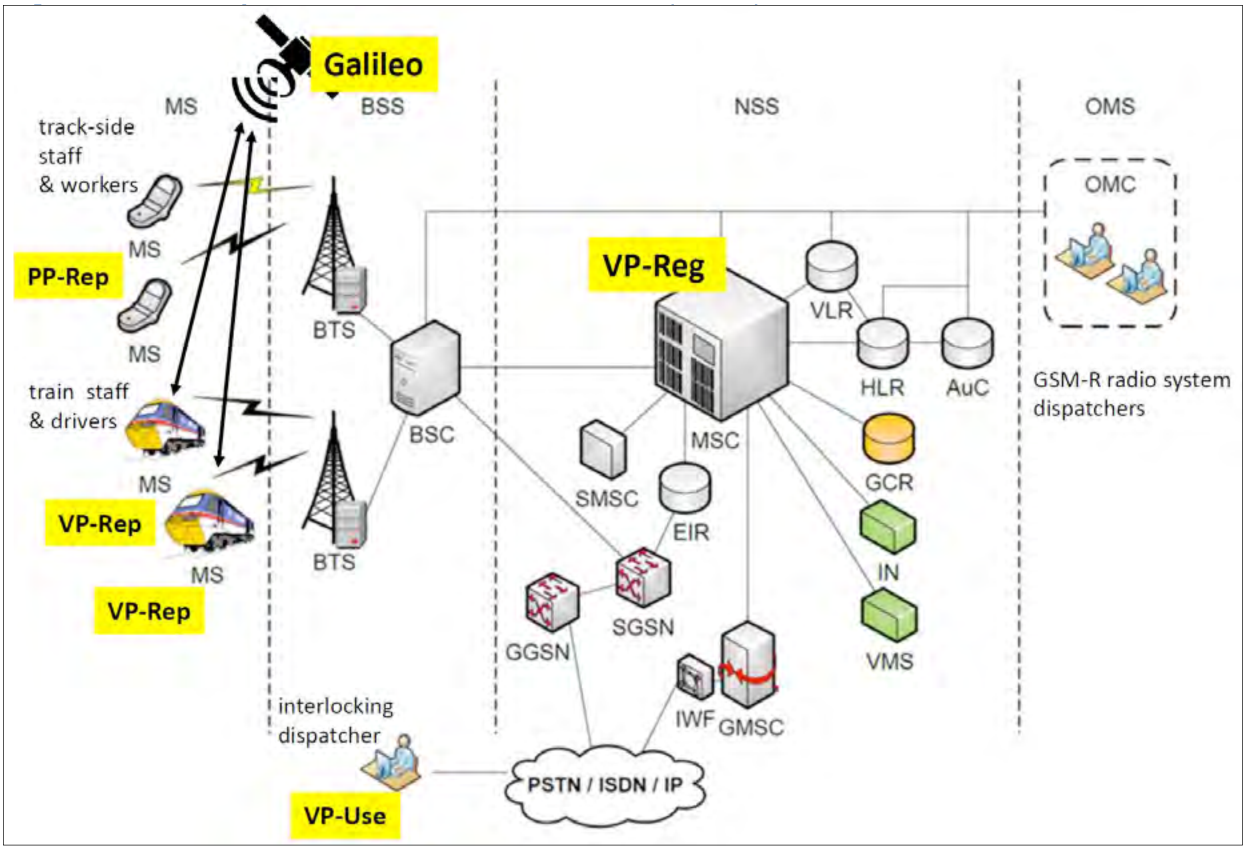
5.4 Using satellite-based technologies for vehicles tracking and other purposes

Satellite-based technologies iare also a viable alternative and have been studied extensively. Several satellite navigation systems are available to users in the TER region.

1) Galileo, the only civil system of navigation and communication developed in the European Union, which is expected to be fully operational at the end 2020. It enables high location accuracy (up to 40 cm) and high signal strength from satellites allowing it to be used in applications related to railway traffic safety.
2) Glonnass (Global Navigation Satellite System), a system developed by the Russian Federation
3) GPS (Global Positioning System), a system developed by the United States of America
4) Beidou, a Chinese system that is expected to have increased coverage of the Eurasian continent by the end of 2020 as a result of the launch of additional satellites.

Although satellite-based technologies do have limitations relating to coverage and accuracy, this accuracy is increasing with the implementation of Galileo.

Figure II–18 Global System for Mobile Communication – Rail (GSM-R) overall structure



Source: EIRENE SRS.[45]

If Galileo is used it would require not only satellite navigation but also mobile data transmission systems. In this respect, the use of GSM-R (future FRMCS) is the simplest and most economically feasible solution for rail industry (figure II-18 above). Trains could be equipped with Vehicle Position Reporting (VP-Rep) units to determine a vehicle's current position, speed and direction and report these parameters to a centralised database – preferably to Vehicle Position Register (VP-Reg) implemented within GSM-R NSS and cooperating directly with MSC. Reliable, precise and frequently updated positions of vehicles could be used by station interlockings and block systems thanks to local modules (VP-Use) as well as by ETCS which is already prepared[46] to use virtual balises based on satellite navigation. The introduction of satellite navigation for trains opens doors to other functionalities for example for track-side staff and track workers who could be equipped with Personal Position Reporting units (PP-Rep) which could be integrated into their mobiles (OPH and OPS – operational purpose handheld and operational purpose handheld for shunting). Such solutions are even capable of working in tunnels thanks to inertial accelerometers.

45 Visualisation based on GSM-R overview taken from EIRENE SRS

46 ERTMS/ETCS System Requirements Specification, issue 3.4.0 which is applicable for all new installations on-board of the trains since January 2019 foresees satellite based coordinates defining reference locations in radio messages transmitted by GSM-R. As a result virtual balises can be introduced without any changes in ETCS and GSM-R specifications.

5.5 Future Railway Mobile Communication System (FRMCS)

As identified above, the current GSM-R system is based on obsolete technology and as such the railways have, through a coordinated initative, started to work on the Future Railways Mobile Communication System FRMCS.

The GSM-R, which is a narrowband system based on 2G technology, will be replaced by FRMCS 5G-based communication technology providing better critical means of communication as well as additional non-critical means of communication including broadband services.

The three critical communication services are voice for operational purposes (especially between dispatchers and train drivers), voice for shunting and data transmission for ETCS (especially between Radio Block Centres and ETCS on-board units for ETCS levels 2 and 3). This update is necessary as, first of all, narrowband GSM-R cannot meet the growing demand for non-critical services, especially those requiring large amounts of data and therefore broadband services improve operation. Secondly, the old technology offers limited possibilities in terms of protection against an increasing number of hazards including cyber-attacks and cyber-crime. Thirdly, GSM-R is expected to be supported by the industry only up to 2030. It is therefore assumed that rail must be ready to begin transitioning to a new communication system by 2022, at the latest by 2025.

For this to happen, firstly the FRMCS must be fully standardised technically, then in EU, it must become legally binding (the GSM-R documents are currently binding on the basis of the EU regulations) and then it must be introduced along railway lines to replace GSM-R by 2030, without compromising safe operation, particularly during the transition period. Standardisation processes consider the implementation of current GSM-R (180 000 km of lines and more than 40 000 of trains only in Europe) with 99.95 per cent availability.

The overall structure of mobile communication will be cellular and very similar to GSM-R shown in figure II-16. However, there will be significant differences in future technical solutions. It is intended to migrate seamlessly to a new **core** ensuring the same functionalities of the Network Switching Subsystem. It will also need to integrate well with the backbone and local **transmission networks**, consisting in particular of fibre-optic cables and transmission equipment to migrate seamlessly to new solutions. There is still an open question whether new **radio sites** will have to be installed. It will rely on tried and tested basic technology to ensure appropriate performance and use defined frequency band. It will also rely on the ability and willingness of rail infrastructure operators to move towards the installation of new sites, taking into account not only financial but also other constraints such as land, environmental and regulatory constraints. The GSM-R frequency bands must be retained at least during the transition period.

From the point of view of functionality, FRMCS is expected to offer more than GSM-R as it is designed to provide: train, multi-train, shunting, banking and maintenance voice communication, as well as ground-to-grand communication (currently almost exclusively cable-based), as well as data communication for automatic train control (ATC), automatic train operation (ATO), train integrity testing, remote control of engines, trackside maintenance warning systems, real time monitoring and control of critical infrastructure, asset management, on-board safety devices, etc. The approach to emergency communication is also expected to be significantly improved. While GSM-R offers REC (Railway Emergency Calls), FRMCS will also allow for public emergency calls as well as public emergency warnings.

5.6 Automatic Train Operation (ATO)

One of the challenges for the development of control systems is the implementation of technology that enables automatic train running (Automatic Train Operation – ATO).[47] The purpose of these systems is to eliminate or at least limit the role of a driver in the driving process. Conceptual work and the first experiments on ATO systems were carried out as early as in the 1960s. The large-scale implementation of such systems took place in the 1990s in metros and urban rail systems.

Some ATO systems are linked with Automatic Train Control (ATC) and in many cases Automatic Train Protection (ATP) where standard signalling operations such as route setting and train regulation are carried out by the system. The ATO and ATC/ATP systems will work together to maintain a train within a defined tolerance level. The five Grades of Automation (GoA) for trains are set out in the figure below (figure II-19). This automation enables: Improved punctuality, capacity, energy efficiency, flexibility and cost effectiveness.

Figure II–19 Main functions of ATO system

Grade of Automation (GoA)	Journey	Departure	Stopping at the station	Door closure	Disruption management
GoA 1	Locomotive driver with train protection system (ZUB, ETCS, etc.)	Locomotive driver	Locomotive driver	Locomotive driver	Locomotive driver
GoA 2	Locomotive driver with Automatic Train Operation (ATO) train protection system (ETCS)	Locomotive driver or automatic (ATO)	Automatic (ATO)	Automatic (ATO) or by locomotive driver	Locomotive driver
GoA 3	ATO, without locomotive driver, with train crew on board	Automatic (ATO)	Automatic (ATO)	Automatic (ATO) or by train crew member	As required: member of train crew
GoA 4	ATO, completely autonomous train journey without staff	Automatic (ATO)	Automatic (ATO)	Automatic (ATO)	As required: automatic, remote or with intervention staff

Source: ATO Basic Communication, smart rail 4.0. November 2018. www.smartrail40.ch.

Recent ATO tests include:

- August 2018 – high-speed train on the Beijing-Shenyang line (China)
- December 2018 – freight train on the Betuwe line (Netherlands)
- March 2019 – passenger train on the Groningen – Zuidhorn (Netherlands) line

[47] *ATO Basic Communication, smartrail 4.0.*, November 2018., www.smartrail40.ch [acces: 25 August 2019].

- 2019 – passenger train on the Groningen – Zuidhorn (Netherlands)
- 2019 – shunting locomotive, stations in Paris
- 2019 – regional diesel train in Northern Germany
- 2019 – electric multiple unit, Russian Federation.

Furthermore, a number of additional tests are planned:
- 2021 – France: freight trains
- 2022 – China: Beijing – Zhangjiakou, 350 km/h
- 2023 – France: RER, Paris
- 2025 – new generation TGV trains.

5.7 Conclusion

There will be a major technological leap in this area in the coming years and that many new solutions focused on rail traffic automation and the advancement of IT applications will be feasible. The development of technologies dedicated to the rail industry essentially follows dynamic development in the field of ICT.

The development of mobile communications systems (5G technology) and the improved quality of satellite-based navigation (GALILEO) should be expected in the coming years. This will be reflected in the development of rail traffic control and the management and maintenance of the infrastructure and rolling stock. The development of new systems should be followed by technology ensuring the safe operation of such systems.

The use of the European Rail Traffic Management System (ERTMS) is increasing in European States. It should also be noted that the rail traffic management system used in China (CTCS) is consistent with the European ETCS. This means that, in the field of telecommunications and rail traffic management, the development will not involve new competitive systems but will rather focus on the improvement of a uniform system for the Eurasian market.

New signalling systems, despite falling prices, are expensive and their implementation is a long-term process. In addition, consistency of investments in rolling stock with on-board CCS equipment and infrastructure with trackside equipment is required. For this reason, in many States, the new ETCS and older generation signalling systems will continue to operate in parallel for a while.

In the field of satellite navigation, the rapid development of applications for the rail industry based on the GALILEO for the EU and associated States, on GLONASS for the Russian Federation and the Commonwealth of Independent States and on BEIDOU for Asian region are expected in the coming years.

The unification and globalisation of technical solutions in the field of telecommunications and traffic management is likely to encourage the development of the rail market. This technological progress will probably manifest itself through the evolution of current systems such as ERTMS or FRMCS.

6. Operation and Maintenance in HSR Management Systems

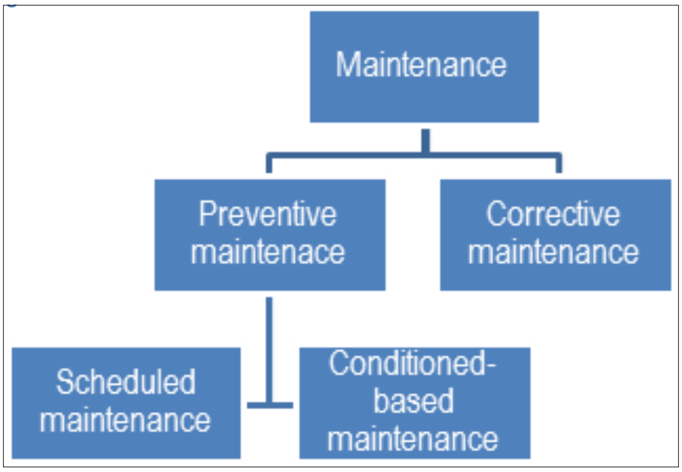
6.1 Maintenance

6.1.1 Specificity of High-Speed Line Maintenance

Definition and purpose

Stringent maintenance requirements are necessary to ensure a safe, comfortable and timely HSR system. Generally, the objective of maintenance is to maintain technical parameters of the system components at the same level of quality and safety. This is done through planned and unplanned maintenance (the latter is relevant when a failure occurs). Planned maintenance is divided into preventive maintenance and corrective maintenance.

Figure II–20 Classification of maintenance activities



Source: Own work.

Efficient maintenance systems aim to:

- ensure the safety of the system and the reliability and availability of system infrastructure;
- ensure dynamic maintenance with a quick response time at an optimal cost;
- establish an extended data base ensuring accurate analyses to assist maintenance planning and categorisation (e.g. short, middle or long-term maintenance);
- address asset management issues/requirements.

Generally, four levels of maintenance are identified:

- **Level 1:** Interventions in situ; no intervention of the supplier is necessary; maintenance can be carried out without adversely affecting the availability of the infrastructure and the regularity of operations.
- **Level 2:** Intervention of the maintenance team from the maintenance base; maximum availability to ensure redundancy of parts; interventions require control devices and special tools in some cases.
- **Level 3:** Intervention of the supplier; control and repair performed by the technicians of the supplier at the supplier's site; if possible, application of standard exchange of parts.
- **Level 4:** Complex replacements and repair works. These have a significant impact on the availability of infrastructure.[48]

[48] Maintenance of High-Speed Lines. Report. Hugo Goossens, E-RAILCONSULT. UIC 2010.

Legal obligation

In HSR systems, compliance with maintenance procedures is particularly important.

In the European Union, infrastructure maintenance processes are subject to the TSI INF (which describes maintenance rules) and the Directive of railway safety 798/2016. Maintenance rules are developed within the procedures specified in the infrastructure manager's safety management system. The maintenance file shall be prepared before a line is put into service as the part of the technical file accompanying the declaration of verification. The maintenance plan for the subsystem shall be developed to ensure that the requirements set out in this TSI are maintained throughout the lifetime of the subsystem.

Every facility and subsystem shall have a *maintenance file* containing the following track geometry related quality and limits on isolated defects:

- A set of values for immediate action limits;
- The measures taken (for example speed restriction, repair time) when prescribed limits are not met.

The infrastructure manager shall have a maintenance plan containing the above-listed items together with at least the following:

- A set of values for intervention limits and alert limits;
- A method statement, professional competences of staff and personal protective safety equipment necessary to be used;
- The rules to be applied for the protection of people working on or near the track;
- The means used to check that in-service values are respected;
- The measures taken, for speeds of more than 250 km/h, to mitigate the risk of ballast pick up.

Background for condition-based maintenance (CBM)

Condition-based maintenance has been introduced to maintain the correct equipment at the right time. CBM focuses on the use of real-time data to prioritise and optimize maintenance resources. The system that underpins this continually assesses the condition of the equipment, and only reacts when maintenance is actually necessary.

In recent years, a special emphasis has been put on the implementation of condition-based maintenance, as maintenance costs have a strong impact on the life-cycle of infrastructure, as cost considerations have become one of the most important areas of focus for the railways. The latest trend is to base the maintenance on the method of assessing technical condition of a device and to determine, by means of the acquired data, which maintenance activities that should be performed in a given moment.

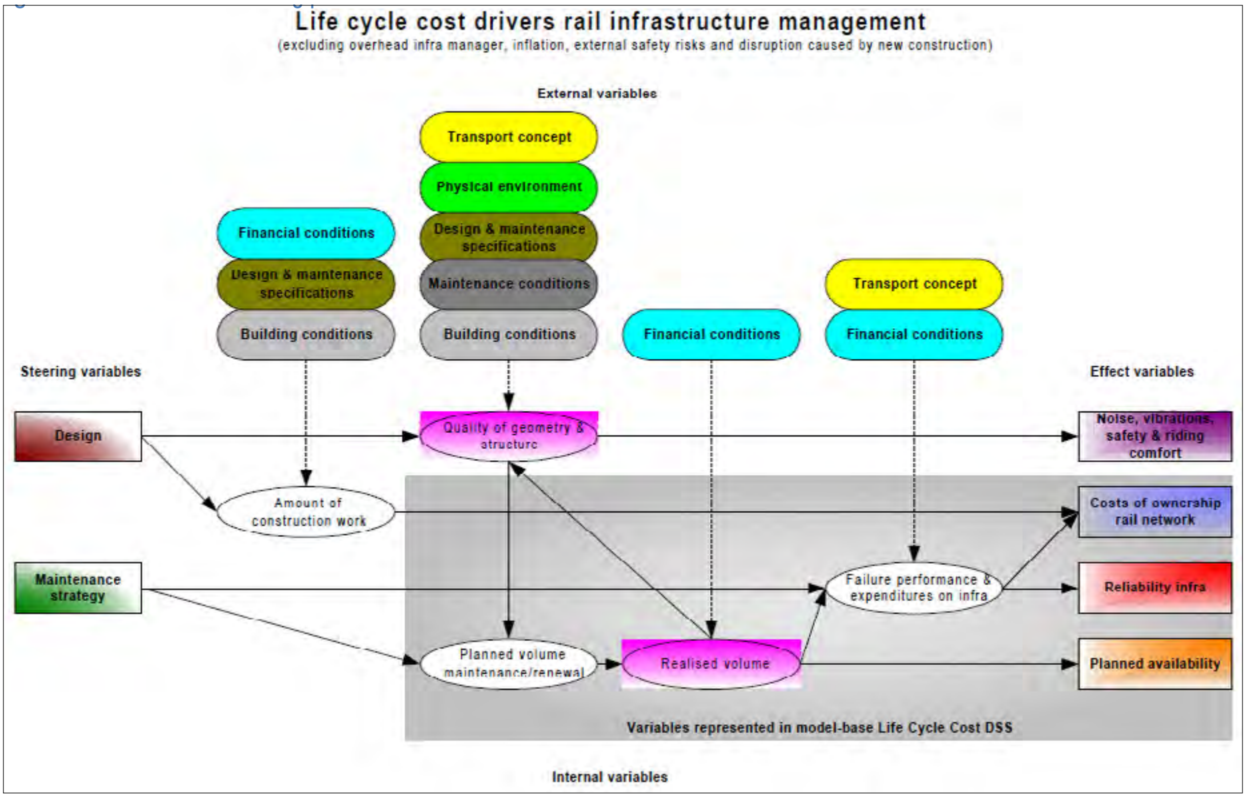
Significant progress has been made in recent years in improving the economic efficiency of maintenance processes. Large-scale implementation of IT systems has made it possible to gather a large amount of data on the scope and cost of maintenance works. The data collected has become the basis for the analysis on the classification of costs and their origins and the subsequent implementation of maintenance planning tools based on the following categories:

Document preparation costs

- Investment costs
- Maintenance costs
- Operating costs
- Disposal costs.

Figure II-21 shows the main life-cycle cost drivers in rail infrastructure management, excluding the overheads of the infrastructure manager, inflation, external safety risks and disruption caused by new construction.

Figure II–21 Factors influencing performance of rail infrastructure



Source: Zoeteman Arjen: *Life-cycle cost analysis for managing rail infrastructure*. Concept of a decision support system for railway design and maintenance.[49]

6.1.2 Maintenance management practices

This section sets out a number of examples of different maintenance management practices.

Example 1: Infrastructure maintenance strategy – China Railway, high-speed lines up to 350 km/h

Maintenance works are divided as follows:

1) Preventive maintenance
- Daily inspection
  Every day, the first train is run without passengers as an inspection train to check whether the HSR equipment is in good condition to operate the first passenger train.
- Comprehensive tests
  Performed by comprehensive inspection train every 10 days to carry out a physical examination of HSR infrastructure (track, signals and communications, catenaries, and wheel–rail interaction).

[49] A. Zoeteman, *Life-cycle cost analysis for managing rail infrastructure. Concept of a decision support system for railway design and maintenance*, Delft University of Technology 2001.

- Periodical inspections
  Performed by an inspection train at different intervals (month, quarter, year).
  The Communication and signal maintenance focus remains on preventive maintenance through a combination of on-the-ground monitoring, data collected by inspection trains, and the remote monitoring of the on-board systems.

2) Corrective maintenance

Depending on the type and level of HSR faults detected, the railway maintenance department repairs or replaces the track and catenary components during its maintenance activities. CRC also uses a maintenance window of 240 minutes each night to conduct a static periodic inspection of the line and make any necessary track geometry adjustments.

Table II–21 High-speed infrastructure maintenance schedule in China Railways (CRC)

Method	Subject	Equipment	Interval
Dynamic	Track geometry status	Integrated test train	10 days
	Vehicle dynamic response	Integrated test train	10 days
	Wheel and rail dynamics	Integrated test train	10 days
	Unit status	Comprehensive inspection train	Quarter
	Rail detection	Rail detection train	Month
	Subgrade, track bed status	Address radar detection train	Year
	Track stiffness	Track loading train	Year
	Tunnel lining status	Tunnel inspection train	Year
Static	Track geometry status	Track inspection equipment	Month
	Line profile	Profile tester	Year
	Tunnel, track bed surface condition	Laser profile measuring instrument checker	Year
	Switch and regulator	Inspection equipment	Year
	Rail status	Flaw detector, profile inspection equipment	Month
	Track	Track monitoring device	Year
	Precision measurement network	Total station precision measurement car	Year

Source: China's High-Speed Rail Development. Martha Lawrence, Richard Bullock, and Ziming Liu. World Bank Group, 2019.[50]
UIC IRS 60675 Implementation of a high-speed – Railway – Operation Phase.[51]

Example 2: Outsourcing of some activities in ADIF (Spain)

In traditional integrated railway enterprises in Europe, the function of maintenance management is performed by the companies themselves.

ADIF in Spain has adopted a different approach for the Zaragoza – French border line where a contract with an external party for the maintenance of infrastructure, track, and trackside devices has been established. In this case, ADIF entered into a 4-year contract worth over €52 million for the carrying out of the following works:

- Maintenance of track geometry quality
- Maintenance of the geometric quality and the condition of the track equipment
- Monitoring and maintaining proper operation of the components of the track superstructure
- Maintenance of longitudinal and transversal drainage systems while in full operational status
- Maintenance of line enclosures and fencing, including their anti-vandal security doors
- Other related tasks.

[50] M. Lawrence, R. Bullock, and Z. Liu, *China's High-Speed Rail Development*, World Bank Group 2019.

[51] UIC, *UIC IRS 60675 Implementation of a high-speed – Railway – Operation Phase*, 2018.

6.2 Operation

6.2.1 Organization

The planning of high-speed line rail traffic management systems is a very important economic issue. The definition of the scope of activities and organizational rules should take place at the stage of the feasibility study for the construction or modernisation of the line.

Many entities are involved in the operational process, each with their own task and according to relevant national and international legislation. The duties and responsibilities of the infrastructure managers in the EU are set out in the following directives:

- Directive 2012/34 establishing a Single European Railway Area and concerning the rules of infrastructure availability to the operators.
- Railway Safety Directive 798/2016.

In some cases, a similar approach is also applied in other States outside the European Union. The division of responsibilities between operational entities is as follows:

1) Infrastructure manager that performs the following tasks:
   - Rail traffic management
   - Maintenance organization (can be performed as part of outsourcing)
   - Ensuring the required level of safety

2) Railway carriers (there may be several of them on a railway line or network):
   - Perform transport according to the planned timetable
   - Manage rolling stock and cabin crew

3) National safety authorities as supervisory authorities are in charge of:
   - Issuing certificates on infrastructure components and rolling stock in service
   - Issuing licenses for carriers and authorisation for the infrastructure manager
   - Supervision over railway safety.

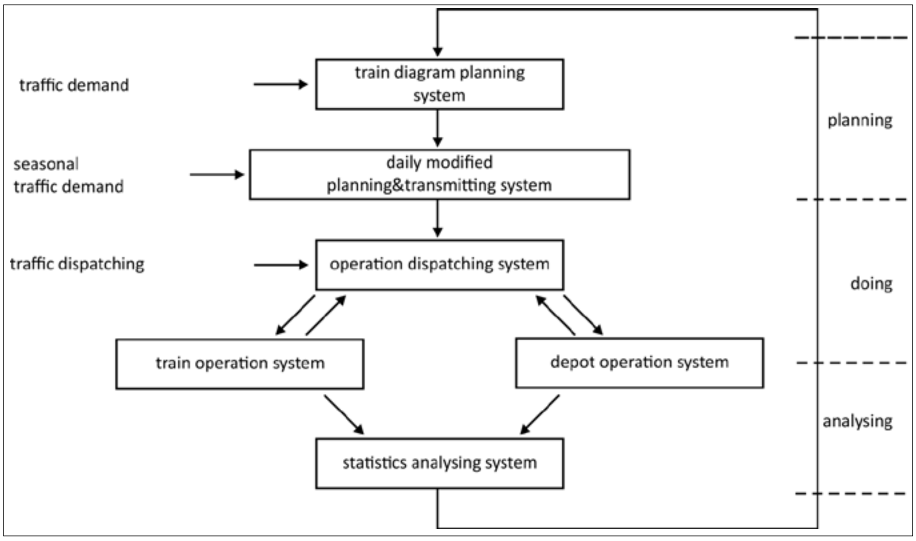
6.2.2 Operations management

Efficient operations management requires:

- Smooth traffic management on high-speed lines
- Optimal integration of high-speed lines into smaller or bigger railway nodes of the existing conventional network
- Structured crisis management resulting from emergency situations
- Planning of line closures for maintenance works
- Cross-border co-operation.

Operational control systems are based on the pillars of planning (of operations and maintenance schedules), implementing and analysing as shown in figure II-22:

Figure II–22 Train Operation Control System



Source: High-Speed Train Operation Control System. Bei Wang.
IOP Conf. Series: Materials Science and Engineering 452 (2018) 042109.[52]

6.2.3 Traffic Control Centres

Control centres are set up for traffic management on the HSR network. Centralised Traffic Control (CTC) consolidates train routing decisions that were previously carried out by local signal operators or the train crews themselves. The system consists of a centralised train dispatcher's office that controls interlocking and traffic flows in portions of the rail system designated as CTC territory. One hallmark of CTC is a control panel with a graphical depiction of the railroad.

The location of these centres depends on the design of the high-speed network. In addition to the primary service of high-speed lines, control centres are also established on the outskirts of the high-speed network. They play a key role in integrating traffic at the interface between high-speed and conventional lines. The number of centres also depends on the structure of the high-speed network. In France, for example, with a monocentric network, CTCs are located in the centre of the system (in Paris) and at the ends of outbound lines from Paris. A similar situation is also seen in Spain. CTC's location in Germany is highly diversified due to the polycentric high-speed network system. The main locations of the operations centres in Europe is shown in figure II-23.

[52] B. Wang, *High-Speed Train Operation Control System*, "IOP Conf. Series: Materials Science and Engineering 452 (2018) 042109".

Figure II–23 Location of the operations control centres in Europe

Source: UIC Atlas of High-Speed Railways, 2019.

6.3 Conclusion and recommendation

The plans for the maintenance and operation of high-speed railway lines need to be determined during the feasibility stage. General recommendations for the maintenance and operations include:

- The maintenance of the railway line should be performed by the infrastructure manager on its own or in outsourcing depending on appropriate technical and economic analyses. The outsourcing option may, from the economic and organizational point of view, be attractive to smaller rail networks where the fixed costs of technical equipment and maintenance are relatively high compared to total costs.
- Condition-based maintenance is recommended in order to allow cost optimisation, but this requires extensive experience of the relevant entities or the transfer of appropriate technology, for example from the manufacturer. The full transition to the condition-based maintenance model involves the development of appropriate skills, which is a time consuming process which ultimately results in increased safety and economic efficiency for rail traffic. The operation of such systems requires a large transfer of data which is feasible with the use of 5G technology.

The supply industry is in the process of unifying a number of processes in the field of railway maintenance across Europe. This is also happening in Asia which will facilitate interoperability. Work on the regulatory framework within the TSI 2022 Project is currently underway where rail digitalisation and its interoperability is one of the main tasks. This includes new legal standards for telecommunications, the development of ERTMS towards the automation of trains and software for rail traffic control.

7. Examples of HSR projects in TER States

7.1 Background

The total number and length of high-speed lines in TER States with high-speed trains with a design speed of 250 km/h running in Poland and the Russian Federation, but on upgraded conventional lines. For example, in Poland, the upgraded line has track geometry that allows operation of up to 300 km/h, but only after the power supply system was changed and appropriate traffic control equipment was installed. The main example of a fully high-speed line in the TER region is the Ankara – Konya line in Turkey. In Austria, a system is being developed which integrates new lines with a speed of 250 km/h with the modernised ones that allow speeds of 200-230 km/h.

Currently TER States are preparing a large number of projects for new high-speed lines. In most cases, feasibility studies have been completed along with demand and economic analyses. To facilitate this analysis the following HSR projects have been analysed in a detailed manner:

1) Prague – Dresden (Czechia, Germany)
2) Warszawa – Łódź – Poznań/Wrocław (Poland)
3) Rail Baltica (Estonia, Latvia, Lithuania, Poland)
4) Moscow – Kazan (Russian Federation)
5) Belgrade – Hungarian Border (Serbia)
6) Halkali – Kapikule (Turkey).

These case studies have been supplemented by the following case studies on the implementation of high-speed trains running also on conventional lines:

1) Railjet in Austria
2) Sapsan trains on the Moscow – Petersburg Line
3) Allegro: St. Petersburg – Helsinki
4) Strizh: Moscow – Warsaw – Berlin
5) ED250 services in Poland
6) Ankara – Konya and Ankara – Istanbul in Turkey.

7.2 Examples of high-speed lines projects

7.2.1 Prague to Dresden High-Speed Line

Project description

The new HSR Prague – Dresden[53] is a part of TEN-T Core network, Orient/East-Med corridor. The length of the railway is 140 km with 123 km of new track. It is divided into the following sections:

1) Dresden – Usti nad Labem (56 km);
2) Usti nad Labem – Prague (81 km) with subsections:
   - Usti nad Labem – Litomerice/Lovosice
   - Litomerice/Lovosice – Prague.

[53] *New Railway Line Dresden – Prague in the TEN-T Orient/East-Med Corridor Prefeasibility Study*. Prepared for: Saxon State Ministry for Economic Affairs, Labour and Transport Ministry of Transport of the Czech Republic and SŽDC, December 2015.

Now in the planning phase, the feasibility study and the preparatory study are complete and the routing proposal has been prepared. In February 2019, the Ministry of Transport of Czechia indicated the sections Prague Litomerice/Lovosice and Usti nad Labem – CZ/DE border as one of the pilot high-speed lines to be constructed. The project is supposed to be supported by national and European funds.

The aim of the project is both to remove the bottleneck at the border and at main junctions, as well as to shorten the distance and travel time between Prague and the region of Saxony. The new line is expected to improve the competitiveness of rail between these two areas. The project provides for the high-speed line to have maximum speeds of between 200 and 350 km/h, depending on the section as well as the functional separation of traffic between the new and old line.

Investment and effects

The new high-speed rail line Dresden – Prague is considered to be one of the most important railway projects in Central Europe, linking Germany and Czechia with a cross border tunnel through the Ore Mountains. It is a vital part of the Orient/East-Med Corridor of the Trans-European Transport Network, which links the ports of the North Sea and Baltic Sea and the economic centres in the region of South-East Europe.

The newly planned railway line, which will serve both passenger and freight transport, will reduce travel time for passengers between Dresden and Prague from more than two hours to less than one hour. It will further increase the capacity of freight transport, reduce noise and traffic pollution in the Elbe Valley and provide a flood-safe connection to Czechia. The aim of the new railway line is to prevent a potential shift from rail to road due to insufficient capacity on the current rail network.

Scope of the project

- **Dresden – Usti nad Labem**

  The length of the section is approximately 56 km of which about 43 km is new track. The most challenging section of the line is the twin-tube tunnel beneath the Ore Mountains which will be at least 26 km long. The length of the tunnel on the German side will be just over 15 km and about 11 km on the Czech side. The historical corridor of Elbe Valley is too long and not capable of accommodating another line.

  Traffic on the section is planned to be 16 pairs per day of high-speed passenger services and up to 75 pairs per day of freight transit traffic. The intention is also to provide regional passenger trains running between Dresden and the region of North and West Bohemia (8 pairs per day). Due to the dominance of freight traffic, the design speed of the section is 200 km/h with freight trains limited to 120 km/h and passenger trains to 200 km/h. The maximum gradient is set at 12.5 per mil to facilitate freight movements. Additional passing loops have been foreseen close to the entrances of the tunnel and in Goes to maximise capacity, along with a branch in the direction of Teplice from Usti nad Labem as well as from Dresden.

  There are also two loops planned. Both are located in close proximity to the tunnel portals, with the distinction between the first one (Goes or Heidenau, depending on the line alternative) in Germany and the second one (Stradov) in Czechia. The loops will provide sufficient capacity for future expansion of passenger traffic. At the same time, a branch in the direction of Teplice from Usti nad Labem as well as from Dresden is being considered. A loop is also planned in Goes to provide sufficient capacity in the future.

  Apart from the shortening of the route and the reduction of travel time, one of the effects to be accomplished is less noise, as large part of the traffic will be diverted beyond the, now overloaded, Elbe Valley.

- **Usti nad Labem – Litomerice/Lovosice – Prague**

  Two subsections are considered between Usti nad Labem and Prague. The first subsection, Usti nad Labem – Litomerice/Lovosice will have mixed traffic, while the second subsection Litomerice/Lovosice – Prague will only have passenger traffic and therefore has a design speed of 320 km/h. The line is intended to serve only high-speed passenger connections from Prague to Germany and the region of North and West Bohemia. A regional terminal is being considered to improve transport services in Lovosice, Litomerice and Roudnice area, together with interconnections with the existing network. Nearby Líbeznice a branch line is proposed to connect the existing line towards Neratovice, which will intensify suburban traffic to the Melník district. The diversion of the majority of long-distance rail traffic from the existing lines along the Vltava River valley will help to create better opportunities for improving the frequency of commuter trains running from Kralupy nad Vltavou to Prague. The length of the Prague – Usti nad Labem section is 81 km of which 77 km will be new.

  The line will be routed along the D8 motorway to minimise the adverse impact on the local landscape. In the suburbs of Prague, the route will enter a 4.5 km tunnel under the densely urbanised areas of Prosek and Strizkov. The end of the tunnel is planned near the Vysocany railway station. The line will then follow the existing railway line from Lysa nad Labem to the main rail station in Prague and will cross over the area at Balabenka and several major streets. On the last 4 km to Prague's main railway station, the line will utilize the existing track running through tunnels under Vítkov hill.

Technical parameters

The parameters of the high-speed line Dresden – Prague have been shown in table II-22.

Table II–22 Parameters of the high-speed line Dresden – Prague

	Dresden – Usti nad Labem Section	Usti nad Labem – Prague Section
	Length of line	
Current route	85 km	106 km
New route	56 km	81 km
Length of new track	43 km	77 km
Length on German territory	22.5 km	
Length on Czech territory	20.5 km	81 km
	Travel time by train	
Current route	72 min	74 min
New route (incl. 2 min stop)	25 min	27 min
	Type of traffic	
Current route	mixed	mixed
New route	mixed: freight and passenger long-distance	passenger high-speed
	Design parameters	
Maximum design speed	up to 230 km/h	up to 350 km/h
Freight traffic speed	120 km/h	120 km/h
Number of line tracks	2	2

Table II–22 Parameters of the high-speed line Dresden – Prague (continued)

	Dresden – Usti nad Labem Section	Usti nad Labem – Prague Section
Design parameters		
Electrification	15 kV 16,7 Hz/25 kV 50 Hz change of traction current originally planned between the Usti nad Labem main station and the tunnel exit on the Czech side**	25 kV 50 Hz (3 kV DC)
Signalling system	ETCS	ETCS
Communication system	GSM-R	GSM-R
Maximum gradient	12,5‰ depends on the freight train parameters	>12,5‰

* In the Litomerice/Lovosice – Prague section; ** will be optimised in future planning.
Source: New Railway Line Dresden – Prague in the TEN-T Orient/East-Med Corridor Prefeasibility Study. Prepared for: Saxon State Ministry for Economic Affairs, Labour and Transport Ministry of Transport of the Czech Republic and SŽDC. December 2015. Feasibility study of the new line Prague – Drážďany. 2019.[54] Outputs from international meetings of work group.

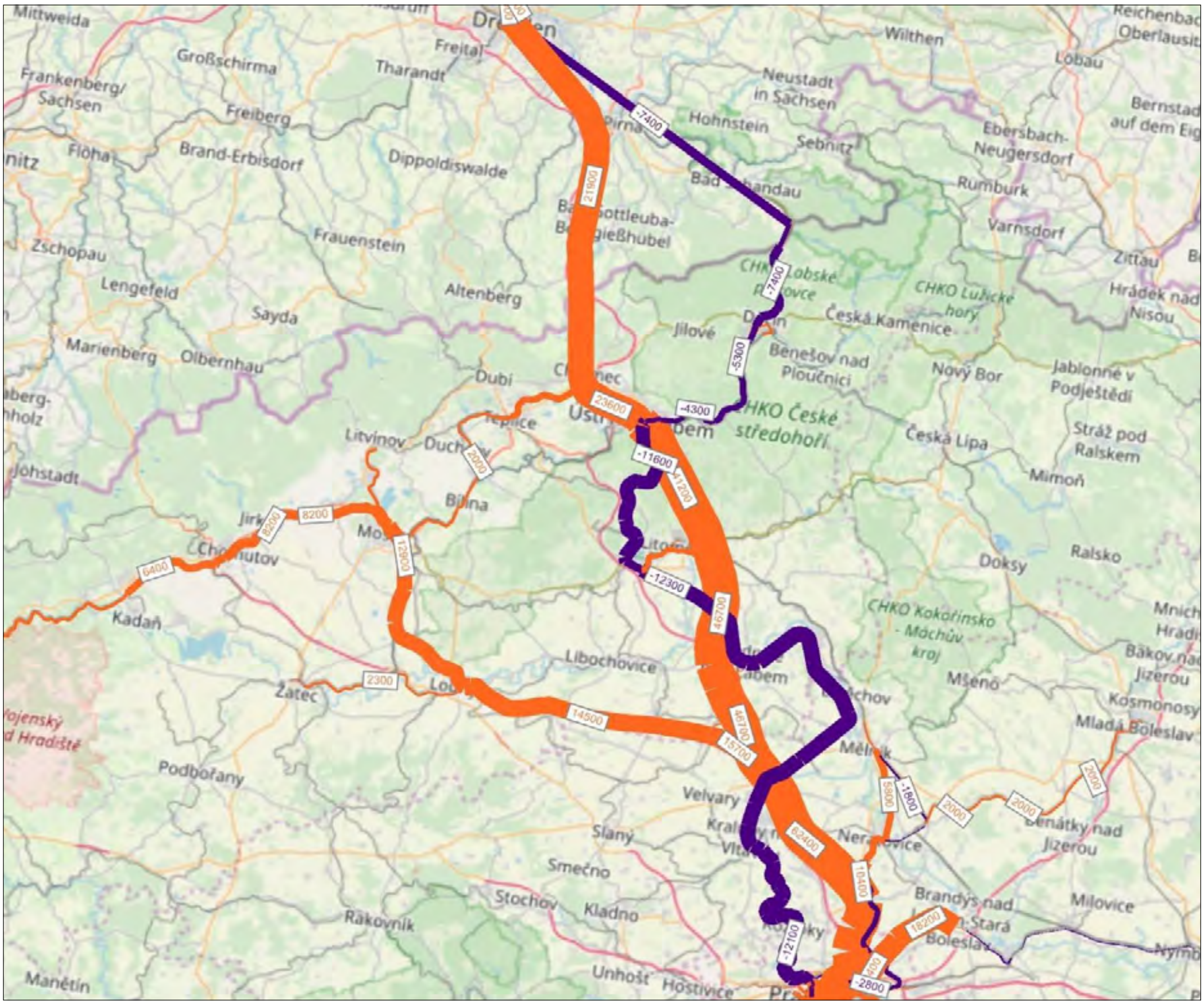
Traffic volume forecast

According to the projections in the master plan for HSR development in Czechia, the traffic volume in 2045 will be 22,000 people daily on the Usti nad Labem – Dresden section and up to 63,200 people on the Usti nad Labem – Prague line closest to Prague as set out in figure II-24 below.

© ADOBE STOCK

[54] CEDOP & Egis Rail;, *Studie proveditelnosti nového železničního spojení Praha – Drážďany*, 2019.

Figure II–24 Forecast of the passenger traffic flow on the Prague – Dresden line



Source: Feasibility study of the new Prague – Drážďany line. 2019.

Transport capacity

The current plan is to implement an hourly high-speed passenger service (double the current offer) and to further increase freight traffic above the current forecast (135 trains per day). Four freight trains per hour in each direction could run during the day (6 a.m. – 10 p.m.), when express trains and commuter trains are operated. Up to eight freight trains per hour could run in each direction during the night (10 p.m. – 6 a.m.) in the absence of, or with relatively minor passenger traffic. Up to 150 freight trains per day and per direction could run on the new line in the Dresden – Usti nad Labem section, under the parameters and assumptions considered.

Economic effects of the project

By removing capacity "bottlenecks" on the existing network, rail transport along the TEN-T Orient/East-Med-Corridor will be improved. The main economic benefits and opportunities are the creation and development of trade and commerce and the establishment of new business, as well as inward investment in the regions which will become more accessible by rail. In terms of accessibility, the project will improve public access to education, training and job opportunities. It will also expand travel-to-work areas for businesses in the search for new employees, create new jobs during the construction phase and subsequent operation of rail services. Faster travel times will also increase tourism and leisure travel.

Modal shift will also lead to environmental benefits including lower levels of noise pollution compared to road transport, reduced CO_2 emissions resulting from a switch to electric traction and a better adaptation to climate change in the Elbe Valley. Finally, modal shift may also lead to improved road safety.

According to the *Studie proveditelnosti nového železničního spojení Prague – Drážďany*[55] estimated investment costs on the Czechia side is planned to be CZK 132 billion (excluding branch to Most) with an Internal rate of return for the project of 8.30 per cent.

7.2.2 High-speed line Warsaw – Lodz – Poznan/Wroclaw (Poland)

Background

The initial plans for a high-speed line in Poland were developed in the 1980s for the CMK (Central Trunk) Warsaw – Katowice. The second high-speed line was planned for the East – West axis: Warsaw – Lodz – Poznan – Berlin. At the beginning of the 1990s, a feasibility study was prepared for the line connecting the western and eastern borders of Poland as part of the Berlin – Moscow line.

In 2001, plans were put forward to modify the foreseen high-speed network in Poland with the development of the following axes:

- Southwestern Poland – North-eastern Poland (connecting Wroclaw and Bialystok via Warsaw)
- North-western Poland – South-eastern Poland (connecting Szczecin, Poznan and Lublin, Rzeszow via Warsaw)
- North Poland – South Poland (connecting Gdansk –- Lesser Poland Region and Upper Silesia Region via Warsaw)
- Greater Poland Region – Lesser Poland Region (Poznan – Cracow via Lodz)

The axes were to build to high-speed standards, complemented by lines modernised to higher technical parameters.

As a first step, the prefeasibility study for high-speed line from Warsaw to Lodz was completed in 2005. In 2006, the EU granted funds as part of Operational Program Infrastructure and Environment for the feasibility study and other preparatory works of the new line construction. A similar feasibility study on the modernisation of the CMK line (upgrading to the high-speed line parameters and expanding the line to Katowice and Cracow and to the border of the country) also received funding.

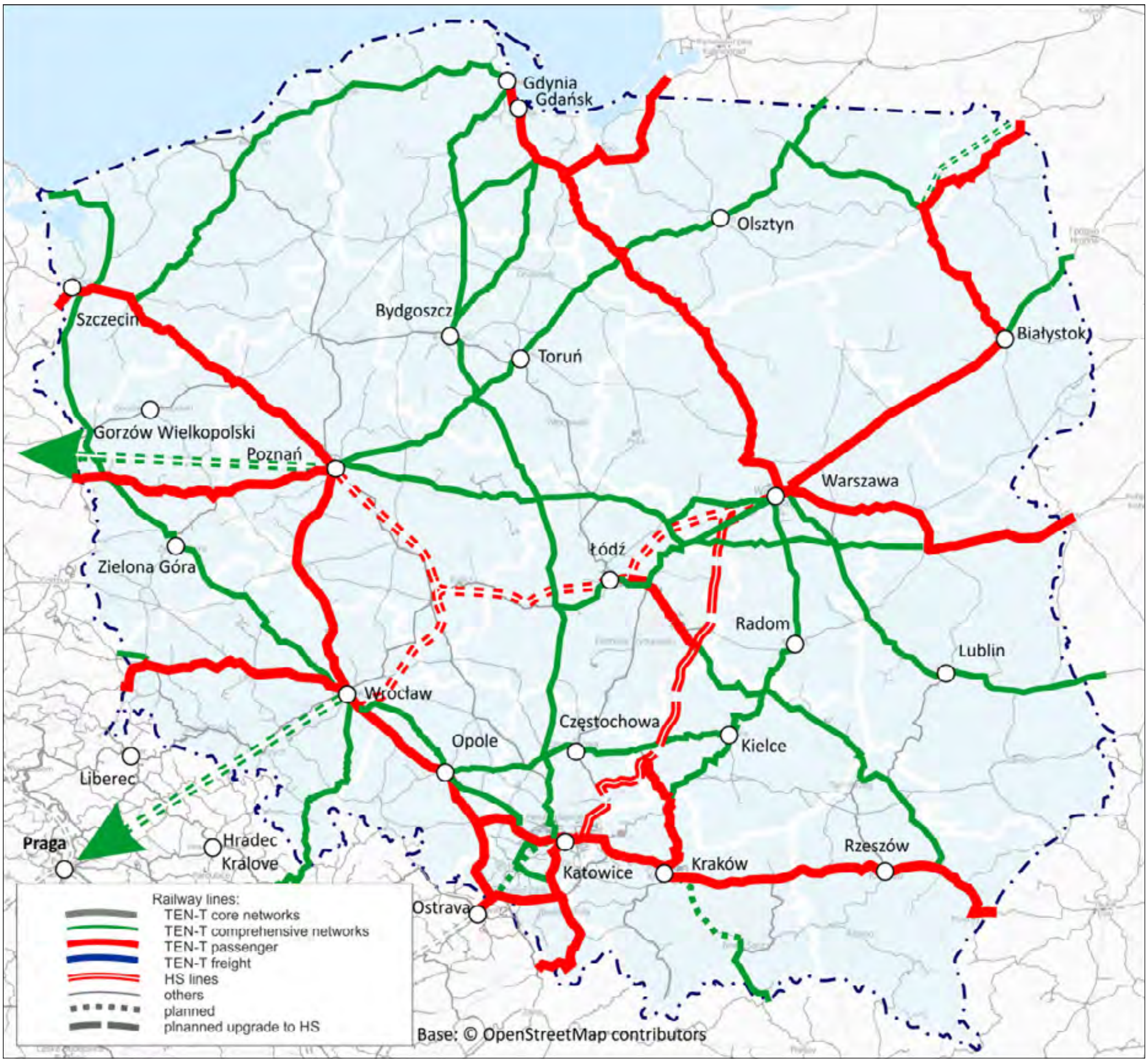
The Resolution of the Council of Ministers regarding the Program for the construction and launch of high-speed rail transport in Poland was adopted in 2008. It included the following projects:

- Construction of the high-speed line Warsaw – Lodz – Kalisz/Ostrow Wielkopolski – Poznan/Wroclaw;
- Modernisation of the CMK high-speed line and extension of the line to Katowice and Cracow and construction of an additional high-speed line from Katowice to Ostrava;
- Construction of the high-speed line to Germany and Czechia;
- Complementary activities including modernisation of nodes, railway lines and other supporting and development studies.

In December 2011, the Polish Government suspended HSR related works in Poland up to 2030 but after 2015, they restarted. The new line has been incorporated into the TEN-T network, in line with the EU Regulation 1315/2013.

[55] CEDOP & Egis Rail;, *Studie proveditelnosti nového železničního spojení Praha – Drážďany...*, op. cit.

Figure II–25 Trans-European passenger transport network with high-speed line on the background of complex network in Poland due to the EU Regulation 1315/2013



Source: EU Reg. 1315/2013.

Scope of the HSR project Warsaw – Lodz – Poznan/Wroclaw

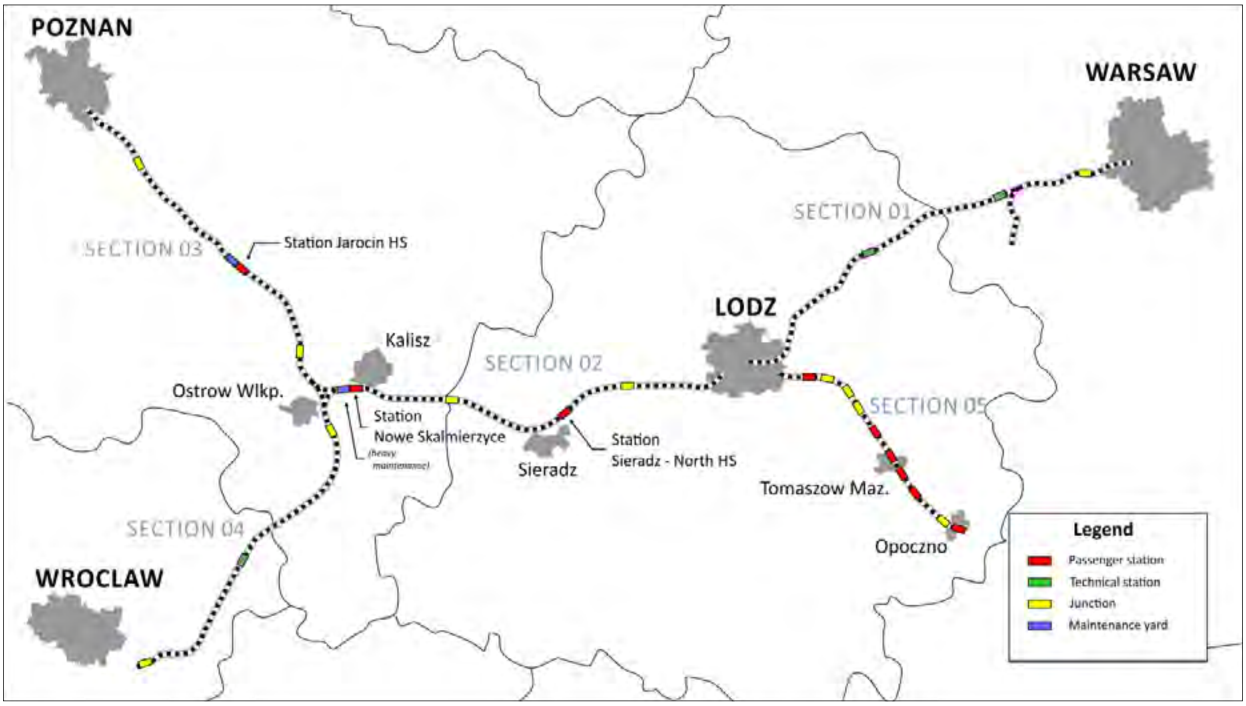
The "Feasibility Study for a HSR Warsaw – Lodz – Poznan/Wroclaw"[56] is a key document for the implementation of the Program. The work began in 2010 and was completed in 2013 including environmental impact reports. Two routes of the line were analysed in the study with additional variants also assessed. The most suitable option was to connect Warsaw via the centre of Lodz (tunnel with underground station), Kalisz and Ostrow Wielkopolski (with station between cities) and then splitting to Poznan and Wroclaw. Two additional connections were also planned:

- In the Ostrow Wielkopolski area, a connection between Poznan and Wroclaw branch lines, will create a high-speed link between Poznan and Wroclaw and the south of Greater Poland.
- In the area of Wroclaw, a direct connection from Poznan to Opole and Katowice.

[56] Consorcium IDOM Ingenieria y Consultoria S.A. & IDOM Inżynieria Architektura i Doradztwo Sp. z o.o., *Feasibility Study to construction high-speed line Warszawa – Lodz – Poznan/Wroclaw*, Warsaw 2013.

In addition, the feasibility study on connecting the new line to the CMK line was prepared in accordance with EU Regulation 1315/2013 which required the modernisation of the existing line in the Lodz – Opoczno section.

Figure II–26 Route of high-speed line Warsaw – Lodz – Poznan/Wroclaw



Source: Feasibility Study for the construction of high-speed line Warszawa – Lodz – Poznan/Wroclaw. IDOM, Warsaw 2013.

The design of the Warsaw – Lodz – Poznan/Wroclaw line includes a new section of the line connecting this line to the CMK line. This section would start 28 km from the Warszawa Zachodnia station to the Korytów station on the CMK line in the direction to Katowice. Trains departing from Warsaw to Katowice and Krakow will use part of the section from Warsaw to Lodz and will then travel south along the route from Korytów to Gdansk that was planned in the 1970s (extension of the existing CMK line to the north). The link to planned to the new airport on the west of Warsaw was also planned.

The recommended route was agreed in 2012 (figure II-24); the selected option was identified, and the study was completed in 2013.

Following the adoption of the EU Regulation 1315/2013, the next step in the implementation of the Program was the development of a prefeasibility study for the high-speed lines Wroclaw – Prague and Poznan – Berlin, as the extension of Warsaw – Lodz – Poznan/Wroclaw line, with its inclusion in the trans-European high-speed line network.

Studies for the Lodz Railway Node were also completed as part of the project. The Lodz Railway Node was to provide a link to the conventional railway network. The idea of the redesign of the node was presented in 2007. The concept included the construction of a cross-city line in a tunnel under the city centre and the construction of a new underground station. The feasibility study, completed in 2011, included the construction of two tunnels, for conventional and high-speed rail. The project is now in the implementation phase and is expected to be completed by 2023. The Lodz Fabryczna railway station was built and opened in December 2016 and was the first fully equipped high-speed rail station in the country.

As a result of reviving the HSR concept in Poland from the beginning of the 2016, in 2017, modifications to routes were considered in relation to the plan to build a new central airport west of Warsaw (approximately 30 km).

Technical specification

Table II–23 Parameters of the line

Parameter	Warsaw – Lodz – Poznan/Wroclaw line
Length	448 km
Basic parameters	Complies with TSI INF, TSI SRT, TSI PRM
Maximum speed	350 km/h
Electrification system	25 kV 50 Hz 3 kV DC in existing nodes
Signalling system	ERTMS 2

Source: Feasibility Study for the construction of high-speed line Warszawa – Lodz – Poznan/Wroclaw. IDOM, Warszawa 2013.

Traffic forecast

The table below sets out the assumed travel times between Polish regions (table II-28) assuming maximum speeds of 300-350 km/h.

Table II–24 Assumptions of travel time between Polish regions

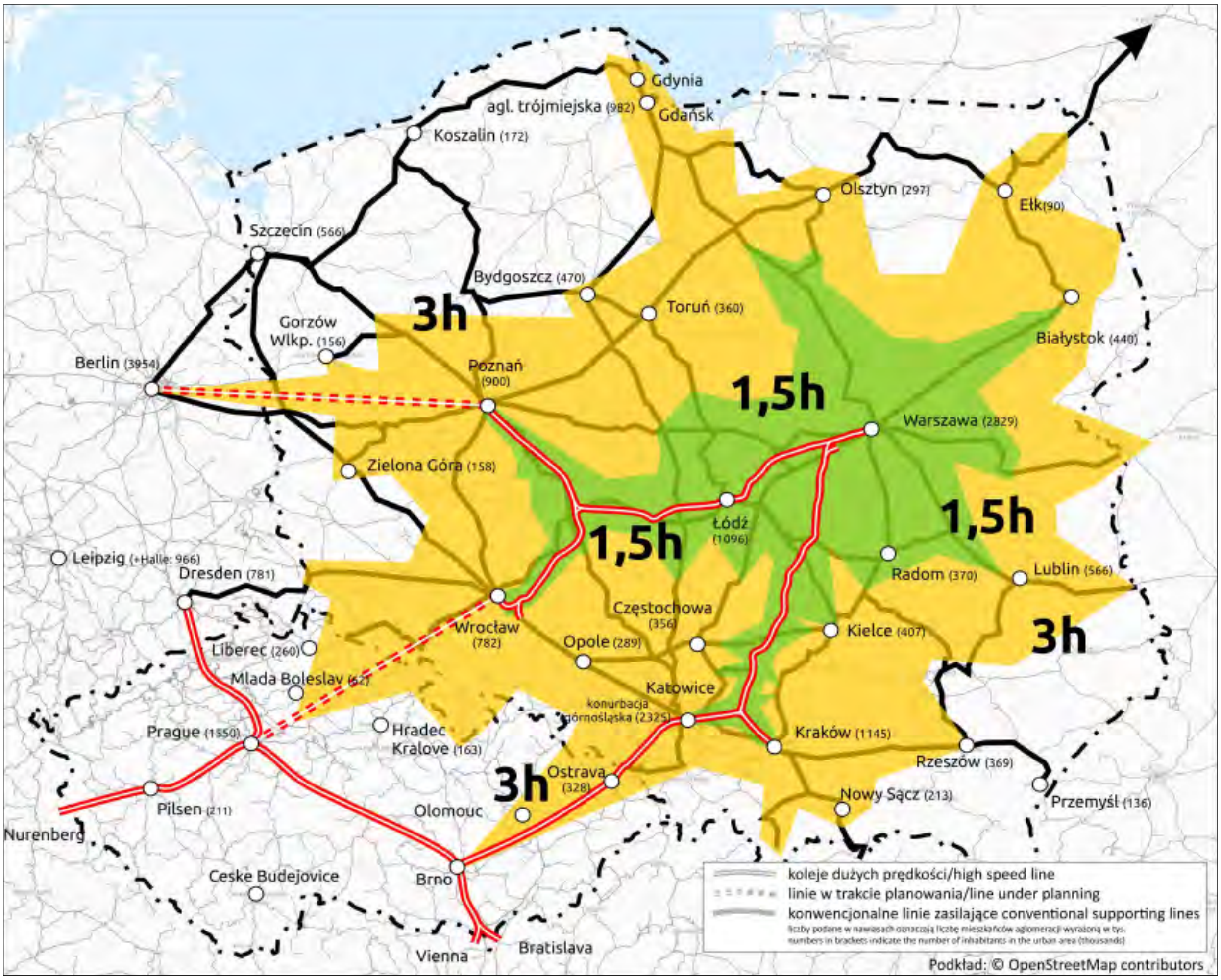
Connection	Travel time
Warsaw to the major cities of Poland at a distance of 300 km (Poznan, Wroclaw, Cracow, Katowice, Lodz, Bialystok)	1 hour 30 minutes or less
West Poland cities to East Poland cities (Poznan – Lublin/Bialystok, Wroclaw – Bialystok/ Lublin, Poznan – Cracow)	3 hours or less
Warsaw to the cities of the neighbouring provinces (Szczecin, Zielona Gora, Jelenia Gora, Zgorzelec, Zakopane, Rzeszow, Olsztyn, Gdansk)	3-4 hours or less

Source: Directions of high-speed rail development in Poland. PKP PLK S.A., Warsaw 2011.[57]

Given this new infrastructure figure II.36 shows the accessibility of Polish Regions from Warsaw with 1.5 hours and 3 hours travel time by high-speed services. The subsequent image, figure II-37, shows the expected travel time savings.

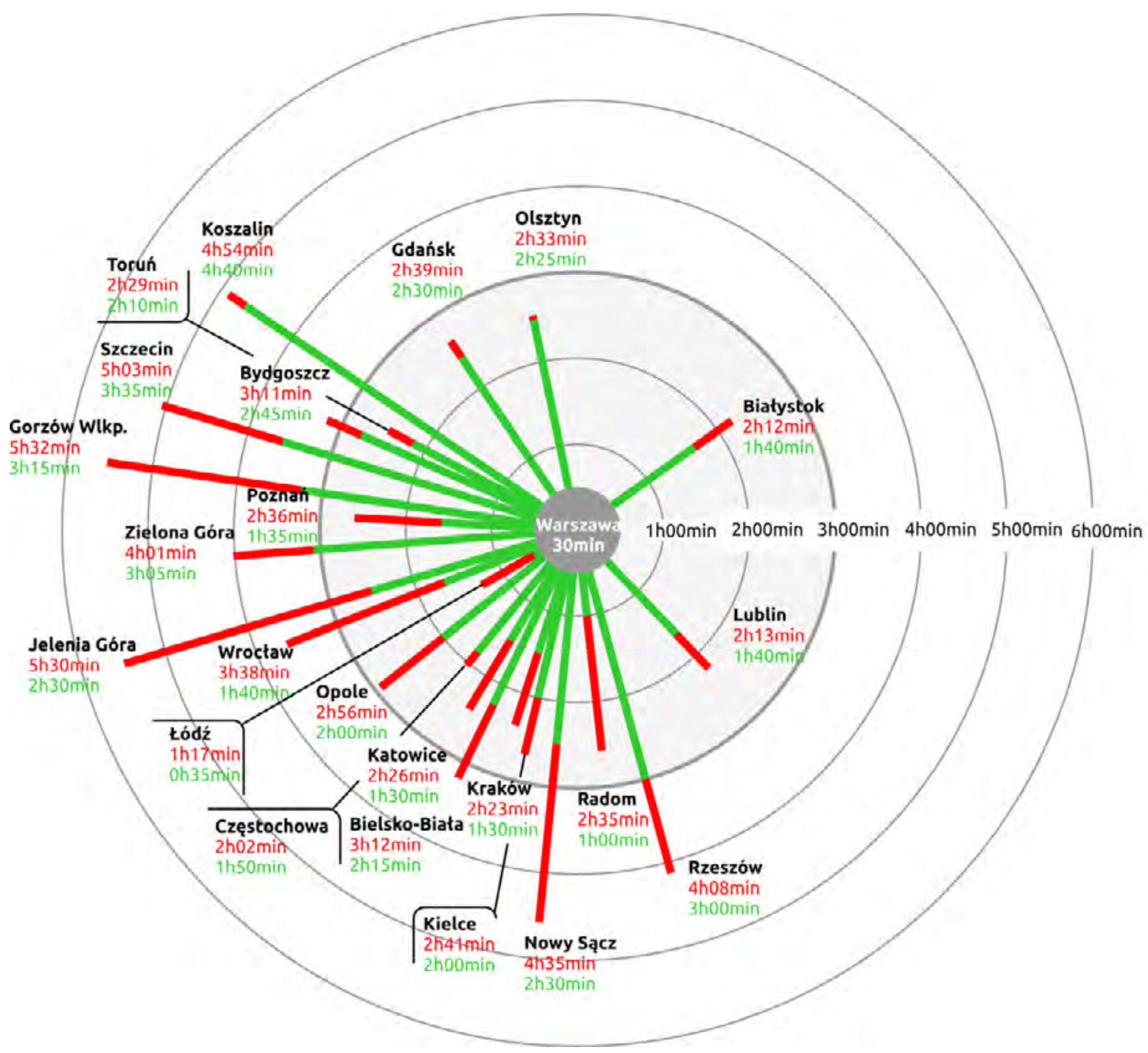
[57] PKP PLK S.A., *Directions of high-speed rail development in Poland.*, Warsaw, 2011.

Figure II–27 **Accessibility of metropolitan areas from Warsaw after completion of high-speed rail system in Poland**



Source: Own work.

Figure II–28 Travel time from Warsaw, current and expected in the high-speed rail program



Source: Own work.

Freight traffic on the high-speed line will be possible as long as enough capacity available.

Table II–25 Estimated demand

Route	Daily number of passengers
Warsaw – Lodz	17 858 – 19 065
Lodz – Kalisz	24 803 – 26 485
Kalisz – Poznan	22 900 – 27 527
Kalisz – Wroclaw	17 392 – 21 806

Source: Feasibility Study for the construction of highspeed line Warszawa – Lodz – Poznan/Wroclaw. IDOM, Warsaw 2013.

Economic indicators

Table II-26 shows the expected costs and economic indicators for the lines

Table II–26 Selected findings for various sections of planned high-speed lines

<table>
<tr><th>Line's section</th><th>ERR [%]</th><th>B/C</th><th>ENPV [billion PLN]</th><th>Estimated construction cost [billion PLN]</th><th>Length [km]</th></tr>
<tr><td>Y: Warsaw – Poznań/Wrocław</td><td>6.3</td><td>1.2</td><td>4.6</td><td>23</td><td>448</td></tr>
<tr><td>Y: Poznań – PL/DE border (Berlin)</td><td>4.6-11.8</td><td>n/a</td><td>1.1-4.4</td><td>8</td><td>171</td></tr>
<tr><td>Y: Wrocław – PL/CZ border (Prague)</td><td>5.4-9.7</td><td>n/a</td><td>2.3-5.4</td><td>10</td><td>148</td></tr>
<tr><td>CMK: Grodzisk – Zawiercie</td><td>6.7-14.5</td><td>2.3-4.6</td><td>2.7-13.7</td><td>5</td><td>224</td></tr>
<tr><td>CMK: Knapówka – Katowice</td><td>9.9-21.0</td><td>1.9-5.1</td><td>5.2-9.4</td><td rowspan="3">10</td><td rowspan="2">138</td></tr>
<tr><td>CMK: Knapówka – Cracow</td><td>9.1-12.0</td><td>1.7-2.5</td><td>2.7-6.3</td></tr>
<tr><td>CMK: Katowice – country border</td><td>up 11.8</td><td>0.7-3.5</td><td>up 7.4</td><td>61</td></tr>
</table>

Source: Data from Feasibilities Studies: Feasibility Study for the construction of high-speed line Warszawa – Lodz – Poznan/Wroclaw. IDOM, Warszawa 2013. Y – means the line in shape of letter Y splitting in two direction.

In 2017, the Polish Government launched new initiatives aimed at the creation of a modern, consistent HSR network in Poland – in cooperation with the EU. The concept is based on being responsible, transparent and presenting sustainable development for the TER region, it has recently also reflected efforts to take into account the post-COVID-19 situation and challenges.

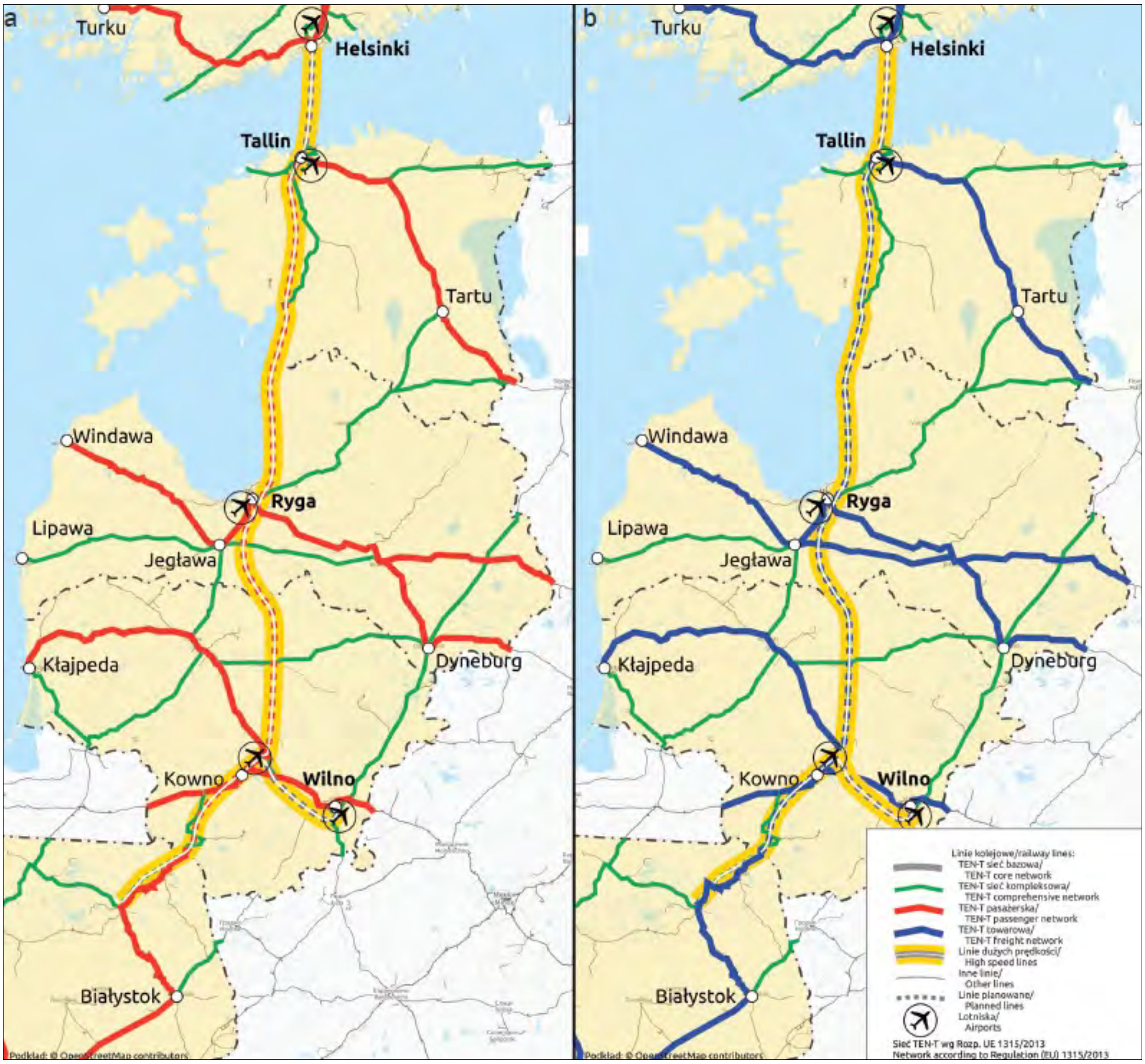
The centre of this network will be the Central Logistic Airport (CPK) – placed in the centre of Poland, 37 km west of Warsaw. There will be 10 new rail connections (called "spokes") covering almost all the country, shortening significantly time of travel to the Airport, also with the use of HSR. This project is one of the highest priorities for the Government and railway industry.

7.2.3 Rail Baltica: Estonia, Latvia, Lithuania, Poland

Background

The initial concept of creating a rail corridor through the Baltic States appeared and was presented in the 1990s, as part of the Trans-European Transport Network (TEN-T) project. It was to have high technical parameters and a link to the European high-speed railway network. After the accession of Estonia, Latvia, Lithuania and Poland to the European Union, the project gained importance as a tool to facilitate European Union integration and was included in the TEN-T Regulation as well as in the North Sea – Baltic Priority Corridor. The line is shown in figure II-29 below.

Figure II–29 Rail Baltica as TEN-T passenger and freight core network



Source: EU Reg. 1315/2013.

The feasibility study of the line was completed in 2011, complemented by an additional feasibility study of the Kaunas – Vilnius line in 2014, which also connects to the airports of the cities.

Technical parameters of the new line

Rail Baltica was assumed to have a maximum speed of no more than 250 km/h for passenger trains and 120 km/h for freight trains (prevailing on this line). Basic technical information is included in the table II-27.

Table II–27 Technical parameters of the Rail Baltica

Parameter	Data
Track width	1 435 mm
Line length	EE: 216 km LV: 263 km LT: 366 km PL: 373-397 km
Maximum speed	passenger trains – 250 km/h freight trains – 120 km/h
Number of tracks	2
Electrification	2 x 25 kV AC
Axle load	25 ton
Minimum length of station tracks	1 050 m

Source: Rail Baltica Global Project Cost-Benefit Analysis, Executive summary. Ernst & Young, 24 April 2017.[58]

Multimodality

It is assumed that the new line will be integrated into the transport structure of the Baltic States. There will be a variety of connections to the airports and road network, the system of new and rebuilt stations will facilitate access to the rail service. The construction of 3 large transhipment terminals is expected for freight transport in:

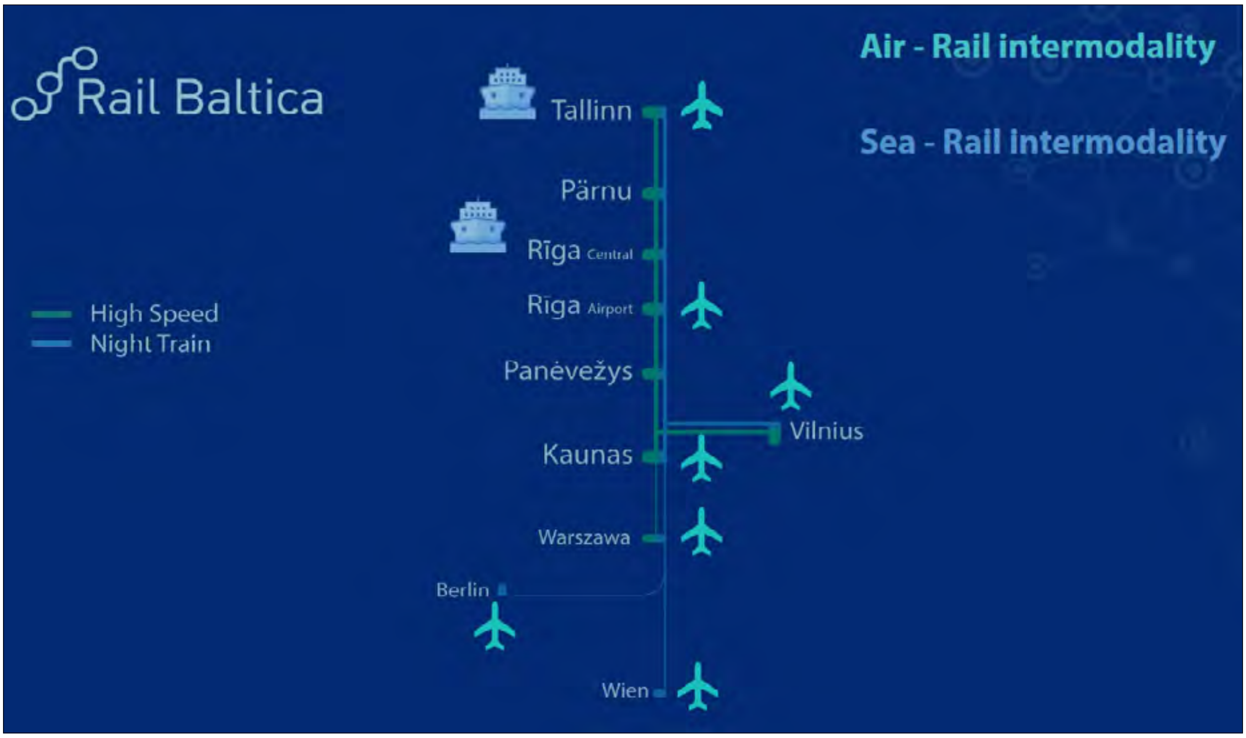
- Muuga in Estonia
- Salaspils in Latvia
- Kaunas in Lithuania.

The new line will allow for passenger interchange to the existing 1,520 mm rail network at the main stations. In the Baltic States, there are five seaports connected to the rail network, including Riga and Tallinn, which are expected to be directly integrated into the new line. The Klaipeda Seaport will be a transhipment point for transport from the East to Scandinavia, including Ukraine and Black Sea region, through the Viking Corridor, which was electrified in 2017.

Rail Baltica is planned to have seven passenger train stations: Tallinn, Parnu, Central Riga, Riga Airport (RIX), Panevėžys, Kaunas, and Vilnius, which will be rebuilt. The railway node in Riga will also be rebuilt and a number of airport links will be added as per the figure below. Connectivity will be further improved following the completion of the undersea line between Tallinn and Helsinki.

58 Ernst & Young, *Rail Baltica Global Project Cost-Benefit Analysis. Executive summary*, 24 April 2017.

Figure II–30 Rail Baltica connection to other modes of transport



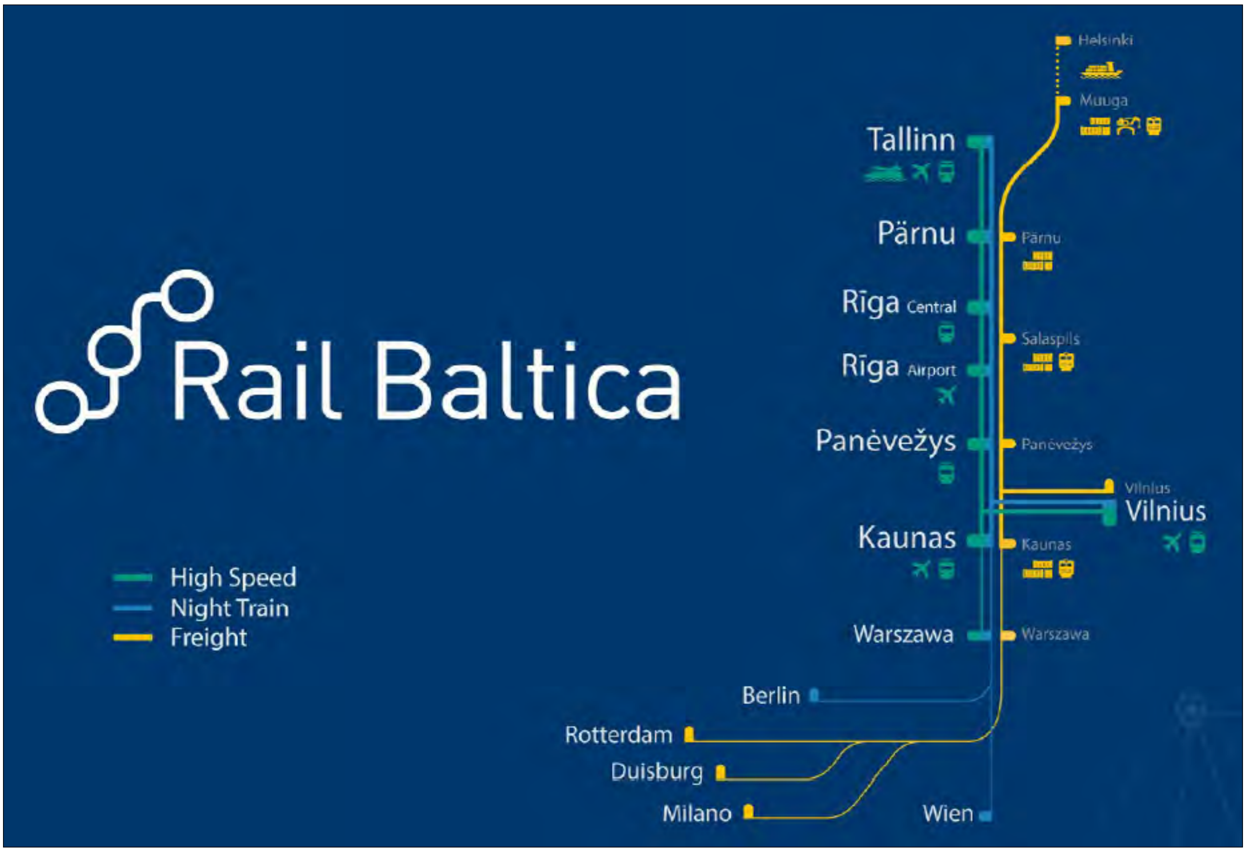
Source: Bedmar J.-M., *Operational Plan: an ambitious transport plan on the service of Baltic and European citizens*, Rail Baltica Forum, 3-4 April 2019, Vilnius, presentation of Rail Baltica Forum, Vilnius, 3-4 April 2019.

Operational plan of the line

Various categories of trains will use the line:

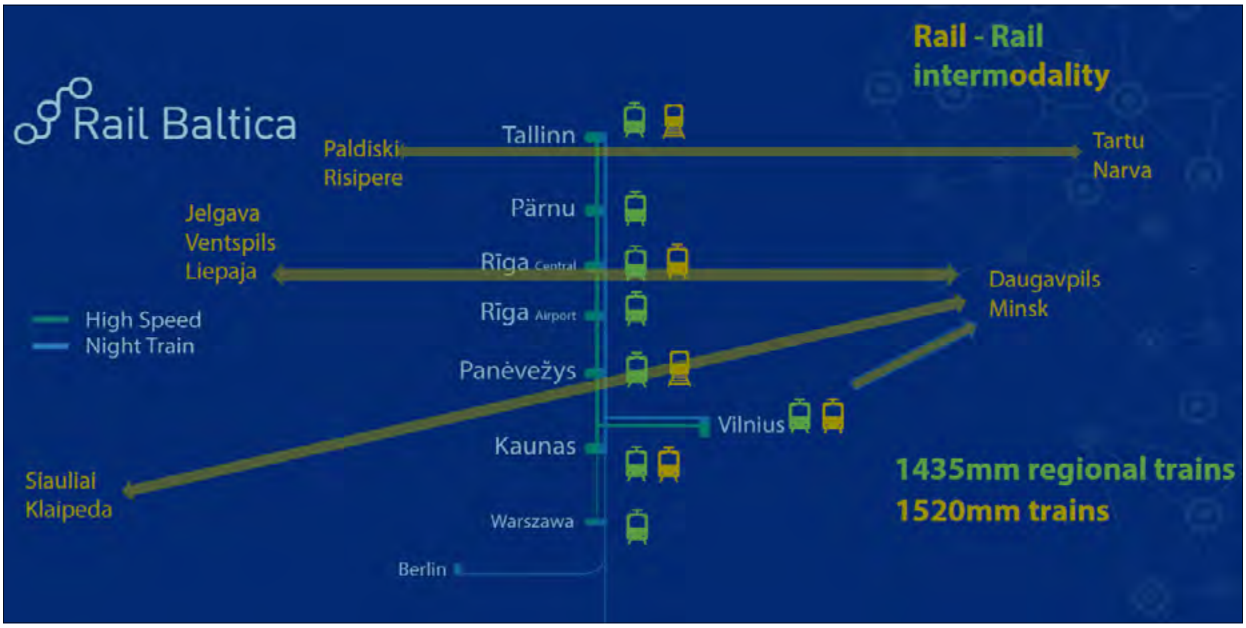
- High-speed trains serving seven international stations in Baltic States along the route at least every two hours;
- Night trains –two connections: Tallinn – Warsaw/Berlin, Vilnius – Warsaw – Vienna, are planned with a maximum speed of 200 km/h;
- Regional trains – maximum speed of 200 km/h – to serve stations of one or two States, nine routes, and 36 regional stations (selected on the basics of the study);
- Freight trains – maximum speed of 120 km/h, estimated at two trains per hour in each direction for any traffic flows.

Figure II–31 Operational Plan of Rail Baltica



Source: Bedmar J.-M., *Operational Plan: an ambitious transport plan on the service of Baltic and European citizens*, Rail Baltica Forum, 3-4 April 2019, Vilnius, presentation of Rail Baltica Forum, Vilnius 3-4, April 2019.

Figure II–32 Rail Baltica to the 1520 network



Source: Bedmar J.-M., *Operational Plan: an ambitious transport plan on the service of Baltic and European citizens*, Rail Baltica Forum, 3-4 April 2019, Vilnius, presentation of Rail Baltica Forum, Vilnius 3-4, April 2019.

Forecasts and operational metrics

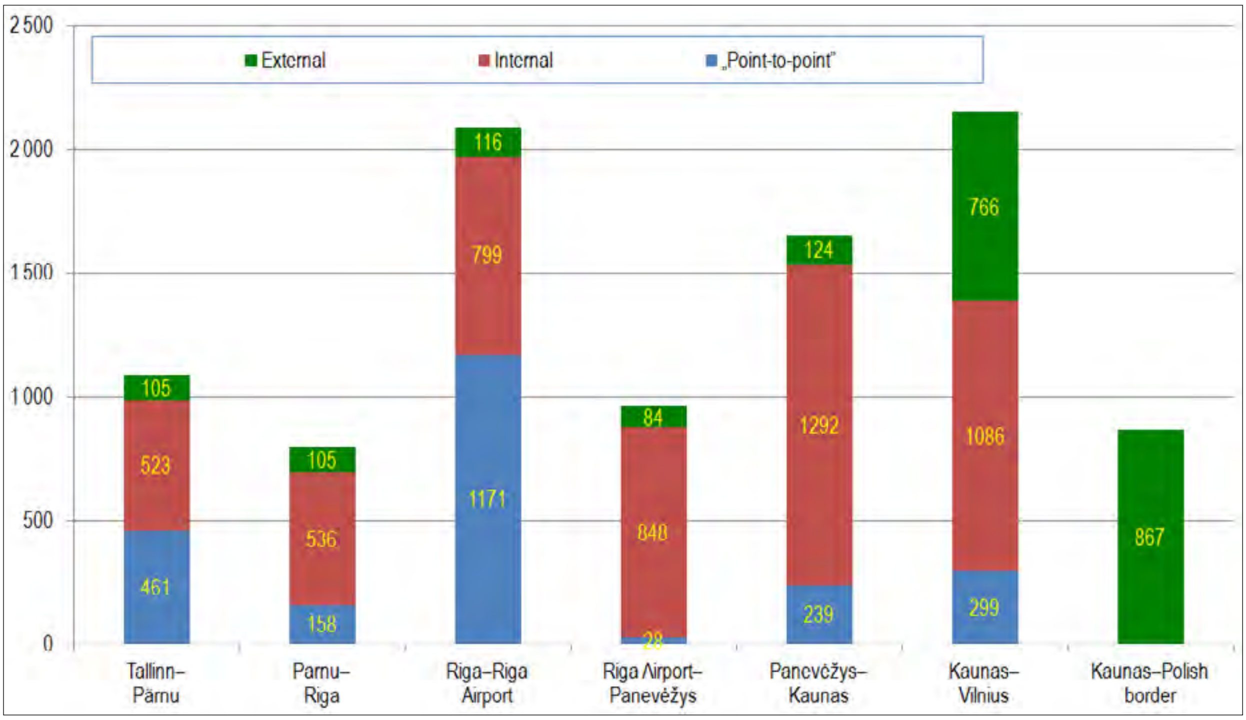
Traffic on Rail Baltica is expected to be between 4.7 million and 7.1 million passengers in 2055 (12.8k to 19.5k per day). The three flows that are expected on Rail Baltica are:

- "Point-to-point" transit between adjacent stations (direct journeys, for example passengers from Tallinn to Pärnu);
- Journeys in the Baltic States area (passengers travelling within the borders of 3 Baltic States);
- Journeys outside the Baltic States (passengers from external States, for example Warsaw – Kaunas).

Point-to-point journeys are mostly expected between the Riga international airport (RIX) and the Riga multimodal public transport hub. Figure II-42 provides an analysis the Rail Baltica's projected traffic flows in 2035. When fully operational, the busiest sections of Rail Baltica will be Panevėžys – Kaunas, Kaunas – Vilnius and Riga (Airport) – Panevėžys.

The highest external passenger flows will occur across the Lithuania-Poland border.

Figure II–33 Base case. Rail Baltica passenger flow breakdown per main sections, thousand PAX in 2035



Source: Rail Baltica Global Project Cost-Benefit Analysis, Executive summary. Ernst&Young, 24 April 2017.

The figure above shows the expected number of passengers on the specific sections of the line. Forecasted travel time is presented in figure II-43.

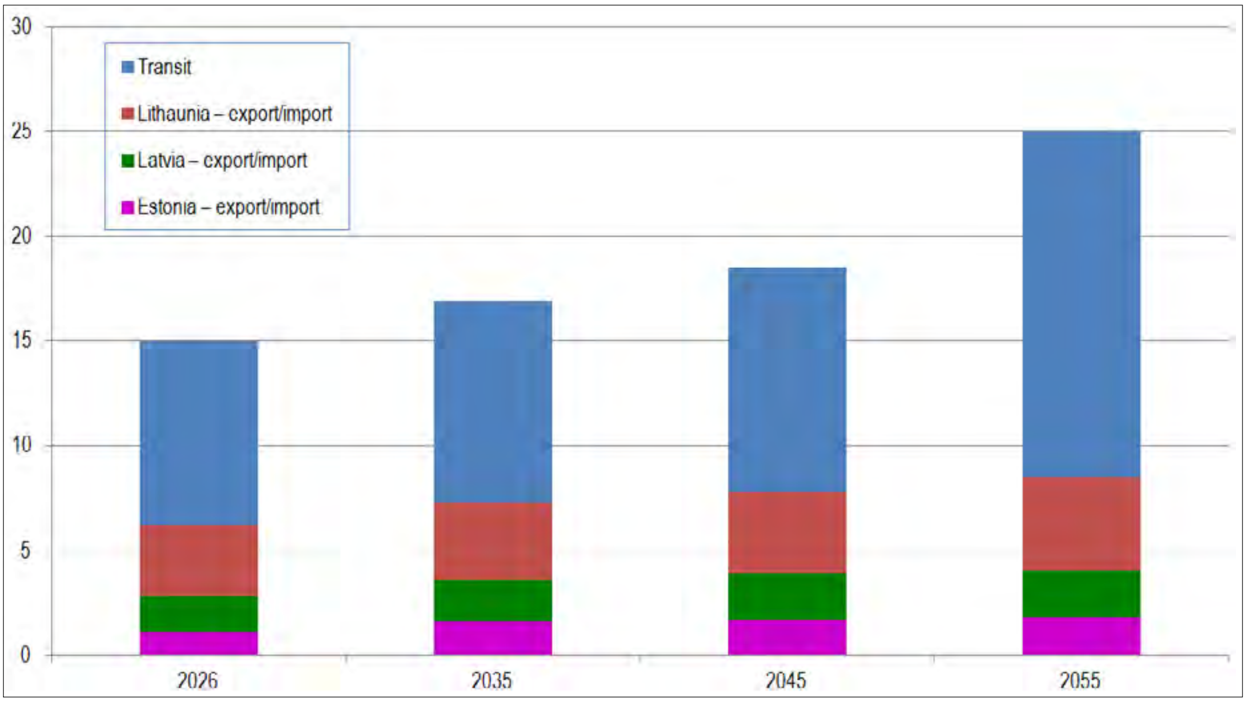
Figure II–34 Forecasted travel time

	Tallinn	Pärnu	Riga	Riga Airport	Panevėžys	Kaunas	Vilnius
Pärnu	00:40						
Riga	01:42	01:00					
Riga Airport	01:52	01:10	00:08				
Panevėžys	02:39	01:57	00:55	00:45			
Kaunas	03:18	02:36	01:34	01:24	00:37		
Vilnius	03:38	02:56	01:54	01:44	00:57	00:38	
Warsawa C.	06:47	06:05	05:03	04:53	04:06	03:27	04:07

Source: Bedmar J.-M., *Operational Plan: an ambitious transport plan on the service of Baltic and European citizens*, Rail Baltica Forum, 3-4 April 2019, Vilnius, presentation of Rail Baltica Forum, Vilnius 3-4, April 2019.

Freight transport in the first year of service is expected to be between 12 million tonnes and 18 million tonnes. In 2055, freight is estimated at 20-25 million tonnes according to the national splits set out in figure II-35. Freight transport will account for 53 per cent of all traffic. Transport to Poland and Germany will account for 10-12 per cent of all freight on the line.

Figure II–35 Freight flow forecasts (million tonnes)



Source: Rail Baltica Global Project Cost-Benefit Analysis, Executive summary. Ernst&Young, 24 April 2017.

Financing

The total cost of the Rail Baltica line has been estimated at €5.788 billion (€6.652 million per km), maintenance and operating costs in 2030 will be €70.7 million (€81k per km), including technical maintenance costs amounting to €58.9 million (€67.7k per km).

The costs of the undersea section of Rail Baltica, currently under review, connecting Tallinn and Helsinki, is estimated at €15 billion.

The international nature of Rail Baltica allows most of investment costs to be funded by European Union, including funding for the development of Trans-European Transport Network and dedicated resources for the new member States of the European Union (up to 85 per cent).

Table II–28 Rail Baltica investment costs in mln EUR, by segments

	Estonia	Latvia	Lithuania	Kaunas – Vilnius	Total
Rail infrastructure	612.9	754.0	761.2	275.7	2 403.8
Electrification	124.3	164.4	171.9	51.8	512.4
Signalling	84.9	99.4	138.2	33.5	356.0
Intersections	142.4	277.8	229.8	33.6	683.6
Bridges	12.6	77.8	184.6	131.5	406.4
Tunnels	0	73.0	0	0	73.0
Stations and facilities for passengers	186.2	300.0	74.6	150.0	710.8
Noise protection	27.2	59.5	33.3	N/A*	120.0
Land acquisition	22.6	50.8	35.0	21.5	129.9
Studies, planning and projects	68.7	111.7	32.0	7.0	219.4
Reserve for contingences	64.1	N/A*	73.7	35.2	173.0
Total	**1 345.9**	**1 968.4**	**1 734.2**	**739.6**	**5 788.1**

* Included in other costs

Source: Rail Baltica Global Project Cost-Benefit Analysis, Executive summary. Ernst&Young, 24 April 2017.

Rail Baltica will be a key driver for further economic growth in Baltic States, both during development (by creating jobs and having an impact on GDP growth of the region, through the direct, intermediate and induced effects of the infrastructural investment), and in the operational phase. The network will provide increased access to the Baltic market, improved competitiveness and investment attractiveness and the support to constant growth of efficiency and competitiveness of the Baltic logistics and transport sector. In the studies carried out to date, the project benefits have been estimated at €16.2 billion. These economic benefits are summarized in table II-29 below. It is also estimated that there will be a 38 per cent reduction in air pollution and a significant reduction in road fatalities on the parallel road network.

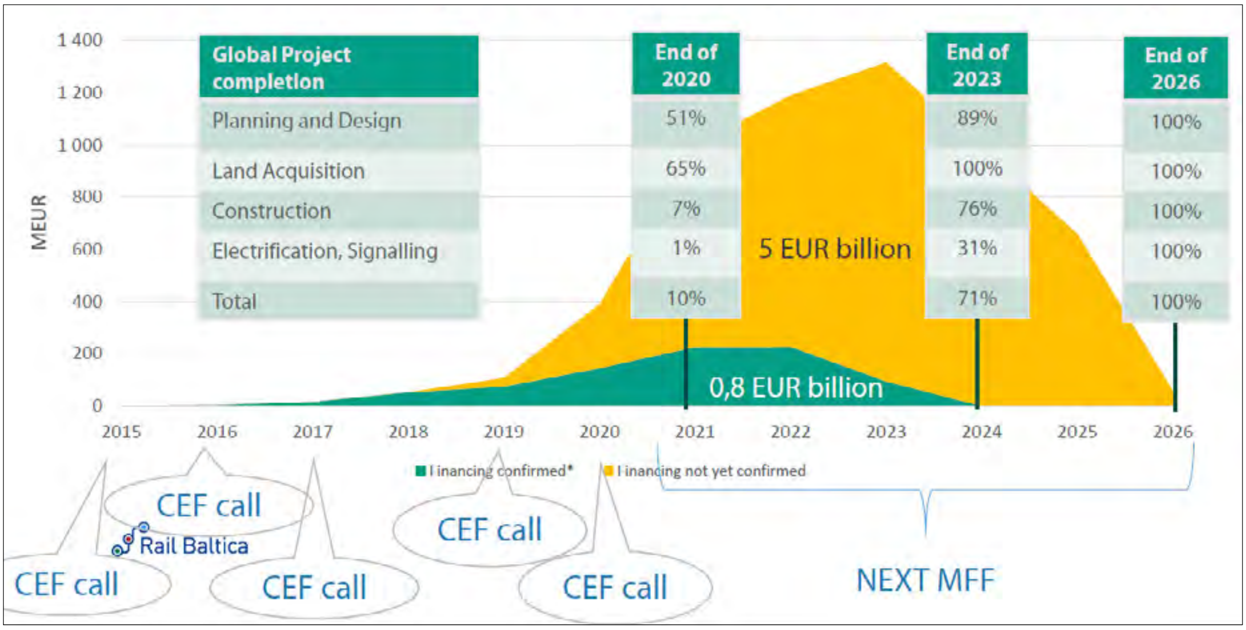
Table II–29 Economic indicators

Specification	Value (million EUR}
Financial flows with fiscal adjustment – nominal values (undiscounted)	
Revenue from infrastructure availability	2 613
Total investment and operating expenses	7 936
Residual value	1 275
Socio-economic effects and net benefits	16 226
Efficiency indicators (discounted)	
Income	+703
Expenses	-4 577
Residual value	+172
Socio-economic effects and net benefits	+4 581
Net cash flow	879
Economic rate of return	6.32%
B/C Ratio	1.19
Net present value	879

Source: Rail Baltica Global Project Cost-Benefit Analysis, Executive summary. Ernst&Young, 24 April 2017.

The project is planned to be completed by 2026 as per the timeline set out in the figure II-36 below.

Figure II–36 Project financing in particular stages



Note: Global Project Financing Status - CAPEX 5.8 bn EUR: forecast based on assumption of having funding available when necessary.
Source: Degutis I., *Rail Baltica: The Future of European Flagship Infrastructure. Project Financing*, Rail Baltica Forum, 3-4 April 2019, Vilnius.

The project of the undersea tunnel connecting Tallinn and Helsinki has also been included in the concept of Rail Baltica. The construction of a rail link tunnel with a journey time of 30 minutes was recommended in February 2015, as a result of the TalsinkiFix study. The length of the tunnel would be 92 km and the total length of the new line would be 107.4 km.

The European Union has allocated €3.1 million to the feasibility study. Construction of the tunnel would facilitate connectivity between the cities, currently served by ferry services with 2.5-hour travel time (during summer season 1 hour 40 minutes). Every year, eight million journeys are made by sea, including both touristic trips and local commuter services.

7.2.4 The Moscow – Kazan high-speed line

Project description

The first stage of the development of high-speed rail services in the Russian Federation will be the construction of the Moscow to Kazan HSL-2 link, which will run across the territory of 5 regions of the Russian Federation: Moscow and Moscow region, Vladimir and Nizhny Novgorod region, Tatarstan. Subsequent development of the rail link includes its extension to Yekaterinburg.

The decision to build this 770-kilometre rail line to link Kazan and Moscow, was first announced in 2013. The plans assumed that this would be the first true high-speed line in Russian Federation with trains operating at speeds of up to 400 kilometres per hour. A train journey from Moscow to Kazan, which takes about 13 hours today, would be shortened to 3.5 hours.

Moscow – Nizhny Novgorod: high-speed traffic to Nizhny Novgorod began in July 2010. Two Sapsan trains run shuttle service between Nizhny Novgorod and Moscow, and one between Nizhny Novgorod and St. Petersburg. The latter journey takes 8 hours and 30 minutes, compared to the previous 14 hours.

Figure II–37 Moscow – Kazan line layout

Source: The Moscow-Kazan high-speed rail line – project description.[59]

[59] *The Moscow-Kazan high-speed rail line – project description*, www.hsrail.ru [acces: 18.06.2019]

The Moscow – Kazan HSR project was discussed as the first link of the large-scale Eurasian high-speed rail corridor Europe – Russian Federation – Asia. The Moscow – Kazan high-speed rail project is considered to be the first step towards the high-speed rail network in Russian Federation, which will eventually be linked to both the Asian and the European rail networks.

In June 2018, China Railway Group Ltd and Ural Highway signed an agreement worth US$2.5 billion to build a high-speed rail line between Yekaterinburg and Chelyabinsk, allowing trains to travel at speeds of more than 250 km/h. Moscow will have high-speed connections to Yekaterinburg, Sankt-Petersburg and Adler (Moscow – Rostov-na-Donu – Adler) under the Rail Transport Development Strategy to 2030.

The role and effects of the Investment

In addition to the travel times savings from Moscow to Kazan as mentioned above, travel time between Nizhny Novgorod and Kazan will be reduced from 10h 32m to 1h 37m. The Moscow – Kazan high-speed link will increase connectivity across the Russian Federation territories and the mobility of population; the average travel time between the capitals of the regions will be 1 hour.

Twenty percent of the total population of Russian Federation lives in the area adjacent to the Moscow – Kazan HSR. More than 373,000 workers will work on the construction of the HSR leading to a multiplier effect for the economy.

Scope of the project and technical parameters

The line will serve 16 stations covering 7 regions of Russian Federation, thus providing efficient rail links between major cities such as Moscow, Vladimir, Nizhny Novgorod, Kazan and others. The project includes the construction of 795 new engineering structures – including: 53 large bridges, 78 medium bridges, 33 railway overpasses and 128 road overpasses.

Technical parameters have been developed following the experience in the TSIs, research studies and European practice assuming a maximum speed of up to 400 km/h and a track gauge of 1,520 mm.

Table II–30 Technical parameters of the line

Parameter	Data
Track length between:	
Moscow – Kazan	700 km
Moscow – Cheboksary	636 km
Moscow – Nizhny Novgorod	409 km
Moscow – Vladimir	187 km
Minimum horizontal curve radius	2 000 m
Maximum gradient	24‰
Number of stations, including:	33
• **start/terminal stations**	3
• **main stations**	3
• **intermediate stations**	7
• **passing stations**	3
• **dispatch stations**	17

Table II–30 Technical parameters of the line (continued)

Parameter	Data
Automatic train control (ATC)	Continuous ALSN and ALS-EN
Communication	Dual fibre optic
Traction power system	2 x 25 kV, 50 Hz 3 kV in Moscow area
Number of main tracks	2
Length of the line, incl.: **non-ballasted (slab) tracks** **ballasted tracks**	1 600.00 km 1 517.00 km 83.00 km
Length of the main station tracks	164.00 km
Construction time [years]	4

Source: Engineering Surveys and Designing of The Moscow — Kazan Section of The Moscow — Kazan – Yekaterinburg High-speed Rail Line, Information Memorandum October 2013, Moscow.

Line capacity

The line is planned to operate:

- Fast suburban trains (up to 200 km/h)
- High-speed trains (up to 400 km/h)
- Night trains (up to 200 km/h)
- Lightweight container trains (up to 160 km/h).

High-speed trains are scheduled to run 34 pairs per day between Moscow and Nihizny Novgorod and 30 between Moscow and Kazan.

Economic effects of the project

According to the JCS "High-speed railway lines" project the total cost is RUB 1,07 trillion. The project assumes significant private capital investment provided by many different and multinational investors. Government investment during the construction phase is not expected to exceed 70 billion rubles annually.

In April 2016, China Railway International Group agreed to provide a loan of RUB 400 billion for the construction of the Moscow – Kazan rail line over a 20-year period. JSC High-Speed Rail Lines reached an agreement with the BRICS New Development Bank in support of the Moscow – Kazan railway line in June 2016. The company also signed agreements with JSC Sogaz Insurance Group and Asian Infrastructure Investment Bank to collaborate on the project in June 2017. The project will also be supported by the Russian Federation Pension Fund, investment, subsidies, the National Wealth Fund, and guarantees.

For the Moscow – Nizni Novgorod section the total cost is RUB 606 billion, of which RUB 193 billion comes from governmental funding under the Complex Infrastructure Modernisation and Development Program until 2024, approved by the government of the Russian Federation on 30 September 2018. RUB 193 billion comes from the budget of OJSC (Russian Federation Railways). Finally, RUB 219 billion comes from equity and debt.

The general budget expenditure is expected to be RUB 2.2 trillion by 2030. The cumulative effect on the total yield of the Russian Federation economy is assumed to be RUB 18.9 trillion. Between 2019-2030, due to the agglomeration effect on total GDP, growth is expected to be RUB 7.2 trillion. At the same time, the gross regional product for Vladimir Region is expected to grow by 58 per cent and for Nizhny Novgorod Region by 76 per cent. The multiplier effect generated during the operation will generate additional tax revenues of 2.3 trillion rubles for the period of 2019-2030, which is more than the overall cost of the project. Furthermore, the new workers mentioned above will have a multiplier effect on the economy.

The project will have a significant role to play in regional development, improving the quality of life of a significant part of the Russian Federation population and stopping the outflow of population. The project is also very popular – according to the results of a survey carried out by local authorities with 85 per cent of residents surveyed supporting it and 50 per cent recognising the possible improvement in mobility as a likely outcome. For residents of the HSR territory, 54 per cent perceive this investment as "very much needed" and 31 per cent as "possibly needed".

Figure II–38 Moscow – Kazan HSL in economic environment

Source: JCS "High-speed railway lines".[60]

[60] JCS "High-speed railway lines", *Moscow – Kazan HSL in economic environment*.

Operating profit of the business EBIT margin is expected to be 51.50 per cent. It should be noted that no government support for operations is planned. The operating break-even point is expected after 3 years.

The project has economic efficiency indicators estimated as shown in table II-31.

Table II–31 Economic efficiency metrics

Project NPV [US$ bln]	Project IRR [%]	Project PBP [years]	NPV E [US$ bln]	IRR E [%]	PBP E [years]
530	5.2	23,6	273	5.3	26.6

Source: Operational efficiency of HSR, Fedor Lychagin, JSC: High-speed rail lines, at: UIC Workshop round table, January 2019.

Calculations were made with the assumption of:

- 160 freight trains
- 75 passenger trains
- 62 commuter trains daily.

As with all rail services, HSR will be much more expensive than freight transport by sea (US$0.11 per kg for maritime transport to US$1.55 per kg for HSR) and much cheaper than freight transport by air (US$2.24 per kg).[61]

7.2.5 The modernisation of the Belgrade – Budapest line (Serbian section)

Project description

The modernisation of the Belgrade – Budapest line has been split into 2 separate projects partially funded by international resources:

- Stara Pazova – Novi Sad is being implemented through a loan from the Russian Federation,
- Belgrade (Central station) – Stara Pazova 34.5 km and Novi Sad – state border (Kelebija) 108.2 km, currently involving the People's Republic of China, Hungary, and the Republic of Serbia, as a project of the (1 + 16) China Central and East Europe States initiative, as set out in the MoU on Cooperation in the Modernisation and Reconstruction of the Hungarian- Serbian Railway, signed between the parties in November 2014.

The aim of this project is to rebuild and modernise the existing single-track rail line Belgrade – Subotica – state border (Kelebija), on the comprehensive rail line Belgrade – Budapest (Corridor Xb), into a modern, interoperable, double-track rail line for mixed passenger and freight traffic, with a speed of up to 200 km/h and in accordance with the relevant TSIs.

61 Fedor Lychagin, "Operational efficiency of HSR. UIC Workshop round table", op. cit.

Figure II–39 Modernised line Belgrade – border with Hungary (Kelebija)

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway connection in the territory of the Republic of Serbia.

The Role and Effects of the Investment

Modernisation of the Belgrade – Stara Pazova – Novi Sad – Subotica – Hungarian border rail line is a national priority, considering Serbia's central geographical location in the Western Balkan region. The railway line is essential to the Pan European Transport Corridor X and the South East Europe Core Transport Network, which links the EU with the Balkans and Turkey and further with the Caucasus and the Caspian Sea, as well as with the Middle East to Egypt and the Red Sea. However, due to years of underinvestment in maintenance and infrastructure, the line is not able to meet current requirements.

Serbia is a signatory to AGC, AGTC and SEECP, as well as to the Treaty establishing the Transport Community. These agreements define the need for infrastructure to comply with international standards and performance criteria. This project will contribute to the achievement of these standards.

The line directly connects three of the five largest cities in Serbia and is of major importance to the Serbian economy by improving rail freight transport and by increasing passenger and freight rail competitiveness.

Scope of the project

- **Stara Pazova – Novi Sad**

  The section Stara Pazova – Novi Sad, due to its complexity, was divided in three parts:

  1) Construction of a new tunnel "Čortanovci" (two single-track tunnels about 2x1.2 km long) and viaduct (about 3 km in length)

     Annex 3.1 of Agreement between the Government of the Russian Federation and the Government of the Republic of Serbia was signed in February 2017 with a value of US$337,6 million of which 85 per cent will be financed by a Russian Federation loan and 15 per cent from the Serbian state budget. Work began on 11 August 2017, it is planned to be completed at the end of 2021.

  2) Reconstruction and modernization of the open railway line (total length 36.2 km)

     Annex 3.2 of the above-mentioned Agreement identifies for this project a value of US$247,9 million for this project with funding also split as in Annex 3.1. A subsequent amendment to this annex led to the value of this project increasing to USD 255,6 million. Work began on 19 March 2018 and is planned to be completed at the end of 2021.

  3) Electrification and equipping railway line with signal-safety and telecommunication systems

     In January 2019, Serbian Railways Infrastructure (SRI) and RŽD International signed a new Contract for the execution of works on the construction of railway infrastructure, which includes funds in amount of €91,7 million for the electrification and signalling of the Stara Pazova – Novi Sad with funding also split as in Annex 3.1. A separate annex for these works is planned to be signed by the end of 2020.

- **Belgrade (Central station) – Stara Pazova and Novi Sad – state border (Kelebija)**

  The project consists of the modernisation of the existing tracks and the construction of the second track with the complete closure of line and stopping of the traffic during execution of works for two sections: Belgrade (Central station) – Stara Pazova 34.5 km and Novi Sad – state border (Kelebija) 108.1 km, totaling 142.6 km, for mixed passenger and freight use and electrified and capable of running with speeds of up to 200 km/h. During execution works all traffic is diverted through an alternative route. Its scope includes design, construction and fit out of the rail line in accordance with EU standards, the law on safety and interoperability of the railway system, according to the TSIs. An independent body – (NoBo) – is chosen to check the compliance of works with the TSIs or European standards.

  A contract of US$350.162 million has been signed for the Belgrade Central Station – Stara Pazova section. A loan agreement of US$297.6 million has been signed with Chinese Export-Import Bank. The agreement entered into force in December 2017. Annex 1 of the Commercial Agreement was signed in July 2018. Works started at the beginning of June 2018.

  For the section Novi Sad – Subotica – state border, the Commercial Agreement, signed in July 2018, amounting to US$1,162.8 million it entered into the force in November 2019. A loan of of US$988,388 million, will support the implementation. The feasibility study with the preliminary design was approved by the State Audit Committee in August 2020. The works on the Novi Sad – Subotica – National Park (Kelebija) section are expected to start in first quarter 2021.

  The implementation of the project is planned for the end of 2023. The financing comes from the budget of the Republic of Serbia (15 per cent of the contracted amount) and from the loan from Export-Import Bank (Exim Bank) of the People's Republic of China (85 per cent of the agreed amount).

Technical parameters

The main technical parameters for the line are set out in the table II-32 below.

Table II–32 Technical parameters of the modernised Belgrade – RS/HU border line

Parameter	Data
Design speed	200 km/h
Structure gauge	UIC GC
Permissible axle load	22.5 t
Permissible load per linear metre	8.0 t
Horizontal curve radius	3 000 m
Rail cant	85 mm
Maximum gradient	12.5‰
Distance between tracks on the open line	4.50 m
Distance between tracks in stations	4.75 m
Distance between straight and passing tracks	6.40 m
Formation width on open line	4.00 + 4.50 + 4.00 = 12.50 m
Length of tracks to be used for passing freight trains	750 m
Electrification system	25kV, 50Hz
Signalling	ETCS Level 2 and INDUSI 60
Platform length **- in major stations** **- in minor stations**	 400 m 220 m
Platform height above high rail level (GIS)	55 cm
Rail type	60 E1
Sleeper type	concrete 2.60 m
Type of points (V tangent / V turnout)	E1-1:14-760 (200 km/h/ 80 km/h) E1-1:18.5-1200 (200 km/h per 100 km/h)
Loading diagram for bridge analysis	UIC 71
Level (Rail/road) crossings	grade separated

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian rail connection in the territory of the Republic of Serbia.

Forecast of Traffic Volumes

The forecasted passenger flows set out in the table below have been calculated taking into consideration the following passenger traffic:

- Commuter and suburban trains (105 trains – as per current traffic volume) on the Belgrade – Batajnica section,
- International and regional trains on the Belgrade – Stara Pazova section, (Belgrade – Šid – Croatia route),
- International and regional trains on the Belgrade – Subotica – Hungary route, on all sections.

Table II–33 Forecast of overall number of passengers per sections

Year	Belgrade – Stara Pazova		Stara Pazova – Novi Sad		Novi Sad – Subotica	
	Daily	Annual	Daily	Annual	Daily	Annual
2025	16 020	5 847 382	13 189	4 814 108	7 657	2 794 899
2030	18 572	6 778 718	15 290	5 580 870	8 876	3 240 054
2040	24 959	9 110 031	20 548	7 500 223	11 930	4 354 362

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway connection in the territory of the Republic of Serbia.

Freight traffic estimated in table II-34 has been forecasted based on the following: analysis of data of the current volume of rail traffic on the Belgrade – Subotica section and information for Corridor X, data on international road traffic at the border crossings with Hungary, specific assumptions on modal shift and the average growth in the volume of transport.

Table II–34 Forecast of freight traffic volume in Belgrade – Subotica line per sections

Year	Section	Total [t]	National traffic [t]	International traffic		
				Import [t]	Export [t]	Transit [t]
2025	Belgrade Marshalling Yard – Batajnica	10 069 367	1 928 199	1 371 199	1 000 293	5 769 676
	Batajnica – Stara Pazova	10 150 917	1 961 901	1 402 224	1 017 116	5 769 676
	Stara Pazova – Novi Sad	7 271 340	721 566	823 530	638 201	5 088 043
	Novi Sad – Subotica	7 409 194	482 049	1 160 270	620 645	5 146 230
	Subotica – Subotica border	7 254 299	0	1 347 878	758 003	5 148 418
2030	Belgrade Marshalling Yard – Batajnica	12 176 252	2 460 925	1 750 036	1 276 656	6 688 635
	Batajnica – Stara Pazova	12 280 333	2 503 939	1 789 633	1 298 126	6 688 635
	Stara Pazova – Novi Sad	8 684 938	920 921	1 051 056	814 524	5 898 437
	Novi Sad – Subotica	8 854 070	615 231	1 480 831	792 117	5 965 891
	Subotica – Subotica border	8 656 124	0	1 720 272	967 425	5 968 427
2040	Belgrade Marshalling Yard – Batajnica	15 528 307	3 307 277	2 351 902	1 715 719	8 153 409
	Batajnica – Stara Pazova	15 668 183	3 365 084	2 405 117	1 744 573	8 153 409
	Stara Pazova – Novi Sad	10 934 987	1 237 641	1 412 532	1 094 652	7 190 161
	Novi Sad – Subotica	11 153 860	826 819	1 990 114	1 064 539	7 272 388
	Subotica – Subotica border	10 887 520	0	2 311 902	1 300 139	7 275 479

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway connection in the territory of the Republic of Serbia.

Table II–35 Average annual growth rates for freight traffic volume [%]

Period	GDP growth rate	Growth rate for national traffic, import and export	Growth rate for transit traffic
2020-2025	5.0	6.5	5.0
2026-2030	5.0	5.0	3.0
2031-2040	4.0	3.0	2.0
2041-2048	2.5	2.5	2.0

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway in the territory of the Republic of Serbia.

Line capacity

Line capacity forecasts are shown in table II-36 below.

Table II–36 Capacity of the rail line by sections

Section		Beograd Central – Batajnica	Batajnica – Stara Pazova	Stara Pazova – Novi Sad	Novi Sad – Subotica
Relevant section		Zemunsko Polje – Batajnica	Nova Pazova – Stara Pazova	Petrovaradin – Novi Sad	Lovćenac – Bačka Topola
Average time for minimum train headway (min)		Direction A: 3.10; Direction B: 3.01	Direction A: 4.91; Direction B: 4.48	Direction A: 4.39; Direction B: 4.51	Direction A: 4.52; Direction B: 4.5
Capacity (number of trains) for period of	**1 440 min**	Direction A: 233; Direction B: 239	Direction A: 166; Direction B: 180	Direction A: 163; Direction B: 160	Direction A: 159; Direction B: 160
	1 320 min	Direction A: 214; Direction B: 219	Direction A: 152; Direction B: 165	Direction A: 149; Direction B: 146	Direction A:146; Direction B: 147
	60 min	Direction A: 12; Direction B: 12	Direction A: 9; Direction B: 9	Direction A: 8; Direction B: 8	Direction A: 8; Direction B: 8

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway connection in the territory of the Republic of Serbia.

The following passenger trains will be operated on the Belgrade Central Station – Batajnica section:

- Suburban/commuter trains
- international and regional trains in direction Belgrade – Šid – Croatia
- international and regional trains in direction Belgrade – Subotica – Hungary.

Freight trains run through Railway marshalling yards and Ostruznica.

Planned timetable

Table II-37 below identifies the number of intercity trains expected on the line after completion of the project.

Table II–37 Estimated number of operated trains

Routes	Numbers of pairs of trains		
	2025	**2030**	**2040**
Belgrade – Vienna	4	2	2
Belgrade – Budapest	4	2	2
Niš – Vienna		2	2
Niš – Budapest		2	2
Subotica – Bar	1 (during season)	1 (during season)	1 (during season)

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway in the territory of the Republic of Serbia.

The tables below show the planned level of regional traffic for the Belgrade – Novi Sad section (table II-39) and the Novi Sad – Subotica section (table II-39).

Table II–38 Estimated number of regional trains running on the Belgrade – Novi Sad section

Period	Train Headway	Number of pairs of trains/day
2018-2024	60 min	16
2025-2039	30 min (during peak hours) 60 min (during off-peak hours)	24
2040-2048	30 min	32

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway in the territory of the Republic of Serbia.

Table II–39 Estimated number of regional trains running on the Novi Sad – Subotica section

Period	Train Headway	Number of pairs of trains/day
2018-2029	60 min (during peak hours) 120 min (during off-peak hours)	10
2030-2049	60 min	16

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway in the territory of the Republic of Serbia.

Economic effects of the project

Following a detailed assessment of the project, the main findings of the pure financial assessment were:

- The internal rate of return is -4.23 per cent (negative and below discount rate);
- The net present value is negative €-1,020 m;
- The cost/benefit ratio is 0.078, which is lower than one.

The wider economic analysis gave the following results:

- The internal rate of return is 11.50 per cent (it is positive and higher than discount rate);
- The net present value is positive, €1,048.9 m;
- The cost/benefit ratio is 2.407 which is higher than one.

The assumptions for the different "scenarios" and the results of the sensitivity analysis for the economic analysis are given in table II-40 below. As a result of these calculations and the expected economic benefits the project was deemed viable.

Table II–40 Economic results

		FNPV-EUR	FIRR	FBCR
Main variant		1 048 856 447	11.50%	2 407
Investments	+20%	858 191 744	9.90%	1 984
	-20%	1 158 110 932	13.20%	2 783
Traffic volume	+20%	1 397 862 422	13.17%	2 853
	-20%	653 095 910	9.57%	1 905

Source: Feasibility Study, Saobraćajni Institut CIP 2015. Project of modernisation and reconstruction of Hungarian – Serbian railway in the territory of the Republic of Serbia.

7.2.6 Halkalı – Kapıkule Rail Line Project

Project description

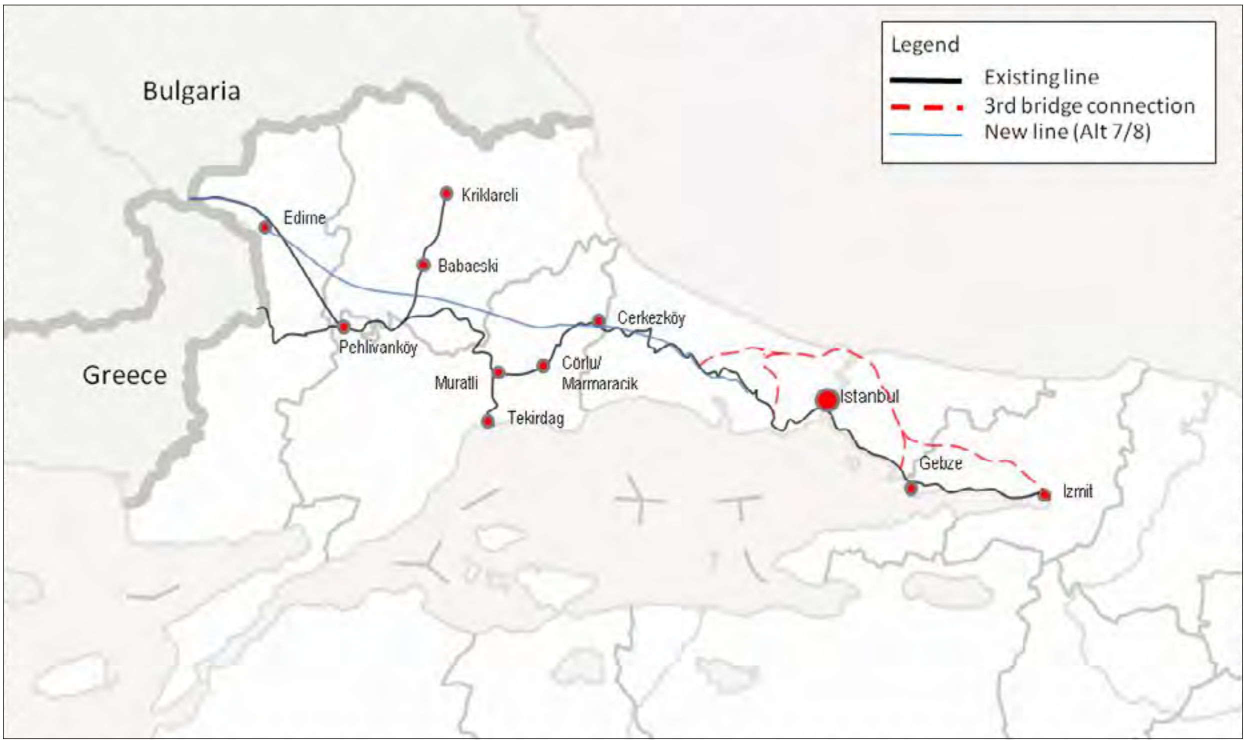
The new high-speed rail line Halkalı – Kapıkule[62] is part of TEN-T network, Orient/East-Med Corridor. The line will connect the Istanbul metropolitan area to the Turkish/Bulgarian border in Kapıkule/Svilengrad. The line will be 229 km long, of which 135 km is on a new alignment and 94 km is along the old line. It is divided into three sections:

- Halkalı – Çerkezköy (78 km)
- Çerkezköy – Edirne (135 km)
- Edirne – Kapıkule (16 km).

The feasibility study was completed in 2018, and the contract for the construction was signed in July 2019. The line is expected to be completed by 2023. The line between Çerkezköy and Kapıkule is co-funded by the European Union.

The main role of the line is to provide a high-capacity rail connection between Turkey and other European States. It is intended to double the old single-track line that will then serve only local traffic. The new link will provide higher speed and much higher capacity. It will also be about 60 km shorter. Freight traffic will be the prime user of the line and the line is closely linked to the so-called third Bosporus Bridge Project. The bridge will establish a rail link between Asia and Europe to serve the Halkalı – Kapıkule line (HKRL). Interviews with stakeholders, i.e. shippers, operators and forwarders showed that 90 per cent of the traffic volume using the line would cross the bridge.

Figure II–40 Location of the old and the new Halkalı – Kapıkule rail line together with third bridge connection



Source: Feasibility Study for Halkalı – Kapıkule Railway Line Project, 2018.

[62] *Feasibility Study for Halkalı – Kapıkule Railway Line Project*, 2018.

The role and the effects of the investment

The project of a new double-track line, which will be operated along with the existing single-track line, will provide sufficient capacity for a corridor which is currently suffering low quality, capacity and reliability. This segment of the TEN-T rail network extension on Turkish territory is a short but very important part of the overall development.

Connecting the European and Asian rail networks by means of a fixed link (third bridge) is a key component of HKRL and will provide significant benefits, with the estimated volumes making an important contribution to the economies of Turkey and Europe. Improving service quality and costs in this corridor will make it possible for the market to further intensify the trade exchanges and address environmental concerns. Furthermore, the construction of HKRL will create the necessary conditions to significantly improve passenger transport in the area of Istanbul.

Scope of the project

The project involves the construction of a new route with a design speed of 200 km/h, independent of the existing line, with horizontal and vertical alignment optimised for high-speed passenger and freight trains. It is designed as double track except for Halkalı – Ispartakule section, which is expected to have four tracks. It will be fully electrified, fitted with ERTMS ETCS Level 1 (upgradable to Level 2 by 2030) and compliant with European TSIs to provide compatibility at the border. The number of stations is reduced to six major stations. The design allows freight trains to operate at 100 km/h between passenger trains. There is a dedicated freight terminal in Çerkezköy and the new stations in Lüleburgaz, Büyükkarıştıran and Babaeski are intended to be used for freight transport. Additional sidings and passing loops are provided between Babeski and Edirne.

- **Halkali – Çerkezköy**

  The length of the section is 78 km along the existing line. The design speed for this section is 130 km/h in order to limit the impact on densely populated urban areas. The Halkalı – Ispartakule (10 km) section will have four tracks, two for suburban trains and two for regional and international passenger trains and for freight trains to the terminals and ports around Halkalı. The node connecting to the third Bridge will be on the forty-first km of the line. The section between Halkalı and forty-first km is intended to serve the Istanbul urban area, while the Anatolian transit will join the HKRL at forty-first km. Installation of the ETCS Level 1 is planned on the line.

- **Çerkezköy – Edirne**

  The section is newly aligned to shorten the total length of the line. The corridor is in close vicinity to the E80 motorway alignment. The maximum speed of the section is 200 km/h, the total length – 135 km. There are three stations planned for this section: Lüleburgaz, Büyükkarıştıran, and Babeski. They are located at 4 to 5 km away from their respective towns.

- **Edirne – Kapıkule**

  This is the shortest section near the border, where the new and the old line follow the same corridor to the border crossing at Kapıkule. The maximum speed of the section will be 200 km/h. No additional stations are planned.

Technical parameters

The operating speed of the line is planned to be 200 km/h on sections outside densely populated areas. The electrification system is 25 kV. The line will comply with the following TEN-T criteria:

- Electrified: line tracks and sidings, as far as necessary for electric unit operations, track gauge: standard 1,435 mm;
- Connection with freight terminals;
- 100 km/h line speed for freight trains;
- Minimum allowable train length (freight) 740 m;
- 22.5 tonnes axle load.

Table II–41 Parameters of the high-speed line with respect to TSI

Content		TSI Requirement	Comments
Design solution is clearly defined and documented			
Structure gauge	INF TSI 4.2.3.1		GC 1 435 mm – compliant
Distance between track centres	INF TSI 4.2.3.2	Up to 200 km/h 3.8 m Up to 250 km/h 4.0 m	4.5 m
Maximum gradients	INF TSI 4.2.3.3	Specifications for stations and stabling sidings (max. 2.5 ‰) and for passenger lines (max. 35 ‰).	The max. longitudinal gradient is 12.5 ‰, which is normal for freight lines. There is an exception near Çerkezköy where a length of 650 m has a gradient of 16‰. due to existing conditions, but still within limit. All stations except Edirne are horizontal. Edirne has a longitudinal gradient of 1.15‰, which is still within limit.
Minimum radius of horizontal curve	INF TSI 4.2.3.4	Min radius: V=200 km/h: r_{min} = 1 510 m V=160 km/h: r_{min} = 970 m	Except for Edirne und Çerkezköy, where there are existing conditions, the min. radius is within limits for a 200 km/h speed. In the main the route is designed with a min. radius of 3 500 m, which would allow for a speed of 300 km/h
Nominal track gauge	INF TSI 4.2.4.1		Compliant
Cant	INF TSI 4.2.4.2	Max u = 160 mm (4.2.4.2, ballast and mixed traffic) Max uf = 153 mm (4.2.4.3)	To be confirmed at detailed design
Design geometry of switches and crossings	INF TSI 4.2.5.1		To be confirmed at detailed design
Usable length of platforms	INF TSI 4.2.9.1 bzw. 4.2.1	max 400 m	Compliant
Platform height	INF TSI 4.2.9.2	Platform height 550 or 760 mm	To be confirmed at detailed design

Table II–41 Parameters of the high-speed line with respect to TSI (continued)

Content		TSI Requirement	Comments
Design solution is clearly defined and documented			
Platform offset	INF TSI 4.2.9.3		To be confirmed at detailed design
Track layout along platforms	INF TSI 4.2.9.4		All platforms are horizontal – see point 2.3
Geometry of the overhead contact line	ENE TSI 4.2.9		To be confirmed at detailed design
Pantograph gauge	ENE TSI 4.2.10		To be confirmed at detailed design
Platform width and edge of platform	PRM TSI 4.2.1.12		To be confirmed at detailed design
End of platform	PRM TSI 4.2.1.13		To be confirmed at detailed design

Source: Feasibility Study for Halkalı – Kapıkule Rail Line Project, 2018.

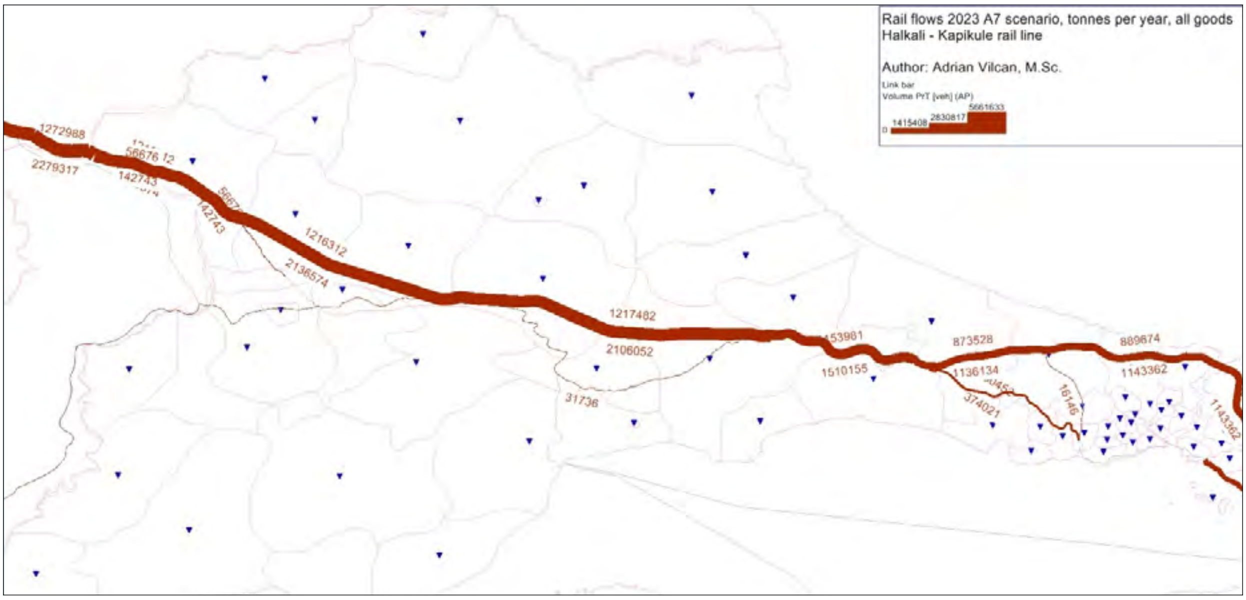
Forecast of Traffic Volume

The new line provides capacity for approximately 54 train pairs a day, which is sufficient to allow for long-term growth. In 2012, a total of about 1.5 million tonnes were identified as the potential of rail freight haulage on the line (two-thirds imports and one-third experts).

This demand is expected to rise to about 3.4 million tonnes by 2023. In 2030, the volumes are expected to amount to 4.4 million tonnes and in 2046 – to 9.6 million tonnes. Approximately 5.8 million tonnes are forecasted to be transported over the third Bosporus bridge (60 per cent).

Approximately 9.4 million tonnes at the border with Bulgaria are expected to be transported using the new line. This volume is split between the local markets in the Istanbul area and the Anatolian part to be transported over the third bridge. The traffic forecast for 2023 is shown in figure II-41.

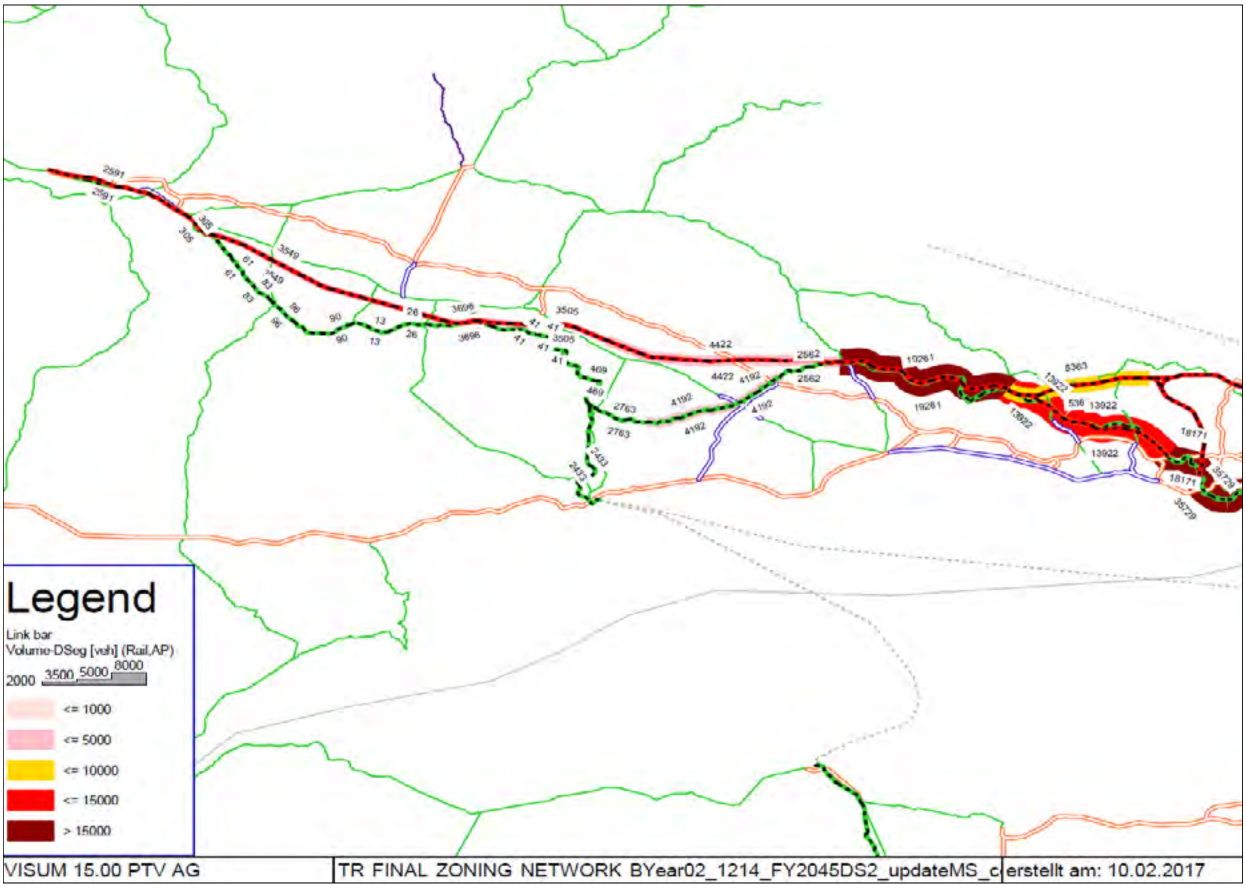
Figure II–41 Rail freight flows on the Halkalı – Kapıkule rail line, forecasts 2023, tonnes per year, all goods



Source: Feasibility Study for Halkalı-Kapıkule Rail Line Project, 2018.

The estimated passenger traffic for 2046 is shown in figure II-42.

Figure II–42 Forecast HKRL Rail Daily Flows, WP (Alt. 7) 2046



Source: Feasibility Study for Halkalı – Kapıkule Rail Line Project, 2018.

Line capacity

With the double track, there is capacity to run freight trains throughout the day. Two freight trains with maximum speed of 100 km/h can run between 6 a.m. and 12 p.m. and four with a maximum speed of 80 km/h between 12 p.m. and 6 a.m. In total, 54 freight trains per day per direction are planned. The average speed of the freight trains is 60 km/h.

Planned timetable

The table below (table II-42) illustrates schematically how train operations used the available infrastructure in 2012 (before closing of the line) and what are the possible train routes in 2023.

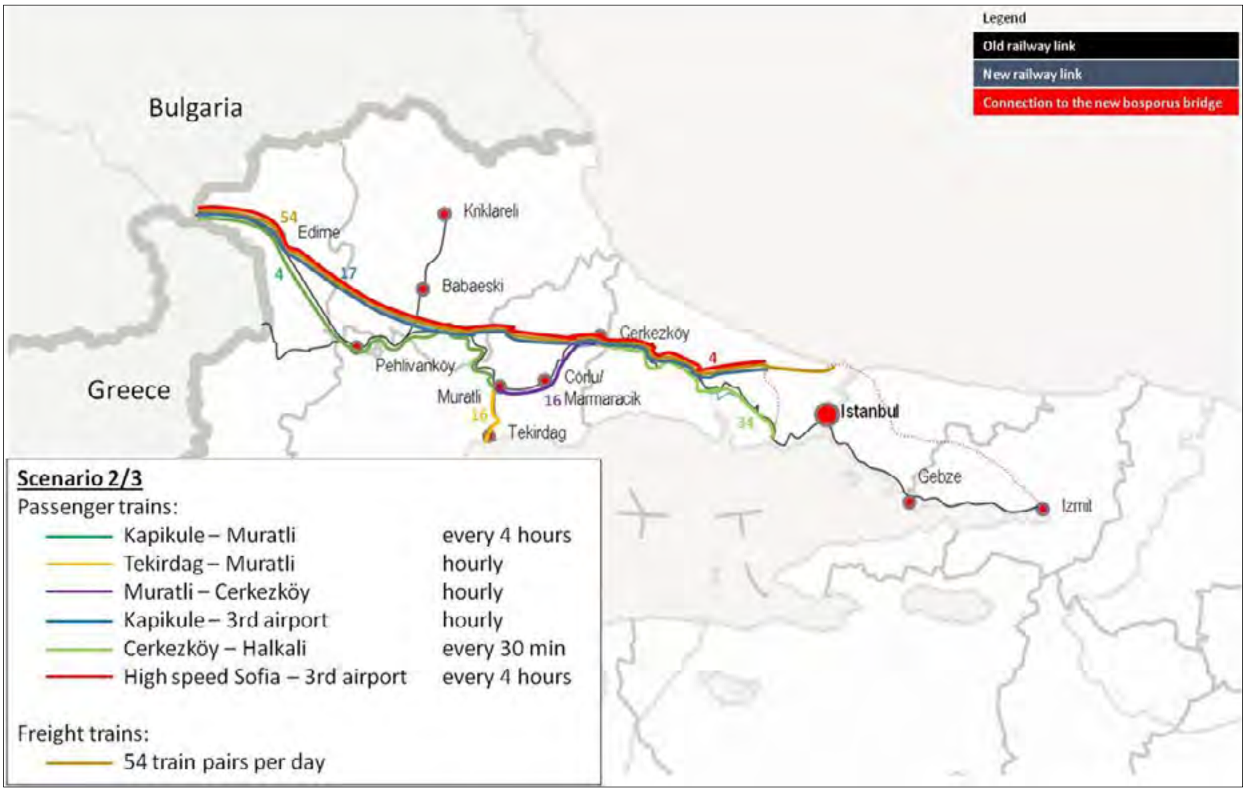
Table II–42 Utilization of infrastructure in past and future

Train service	2012	2023 WP
International passengers	1 pair of night trains HK – Sofia/Bucharest	4 pairs of HST Sofia – 3rd Airport via HS line
Domestic passenger	2 pairs Çerkezköy – Halkalı İstanbul 2 pairs Kapıkule – Halkalı Istanbul 2 pairs Tekirdağ – Muratlı	17 pairs Kapıkule – 3rd airport via HS line 34 pairs Çerkezköy – Halkalı via HS line 16 pairs Çerkezköy – Muratlı old line 4 pairs Kapıkule – Muratlı on old line 16 pairs Tekirdağ – Muratlı
Freight trains from East İstanbul and beyond	Via Ferry Haydarpaşa – İstanbul Sirkeci to EU or starting from Halkalı Average 40 per week	Via 3rd bridge and HS line to EU Average 50 per week
Freight trains from Bursa	NA	Via 3rd bridge and HS line to EU 5 per week
Freight trains from İzmir direction	Ferry to Tekirdağ (not regular) Average 2 per week	Ferry to Tekirdağ Average 6 per week

Source: Feasibility Study for Halkalı – Kapıkule Rail Line Project (2018).

In this scenario some passenger trains will use the new line. Towns and villages along the old line that are not connected to the new line will be served by trains running on the old line.

Figure II–43 Passenger operations, scenario



Source: Feasibility Study for Halkalı – Kapıkule Rail Line Project, 2018.

Economic effects of the project

The Cost-Benefit Analysis (CBA) findings set out in the table below show that construction is economically feasible and beneficial to society. The net present value is positive, the economic rate of return is higher than the reference economic discount rate (5 per cent for this project) and the Benefit/Cost ratio is greater than one (table II-43).

Table II–43 Results CBA (present values, prices 2016)

	Low season VoT	Annual average VoT
ENPV, € million	-35.7	653.7
ERR	4.8%	8.6%
Benefit/Cost ratio	0.96	1.67

Source: Feasibility Study for Halkalı – Kapıkule Rail Line Project, 2018.

The analysis undertaken shows that around 4 per cent of the investment costs can be covered by the revenue from access charges.

Table II–44 Findings of the financial analysis on investment (present values, prices 2016)

Economic indicator	Value
FNPV/C, € million	-946.3
FRR/C	-3.5%
FNPV/K, € million	-751.5
FRR/K	-3.4%

Source: Feasibility Study for Halkalı – Kapıkule Rail Line Project, 2018.

7.3 Example of existing high-speed operations in TER States

7.3.1 Railjet in Austria

The characteristics of the System

The Railjet train is based on two principles:

1) The use of both newly constructed high-speed lines with a maximum speed of up to 250 km/h and conventional lines modernised to 200-230 km/h. This network has also been adapted in order to establish connections to neighbouring States.
2) Rolling stock based on locomotives and carriages with technical solutions falling within the category of high-speed train.

The first Railjet trains were launched by ÖBB in 2008. The services were initially launched between Vienna, Munich, and Budapest in 2008, to be extended to Zurich one year later. The trains also serve domestic stops in Linz, Salzburg, and Innsbruck.

In 2011, additional services were added to Frankfurt am Main, and to Graz, Klagenfurt, and Villach. In 2014, the services were launched to Prague and in 2017 to Venice. These services have been made possible with the use of multi-system locomotives which allow for possible extensions to other neighbouring States.

Rolling stock

Railjet is a traditional push-pull train. The configuration (number of cars) of the train cannot be changed during service. The maximum speed of 230 km/h enables Railjet to be rated as high-speed train. Although Railjet trains are generally operated in single formation, they can be coupled together in the event of increased traffic.

Figure II–44 Railjet train with CD locomotive, Česká Trebova

Source: Kajetan Steiner.

Table II–45 Basic technical parameters of Railjet trains

Number of built	**ÖBB 60 trains, ČD 7 trains.**
Construction years	2008-2012 and 2015-2016 (ÖBB), 2013-2014 (ČD)
Train type	push-pull
Track gauge	1 435 mm
Length	185.8 m (without locomotive) or 205.38 m (with locomotive)
Number of seats	ÖBB: 404 (01-51) or 442 (52-60), ČD: 442
Maximum speed	230 km/h
Maximum traction force	300 kN
Voltage	class 1116 locomotive: 15 kV, 16.7 Hz, 25 kV, 50 Hz class 1216 locomotive: 15 kV, 16.7 Hz, 25 kV, 50 Hz, 3 kV DC, 1.5 kV DC
Signalling systems	For Austrian and German networks: PZB, LZB, ETCS Additional: EVM (MÁV), ZUB 121 (SBB), Integra-Signum (ČD), SCMT (FS)

Source: Selected from manufacturer data sheet.

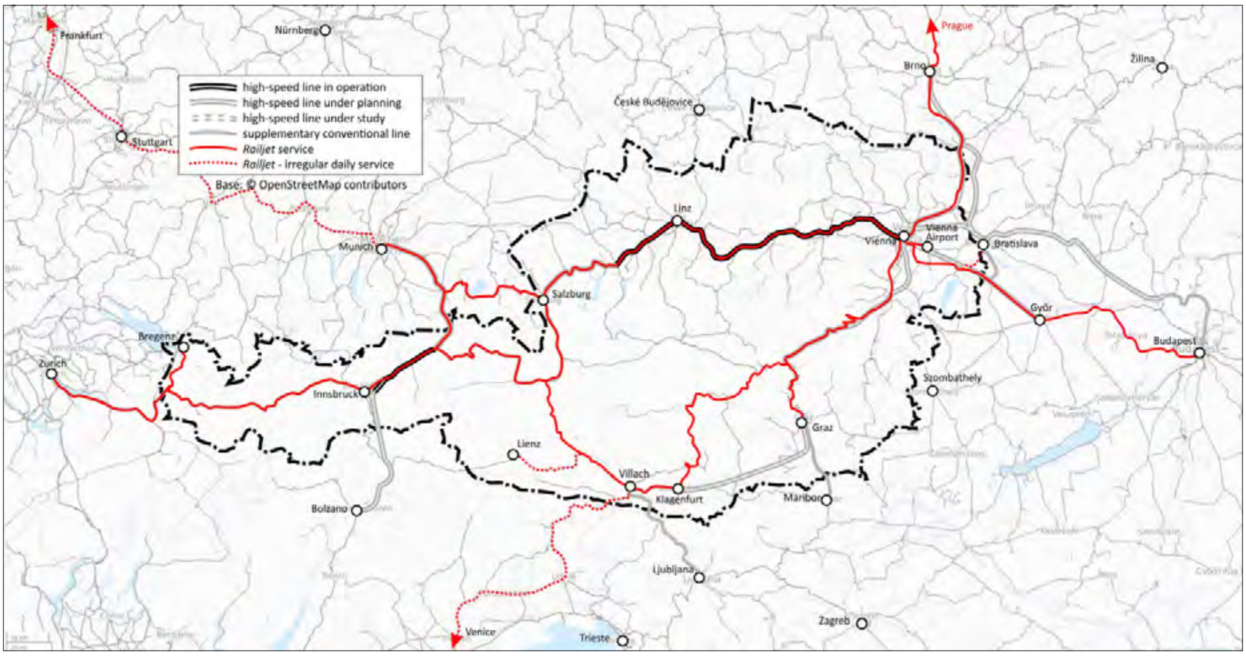
Operation

The frequency of Railjet services is close to that of former IC/EC trains, i.e. every 1-2 hours on main routes. On long-distance routes (e.g. Vienna – Frankfurt), no more than 2-3 pairs of trains per day are operated.

The average speed achieved by Railjet trains is 120-140 km/h, the maximum is 200-230 km/h. This is due to the terrain where speeds of more than 200 km/h on modernised conventional lines is difficult in undulating areas or in mountains where speeds above 100-120 km/h are rare. This means that in some cases domestic travel times can be significantly longer using domestic routes as opposed to passing through a neighbouring country (e.g. between Salzburg and Innsbruck).

Achieving speeds of more than 200 km/h is possible, for example on the DB network, in particular on ABS lines (German: Ausbaustrecken – upgraded lines) or NBS (German: Neubaustrecken – new high-speed lines). The maximum speed on the ČD or MÁV network is 160 km/h.

Figure II–45 Railjet routes (2019)



Source: OBB timetable.

7.3.2 High-speed trains in the Russian Federation

Sapsan: Moscow – Saint Petersburg and Moscow – Kazan

The characteristics of the System

Sapsan trains are dedicated to the Moscow – St. Petersburg (650 km) service, and for a period to the Moscow – Nizhny Novgorod (443 km) line. Since the line linking the old and new capitals of the Russian Federation is characterised by mostly long, straight sections, due to its location on flat terrain, adaptation to speeds of more than 200 km/h required only the installation of a new signalling system. In addition, it was necessary to reduce the number of commuter trains running on the lines, likely extending their travel time due to limited line capacity. The line to Novgorod is a conventional line with a maximum speed of 160 km/h. Plans to launch Sapsan service to Helsinki were eventually abandoned in favour of the Pendolino Allegro trains. The Moscow – Nizhny Novgorod line is no longer served by Sapsan and the express trains to Novgorod are Talgo coaches pulled by standard locomotives. This will change with the upgrade of the line as mentioned in previous sections.

Rolling stock

The Sapsan is a variation of the Siemens ICE3M high-speed train, adapted for use on the RZD network (track gauge, gauge, and adaptation to harsh winter conditions). These are 10-cars units, designed to run on a 1,520 mm track, electrified to 3 kV DC or 25 kV 50 Hz, with a maximum speed of 250 km/h. Initially, a total of 60 trains were ordered. In June 2019, a further 13 units were ordered.

Table II–46 Basic technical parameters of Sapsan trains

Number of trains built	25 (3 kV DC) + 4 (3 kV DC/25 kV 50 Hz)
Track gauge	1 520 mm
Configuration of trains	M+T+M+4T+M+T+M
Total length	250 000 mm
Number of seats	500 + 104
Weight	662/678 t
Power	8 000 kW
Maximum traction force	328 kN
Maximum speed	250 km/h
Signalling system	KLUB-U

Source: Siemens, RZD data.

Figure II–46 Sapsan in Nizhny Novgorod station

Source: Marek Graff.

Operation

Commercial services were launched in December 2009. Sapsan trains between Moscow and St. Petersburg, replaced classic locomotive-driven trainsets (with a travel time of 8-9 hours or more). The popularity of the new services (nearly 5 million in 2016-2017) has resulted in a significant fall in flights between the two cities.

Travel time from Moscow to St. Petersburg is between 3.30 and 4.04 hours depending on the service. Ticket prices range from US$100 to more than US$200 in peak times. The trains operate 12 pairs per day.

On 1 March 2018, RZD reopened the decommissioned Saint Petersburg – Moscow – Nizhny Novgorod line, which allows for an 8-hour 15-minute through service.

Allegro: St. Petersburg – Helsinki

The Characteristics of the System

The introduction of the Pendolino Allegro service between Helsinki and St. Petersburg lead to a travel time reduction from 5.5 hours to 3.5 hours also thanks to the modernisation of the line and the construction of new sections. The new Kerava – Lahti line was constructed in Finland with a higher maximum speed of 220 km/h and shorter route. The reconstruction of the Helsinki node also facilitated the operation of high-speed trains. The section from Lahti to Kouvola and then Luumäki was double-tracked and the level crossings were removed, allowing for a higher speed (160-200 km/h) on the section. The Russian Federation sections St. Petersburg – Vyborg (two-track) and Vyborg – Buslovskaya (– border with Finland; single-track) had already been adapted to 160 km/h (for trainsets), thus the increase in speed to 200 km/h (for EMUs) required minimal effort. Due to the virtually identical width of the track in both States, the length of time at the state border is reduced to a minimum. Services began in December 2010.

Rolling stock

The ordered trainsets were manufactured as double-voltage (25 kV 50 Hz, 3 kV DC) seven-car sets, allowing them to move on the VR – 1,524 mm, RZD – 1,520 mm tracks, with a maximum speed of 220 km/h, with a design similar to those already used on the VR network.

In January 2010, testing began on the Finnish rail network at a maximum speed of 220 km/h. Two trains were also tested by RZD – near St. Petersburg, and on the test track in Shcherbinka near Moscow. Delivery was completed at the end of 2010. The trains are equipped with an electrohydraulic body-tilting mechanism (8°). The trains are designed to operate within the temperature range of –40°C to 40°C.

Table II–47 Basic technical parameters of Allegro trains

Class	Sm6
Years of manufacture	2009–2010
Number of units produced	2 + 2
Track gauge	1 520/1 524 mm
Maximum speed	220 km/h (VR), 200 km/h (RZD)
Voltage	25 kV 50 Hz, 3 kV DC
Train set configuration	2S + 3D + 2S (S =(1A)'(A1)', D=2'2')
Number of passenger seats	352 (1st class + 2nd class)
Total weight	423 t
Unit length	184 800 mm
Total power	8 x 690 kW
Automatic coupling	Scharfenberg
Body tilting mechanism	Electro-hydraulic
Signalling system	ATC/JPV, CLUB

Source: Producer data sheet

Figure II–47 Allegro in Kuovola

Source: Marek Graff.

Operation

In total, 4 trains were produced for the operator Karelia Trains (VR and RZD), which were split between Finnish and Russian Federation railways (2 + 2).

Pendolino Allegro services stop – with the exception of start and end stations – in Lahti, Kouvola (VR) and Vyborg (RZD). The series is assigned to and serviced at Ilmala in Helsinki and Metallostroy in St. Petersburg (together with the Sapsan trains). With the introduction of Pendolino Allegro, conventional day-trains have been withdrawn between Helsinki and St. Petersburg such as Repin (RZD rolling stock) and Sibelius (VR rolling stock). The number of passengers is expected to triple to 600,000 in the coming years.

Strizh: Moscow – Nizhny Novgorod and Moscow – Minsk – Warsaw – Berlin

Main characteristics

Strizh trains are locomotive pulled Talgo car trains, some equipped with automatic gauge changing bogies to speed up border crossings

Rolling stock

Talgo 250 cars for RZD follow the GOST standard (the range of – 03-BM), applicable to the RZD or BC rail networks (equivalent to UIC/TSI standards in EU States) and are designed for use in the temperature range of -40˚C – +40˚C. The total number of seats on the Talgo 250 is 224 (type A) or 410 (type B). The total length of the train is 263.8 m, for a total weight without passengers of 343.1 t.

Figure II–48 Strizh train in Warszawa Wschodnia (Warsaw East) station

Source: Marek Graff.

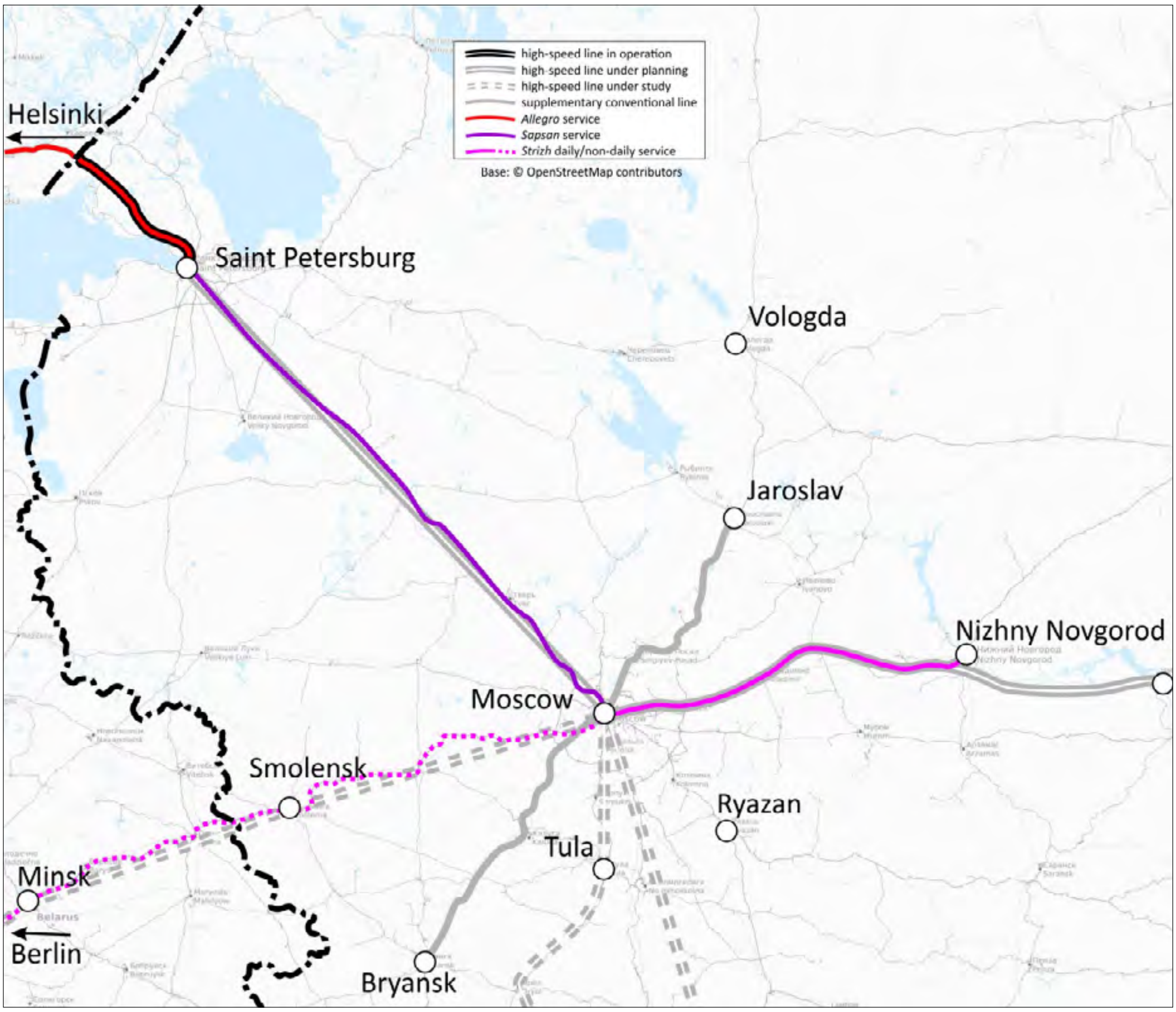
Operation

Talgo 250 services were inaugurated in December 2015 with trains running on the:

- Moscow – Nizhny Novgorod, four trains, running every day (443 km);
- Moscow – Berlin, three trains, running twice a week (1,869 km).

Talgo 250 Strizh trains are designed for speeds up to 250 km/h and they are operated at the maximum speed of: 160-200 km/h on the RZD, BC network, 160 km/h on the Polish network, and 200 km/h on the German network.

Figure II–49 High-speed train lines in Russian Federation (2019)



Source: RZD timetable.

ED250 high-speed trains in Poland

The characteristics of the System

The north-south axis was implemented as part of the Polish High-Speed Rail Program adopted by the government in 2008 with implementation starting in 2016. In addition to the construction of the new Warsaw – Lodz – Poznan/Wroclaw line, the program assumed that the existing line from Warsaw to Katowice would be modernised to at least 250 km/h and extended further south and north. The existing line from Warsaw to Gdansk was also to be modernised to achieve 200 km/h (2020).

Rolling Stock

The first plans to purchase high-speed trains in Poland were developed between 1994 and 1997 however the new contract for the purchase of new trains between Alstom and PKP Intercity was only signed in 2011. The first train was delivered for tests in 2013 and then entered into service in 2014. ED250 trains are electric multiple units consisting of seven cars. Certification tests took the rolling stock to a maximum speed of 293 km/h.

Table II–48 Basic technical parameters of ED250

Class	ED250
Maximum speed	250 km/h
Number of coaches	7
Axle arrangement	(1A' A1')-(1A' A1')-(2' 2')-(2' 2')-(2' 2')- (1A' A1')-(1A' A1')
Traction power	5 500 kW (8 x 708 kW)
Length of train	187.4 m
Axle load	14 300 ÷ 16 800 kg
Weight	395.5 t
Traction supply	25 kV 50 Hz 15 kV 16.7 Hz 3 kV DC
Number of seats	402 (341 – 2 class and 45 – 1 class) plus 2 for PRM
Tilting mechanism	No
Manufacturer	Alstom

Source: PKP Intercity S.A., Alstom.

Figure II–50 ED250 trains at Warsaw Grochow station

Source: P. Juriewcz, PKP Intercity.

Operation

The new trains were designed to create a new EIP (Express Intercity Premium) category providing the highest quality in terms of comfort and travel time. Since 2014 the routes served by the new trains have undergone several changes resulting from the development of different marketing strategies.

Following the significant increase in investment in the railway sector in Poland since 2016, the Journey times between Warsaw and Krakow/Katowice have fallen to less than 2.5 hours and Warsaw to Gdańsk have fallen to less than three hours. Service frequency is every one to two hours on routes to Krakow, Katowice and Gdansk, three per day to Wroclaw, and one pair to Rzeszow or Jelenia Góra.

Current train speeds of 200 km/h are planned to be increased to 250 km/h in 2025.

Figure II–51 ED250 trains routes (2019)

Source: PKP Intercity.

7.3.3 High-speed trains in Turkey

Ankara – Istanbul

System characteristics

The total length of the Istanbul – Ankara HS line is 435 km. The line was built in two stages:

- The first 221 km section at a cost of US$745,8 million, from Sincan (Ankara district) to İnönü, was built in 2003-2007; operation began in March 2009.
- The second section between Eskişehir and Pendik, 214 km, at a cost of US$2.13 billion, which required the boring of 39 tunnels and the construction of 33 bridges, was opened in July 2014, although the line was actually completed in 2016 at a cost of US$2.87 billion. Funds for the construction were obtained, among others, from the EIB (US$1.25 billion), 120 million from EU funds plus a loan from Chinese banks – US$750 million.

Since March 2019, High-Speed Trains have reached the "European" Side of Istanbul (Halkalı) through Marmaray Tunnel under the Bosporus Strait.

Rolling Stock

Trains were purchased in two tranches, with the first EMUs were delivered to TCDD by CAF in November 2007, and the last in 2010.

Table II–49 Basic technical parameters of the HT65000 class

Number of trains constructed	12
Number of coaches in EMU	8
Number of seats	419*
Total length	158 500 m
Maximum speed	250 km/h
Continuous power	4 800 kW
Supply voltage	25 kV 50 Hz

Source: Own study revised by TCDD.
* Tickets are sold for 409 passenger seats and 2 wheelchairs, and there is no sale option for eight passenger seats in the cafeteria wagon.

Operation

There are 16 train trips, eight departures and eight arrivals between Ankara and Istanbul per day. Trains stop at Eryaman, Polatlı, Eskişehir, Bozüyük, Bilecik, Arifiye, İzmit, Gebze, Pendik, Bostancı, Söğütlüçeşme and Bakırköy stations. There are 14 trips (departure and arrival) from Söğütlüçeşme, two of which are from Halkalı (departure and arrival). Travel time between Ankara – İstanbul (Söğütlüçeşme) is approximately 4 h 30 and travel time between Ankara-İstanbul (Halkalı) is approximately 5 h 20. HT 65000 class High Speed Train (HST) sets are operated on the Ankara-İstanbul line.

Ankara – Konya

The characteristics of the System

Konya – Polatlı is a southern branch of the İstanbul – Ankara line, 212 km long (distance Konya – Ankara is 306 km), built in 2007-2011, with a maximum speed of 350 km/h, equipped with the ETCS Level 2 signalling.

Rolling Stock

The HT80000 EMUs were delivered by Siemens (seven trainsets) between 2013 and 2016 and are based on Velaro platform trains. The manufacturer is also responsible for servicing for a period of seven years from the date of purchase. The operation of these trains started in May 2015 on the Ankara – Konya high-speed line. TCDD received the last EMU in February 2016; they have all been in operation since March 2017.

Table II–50 Basic technical parameters of the HT80000 class

Number of trains	7
Number of coaches in train	8
Number of passenger seats	460 (HT80001) (1 trainset),* 519 (HT80101 – HT80106) (6 trainsets)**
Total length	200 720 mm
Maximum speed	320 km/h (HT80001), 300 km/h (HT80101 – HT80106), service speed – 250 km/h
Continuous power	8 000 kW
Supply voltage	25 kV 50 Hz

Source: Own study revised by TCDD.
* Tickets are sold for 444 passenger seats and 2 wheelchairs, and there is no sale option for 16 passenger seats in the cafeteria wagon.
** Tickets are sold for 481 passenger seats and 2 wheelchairs, and there is no sale option for 36 passenger seats in the cafeteria wagon

Operation

The service is operated in the following manner:

- **Ankara-Konya:** 14 train trips, seven departures and seven arrivals per day between Ankara and Konya. Trains stop at Eryaman and Polatlı. The travel time is 1 h 45.
- **İstanbul-Konya:** six train trips, three departures and three arrivals per day between Konya and Istanbul. The trains stop at Eskişehir, Bozüyük, Bilecik, Arifiye, İzmit, Gebze, Pendik, Bostancı, Söğütlüçeşme and Bakırköy stations. There are 4 trips (departure and arrival) from Söğütlüçeşme and two from Halkalı (departure and arrival). Travel time between Konya – İstanbul (Söğütlüçeşme) is approximately 4 h 50 and travel time between Konya- İstanbul (Halkalı) is approximately 5 h 40.
- **Ankara-Eskişehir:** 10 train trips, five departures and five arrivals per day between Ankara and Eskişehir. The trains stop at Eryaman and Polatlı. The travel time is 1h 30.

Table II–51 Ticket Prices for high-speed trains in Turkey

No	Line	Economy (TL)	Business (TL)
1	Ankara-Eskişehir	37.50	54.50
2	Ankara-Konya	37.50	54.50
3	Konya-İstanbul (Söğütlüçeşme)	103.50	150.50
4	Ankara-İstanbul (Söğütlüçeşme)	85.50	124.00
6	Ankara-İstanbul (Halkalı)	96.00	139.50
5	Konya-İstanbul (Halkalı)	114.00	165.50

Source: Turkish Railways.

Figure II–52 The class HT80000 emu in Konya station

Source: Agata Pomykała.

In Turkey, high-speed trains carried:

- In 2018 8.1 mln passengers per year, +13 per cent increase compared to 2017;
- In 2019 8.2 mln passengers per year, +15 per cent increase compared to 2017.

Figure II–53 High-speed train lines in Turkey (2019)

Source: TCDD timetable.

7.4 Conclusion and recommendation

The information on the projects set out above shows that the construction of high-speed rail systems is possible and viable, although with lower efficiency indicators than in early projects implemented in Western Europe and Japan, but still high enough to make a positive investment decision. It should be noted that efficiency of projects in TER States will improve when a complete network is built across the entire Region. Such a network would allow economies of scale to be obtained. It is therefore recommended that further high-speed rail projects be implemented in the context of international cooperation.

Existing HSR projects in TER region show that service quality can be improved through increased commercial speed and the introduction of a new generation of trains.

Except for Turkey, these are cases where trains with a maximum speed of than 200 km/h are put into service on conventional lines not always modernised on their entire length. In both the Russian Federation and in Poland, lines with relatively high parameters have been selected for the use of new trains, which, however, were originally built either in the nineteenth century (Moscow – St. Petersburg) or 50 years ago (Warsaw – Katowice/Cracow) and subsequently modernized.

The projects described above were implemented over a long period ans financed by various sources. These projects share positive experiences and meet national requirements for the high-speed train services. The services enjoy high volumes of passengers and are usually self-sustaining businesses with higher than normal fares which are however accepted by travellers.

A radical improvement in the quality of long-distance passenger transport in TER States is possible only after the construction of a network of high-speed lines. This will make it possible to increase the average commercial speed of trains and reduce travel times, especially on international routes.


519
2010
DB

III. Identification of TER HSR Network

1. HSR projects identified in TER and TER neighbouring States

1.1 High-speed rail network developments in Europe

1.1.1 Concept's development

The concept of the construction a HSR network in Europe appeared in the 1970s. In 1972, a specially appointed Commission within UIC which brought together representatives of European railways, developed a plan for the development of European rail infrastructure. It was based on an analysis of existing and potential links between the most urbanised and economically developed regions in Europe. Their aim was to identify the routes with the largest volume of transport, complementarity of the rail line with the transport chain as well as the definition of the network allowing it to generate profit. As the result of the work, a core network of 40,000 km of main rail lines was designated. In 1985, work began on the preparation of a proposal for a European high-speed network.

In parallel to this, the AGC set out the designated main rail corridors for the pan-European region and the specific main technical parameters for them.

This initiative coincided with the will to accelerate the development of the European network, which was expressed in the Communication COM 86/341 of 30 June 1986 by the Commission of the European Communities. The project was implemented with the participation of 12 States associated in the European Community.

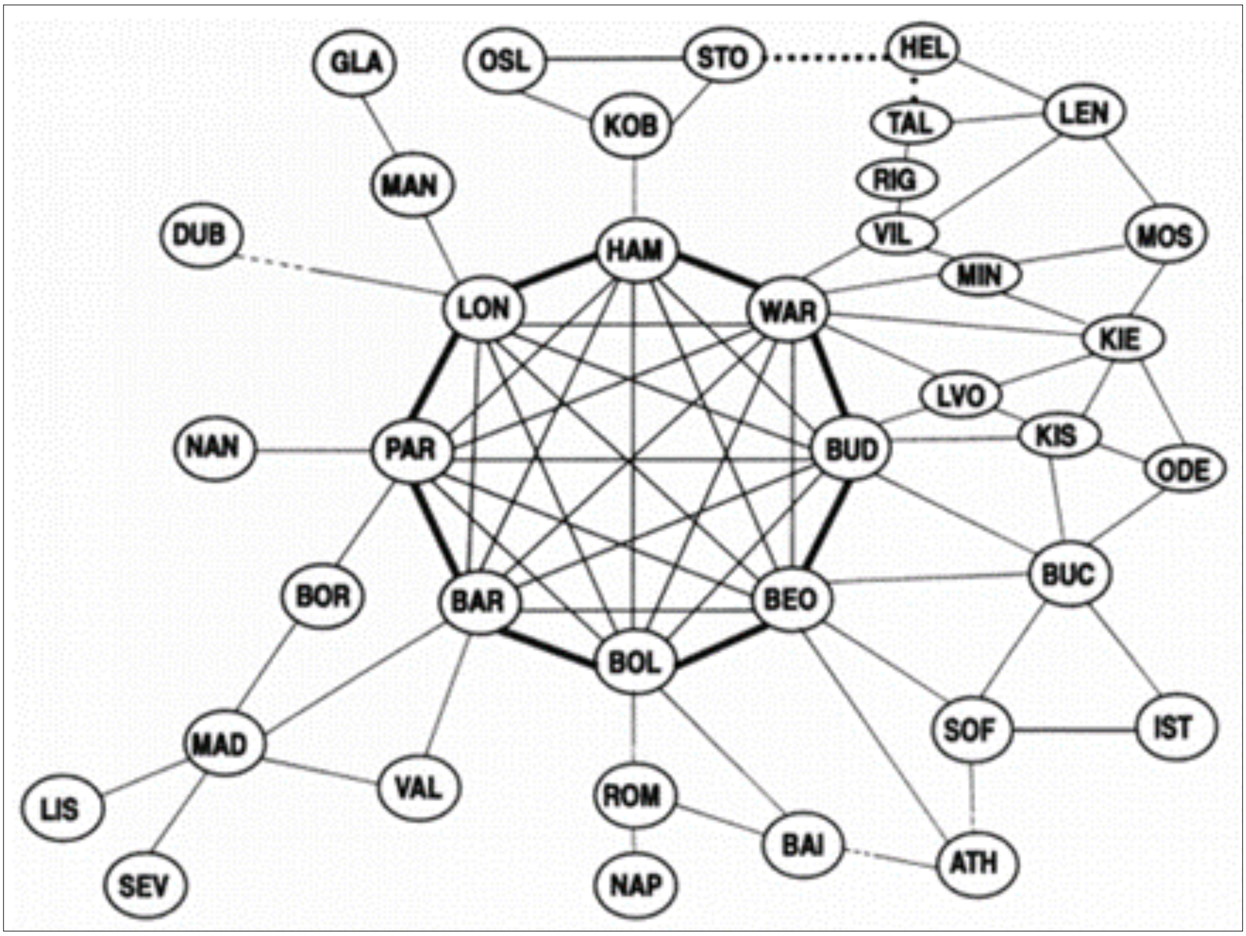
In 1988, UIC set up a special working group (Mission Grande Vitesse) to promote the idea of a European high-speed network and coordinate the activities of rail undertakings that go beyond the European Community. Thanks to additional technical, economic and financial analyses, the first master plan was extended to Central Europe, Scandinavia and the Balkans, and later also to the Baltic States, Belarus, Ukraine, Moldova and the Russian Federation. The long-term Masterplan was presented in 1992 on the occasion of EURAILSPEED 92. The network was initially based on the north-south axis connecting to the main routes of the European Community but was expanded to meet the need for the development of East-West connections. In the central part, covering the densest areas (from London, Paris, Barcelona in the West, to Warsaw, Budapest, Belgrade in the East), gateways were proposed to more peripheral regions (figure III-1):[63]

- London for Great Britain and its islands
- Hamburg towards the Scandinavian States
- Warsaw and Budapest for eastern directions
- Belgrade for the Balkan Peninsula
- Bologna for Italy
- Barcelona and Paris for the Iberian Peninsula and the Atlantic States.

[63] M. Walrave, *The development of high speed rail innovation and tradition. Prospects for the future*, "Rivista Internazionale Di Scienze Sociali", 1993, t.101, no 3, pp. 375–397.

In its plan, UIC proposed the creation of a pan-European network connecting the whole continent using three types of lines: ones with a speed of 300-350 km/h, upgraded to the speed of 200 km/h and lines existing as feeder connections.

Figure III–1 **One of the first concept of the European High-Speed Rail Network**



Source: UIC, Walrave M., *The development of high-speed rail innovation and tradition. Prospects for the future*. Rivista Internazionale Di Scienze. Sociali Internazionale Di Scienzel inno.

In January 1989, a working group established inside the Community of European Railway and Infrastructure Companies (CER) officially presented a development plan to the governments and leaders of the European Community. In December 1989, the European Committee of Ministers adopted a resolution to create a High-Level Group to explore the possibility of establishing a high-speed rail system on a European scale. The first stage of the report was ready in December 1990 and included the European Masterplan project with a time horizon of 2010. In February 1991, the Commission of the European Communities presented a proposal in Brussels regarding the establishment of a high-speed rail network in Europe.

1.1.2 Towards the European high-speed network

Plans for the development of an international transport network in Europe moved to an institutional level in 1996 with Decision No. 1692/96/EC of the European Parliament and of the Council on Community guidelines for the development of the Trans-European transport network, containing maps listing the lines included in the network and new planned lines. The existing and planned rail network in the EU-15 States was indicated on the maps. In addition to conventional rail maps, maps for high-speed rail were also published. This decision has been subsequently amended on a number of occasions to update the network,

A breakthrough in the approach to the development of the TEN-T took place in 2013 with Regulations 1315/2013 and 1316/2013 discussed extensively in previous chapters.

For European Union neighbouring States, transport networks have been established with links to the TEN-T in later EU Regulation 473/2014 and 758/2016. Since the publication of the TEN-T regulations, high-speed rail systems:

- Have further developed technology to reach speeds at and beyond 350 km/h.
- Have experienced lowered costs.
- In the planning approach, more emphasis has been put on the economic efficiency of high-speed rail systems.

1.2 Identification of high-speed rail projects in TER States

1.2.1 General assumption

In order to identify high-speed rail projects, the following documents were reviewed:

1. Specifications of existing high-speed lines with a maximum speed at least 200 km/h.
2. The infrastructure managers' registers.
3. Within the EU area, the lines in the core and comprehensive network identified in the Regulation 1315/2013 are identified as high-speed rail projects.
4. UIC studies, in particular Atlas High Speed Rail. UIC, December 2019.
5. Questionnaire responses sent by TER States.
6. Other public information.

Rules for definition the of high-speed lines are described in Part I of Study ***Methodology, definitions and rules for the identification of high-speed rail projects***.

1.2.2 Regional structure of transport network

The development of the rail network in this area results from geographical and historical conditions as well as from socioeconomic structure and international connections. A significant part of passenger and freight transport takes place within this region. For this reason, and for methodological reasons, the development of the TER HSR network concept was considered at three levels:

- Individual States
- Regions grouping individual States
- Supra-regional corridors connecting those regions.

For the purpose of this analysis, the following regions have been distinguished in the TER network's area and its neighbourhood:

1. Central Europe including Austria, Czechia, Hungary, Poland and Slovakia
2. South-Eastern Europe includes Bosnia and Herzegovina, Bulgaria, Croatia, Greece, North Macedonia, Romania, Serbia and Slovenia
3. Baltic States (Estonia, Latvia, Lithuania)
4. Eastern Europe includes Armenia, Belarus, Georgia and Russian Federation
5. Turkey.

1.3 Central Europe

1.3.1 Up-to-date plans and their coordination

The first plans for high-speed lines in this region were developed as early as in the 1990s. After the accession of this region's States to the EU, the first arrangements of the planned HS lines were carried out. The most important document and the first in the region was the so-called Visegrad Protocol, in which the ministers responsible for transport in Poland, Czechia, Slovakia and Hungary presented their ideas for the development of the transport network in their States and road network, waterways networks and HSR networks links with neighbouring States. The agreement was prepared in April 2010 and forwarded to the European Commission in order to be included in plans for the TEN-T amendment that took place in 2013.

In subsequent years, feasibility studies for individual lines in the States of the region were prepared. In the field of feasibility studies, a joint coordination work between Poland and Czechia has been in operation since 2009 also for the preparation of a new TEN-T network in the region.

On 21 May 2019 in Bratislava, a crucial agreement – Joint Statement concerning the project of HSR network in Central Europe and its financing – was signed by the Ministers of Visegrad Group (Poland, Czechia, Hungary and Slovakia) responsible for transport, development and EU funds, in order to speed up investment and make the network operational.

1.3.2 Austria

Concept development

The Austrian rail system, or even more broadly – the entire Austrian transport system, is a transit one characterised by difficult terrain through the Alps. The program of adapting the rail network to new transport needs, including the construction of a HSR network, is based on activities performed on relatively short line sections.

Status of the preparatory works

The first corridor to be modernised was the Vienna – Linz – Salzburg line. The works started in 1987. First, the Linz – Wels section was modernised to allow for 200 km/h operation accompanied by the elimination of some track geometry constraints. In the 2000s activities focused mainly on the Linz – Sankt Pölten section. The line section between Sankt Valentin and Linz was modernised to 230 km/h in 2007. In 2012, a new 50 km line section was opened between the Wien Meidling station and Sankt Pölten. This route is mostly at 250 km/h and aims to improve the capacity on the most-loaded section of the route – the new route supports transit and long-distance traffic, and the old line handles local and transit traffic. In 2016, the next and a completely new section of the route between Ybbs and Amstetten, was completed with a maximum speed of 250 km/h. In the 2020s, further works are scheduled to increase the speed of the line, mainly between Linz and Salzburg.

The second corridor planned for modernisation is the one from Vienna to the southwest – to Graz, Klagenfurt and Villach, and then to Venice, Trieste and Ljubljana. In this case, apart from modernisation works, the construction of a completely new section of the line between Graz and Klagenfurt was planned (there is currently no direct connection between these two cities). The construction of the new line started in 2001, it is expected to be completed by 2025. The line will have a maximum speed of 250 km/h. Its length will be more than 120 km, of which 33 km in tunnels under the mountains of Koralm. The travel time from Graz to Klagenfurt on this route will be 45 minutes (currentlyit is three hours by rail or two hours by bus). The second newly built line section in this corridor is the tunnel under the Semmering Pass. Its construction will allow travel time to be reduced by 30 minutes due to the shorter route and the higher speed – 250 km/h.

The third section constructed in this corridor is a line from Vienna to Wiener Neustadt, which is to increase the capacity of the Vienna node and separate long-distance and local traffic. In the longer term, a new line will also be created between Graz and Bruck an der Mur. In the coming years, work will be carried out at the exit from the Vienna node on the following sections:

- Wien Meidling – Wampersdorf – Wr. Neustadt – Gloggnitz: upgrade. The project aims to increase capacity in the section Wien – Wr. Neustadt and to reduce travel time in the section Wr. Neustadt – Gloggnitz. Financing is secured with national funds (ÖBB-Rahmenplan)
- Wien Meidling – Altmansdorf: upgrade and track duplication (2020-12/2023)
- Wien Blumenthal – Münchendorf: upgrade up to 200 km/h and track duplication (2014-12/2019)
- Münchendorf – Wampersdorf: upgrade up to 200 km/h and track duplication (2020-12/2023)
- Wampersdorf – Wiener Neustadt: upgrade to 160 km/h (2018-12/2023)
- Wiener Neustadt – Gloggnitz: upgrade to 160 km/h (2023).

The third of the main modernised corridors runs south through the western part of the country connecting Munich in Germany to the Italian city of Bolzano through Innsbruck in Austria. As part of the works, a line section between Wörgl and Volders-Baumkirchen was modernised to a speed of 220 km/h and a freight bypass in Innsbruck was built. The modernisation of the line to the German border is also planned. The largest investment within this corridor is the ongoing construction of a tunnel under the Brenner Pass between Innsbruck and Fortezza in Italy. After its connection to the existing tunnel on the southern freight bypass, the tunnel will be the longest rail tunnel in the world. It is planned as a line designed for 250 km/h. Works on border lines to Czechia, Slovakia and Hungary have also been planned and have partially commenced.

The projects implemented under the Slavkov Working Group are as follows:

- Wien Süßenbrunn (i) – border AT/CZ at Berhardsthal upgrade. The project aims to reduce the travel time between Wien Hbf and Breclav to approximately 45 minutes, increase capacity and safety by removing level crossings and modernise train services. The line is divided into the following sections:
  - Wien Süßenbrunn – Gänserndorf: upgrade up to 160 km/h and capacity increase – 2022-12/2027
  - Gänserndorf – border AT/CZ at Bernhardsthal: upgrade to 200 km/h and capacity increase – 2021
- Gänserndorf – border AT/SK near Marchegg: upgrade to 120 km/h and electrification. The project aims to allow the use of electric traction on the route from Bratislava via Gänserndorf, Stockerau, Tullnerfeld St. Pölten and further, mainly for freight trains and to improve regional transport in the Gänserndorf – Marchegg area.

Parameters and location of the lines

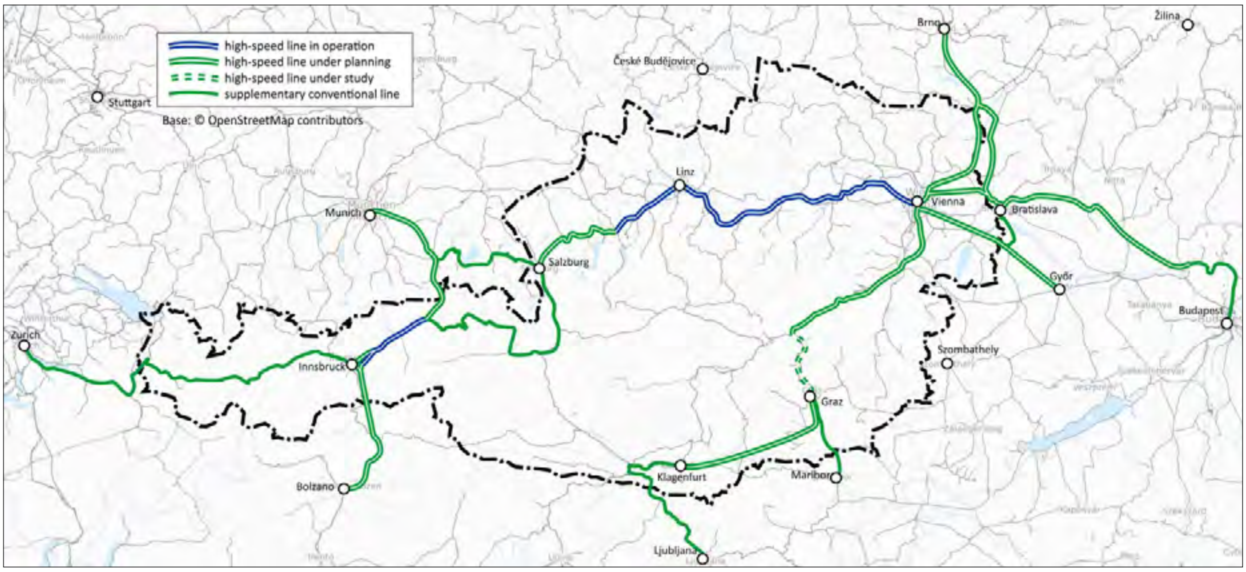
The main data regarding planned high-speed lines in Austria are shown in table III-1. The location of the lines is shown in figure III-2. The map also identifies connections with neighbouring States.

Table III–1 Austria's planned high-speed line main data

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
In operation					
Linz – Wels	19	200	Modernised	1990	
St. Pölten – Ybbs	43	200	Modernised	2001	
Amstetten – St. Valentin	37	200	Modernised	2003	
St. Valentin – Linz	19	230	Modernised	2007	
Wien Knoten Hadersdorf – St. Pölten	50	250	New	2012	
Wörgl – Volders-Baumkirchen	36	220	Modernised	2012	
Wels – Attnang-Puchheim	30	230	Modernised	2012	
Ybbs – Amstetten	17	250	New	2016	
Under construction					
Wien Inzersdorf Ort – Wr. Neustadt	47	200	New	2023	
Graz – Klagenfurt	122	250	New	2025	
Gloggnitz – Mürzzuschlag	28	230	New	2026	
Volders-Baumkirchen – Staatsgrenze AUT/IT (Brenner Base Tunnel)	46	250	New	2027	
Wien Stadlau – Staatsgrenze AUT/SK	38	200	Modernised	2022	
Planned					
Linz – Wels	24	230	Modernised	2026	
Gänserndorf – Staatsgrenze AUT/CZ	47	200	Modernised	2028	
Wörgl – Kufstein – DE	16*		Modernised		* approx
Graz – Bruck an der Mur – Mürzzuschlag	80*		New		* approx
Wien Kledering – Rajka (HU)	30*		New		* approx
Wels – Salzburg	95*		Modernised		* approx

Source: UIC High Speed Rail Atlas 2018, Country Questionnaire, EU Reg.1315/2013.

Figure III–2 Status of HSR network in Austria



Source: Country Questionnaire, UIC High Speed Rail Atlas 2018, EU Reg.1315/2013.

1.3.3 Czechia

Concept development

The development of a high-speed network in Czechia came to a head in May 2017 when the Government approved a key strategic document for the development of HSR in Czechia, known as the Program for the Development of Rapid Services in Czechia.[64] At the government level the objective was to decide on the framework conditions for a further preparation of the HSR project in Czechia and to set out the basic conceptual background for the future decisions and planning.

The HSR ("Rapid Services" – RS) proposal has been identified as a possible solution for the further development of conventional rail covering additional electrification of existing rail lines, their doubletracking etc. with an estimated investment of CZK 250-300 billion. The development of Rapid Services, including the construction of new high-speed lines was recommended as the most suitable solution. It reflects the geographic context of Czechia and Central Europe, their settlement system and the density of the rail and other networks, availability of technologies and know-how, costs, spatial planning processes, protection and tradition, legal framework, socioeconomic trends and their mutual synergies, dependencies and risks.

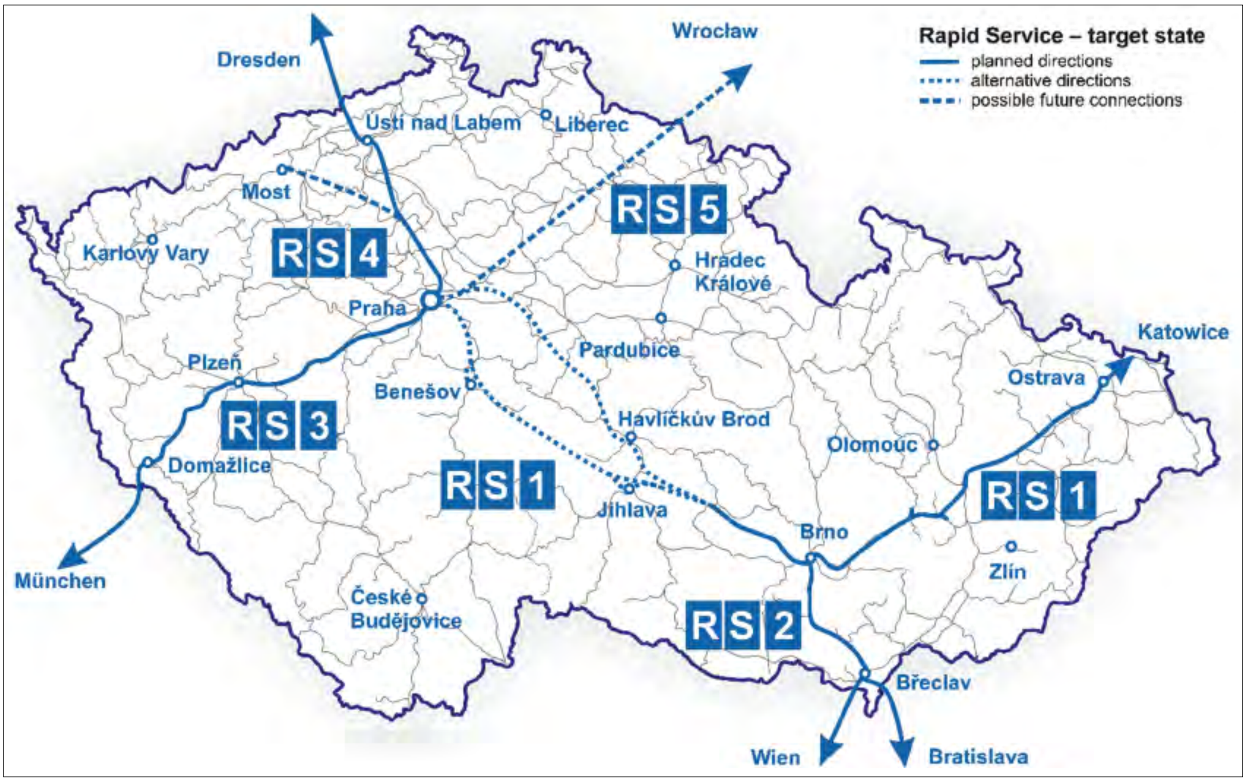
The concept of Rapid Services not only identifies the needs related to infrastructure development, but also sets up a suitable operational model for the entire future system with the aim of creating fast, accessible and high-quality connections between major centres within Czechia and abroad. In this context, it should be noted that the RS system will not only consist of lines with high-speed parameters (above 200 km/h), which will form its backbone, but many conventional lines will be modernised to speeds of more than 200 km/h. This concept will increase versatility, accessibility and attractiveness of this network because it will allow certain regions without a direct link to newly constructed high-speed lines, to be included.

In line with the TEN-T policy, Czechia plans the following HSR infrastructure:

- RS 1: Prague – Brno – Ostrava – Katowice – Warszawa – Žilina (– Košice)
- RS 2: Brno – Breclav – Vienna – Graz – Bratislava – Budapest
- RS 3: Prague – Pilsen – Regensburg – Munich – Nuremberg
- RS 4: Prague – Usti nad Labem – Dresden – Berlin – Hamburg – Leipzig – Frankfurt
- RS 5: Prague – Wroclaw – Warsaw (– Rail Baltica).

[64] *Program for the Development of Rapid Services in the Czech Republic [In Czech: Program rozvoje Rychlých železničních spojení v ČR]*, Prague 2017.

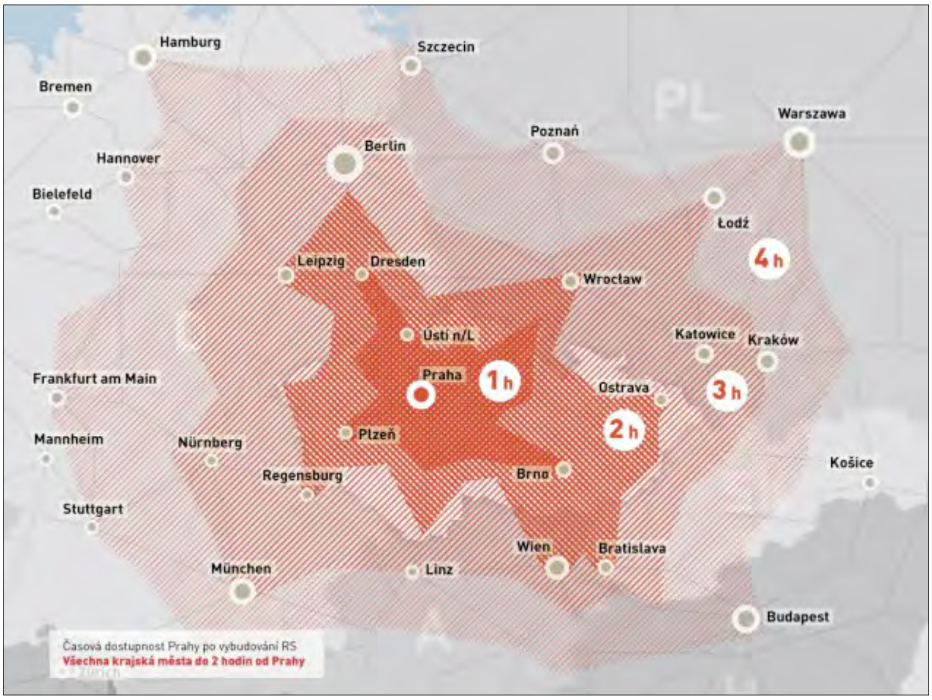
Figure III–3 Proposed routing of the newly constructed HS lines (line RS1 Prague – Brno in variants)



Source: Ministry of Transport, 2017.

The high-speed rail network in Czechia focuses heavily on maintaining good transport connectivity with its neighbouring States in all regions. This is illustrated in figure III-4 with the travel time isochrones from Prague.

Figure III–4 Assumed travel time to Prague from Central Europe cities



Source: Ministry of Transport, 2015.

Status of preparatory works

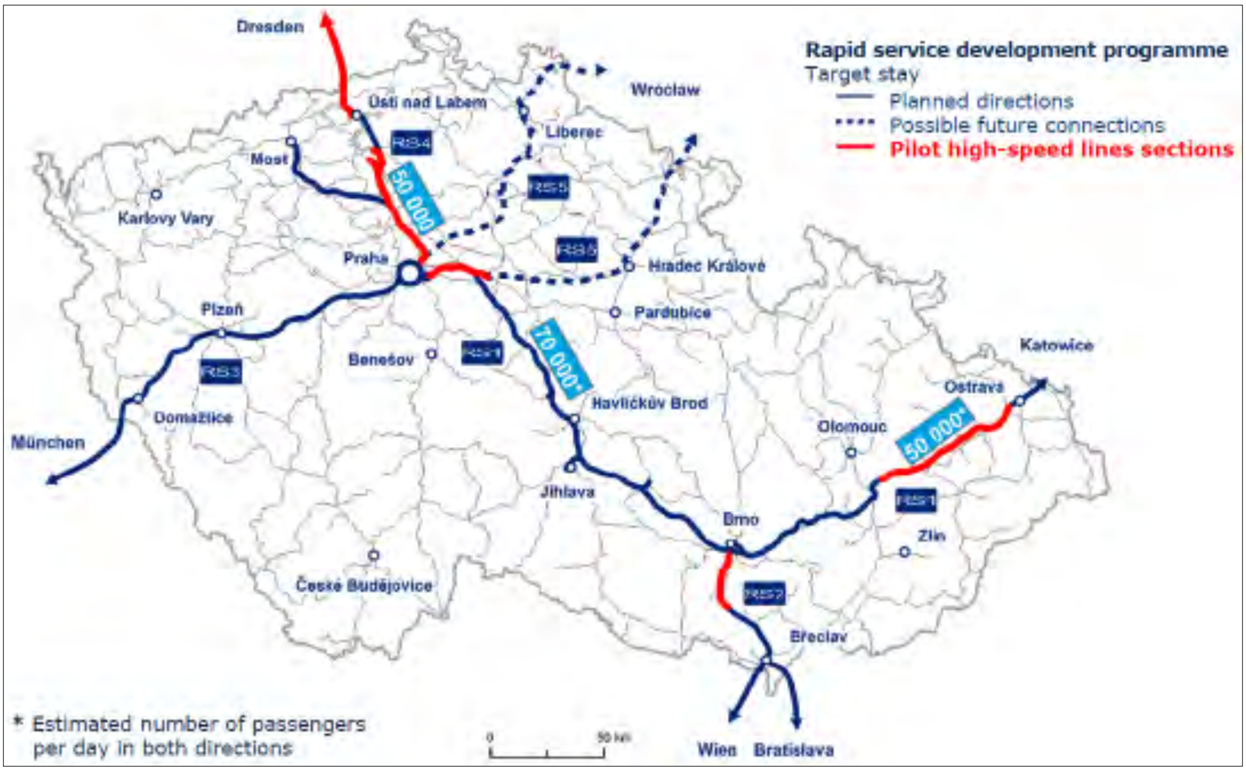
Currently, studies are being carried out for individual line projects. The highest advancement level concerns the so-called pilot sections:

- From Prague towards Dresden
- From Brno to Sakvice (direction Breclav)
- From Prerov to Ostrava
- From Prague to Poricany.

The works on the Prague – Dresden line are the most advanced and were discussed in detail in chapter II section 7.

In 2009, cooperation was established between the Czech and Polish infrastructure managers and ministries responsible for transport, aimed at determining the location of the planned routes and on carrying out joint feasibility studies. In 2011, a letter of intent was signed by the Ministers. For the connection between Prague and Wroclaw, preliminary feasibility studies were carried out adequate to studies made by the Polish side in 2015. Two basic variants of the line location were defined. Then the Czech study was initiated and finished in 2018. The choice of the final variant will be the subject of a joint, full feasibility study.

Figure III–5 Pilot sections selected from planned HSL Network in Czechia



Source: SZDC.

Table III–2 Implementation of Rapid Services System development programme

Period	Action
	Rapid service system
2019-2020	Completion of feasibility studies for individual Rapid Service branches
2020-2023	SŽDC as an authorized investor shall apply for updating of the Land Use Development Regulations
2024-2029	SŽDC shall commence the HSL pre-engineering and engineering (zoning decision, EIA, building permit)
After 2030	SŽDC shall start HSL construction
	Pilot HSL sections
2018-2019	SŽDC as an authorized investor shall apply for updating of the Land Use Development Regulations for pilot HSL sections
2019-2021	SŽDC shall commence pre-engineering for pilot HSL sections (zoning decision and EIA)
2022-2024	SŽDC shall commence engineering for pilot HSL sections (building permit)
After 2025	SŽDC shall start construction of pilot HSL sections

Source: SZDC.

Key line parameters

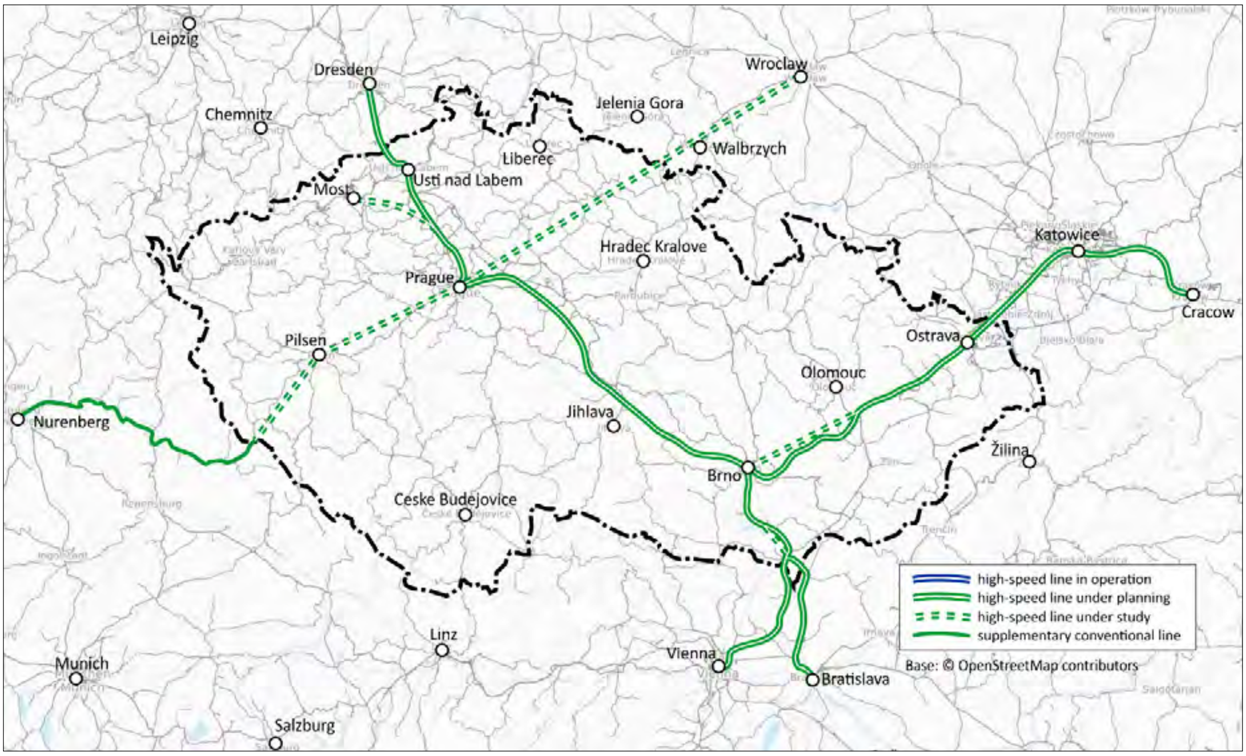
The main data of the planned high-speed lines in Czechia are presented in table III-3 and figure III-6.

Table III–3 The main features of the high-speed lines planned in Czechia

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Prague – Litomerice/Lovosice	58	350	New	ca 2030 (phase 2)	Feasibility study underway
Litomerice/Lovosice – border DE (to Dresden)	40	350; tunnel section 200-250	New	after 2035	Feasibility study underway
Branch odb. Veltrusy – Most	85 *	250	New	after 2035	* approx.
Prague – Brno	206	350	New	after 2035 (phase 2)	Feasibility study underway
Prerov – Ostrava	73	350	New	ca 2028	Tender for Feasibility study
Prague – Pilsen	75	250	New	phase 3	Feasibility study underway
thereof Tunnel section Prague – Beroun	25*		New	phase 2	* approx.
Prague – border PL (to Wroclaw)	165	350	New	phase 3	
Ostrava – border PL (to Katowice)	21	200	New	phase 3	
Sakvice – Breclav	23	350	New	after 2035 (phase 2)	
Brno – Sakvice	35	350	New	ca 2029	
Brno – Prerov	80	200	Modernised	ca 2030	Spatial planning underway

Source: Country Questionnaire, UIC High Speed Rail Atlas 2018, EU Reg.1315/2013.

Figure III–6 Status of planned network in Czechia



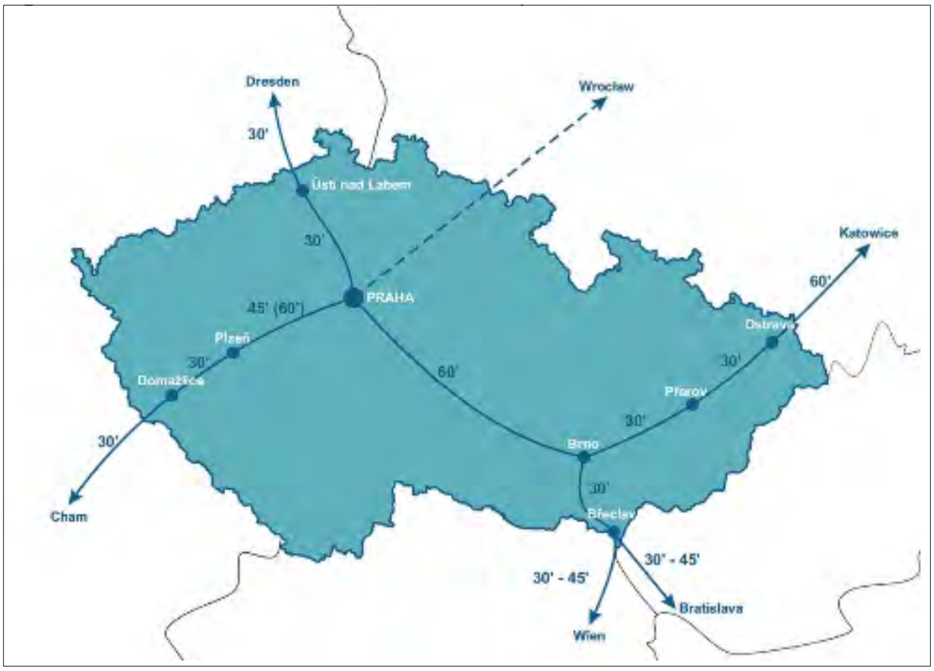
Source: Country Questionnaire, UIC High Speed Rail Atlas 2018, EU Reg.1315/2013.

The pilot sections already selected include: the tunnel under the CZ-DE border (part of Litomerice/ Lovosice - Dresden line), eastbound exit section out of Prague (part of Prague – Dresden/Brno lines), Prerov – Ostrava, Brno – Sakvice. Construction works are expected to be started shortly after 2025.

- Phase 2: time horizon for the planning and start of the construction (ca 2030) of the remaining sections of the following lines: Prague – Litomerice/Lovosice – Dresden/Most, Prague – Brno, Brno – Breclav – AT/SK, tunnel Prague - Beroun
- Phase 3 is expected to be carried out after 2040 or later: Prague – Pilsen – DE, Prague – PL (Wroclaw).

Estimated travel times after completion of the HSR network are shown in figure III-7. They have been shortened, on average, by 50 per cent compared to current travel times.

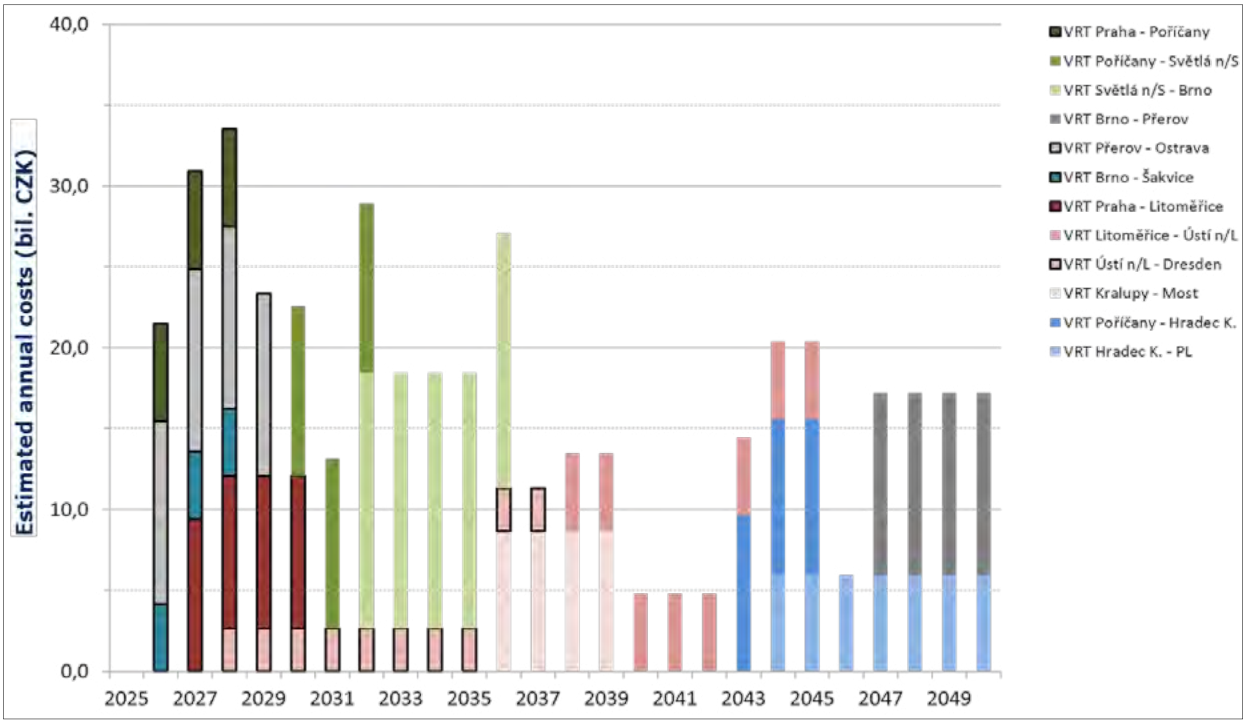
Figure III–7 **Estimated travel times after completion of HSR network in inland and international connections**



Source: Ministry of Transport, 2017.

The overall costs for the project to 2050 are shown in figure III-8.

Figure III–8 **Investment cash flow of high-speed lines construction**



Source: "Progress of Rapid service Preparation" (2019), SZDC.

1.3.4 Poland

Concept development

In Poland, the first concepts on high-speed line construction emerged in the 1930s (Polish production and introduction of the Luxtorpeda project – reaching 140 km/h maximum speed), and then in 1980s. At this time, the first trains with a speed of 160 km/h were put into operation on the CMK line from Grodzisk to Zawiercie. This line was designed in the 1970s with geometric parameters allowing a maximum speed of 250 km/h, with a potential increase of up to 300 km/h. The plans developed in the 1970s already provided for the extension of the CMK line to Gdańsk with parameters allowing for a maximum speed of 300 km/h, with a potential increase of up to 400 km/h. The second high-speed line planned for construction was the East-West axis line through Warsaw, Łódź and Poznań and further to Berlin. In the early 1990s, a study was carried out identifying the location of this line running from the eastern border to Western Poland. It was assumed that this line will be part of the Berlin – Moscow line. The design speed was 300 km/h.

In 2001, the concept of modifying the planned high-speed line network in Poland was presented. It also contained conclusions from the comments submitted to the project from the early 1990s at the stage of its consultation. The new concept was based on the establishment of major transport axes in Poland:

- Southwestern Poland – north-eastern Poland (connecting such centres as Wrocław and Białystok through Warsaw)
- North-western Poland with south-eastern Poland (connecting Szczecin and Poznań with Lublin and Rzeszów via Warsaw)
- Northern Poland with southern Poland (connecting Gdańsk with the Lesser Poland Region and Upper Silesia Region via Warsaw)
- Greater Poland Region – Lesser Poland Region (connection between Poznań and Cracow via Łódź).

These axes were to be based on new high-speed lines complemented by lines modernised to higher technical parameters.

It was also proposed to connect the existing CMK line to the new line through the existing section of line No. 25 from Łódź to Opoczno, which would allow the connection of the six largest agglomerations in Poland (additionally Cracow and Katowice) with a total population of nearly 10 million.

After public consultations in 2005 a Preliminary Feasibility Study for the construction of the Warszawa – Łódź – Poznań/Wrocław line was prepared for PKP PLK S.A. by the Scientific and Technical Rail Centre. In 2006, EU financial support was granted from I&EOP funds for the feasibility study and other preparatory works related to the construction of the new line. At the same time, funds were granted for an analogous feasibility study for the modernisation of CMK to high-speed parameters and its extension to Katowice and further to the southern border of Poland and to Cracow.

The proposed locations of new lines and the fast passenger connection network were also supposed to ensure high transport availability of the new airport for Warsaw, located according to the concept from the 1970s near the intersection of the Warsaw – Łódź – Poznań/Wrocław line and the CMK line extended to Gdańsk and A2 motorway.

In 2008, the Resolution of the Council of Ministers regarding the Program for the construction and operations of high-speed rail transport in Poland was adopted. The implementation of this Resolution was entrusted to PKP PLK S.A. The work was to be supervised by the Interministerial Team for high-speed railways.

Although, in December 2011, the works related to the development of HSRs in Poland was suspended until 2030, the decision was reversed in 2016 and the project was revived.

Since 2017, a new concept is being analysed and developed focusing on the additional construction of high-speed lines to service the planned new airport (CPK) in the Warsaw agglomeration in Poland with the main document out for consultation. There are currently no feasibility studies for new concepts. On 28 October 2020, the Council of Ministers adopted a resolution on the establishment of the multi-annual program "Central Communication Port investment program. Stage I. 2020-2023". From the railway's point of view, this enormous project includes the new intermodal hub (the CPK), it will cover 1 800 km of new rail lines and a dedicated, new rail station at this hub. Investments will start in 2023 together with the construction of the first 530 km of new railway lines. The whole rail part of the CPK project is planned to be finished at the end of 2034, with the addition of 12 new railway routes.

Preparatory works

The layout of international high-speed lines in Poland was determined in 2010 and incorporated into EU Regulations 1315/2013 and 1316/2013, covering the following corridors:

1. The CMK line from Gdańsk via Warsaw to Katowice and Cracow and from Katowice to the state border with Czechia.

   The section of the line from Grodzisk Mazowiecki to Zawiercie (224 km) is currently in operation at a speed of up to 200 km/h. In December 2015, on a part of the modernised CMK line for Warsaw – Katowice and Warsaw – Cracow, high-speed trains with a maximum speed of 200 km/h have started to operate. The higher speed is foreseen until 2023 after completion of the next phase of modernisation works. For the section of the current line towards Katowice and Cracow and the section from Katowice to the state border with Czechia, the feasibility studies were carried out in 2010. In 2011 a preliminary study was carried out for the section from Warsaw to Gdańsk, with an indication of the most favourable route through Płock, Toruń, Grudziądz and Kwidzyn, identified after public consultations.

2. Line Y from Warsaw via Łódź to Wrocław and Poznań and then to Prague and Berlin.

   A feasibility study for the section from Warsaw via Łódź to Wrocław and Poznań was completed and adopted in 2012. In 2015, a preliminary feasibility study was completed for the extension of the Warsaw – Łódź – Poznań/Wrocław line to Berlin and Prague. The location options of the line on the Poznań – border PL/DE and Wrocław – border PL/CZ lines were selected for further studies to be carried out jointly with neighbouring States.

3. Rail Baltica: Warsaw – Białystok – PL/LT border and then to Tallinn (Helsinki) and Vilnius.

   Work is currently underway to complete modified feasibility studies for the Rail Baltica line from Warsaw to the PL/LT border. The Warsaw – Białystok – Ełk line will be modernised to the speed of 200 km/h and a new line (Ełk – PL/LT border) will be built with a maximum speed of 250 km/h. Within the NSB corridor there is also a branch from Warsaw to the PL/BY border (Terespol / Brest). The line is currently being modernised to 160 km/h.

In the study of the directions of development of high-speed lines in Poland (2011), the concept of high-speed lines from Warsaw to Lublin and further to the border with Ukraine was considered. However, it was not considered in further plans. Currently, there are no approved plans to build high-speed lines in Ukraine.

As mentioned above, in 2016 the HSR lines concept was re-introduced and in 2017, works were initiated on the concept of a new central international airport located in the west of Warsaw. The new airport will be a multimodal hub, supported by the new railway network which would be included in the TEN-T high-speed rail network according to the general concept presented in the Study, as its location was already included in the feasibility studies for lines Y and CMK (figure III-9). Additionally, there are concepts to increase the number of high-speed lines in Poland as short connecting and supplementary sections of local and national importance. In 2020, the works are progressing dynamically with the involvement of the PKP PLK company and supported by the Polish government and the EU.

Location and parameters of the lines

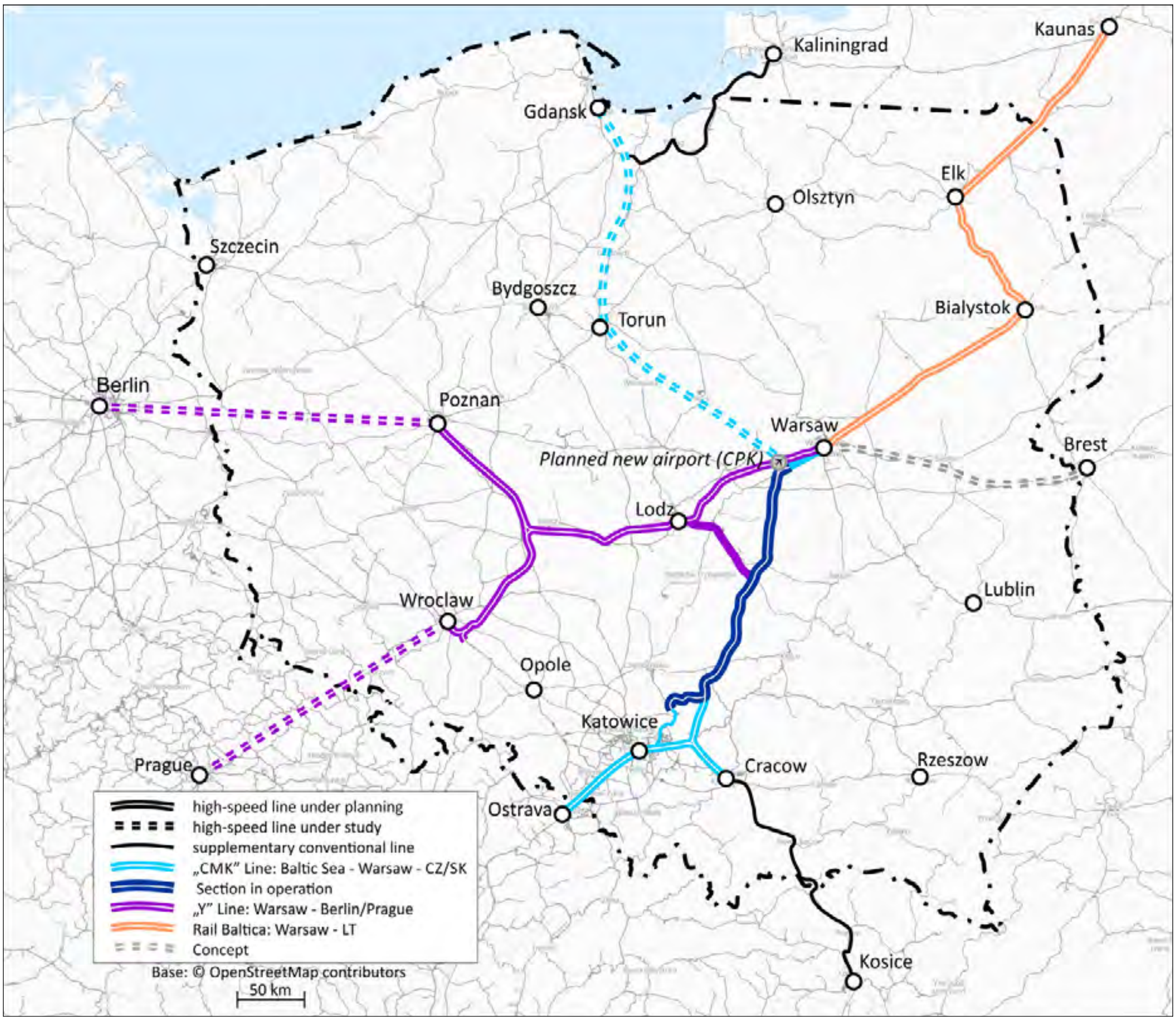
The characteristics of the main high-speed lines planned in Poland are shown in table III-4 based on the previously prepared feasibility studies. The location is shown in figure III-9. The map was prepared considering connections to the neighbouring States, especially Czechia because both (Polish and Czech) networks are highly compatible and since 2009 both networks have been subject to joint arrangements at the planning stage.

Table III–4 Main features of the high-speed lines planned in Poland

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
In operation					
CMK, (Warsaw) Grodzisk Maz. – Zawiercie (Katowice)	224	200	Modernised	2014	To be modernised for 250-300 km/h
Planned					
Line CMK					
Knapówka – Katowice/Kraków	138	300	New	After 2030	
Katowice – PL/CZ Border (Ostrava)	61	300	New	After 2030	
Warsaw – Toruń – Gdańsk	357	350	New	After 2030	
Line Y					
Warsaw – Łódź – Poznań/Wrocław	448	350	New	2030	
Wrocław – PL/CZ Border (Prague)	148*	350	New	After 2030	* depending on final option
Poznań – PL/DE Border (Berlin)	171*	350	New	After 2030	* depending on final option
Łódź – Opoczno (CMK)	92	160	Modernised	2030	
Line Rail Baltica					
Ełk – PL/LT Border	80*	250	New	After 2030	* depending on final option
Warsaw – Białystok – Ełk	277	200	Modernised	2030	
Warsaw – PL/BY Border	187	350	New	After 2030	No plans to build the new line in this moment. This concept has been under feasibility study since 1993 (Cretan TER corridor) Existing line under modernisation up to 160 km/h

Source: EU Reg.1315/2013, UIC High-Speed Rail Atlas 2018, Country Questionnaire.

Figure III–9 Main high-speed corridors in Poland



Source: EU Reg.1315/2013, UIC High-Speed Rail Atlas 2018, Country Questionnaire.

The economic efficiency indicators for the construction of high-speed lines in Poland are shown in table II-26. They confirm the economic efficiency of the high-speed rail system construction in Poland. This is demonstrated by the results of the key indicators – ENPV>0, ERR>SDR and B/C>1. This means that these projects are eligible for public funding support.

1.3.5 Slovakia

Concept development

The concepts of HSR construction were considered in Slovakia in the 1990s and in 2010 as part of proposals for the agreement among the V4 Visegrad States. They covered the connection between Bratislava and Zilina with an extension to the Hungarian and Polish border. However, in Regulation 1315/2013, this line is not included as a high-speed one. As part of the TEN-T network, this connection works as a conventional line with a speed of 160 km/h after modernisation. The TEN-T network also includes the conventional line from the Polish border (Muszyna/Plavec) via Kosice to Miskolc in Hungary. This line has currently low technical parameters but after modernisation to 160 km/h it could play an important role in transit traffic as a complement to the TER HSR network.

The high-speed, TEN-T, node is to be Bratislava. It will be connected to Brno, Vienna and Budapest:

- From the Devínska Nová Ves station near Bratislava to the Czechia border – modernise the existing line to the speed of 200 km/h.
- From Bratislava to Štúrovo – the station on Hungarian border – modernise the existing line to 200 km/h.
- From the Devínska Nová Ves station near Bratislava to the border with Austria, the existing line is being modernised to 160 km/h and included in the Austrian high-speed rail network.
- From Bratislava to Žilina the existing line is modernised to 160 km/h almost along its entire length (200 km) except the Púchov – Považská Bystrica section which is under construction. The works are expected to be completed by 20 January 2020.

Preparatory works

The Bratislava node projects are at an advanced stage:

- Devínska Nová Ves to SK/CZ border – to be completed by the end 2022.
- Devínska Nová Ves to SK/AT – to be completed by the end 2020.
- Bratislava – Štúrovo, planned after 2025.

Parameters and location of the line

The main characteristics of high-speed lines planned in Slovakia is shown in table III-5. The lines are shown in figure III-10.

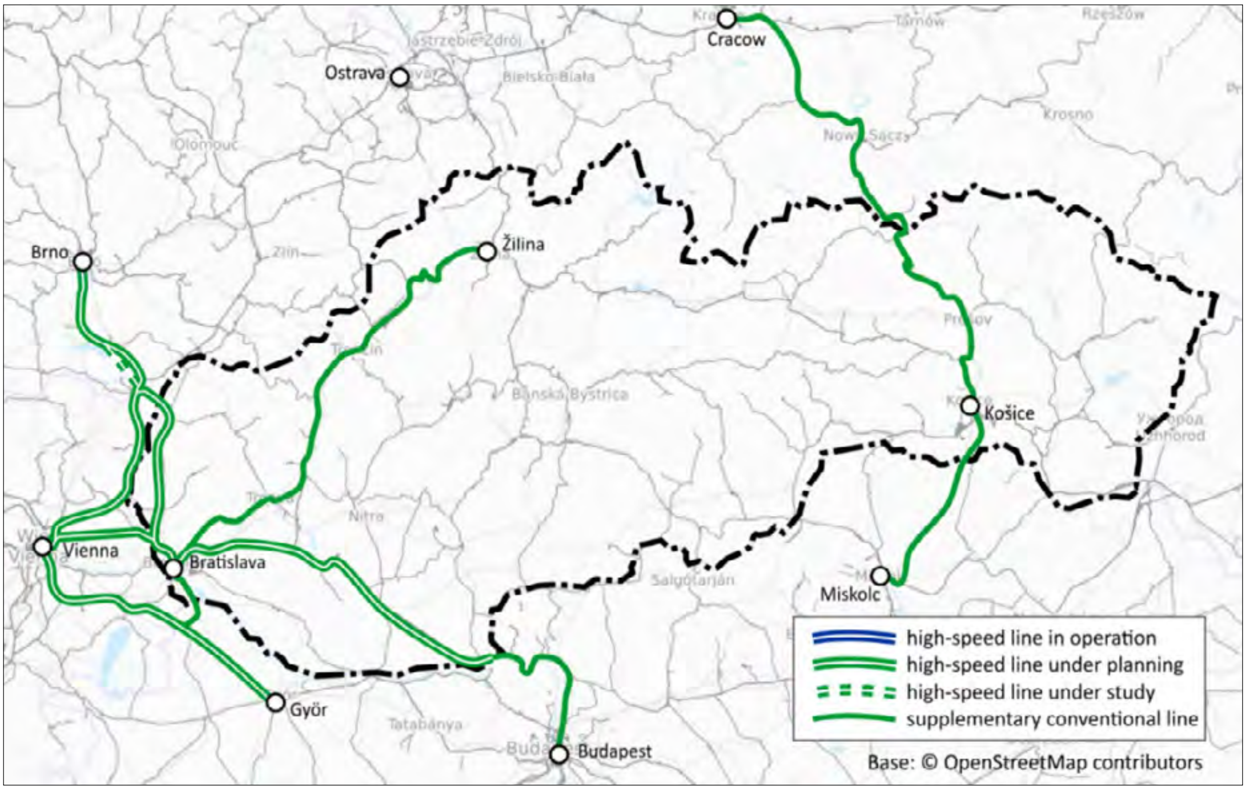
It is recommended to include a conventional line from Plaveč (SK/PL border) to the SK/HU border in the TER high-speed rail system. This line would link the high-speed rail systems in Poland (Cracow node) and Hungary (Miskolc node), including the eastern Slovakia areas of Košice to the TER HSR system. The required parameter for the modernisation of this line is 160 km/h with a potential increase in speed of up to 200 km/h on selected sections.

Table III–5 The main features of the high-speed lines planned in Slovakia

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Devínska Nová Ves – border SK/CZ	58*	200	modernised	2022	* approx.
Bratislava – Štúrovo (border SK/HU)	150*	200	modernised	After 2025	* approx.
Devínska Nová Ves – border SK/AT	4*	160	modernised	2020	* approx. Connection to AT HSL system
Plaveč (SK/PL) – Košice – SK/HU border	125*	160	modernised	After 2030	* approx. Connection between PL, SK and HU HSR system

Source: Country Questionnaire, EU Reg.1315/2013.

Figure III–10 Status of planned HSR network in Slovakia



Source: Own work.

1.4 South-East Europe

1.4.1 Bosnia and Herzegovina

Concept development

As part of the Vc Corridor, it is planned to modernise the existing line from the Croatian border to the Adriatic coast. The line will run from Bosanski Šamac to Čapljina via Sarajevo with a planned increase in line speed to a maximum of 200 km/h. The estimated modernisation cost of the line is €9,875 billion.

The status of preparatory work

The following studies are ongoing:

- Feasibility Study for the section Doboj – Sarajevo
- Prefeasibility Study for the sub-sections: Doboj-Maglaj; Maglaj-Jelina; Jelina-Zenica; Zenica-Podlugovi; Podlugovi-Sarajevo; bypass Visoko-Konjic (to the south)
- Feasibility Study (sections under preparation). General Overhaul completed in 2013 except section Bradina – Raštelica including tunnel Ivan.

Parameters and location of the lines

The main features of high-speed lines planned in Bosnia and Herzegovina are shown in table III-6 with the location is shown in figure III-11.

Table III–6 Main features of high-speed lines planned in Bosnia and Herzegovina

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Bosanski Šamac – Sarajevo – Čapljina	385	200	modernised	2030	

Source: Country Questionnaire.

Figure III–11 Status of HSR network planned in Bosnia

Source: Own work.

1.4.2 Greece

Concept development

The high-speed rail network in Greece is based on the connection of the two largest cities – Athens and Thessaloniki with extensions to the ports of Piraeus and Patra. In the North, there will be a connection through conventional and high-speed lines to the rail networks of Northern Macedonia, Bulgaria and Turkey.

Works on the construction of a new line within the Thessaloniki corridor – Athens have been ongoing since the 1990s. It included the partial modernisation of existing sections (double tracking and electrification), with the construction of new line sections, often in difficult terrain. The line is adapted to speeds in the range of 130-200 km/h but built according to high-speed line standards – with full separation from road traffic, fenceing, long tunnels and viaducts.

The status of preparatory work

Most of the work on the Thessaloniki – Athens corridor has already been completed with the central section still outstanding due to electrification works. Works are also continuing on the Athens – Patra line.

Further development of the HSR network will include the construction of two additional sections – from Thessaloniki towards the border with Turkey (partly a conventional line) and a new section on the Thessaloniki – Athens corridor from Aliartos to Elevsina, west of Athens. This will allow for the further shortening the travel time between the two largest cities of the country, but also will improve the capacity of the node.

Parameters and lines' location

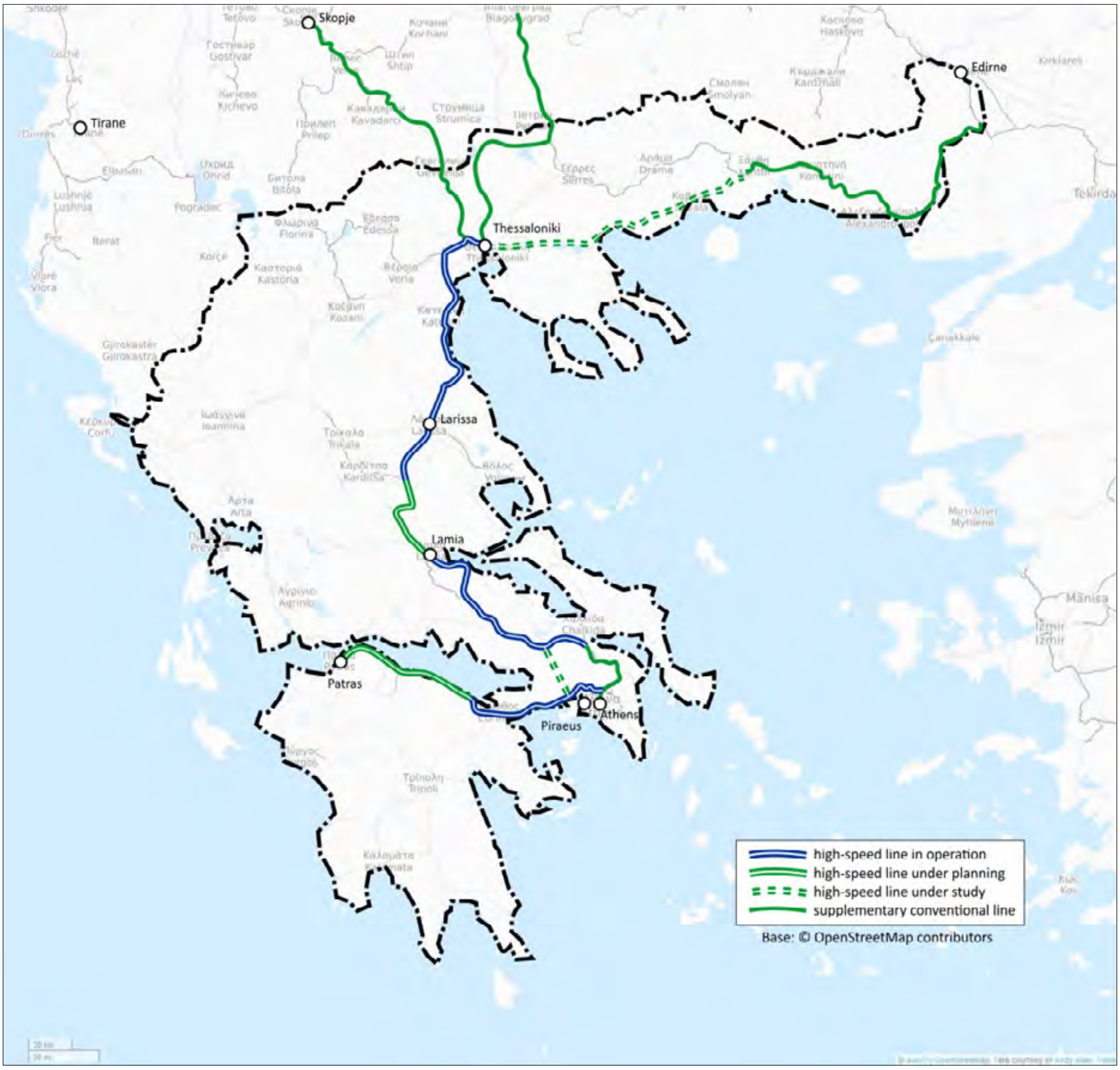
The main characteristics of planned high-speed lines in Greece are presented in table III-7 and are shown in figure III-12.

Table III–7 Main features of the high-speed lines planned in Greece

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
In operation					
Thessaloniki – Paleofarsalos	205		modernised/new		
Paleofarsalos – Domokos	15		modernised		
Lianokladi – Tithorea	55	200	new	2018	
Tithorea – Inoi	94		modernised		
Acharnes – Kiato	102		new		
Under construction					
Domokos – Lianokladi	52	130-160	new		
Kiato – Rio	98		new		
Planned (2050)					
Toxotes – Thessaloniki	175*		new		* approx.
Aliartos – Elevsina	50*		new		* approx.
Rio – Patras	9		new		* approx.

Source: EU Reg.1315/2013.

Figure III–12 Status of HSR network planned in Greece



Source: Own work.

1.4.3 Romania

Concept development

The Romanian National Regulation No. 203 of 2003 concerning the construction, development and modernisation of national and European transport, updated in 2005, called for the development of the high-speed rail network after 2015, depending on agreements with neighbouring States. In this regard, the Ministry of Transport has initiated and developed multiple initiatives at international level to start the development of the Budapest – Bucharest – Constanta high-speed line as an extension of high-speed axis Paris to Budapest.

In November 2007, the Governments of Romania and the Republic of Hungary adopted a Joint Declaration on the high-speed rail line Budapest – Bucharest – Constanta. Official letters to ministries of transport from Hungary and Austria were submitted in September 2008. The first trilateral meeting of the Romanian-Hungarian-Austrian Experts Working Group on the pre-feasibility study took place in 2008. In 2010, it was announced that the Danube Strategy will include a high-speed rail project on the Vienna – Budapest – Bucharest – Constanta line.

The construction of a high-speed line in Romania was also on the agenda of talks among representatives of the Ministry of Transport and Infrastructure in the revision of TEN-T in 2010-2011. EU Regulation No. 1315/2013 set out the new high-speed line from RO/HU border – Arad – Timisoara – Bucharest – Constanca.

The status of preparatory work

No complete feasibility studies have yet been conducted on the new line. In April 2019, €3.1 million were allocated from the Hungarian side for a feasibility study on another section from Budapest to Cluj.

Parameters and location of the line

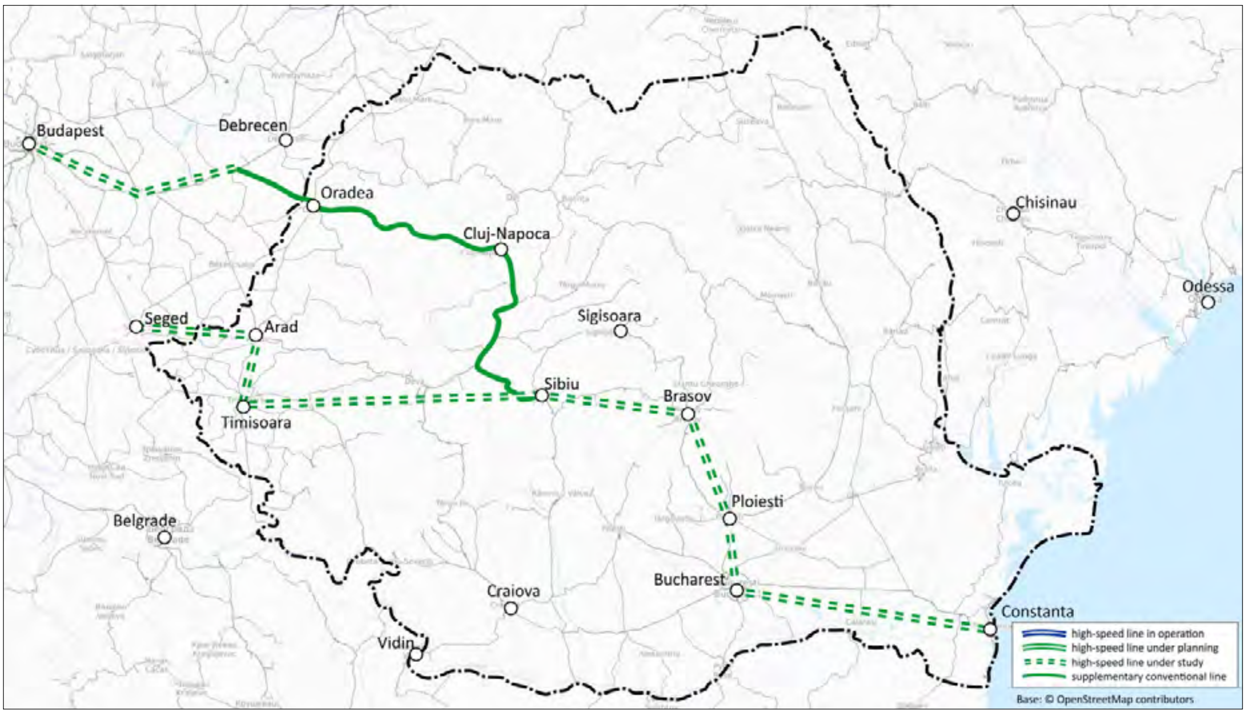
The main features of the high-speed lines planned in Romania are shown in table III-8 and in figure III-13.

Table III–8 Main features of the high-speed lines planned in Romania

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
border HU/RO – Arad – Timisoara – Sibiu – Brasov – Bucharest	600*	300	new		* approx
Bucharest – Constanca	210*	300	new		* approx
border HU/RO – Oradea – Cluj-Napoca – Sibiu	350	160	modernised		

Source: EU Reg.1315/2013. UIC.

Figure III–13 Status of HSR network planned in Romania



Source: Own work.

1.4.4 Serbia

Concept development

The first high-speed line planned in Serbia is part of the Budapest – Athens Corridor which is to connect Central and Southeast Europe – between Budapest (Hungary), Belgrade (Serbia), Skopje (North Macedonia), Athens and the port of Piraeus (Greece). The planned speed is between 160 km/h and 200 km/h.

The network in Serbia could be described as double Y with the main line from Nis via Belgrade to Indjija, split at the ends into sections from Nis to the borders of Bulgaria and North Macedonia in the south, and from Indjija to the borders of Hungary and Croatia in the north. The network consists of sections that should be regarded as conventional supplementary lines (with the speeds of 120-160 km/h) and HS (200 km/h and more).

Status of preparatory works

The part of the rail line within Budapest – Belgrade rail project on the territory of Serbia is currently under construction. The length of this rail line from Belgrade to border with Hungary is 183.1 km with a value of €1,8 billion.

There are also some modernisation projects regarding conventional sections including the modernisation of the Nis – Dimitovgrad (BG) line with electrification, modernisation of the Nis – North Macedonia line and modernisation of the Belgrade – Nis and Stara Pazova – Croatian Border line.

Parameters and location of the lines

The main parameters for the high-speed lines planned in Serbia are shown in table III-9 and in figure III-14.

Table III–9 Main technical parameters of high-speed lines planned in Serbia

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Belgrade – border Serbia/Hungary	183,1	200	Modernised	2023	
Belgrade – Nis	244	200	Modernised		Study under preparation

Source: Country Questionnaire, EU Reg.1315/2013.

Figure III–14 Status of network planned in Serbia

Source: Own work.

1.4.5 Slovenia

Concept development

The construction of a high-speed rail line from northern Italy to Ljubljana was initiated as a part of the Trans-European Networks (TEN) as Priority Axis 6 and Pan-European corridor V. In EU Regulation 1315/2013, the line in Slovenia has been indicated as part of the TEN-T comprehensive network (high-speed) from Venice to the border with Croatia. Further extension of this line could include from Slovenian – Croatian state border via Zagreb to the Croatian – Hungarian border and to Budapest. Comprehensive implementation of the planned sections and their continuation in Croatia through Zagreb will enable construction of a high-speed corridor from Venice to Budapest.

Status of preparatory work

According to the feasibility study completed in 2013 this line in not economically feasible. This is the reason that the line is not included in the development transport strategy for Slovenia until 2030 and therefore is not currently planned for construction.

Parameters and location of the lines

The main technical parameters of high-speed lines planned in Slovenia are shown in table III-10 and in figure III-15.

Table III–10 Main technical parameters of high-speed lines planned in Slovenia

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
IT/SK Border – Ljubljana – SI/HR Border	185				Approximation as construction of the line is currently not economically viable

Source: Country Questionnaire, EU Reg.1315/2013.

Figure III–15 Status of HSR lines planned in Slovenia

Source: Own work.

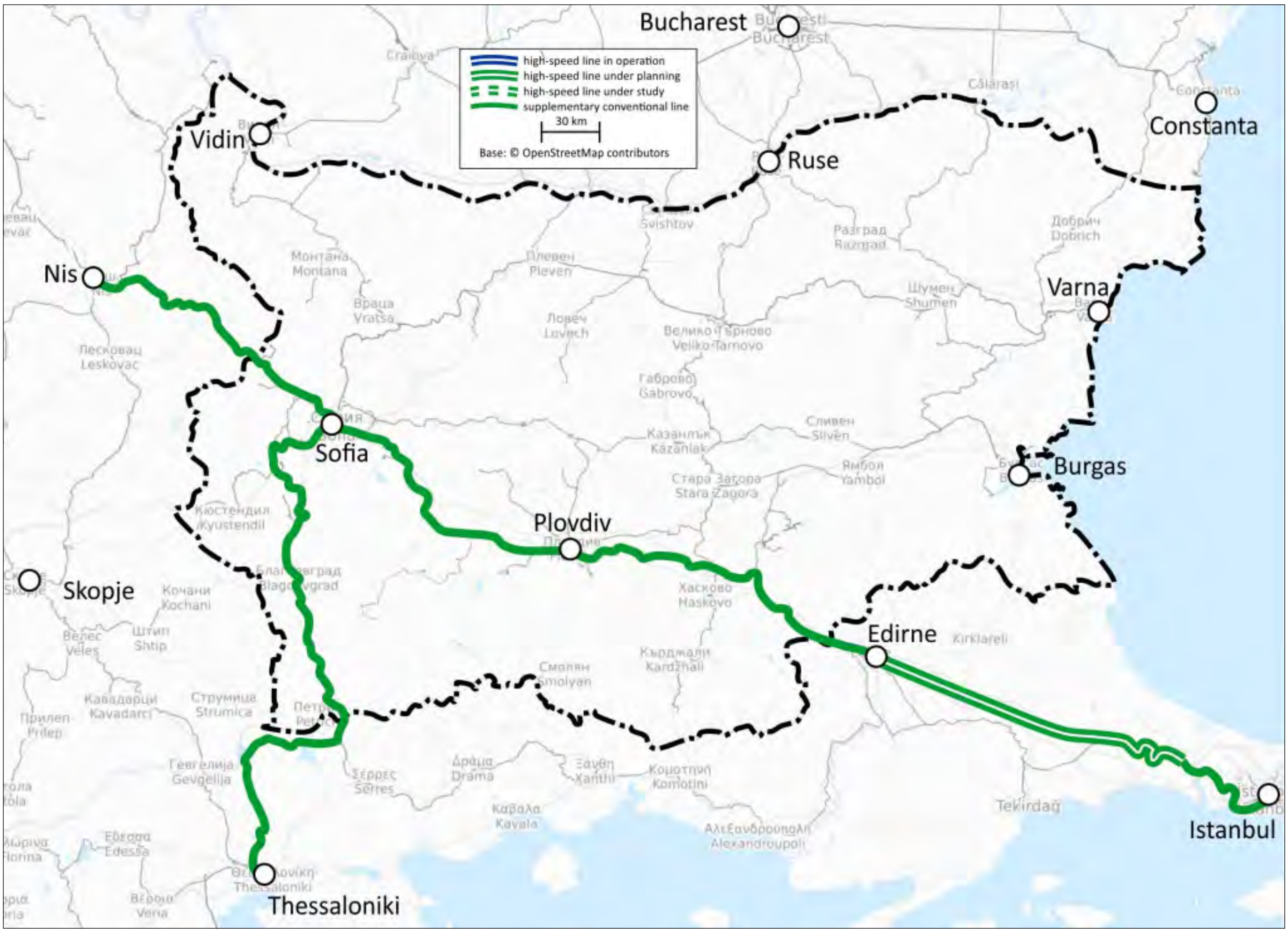
1.4.6 Bulgaria

Due to early construction and the mountainous terrain, the lines in Bulgaria are hard to modernise to higher speeds meaning that current travel times are long due to the low speed (max. 130 km/h).

The rail lines in Bulgaria forms parallel corridors. There are 3 lines heading from Sofia eastwards to the Black Sea ports of Varna and Burgas and to the Turkish border. There are also longitudinal lines crossing the Danube – the western one from Romanian Craiova via Vidin and Sofia towards Thessaloniki in Greece. The last line in the central part of the country goes from Bucharest in Romania via Ruse towards Plovdiv in the south.

There are two lines of high importance with potential for high-speed: the main line coming from the Serbian city of Nis, passing via Sofia, Plovdiv to the Turkish city of Edirne and the branch of the network from Sofia towards Thessaloniki. The Nis – Edirne line has been electrified and has also been partially renewed in recent years.

Figure III–16 Supplementary to TER HSR conventional lines on the territory of Bulgaria



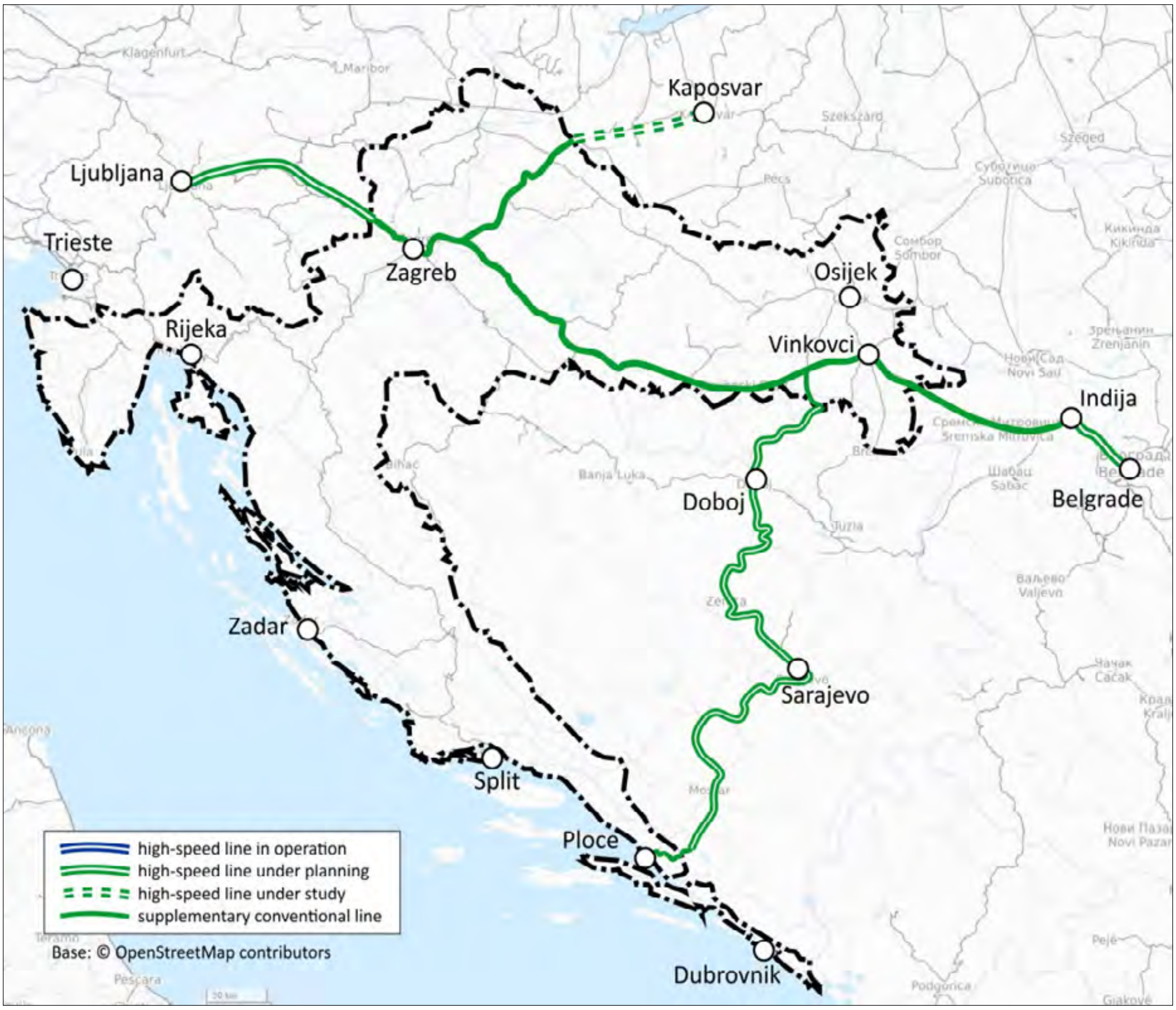
Source: Own work.

1.4.7 Croatia

Croatia does not currently have any high-speed lines. The main international lines are the NW-SE Ljubljana – Zagreb – Vinkovci – Belgrade line and SW-NE Rijeka – Zagreb – Budapest line. The Croatian network is mainly single-track and not electrified. The main NW-SE line is the only one that is mostly double-tracked. It has also been modernised to a speed of 160 km/h on some sections. The route is, however, still not competitive compared to road transport in terms of travel time.

Some analyses and preparatory planning works were conducted in the area of HS rail, especially on the Rijeka – Zagreb Corridor, however, the project has been suspended due to the financial constraints.

Figure III–17 Supplementary to TER HSR conventional lines on the territory of Croatia



Source: Own work.

1.5 Baltic States

Concept development

In 2011, in the project of the new Trans-European transport network, Rail Baltica, was raised for the first time. In 2013 it was included in the priority corridor, North Sea – Baltic Sea (Regulation 1316/2013). Rail Baltica is a priority project of the European Commission. In 2014 RB Rail AS was established by the project's national implementing bodies in the three States – Rail Baltic Estonia OÜ, SIA Eiropas Dzelzceļa līnijas, and UAB Rail Baltica Statyba. The line is expected to be operational in 2026.

The status of preparatory work

The implementation of the Rail Baltica project is currently at the design stage. In Lithuania, the rail line will be connected to Kaunas intermodal terminal by 2020. The construction works on other sections are scheduled to begin in 2021 and end in 2025. The acceptance phase for individual line sections will start in 2024 and will last until 2026.

Parameters and location of the lines

Main technical parameters of Rail Baltica high-speed lines are shown in table III-11 and in figure III-18.

Table III–11 Main technical parameters of high-speed lines planned in Baltic States

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
EE: Rae Junction – Muuga	16.70		new	2026	
EE: Tallinn (Ulemiste) – Parnu – Border EE/LV	200.76	250	new	2026	
LV: Border EE/LV – Riga – RIX – Border LV/LT	234.87	250	new	2026	
LV: Riga Bypass	28.55		new	2026	
LT: Border LT/LV – Kaunas – Border LT/PL	249.00	250	new	2026	
LT: Kaunas Triangle East Junction – Vilnius	93.43	250	new	2026	
LT: Kaunas Bypass (Palemonas – Jiesia)	15.52		new	2026	
LT: Vaidotai branch (Junction – Vaidotai freight station)	8.98		new	2026	

Source: Own study based on Rail Baltica: Preparing the Rail Operational Plan. Final Study Report. 15 November 2018. ETC Gauff Mobility, COWI, Institut fur Bahn Technik Gmbh.

The total length of Rail Baltica in Baltic States: 847.81 km

The section in Poland (Warsaw – PL-LT border): approx. 379 km

FI – EE: FinEst Helsinki – Tallinn tunnel: 107.40 km

Total distance (Helsinki – Warsaw): approx. 1,265 km.[65]

[65] ETC Gauff Mobilty COWI Institut fur Bahn Technik Gmbh, *Rail Baltica: Preparation of the Operational Plan of the Rail. Final Study Report.*15 November 2018.

Figure III–18 Status of HSR network planned in Baltic States and in Poland

Source: Own study.

1.6 East Europe

1.6.1 Russian Federation

Concept development

The concept of high-speed rail network assumes the construction of the lines from Moscow:

- Northwards to St. Petersburg
- Southwards to Sochi on the Black Sea
- Eastwards to the border with Kazakhstan– and westwards to the border with Belarus.

The last of these lines is to be a part of the high-speed line from China via Russian Federation to Western Europe which, as mentioned previously could also carry high-speed freight trains (250-300 km/h). The first section of the new lines planned from Moscow to Kazan. The Russian Federation rail development strategy up to 2030 assumes the construction of high-speed lines (figure III-19).

Figure III–19 Lines planned for construction in rail development strategy in Russian Federation

Source: Development Strategy of Russian Federation Railways until 2030.

The status of preparatory works

The status of development of the Russian Federation HSR network is set in chapter II, section 7.3.2. A graphical representation is set out below.

Figure III–20 Construction project of the Moscow – Kazan line

Source: Russian Federation Railways.

Further projects include new HSR sections from Kazan eastwards, from Moscow to Sochi (Adler), and from Moscow to Smolensk and Krasnoye (border RU/BY). The HSL network will be complemented by conventional line modernised to the speed of 160 km/h.

Parameters and location of the lines

The main technical parameters of the high-speed lines planned in Russian Federation are shown in table III-12 and in figure III-21.

Table III–12 Main technical parameters of planned high-speed lines in Russian Federation

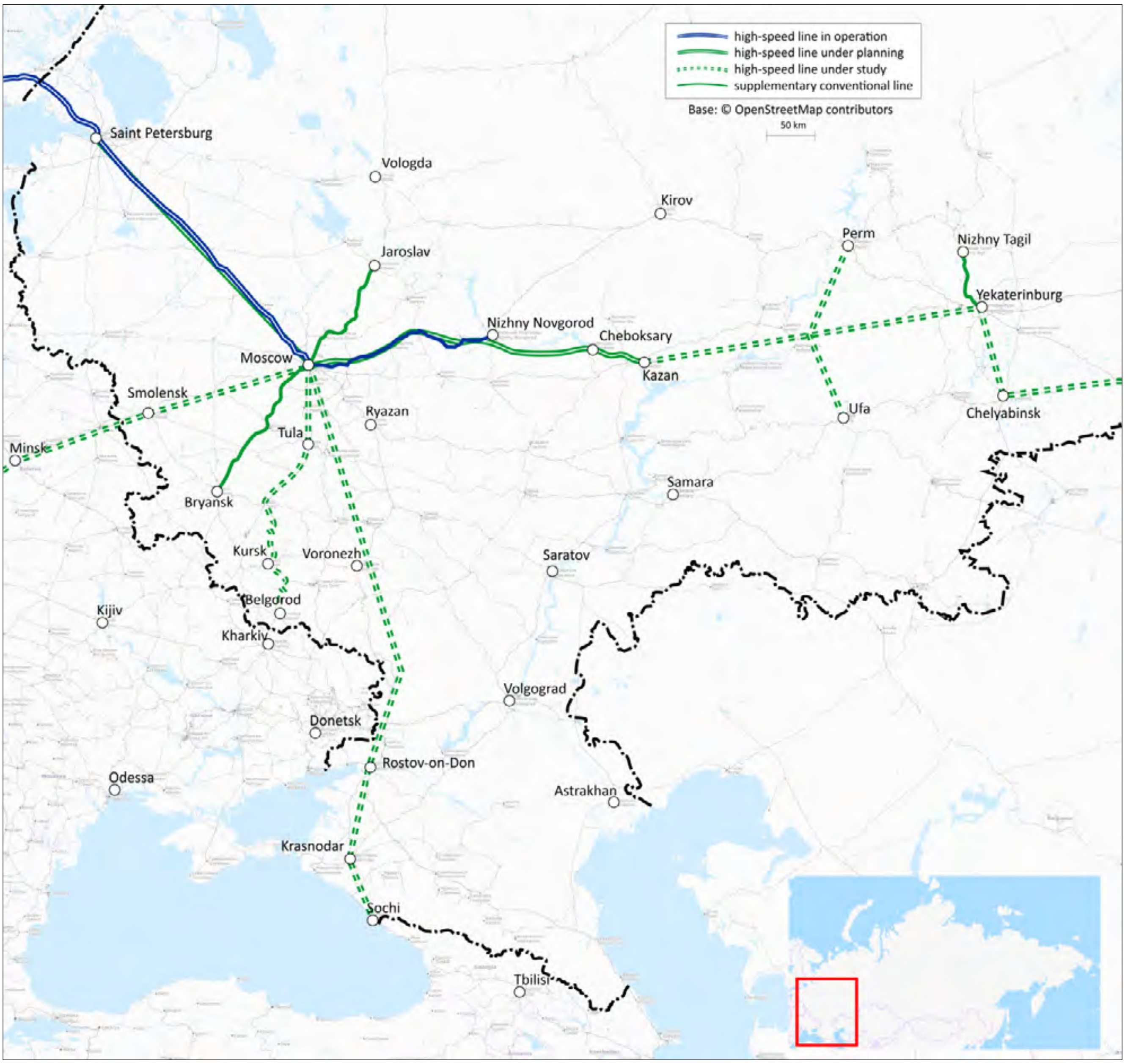
Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
In operation					
Moscow – St. Petersburg	640	250	modernised	2009	
St. Petersburg – Buslovskaya (border RU/FIN)	167	200	modernised	2010	
Moscow – Nizhny Novgorod	425	160	modernised	2010	
Planned					
Moscow – Nizhny Novgorod – Kazan	772	400	new	2024	
Yekaterinburg – Chelyabinsk	192	400	new	2024	
Kazan – Yekaterinburg	763	400	new	2028	
Moscow – Tula	197	400	new	2028	
Moscow – Smolensk – Krasnoye (border RU/BY)	463	400	new	2029	
Moscow – St. Petersburg	659	400	new	2029	
Moscow – Adler (Sochi)	1549	400	new	Beyond 2030	
Branches from Kazan – Yekaterinburg high-speed line to Perm and Ufa	410	400	new	Beyond 2030	
Chelyabinsk – Kurgan – Kazakhstan border	457	400	new	Beyond 2030	

Table III–12 Main technical parameters of planned high-speed lines in Russian Federation (continued)

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Planned					
Tula – Belgorod	501	200	modernised	2023	
Yekaterinburg – Nizhny Tagil	149	160	modernised	2023	
Moscow – Bryansk	387	160	modernised	2029	
Moscow – Yaroslavl	282	160	modernised	2030	

Source: UIC High-Speed Rail Atlas, Country Questionnaire.

Figure III–21 Status of HSR network planned in Russian Federation



Source: Own work.

1.6.2 Armenia

The rail system in Armenia is limited with one main line connecting the biggest cities of Yerevan, Gyumri and Vanadzor with an arch-shaped line. There are also lines to Kars in Turkey and Nakhichivan in Azerbijan, both currently not in operation.

All the lines are single track and electrified (only the short line form Gyumri to the Turkish border remains unelectrified). There are no plans to build a HSR network in Armenia.

Figure III–22 Status of conventional lines on the territory of Armenia

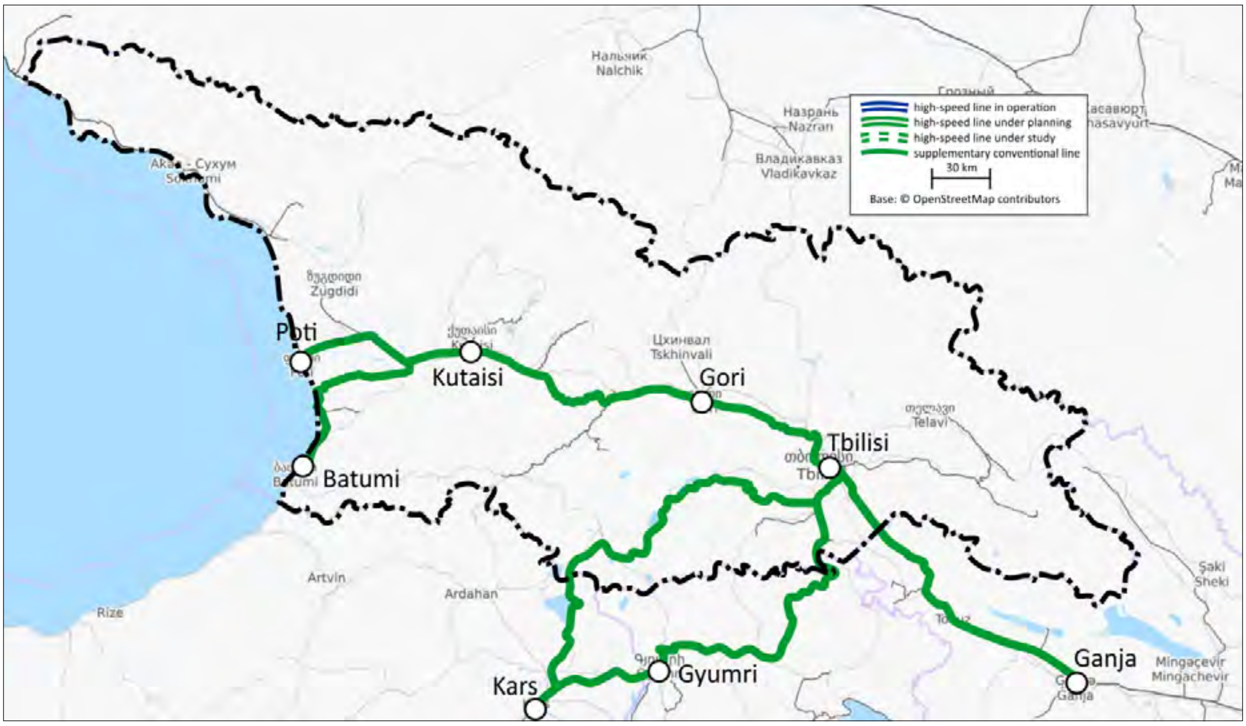
Source: Own work.

1.6.3 Georgia

There are no plans to build a HSR network in Georgia. The main line in the country runs from the Black Sea ports of Batumi and Poti through capital city of Tbilisi to the border with Azerbaijan and later towards its capital – Baku. The line is electrified and mostly doubletracked. It has also partially been modernised in recent years.

Apart from the main East-West line, the Georgian network consist mainly of branch single track lines creating a typical linear system. There are also two international connections on the south: from Tbilisi to Vanadzor in Armenia and from Tbilisi to Kars in Turkey. The line Tbilisi – Kars is a recently launched one with some newly built and modernised sections. The line is equipped with a gauge changing facility at the border. The line is currently used by freight traffic, but passenger services are also planned.

Figure III–23 Status of conventional lines on the territory of Georgia



Source: Own work.

1.7 Turkey

Concept development

The HSR system in Turkey at the current state of development is monocentric with Ankara as the main hub. The first high-speed line connecting the capital Ankara to Eskişehir, was commissioned in March 2009. Its length is 245 km, of which 221 km of the newly constructed Sincan – Eskişehir section, and 24 km of the conventional section between Ankara and Sincan. The Ankara – Eskişehir line was at the same time the first section of the Ankara – Istanbul rail corridor. The section between Eskişehir and Pendik was opened in 2014. Further details on this line, as well as the status of works are set out in chapter II section 7.3.4.

Parameters and location of the lines

The main technical parameters of the high-speed lines planned in Turkey are presented in table III-13 and in figure III-24.

Table III–13 Main technical parameters of high-speed lines in Turkey

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
In operation					
Ankara – Sincan – Eskisehir	221	250	New	2009	
Polatlı – Konya	212	250	New	2011	
Eskişehir – Izmit – Pendik	155	250	New	2014	
Under construction					
Bursa – Bilecik	106	200	New	2022	
Ankara – Sivas (Kayaş – Sivas)	393	250	New	2020	
Ankara – Izmir (Polatlı – Uşak – Izmir)	508	250	New	2023	
Konya - Karaman	102	250	New	2020	
Adana – Incirlik – Toprakkale	79	250	New	2021	
Ankara – Istanbul Doğançay Relocation 1	14	250	New	2021	
Ankara – Istanbul Doğançay Relocation 2	12	250	New	2023	
Ankara – Istanbul T26	8	250	New	2021	
Sivas – Zara	74	200	New	2023	
Aliağa – Çandarlı – Bergama	57	160	New	2022	
Karaman – Ulukışla	135	200	New	2022	
Adana – Mersin	67	160	New	2021	
Toprakkale – Bahçe (Tunnel)	13	200	New	2023	
Bahçe – Nurdağ (Fevzipaşa By-pass line)	17	160	New	2021	
Nurdağ – Başpınar	56	160-200	New	2022	
Akçagöze – Başpınar (By-pass line)	11	160	New	2020	
Çerkezköy–- Kapıkule	153	200	New	2023	

Table III–13 Main technical parameters of high-speed lines in Turkey (continued)

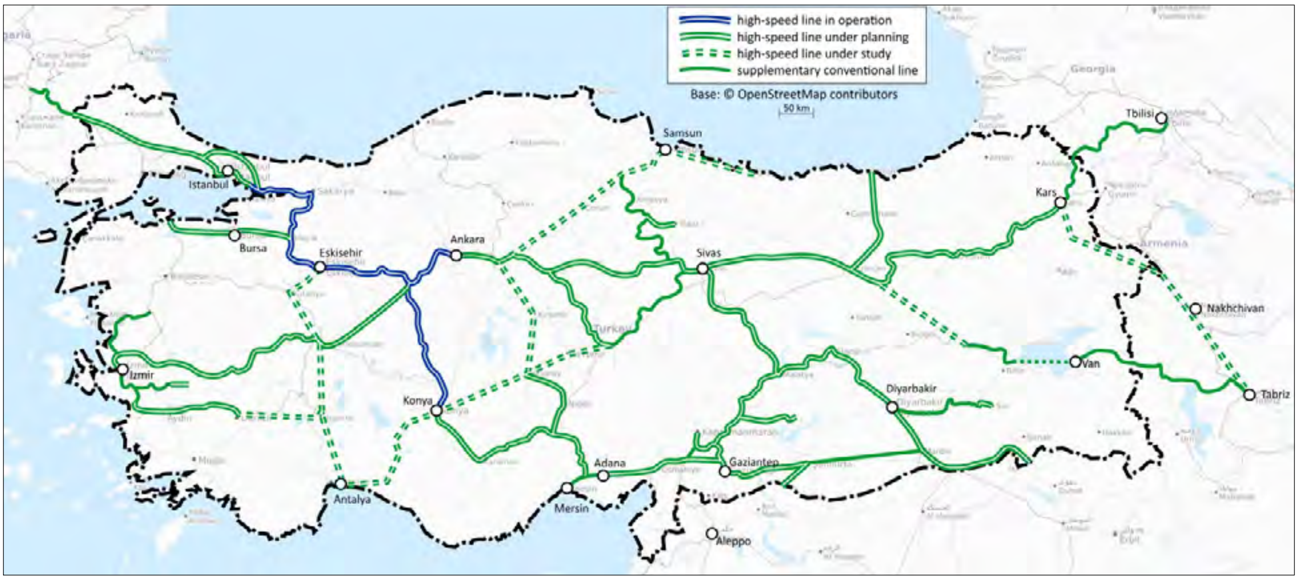
Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Planned					
Yerköy – Kayseri	148	200	New	2025	
Halkalı-Kapıkule	76	200	New	2024	
Toprakkale – Bahçe	45	200	New	2023	
Aksaray – Ulukışla	86	200	New	2024	
Ulukışla – Yenice	110	160-200	New	2025	
Selçuk – Ortaklar	14	160-200	New	2024	
Ortaklar – Aydın	33	160	New	2024	
Aydın – Denizli	130	160	New	2024	
Sivas – Çetinkaya – Malatya	229	200	New	2027	
Gaziantep – Şanlıurfa	120	200	New	2027	
Gaziantep – Kahramanmaraş	46	200	New	2029	
Nusaybin – Cizre – Silopi – Habur	133	200	New	2027	
Gölbaşı – Adıyaman – Kahta	98	200	New	2029	
Erzincan – Erzurum	210	200	New	2027	
Erzurum – Kars	205	200	New	2027	
Tokat – Turhal	42	200	New	2029	
Malatya – Elazığ	126	200	New	2029	
Siirt – Kurtalan	36	160	New	2029	
Bergama – Soma	42	160	New	2025	
Şanlıurfa – Mardin	185	160	New	2027	
Ödemiş – Kiraz	30	200	New	2029	
Sivas – Erzincan (Zara-Imranlı)	168	200	New	2029	
Gebze – Sabiha Gökçen Airport – Yavuz Sultan Selim Bridge – Istanbul Airport – Halkalı	118	200	New	2025	
Eskişehir – Kütahya – Afyonkarahisar – Burdur/Isparta – Antalya	423	200	New	2025	
Kayseri – Nevşehir – Aksaray – Konya – Seydişehir – Antalya	444	200	New	2027	
Samsun – Çorum-Kırıkkale	292	200	New	2025	
Kırıkkale – Kırşehir – Aksaray	235	200	New	2025	
Bandırma – Bursa	74	200	New	2025	
Bursa – Gemlik	24	200	New	2029	
Elazığ – Diyarbakır	150	200	New	2029	
Erzincan –Trabzon	248	200	New	2029	
Diyarbakır – Mardin	102	200	New	2029	
Erzincan – Muş	210	200	New	2029	
Istanbul Airport – Çatalca	21	200	New	2025	
Konya – Seydişehir	86	200	New	2025	

Table III–13 Main technical parameters of high-speed lines in Turkey (continued)

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Planned (continued)					
Mürşitpinar – Şanlıurfa	63	200	New	2029	
Samsun – Çarşamba – Fatsa – Ordu Survey – Project Works	144	200	New	2029	Survey-Project Works to be completed in 2022
Malatya – Narlı	182	200	New	2027	
Denizli – Dinar – Karakuyu – Survey – Project Works	122	200	New	2029	Survey-Project Works to be completed in 2022

Source: UIC Atlas High Speed Rail 2018, Country Questionnaire, Revised by TCDD.

Figure III–24 Status of HSR network planned in Turkey

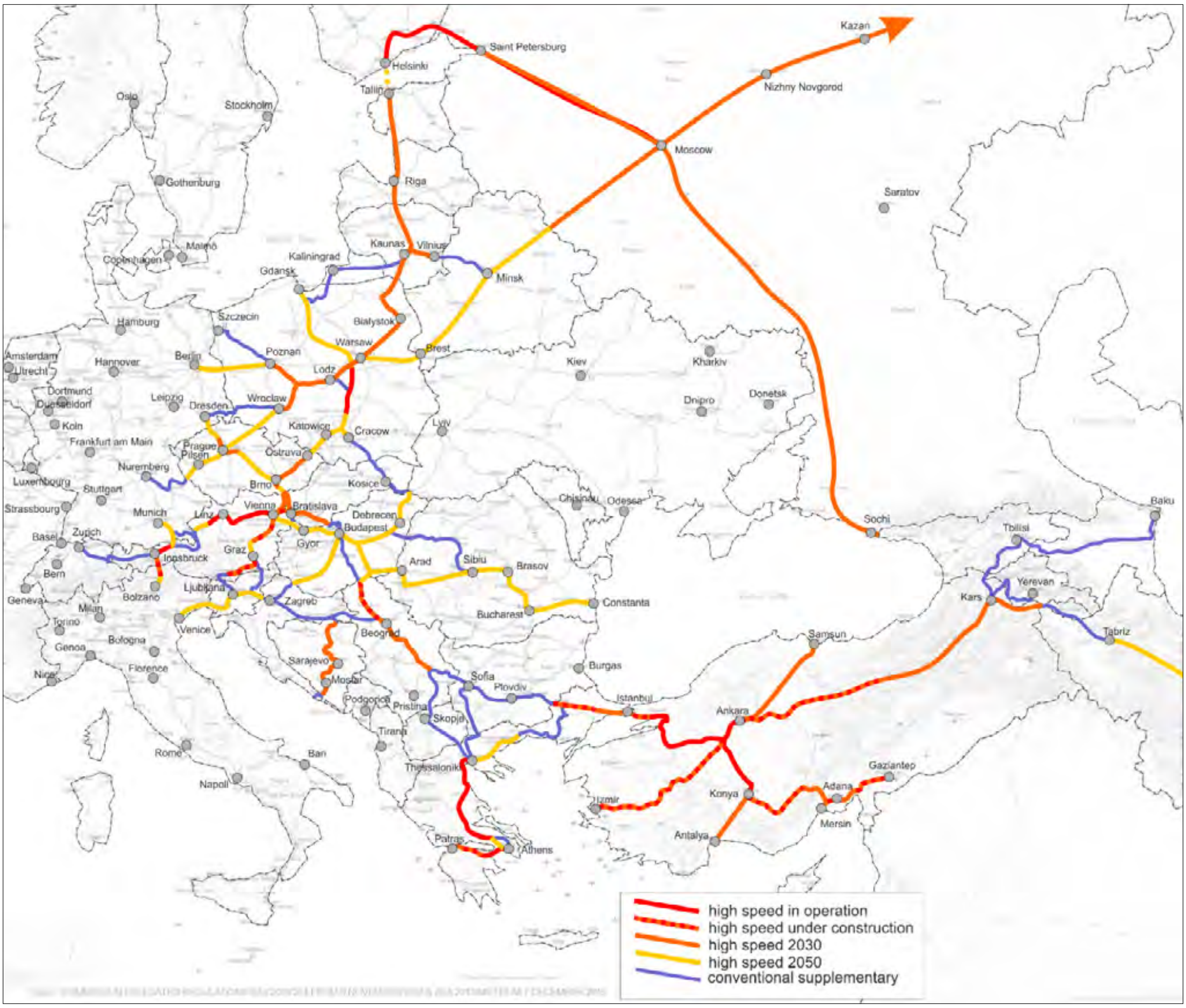


Source: Own work.

1.8 Summary of HSR projects

The HSR projects identified in TER States are shown in figure III-25. The map shows high-speed lines in operation, under construction, planned and supplementary conventional lines, which link high-speed lines into a common network for rapid passengers' trains as well as dedicated freight trains.

Figure III–25 HSR projects identified in TER States and in the Region including complementary conventional lines



Source: Own work based on EU Regulations 2019/254 and 2017/649.

2. TER HSR connection to neighbouring States

2.1 General

The HSR system in TER States will need to be connected to HSR systems in neighbouring States. The quality of these connections is crucial for the functioning of both the TER HSR system and the systems in the neighbouring States. In most neighbouring States HSR systems already exist, particularly in Western European States (Germany, Italy and Switzerland) and north in Finland.

Connections to the States neighbouring on the east with TER States are only at the project stage and these are connections between Turkey and Iran and the Russian Federation and Kazakhstan. The HSR project in Belarus is also part of the planned transport corridor from Europe to China via Moscow and Kazakhstan (more information in section III-3).

No high-speed lines are currently planned in the following States neighbouring the TER region: Montenegro, Moldova and Albania. There are no proposals for high-speed lines in Ukraine. For the neighbouring States identified in this section, the description was made on the basis of available documents, e.g. feasibility studies and other documents. There may also be plans to build high-speed TEN-T lines (e.g. in Hungary and the Baltic States). There are no such plans to build HSR lines to Ukraine yet in the neighbouring TER States.

The absence of high-speed line projects in these States does not imply that their population will benefit from the high-speed rail systems in the TER States. Access to the TER nodes from neighbouring States can be made by conventional rail. Nevertheless, in the development plans for the construction of lines in TER States, connections with neighbouring States via high-speed lines or at least conventional lines should be considered in each individual case already at the stage of feasibility studies.

2.2 Germany

Details of the German network were included in Phase I of the High-Speed Masterplan.

Connections to TER States

The rail network in Germany is a dense system and strongly integrated with systems in the neighbouring States. There are a number of cross-border connections: – urban services (S-bahn), regional, long-distance conventional and high-speed services, as well as freight services including container express trains. While there are high-speed cross-border connections, there is no line with a speed of more than 160 km/h. Currently, the German rail system is connected to three TER rail networks in Poland, Czechia and Austria. The quality of these connections is very important for the functioning of international rail connections between these States. These connections are included in the EU's TEN-T network and AGC lines. They are as follows:

- North Sea – Baltic (Belgium/Netherlands – Germany – Poland – Lithuania – Latvia – Estonia – Finland) [AGC E-20]
- Orient – East Med (Germany – Czechia – Slovakia/Austria – Hungary – Romania – Bulgaria – Greece) [AGC E-50]
- Rhine – Danube (Germany – Austria/Czechia – Slovakia/Hungary – Romania) [AGC E-50]
- Scandinavian – Mediterranean (Finland – Sweden – Denmark – Germany – Austria – Italy) [AGC E-50].

Advancement of works on rail connections between Germany and TER States

The plans for high-speed connections include between:

- Poland and Germany, Poznań – Berlin line for which a preliminary feasibility study has been carried out by the Polish side
- Czechia and Germany, Prague – Dresden line for which design work is underway
- Germany and Austria, Munich – Innsbruck – Bolsano line (depending on the section – existing, under construction or in preparation).

Some additional lines will have high-speed capabilities only on one side of the border for example the Pilzno (CZ) – Nuremberg (DE) line on the Czech side, Nuremberg (DE) – Passau – Linz (AT) on the German side (modernised line), Vienna (AT) – Linz – Salzburg – Munich (DE) on the Austrian side. Important network extensions are also complementary conventional connections: Berlin (DE) – Szczecin (PL) and Dresden (DE) – Wrocław (PL).

The above examples show the need for better coordination of HSR projects at European level.

2.3 Hungary

Concept development

In 2003, the concept of the Budapest – Bucharest – Constanta line emerged as an extension of the high-speed axis from Paris to Budapest. International government agreements in 2007, 2008 and 2010 between the concerned States set the foundation for the development of this project.

HSR projects in Hungary are part of the TEN-T. This network assumes the connection of Budapest to the following neighbouring States:

- Austria (Vienna) by a new HS line through Gyor with branches to Slovakia and Czechia (direction Bratislava, Brno)
- Croatia (Zagreb) as a section of the international connection Budapest – Zagreb – Ljubljana – Venice
- Serbia (Belgrade) as an element of the corridor to the Greek HS line (via Sofia or Skopje)
- Romania (Bucharest and Constanca – Black Sea).

Status of preparatory work

New HSR projects are currently being studies for the following routes:

Budapest – Győr. This is the project of new high-speed line with maximum speed of up to 300 – 350 km/h. As part of the western branch of the V4 HSR plan, the project also contributes to the overall goal to reduce the travel time to less than two hours between Budapest-Kelenföld and Wien Hbf. A pre-feasibility study for this section already exists and the detailed feasibility study (to determine the alternative routes) is currently underway and is expected to be completed by mid-2021.

Győr – Hegyeshalom: upgrade to 200 km/h. A possible element of the western branch of the V4 HSR plan, the project also contributes to the overall goal to reduce the travel time to less than two hours between Budapest-Kelenföld and Wien Hbf. The feasibility study will decide between upgrade or new track at the Győr – state border section. Hungary hopes that a HSR link between Budapest and Bucharest can be launched after the modernisation of the rail line connecting Budapest to Belgrade. In February 2018, the government approved the financing of €3.1 million for a feasibility study on a project for the construction of an upgraded rail line linking Budapest to Cluj in western Romania, with a maximum speed of 160 km/h.

Another project is the modernisation of the existing line from Budapest to the border with Serbia. In 2017, Hungary's state-run rail operator MAV opened a tender for the renewal of the Budapest – Belgrade rail line. The project envisages the upgrade of the rail line connecting Soroksar, on the outskirts of Budapest, to Kelebia on the border with Serbia. The maximum speed for the Hungarian section will be 160 km/h. At the same time, the TEN-T network plans to connect Budapest to Szeged on the border with Serbia and Romania by high-speed line, where this line would split into branches to Bucharest and Belgrade through Subotica.

The technical parameters of these lines are not yet specified. It could be assumed that due to the long distances and transit nature of rail services in Hungary, they could have a speed of 300-350 km/h, which is technically feasible given the favourable topography of Hungary.

Parameters and location of the lines

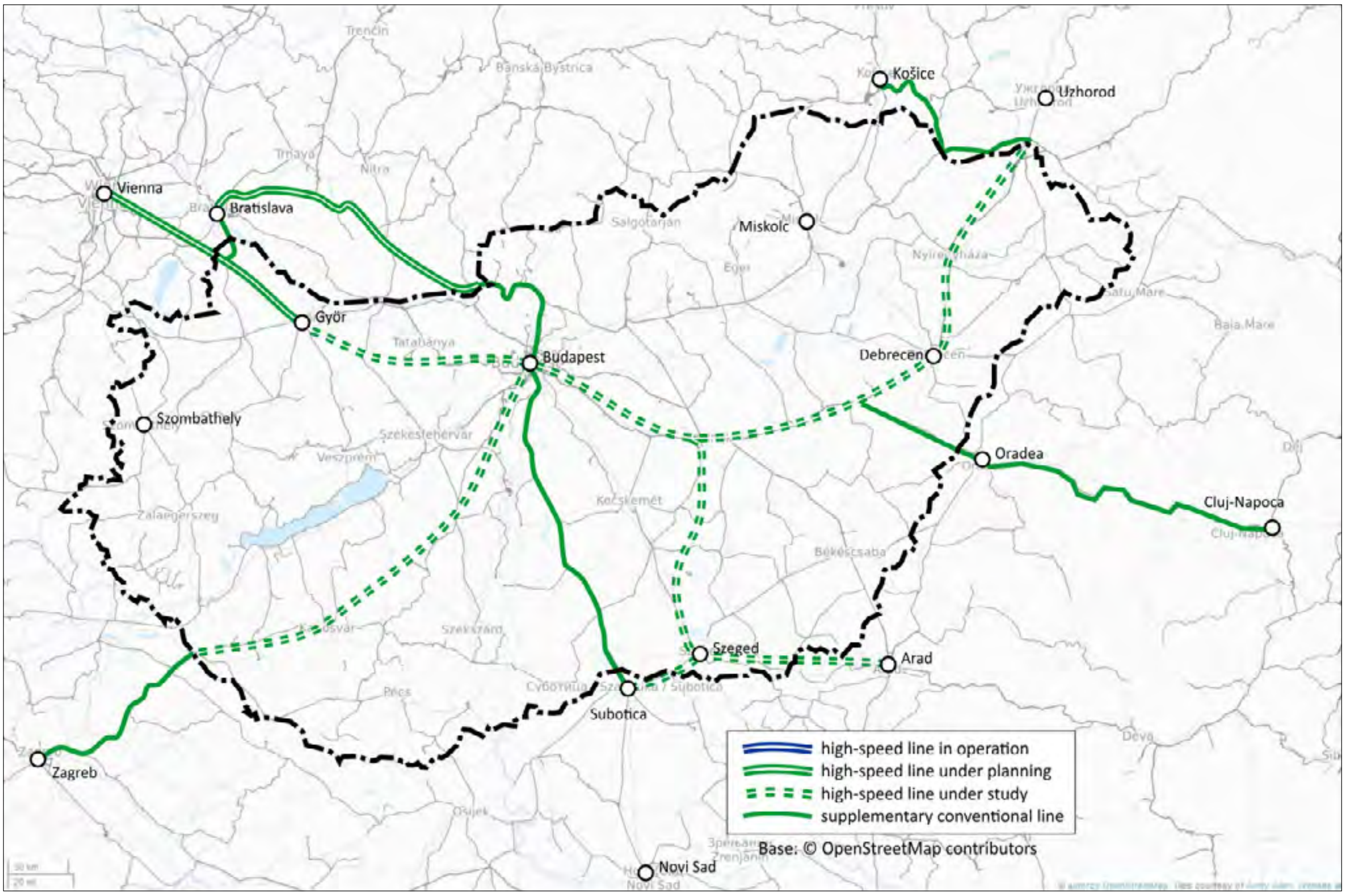
The main characteristics of the planned high-speed lines in Hungary are shown in table III-14. The lines are presented in figure III-26.

Table III–14 The main features of the high-speed lines planned in Hungary

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Budapest – Györ	100*		New		* approx
Gyor – border HU/AT	50*		New/ modernised		* approx
Budapest – Dombovar – Zakany	230*		New		* approx
Budapest – Cegled	65*		New		* approx
Cegled – Szeged	115*		New		* approx
Szeged – Röske	13*		New		* approx
Szeged – Nagylak	45*		New		* approx
Cegled – Debrecen – Nyiregyhaza – Zahony	290*		New		* approx
Püspökladány – border HU/RO	60*	160	New		* approx

Source: EU Reg.1315/2013.

Figure III–26 Status of planned HSR network in Hungary



Source: EU Reg.1315/2013.

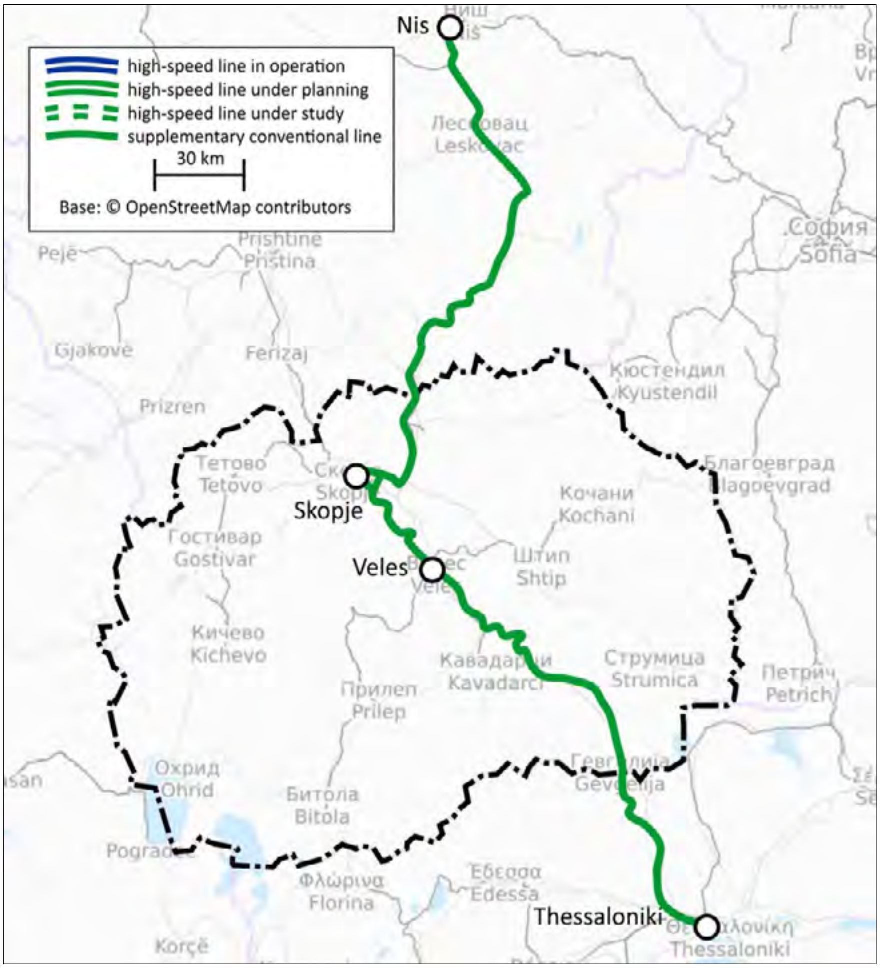
2.4 North Macedonia

The rail network of North Macedonia is small in size. The network consists of conventional lines, the majority of which are not electrified, single track lines. The oldest one, built in 1873 along the Vardar River valley, links Skopje with Greek Thessaloniki and serves as the core line for the country. In Skopje, it splits into two lines heading northward – to Nis and Pristina. Generally speaking, all the other lines, are perpendicular branches with no international sections at the moment. Nevertheless, the line from Bitola to Florina in Greece is under reconstruction and direct links to Albania and Bulgaria are planned.

There is no plan for a HSR in North Macedonia. Nevertheless, the main line from Serbian Nis to Thessaloniki in Greece via the capital city of Skopje is regarded a supplementary conventional TER line as it is able to provide the fastest link between Thessaloniki or Athens and central Balkans.

The line from Nis in Serbia enters the country at the border village of Tabanovtse, then runs approximately 50 km to Skopje via Kumanovo. From the capital city the line goes southwards via Veles to Gevgelija at the Greek border, and then to Thessaloniki. The distance from Skopje to the border is approximately 160 km. The line is the only electrified line in the country. The operational speed on the line is 100 km/h. Current travel time between the borders is about three hours including a 20-minute stop in Skopje. There is also a bypass of Skopje for the freight trains that shortens the route.

Figure III–27 Supplementary to TER HSR conventional lines on the territory of North Macedonia



Source: Regulation (EU) 1315/2013.

2.5 Switzerland

Connections to TER States

Due to its location, Switzerland is a very important transit country for European transport. Key routes connecting the Mediterranean Basin, Central Europe and Scandinavia run through its territory. At the same time, however, from the point of view of TER network, connections in Switzerland are poorly developed. There is one main connection that runs along conventional lines from Innsbruck through Liechtenstein to Zurich.

The HSR system in Switzerland

The development of HSR is limited by natural topography. This means that out of three existing and one planned high-speed line sections, only one runs above ground. The others are long tunnels – the Ceneri Base Tunnel, the Lotschberg Base Tunnel and the Gothard Base Tunnel.

The main high-speed lines in Switzerland are North-South lines:

- A western one leading from Novara via Bern
- An eastern one from Milan via Zurich.

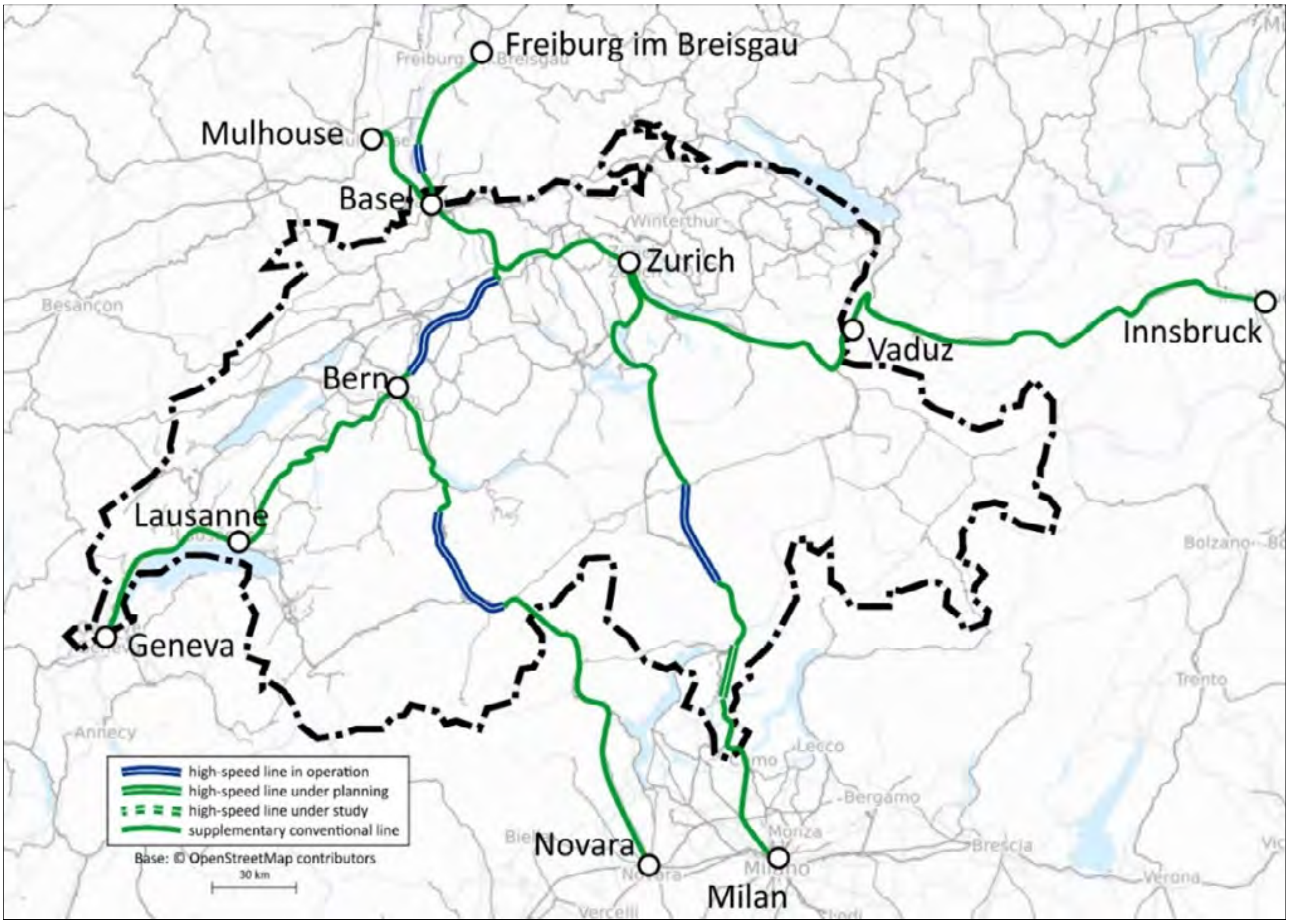
Both lines then converge in Basel and connect to the German Rhine corridor.

Table III–15 Existing and planned high-speed rail lines in Switzerland

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Mattstetten – Rothrist	52	200	Modernised	2004	
Frutigen – Visp (Lötschberg base tunnel)	35	250	New	2007	
Erstfeld – Biasca (Gotthard base tunnel)	57	250	New	2016	
Giubiasco – Lugano (Ceneri base tunnel)	15	250	New	2019	

Source: UIC High-Speed Rail Atlas 2018, EU Reg.1315/2013.

Figure III–28 Target high-speed rail network in Switzerland with complementary sections



Source: UIC High-Speed Rail Atlas 2018, EU Reg.1315/2013.

Advancement of work on rail connections between Switzerland and TER States

No high-speed rail lines are planned between Switzerland and TER States.

2.6 Italy

Connections to TER States

Italian rail connections to neighbouring States are technologically difficult, as almost the entire Italian land border runs through mountains. The construction of high-speed lines to most of the neighbouring States is planned.

There are three corridors towards TER States:

- North from Verona via Bolzano to Innsbruck in Austria, from where it is extended north to Munich. The high-speed line section, i.e. the base tunnel under the Brenner Pass, is already under construction on the border section. It is expected to be opened in 2025-2026.
- Towards Klagenfurt, in Italy, it is a conventional line.
- Towards Slovenia as an extension of the corridor running through the Po Valley. The line could run from Venice towards Trieste to Ljubljana and further in direction to Croatia.

The HSR system in Italy

The high-speed rail system in Italy is described in detail in Phase 1 of the High-Speed Master Plan.

Advancement of work on rail connections between Italy and TER States

As part of the HSR system, the line from Verona via Bolzano to Innsbruck in Austria is planned. It will be extended further north to Munich. The high-speed line section, i.e. the base tunnel under the Brenner Pass, is already under construction at the border. It is expected to be opened around 2025-2026.

Within the TEN-T network an extension of the corridor through the Po Valley towards Slovenia is planned. The line will run from Venice towards Trieste and then to Ljubljana.

2.7 Finland

Connections to TER States

Finland's rail network is poorly connected to the rest of the European network, mainly due to its coastal location and low population density, especially in the northern part of the country but also as a result of different gauges (1,524mm as opposed to 1,435mm and 1,520mm in neighbouring networks) and traction supply.

Currently, there is one land network connection to Sweden (Haparanda – Tornio) – non-electrified and used only for freight traffic and four connections to the Russian Federation, but only one (Vainikkala) used in passenger and freight traffic, and the other (Parikkala, Niirala, Vartius) – dedicated only to freight transport. The Vainikkala border crossing is located on the main line Helsinki – Saint Petersburg with a speed of 200-220 km/h.

The HSR system in Finland

The existing high-speed line in Finland is the Helsinki to St. Petersburg line set out in chapter II section 7.3.

Plans for the construction of new sections of high-speed lines[66] are associated with the Rail Baltica project through the undersea connection between Helsinki and Tallinn discussed previously. The line is planned with a track gauge of 1,435 mm and is to have three underground passenger stations (Helsinki, Pasila (Airport) with passing loops. At the same time, north of Pasila station the line would pass under existing gauge lines.

In addition, two high-speed lines are planned to lead east and west. The eastern line is to start at the airport, run via Porvoo to the town of Kouvola. The western line is to be a shorter route between Espoo in the suburbs of Helsinki and Salo. All new lines in Finland are planned to be operated at 300 km/h and their opening is planned after 2030.

Table III–16 Existing and planned high-speed rail lines in Finland

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Tikkurila – Tampere	171	200	Modernised	before 2000	
Kerava – Hakosilta	63	220	New	2006	
Hakosilta – Kouvola	72	200	Modernised	2006-2010	
Kouvola – Luumäki	55	200	Modernised	2010	
Lielahti – Seinäjoki	154	200	Modernised	2008	
Seinäjoki – Oulu	335	200	Modernised	2017	
Kirkkonummi – Turku	156	180-200	Modernised	before 2000	
Tallinn (EST) – Helsinki – Helsinki Airport (tunnel)	107	200	New	2040	Estonian, Finnish and international sections: 1 435mm; between Pasila and Airport 1 435/1 524mm
Espoo – Salo (new)	95	300	New	2031	
Helsinki – Airport – Kerava (long – distance)	30	300	New	After 2030	
Kerava – Tampere (new)	160*	300	New	After 2030	* approx.
Helsinki Airport – Kerava – Porvoo – Kouvola	130*	300	New	After 2030	* approx.

Source: UIC High-Speed Rail Atlas 2018, EU Reg.1315/2013.

66 Finest Link, *Transport development between Helsinki-Tallinn twin cities. Feasibility study of the Helsinki-Tallinn fixed link*, January 2018.; S. Lindström, Rail Baltica and National Transportation Infrastructure Development in Finland, "Rail Baltica Forum, 3-4 April 2019, Vilnus", 2019.

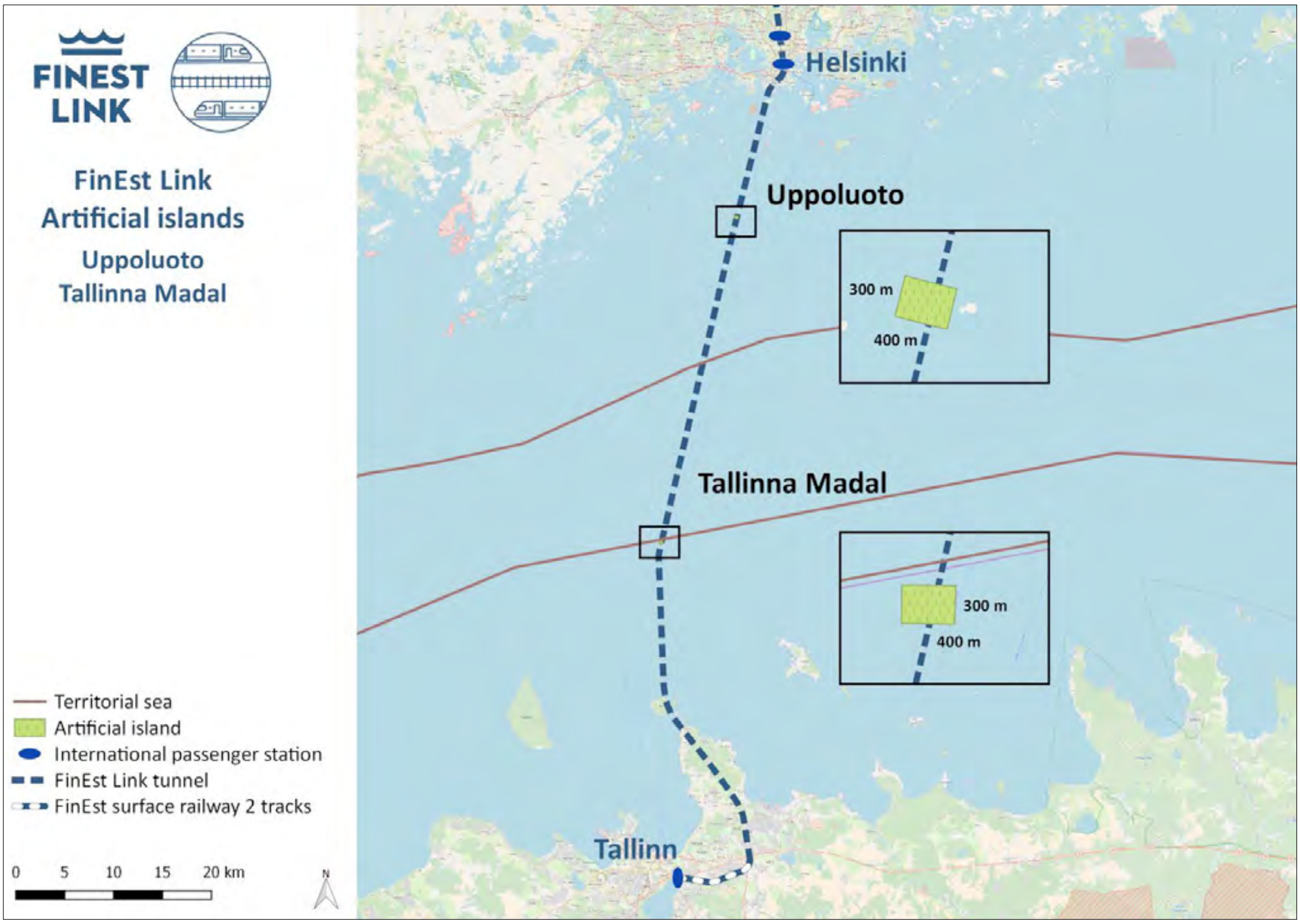
Figure III–29 Target high-speed rail network in Finland with complementary sections

Source: Own work.

Advancement of work on rail connections between Finland and TER States

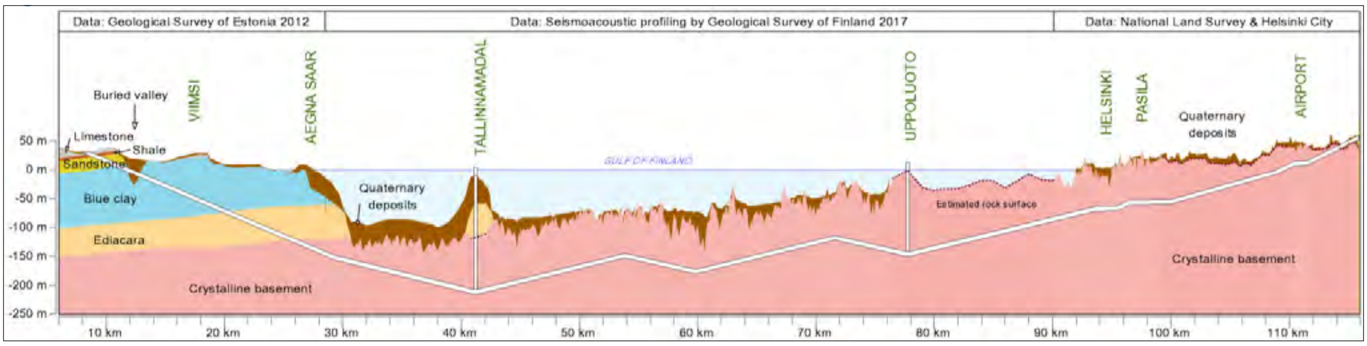
The extension of the Rail Baltica line from Tallinn to Helsinki via the undersea tunnel can be regarded as a connection between Finland and TER States. The feasibility study was completed in February 2018. The route is set out in the figures below.

Figure III–30 Tunnel route under the Gulf of Finland



Source: Transport development between Helsinki-Tallinn twin cities. Feasibility study of the Helsinki-Tallinn fixed link. Finest Link January 2018.

Figure III–31 Tunnel cross section



Source. Transport development between Helsinki-Tallinn twin cities. Feasibility study of the Helsinki-Tallinn fixed link. Finest Link. January 2018.

In July 2019, FinEst Bay Area Development signed a memorandum of understanding with China Rail International Group (CRIG), China Rail Engineering Company (CREC), China Communications Construction Company (CCCC), and the financier Touchstone Capital Partners (TCP) for the construction of the Tallinn-Helsinki undersea twin tunnel.

In March 2019, FinEst Bay and TPC signed an agreement for the provision of a €15 billion funding for the Helsinki – Tallinn rail tunnel project, with construction works estimated at €12.5 billion. The funds come in addition to the previously announced €100 million funding agreed with ARJ Holding LLC in 2018.

Also, in March of the same year, it was announced that ÅF Pöyry – AINS consortium will carry out conceptual design of the project which will include four stations, a depot and two artificial islands. Conceptual design of the FinEst Bay Area project began in May 2018 at the same time as the environmental impact assessment (EIA) process. The EIA program was delivered to the Finnish authorities in January 2019.

2.8 Iran

Connections to TER States

Following recent investments, Iran's rail network is becoming increasingly connected to neighbouring States. In recent years, a rail line to Basra in Iraq was built, the first rail connection with that country. A line to the border with Turkmenistan in the Caspian Sea region was also constructed. In the east of the country there are connections to the network of Turkmenistan east of Mashhad, and Pakistan east of the city of Zahedan. From the point of view of integration with the TER network, plans for the west corridor are important. Modernisation with partial construction of new sections on the Tehran – Tabriz line are underway, following completion of the Mianeh – Tabriz section, the line will become a high-speed line.

Tabriz is a nodal city from which an existing rail line leads within the territory of Turkey to the city of Van. This line, however, is separated from the rest of the Turkish rail network, and the coaches are transported between Van and Tatvan by ferries on Lake Van. The second border line connects Tabriz and Nakhichevan in Azerbaijan. According to Turkish plans, survey studies for the new rapid line to Iran from Kars located on the main Turkish high-speed/rapid east-west line is under construction making it part of the main axis of the Turkey – Iran connection.

The HSR system in Iran

Iran has relatively good conditions for the development of the rail network due to the concentration of the population in urban centres spread over large distances. High-speed lines are likely to be competitive in comparison to car and air transport. Currently, the existing rail network is being expanded and modernised. The current network does not connect some key urban centres. Current works include the construction of new lines, as well as extensive modernisation and electrification of existing lines. The network is to provide access to all large urban centres and facilitate international transport. It assumes the use of both high-speed and conventional lines, with high-speed lines to be concentrated in the capital, Tehran. The plan almost doubles the length of the network by 2025.

There are two important high-speed projects underway. The main project is the construction of a new high-speed line from Tehran through the airport and the city of Qom to Isfahan. This line is designed for a speed of 250-300 km/h. It is not only to facilitate transport between these three cities, but also to reduce the travel time further to the city of Shiraz, where a conventional rail line was built in 2009. The second project is the modernisation of the Tehran – Mashhad line in the east of the country. After electrification, the line will be adapted to a speed of 250 km/h.

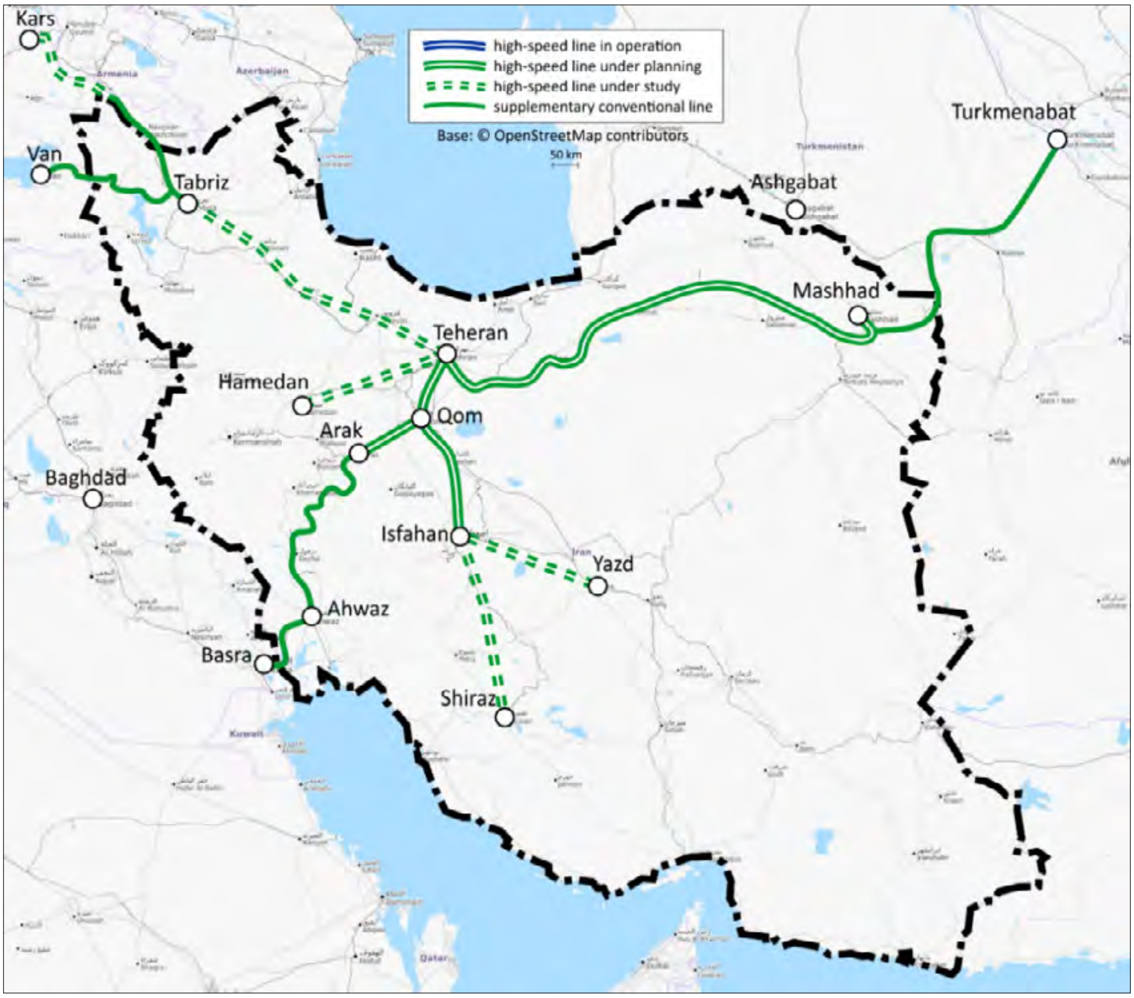
Further plans include the construction of the Qom – Arak, Tehran – Hamedan high-speed line and the modernisation or construction of the Tehran – Tabriz line. One of the concepts also provides for Iran to be located on one of the branches of the New Silk Road connecting Asia and Europe. The route would run from Urumqui in China via Almaty, Samarkand and Ashgabat, then through Iran along the Tehran – Mashhad line (or with its use), and then through Tabriz, via Azerbaijan to the city of Kars in Turkey.

Table III–17 Existing and planned high-speed rail lines in Iran

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Teheran – Qom – Isfahan	410	250	New	2021	Design speed 300 km/h
Teheran – Mashhad	910*	250	Modernised	N/A	* approx.
Qom – Arak	150*	N/A	New	N/A	* approx.
Teheran – Hamedan	380*	N/A	New	N/A	* approx.
Isfahan – Shiraz	450*	N/A	New	N/A	* approx.
Teheran – Tabriz	570*	N/A	New/ Modernised	N/A	* approx.

Source: UIC.

Figure III–32 Target high-speed rail network in Iran with complementary sections



Source: Own work.

Advancement of work on rail connections between Iran and TER States

Modernisation with partial construction of new sections on the Tehran – Tabriz line is currently underway, upon completion of the Mianeh – Tabriz section, the line will become a high-speed line.

2.9 Kazakhstan

Connections to TER States

Kazakhstan's rail network runs on 1,520 mm gauge, the same as in all neighbouring States except China (1,435 mm). It is well connected to the networks in the States of the former USSR, especially to the Russian Federation network. In a few cases, Kazakhstan lines are even transit ones between different cities in the Russian Federation (such as Chelyabinsk/RU – Petropavl/KZ – Omsk/RU, Chelyabinsk – Orsk). The basic connection to the TER network is to be the high-speed line – the New Silk Road connecting China with Europe. In Kazakhstan, it will run between the Russian Federation and Chinese border (to Urumqi) via Petropavlovsk, Nur-Sultan, Karaganda, Balkhash and Almaty.

The HSR system in Kazakhstan

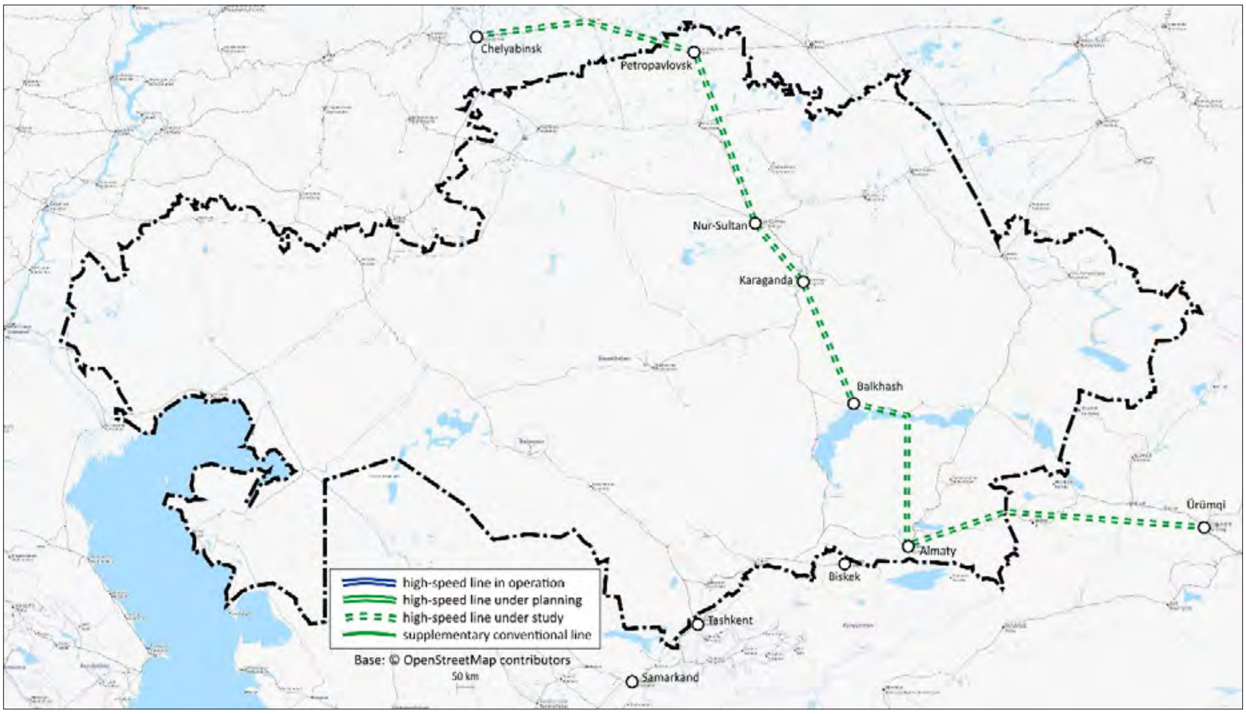
Kazakhstan plans the construction of only one high-speed line. The initial project assumed the construction of a line between the two largest cities of the country – Nur-Sultan and Almaty. The line was to be adapted to a speed of 250 km/h. The current plans assume development of the planned line to act as a transit network on the China – Europe line. The line would run from the Chinese border west of the city of Urumqui to Almaty before proceeding north to Nur-Sultan and on into the Russian Federation to Petropavlovsk and then to Chelyabinsk.

Table III–18 Existing and planned high-speed rail lines in Kazakhstan

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Border RU – Petropavlovsk	65*	N/A	New	N/A	* approx.
Petropavlovsk – Nur-Sultan	450*	N/A	New	N/A	* approx.
Nur-Sultan – Almaty	1 100*	N/A	New	N/A	* approx.
Almaty – Border CN	310*	N/A	New	N/A	* approx.

Source: UIC High-Speed Rail Atlas 2020.

Figure III–33 Target high-speed rail network in Kazakhstan with complementary sections



Source: own work.

Advancement of work on rail connections between Kazakhstan and TER States

In 2011, Kazakhstan began to develop a feasibility study for the construction of a new Nur-Sultan – Almaty rail line. It was planned that the total length of the new rail line would be 1,011 kilometres running via Karaganda and Balkhash, 300-400 kilometres shorter than the existing route. The project is currently on hold due to its high cost. The project to construct a new line has returned as part of the New Silk Road connecting China with Europe.

2.10 Belarus

Connections to TER States

Belarus plays an important transit role, also between TER States although not all connections are currently open. The Belarusian network uses a 1,520 mm gauge, thus requiring a gauge change at the border with Poland where there is an extensive logistics infrastructure system for transhipment or the change of wagons. At the border crossing in Brest, there is also an automatic rail gauge change station used by some international passenger trains. The most important international route passing through the territory of Belarus is the Moscow – Minsk – Warsaw – Berlin line. It enters Poland through the Brest/Terespol border crossing. The border with the Russian Federation is between the cities of Orsha (BY) and Smolensk (RU) in Krasnoye.

The HSR system in Belarus

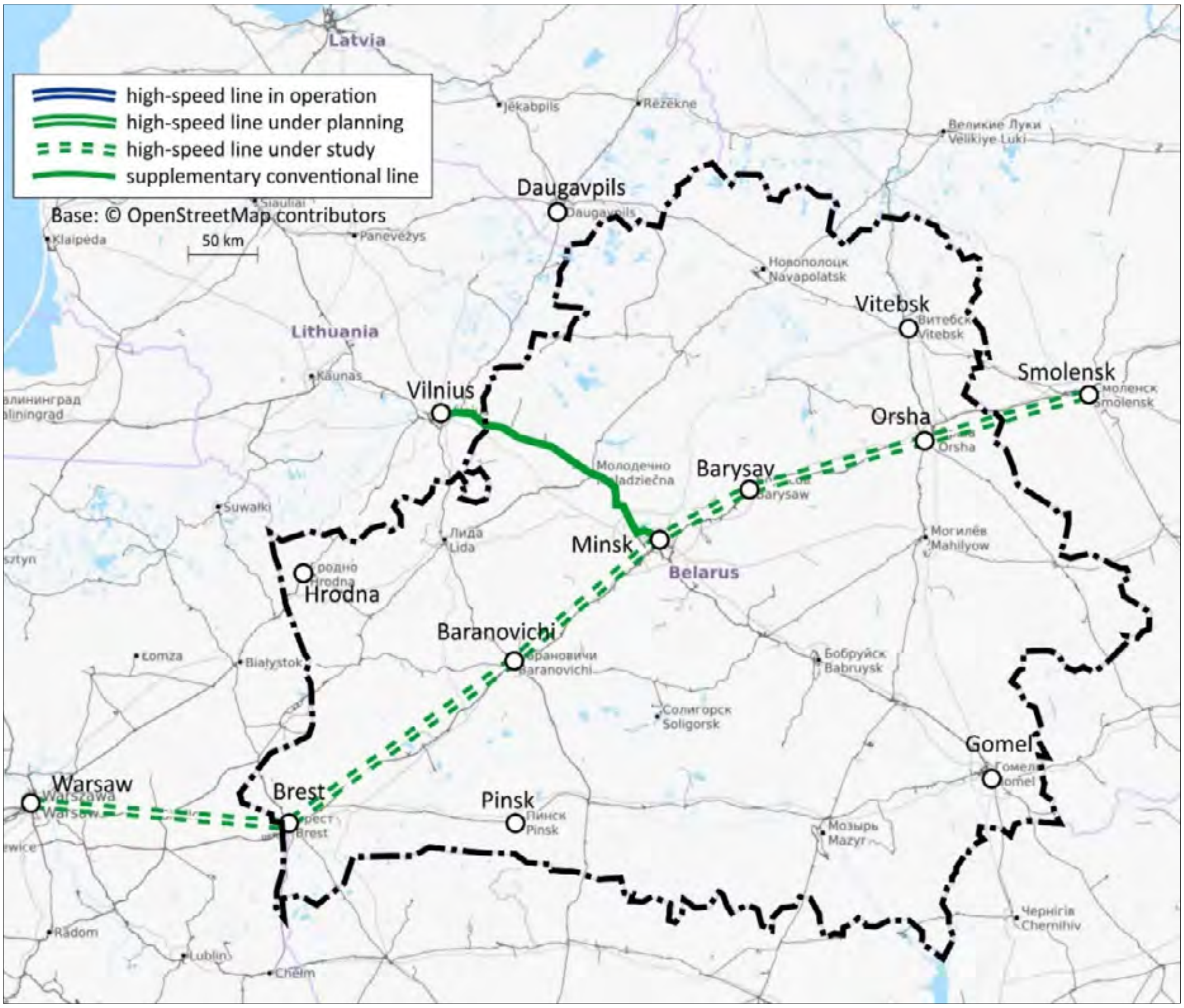
Plans to build a high-speed line in Belarus are closely related to the planned modernisation of international corridors. The possibility of constructing a new high-speed line along the east-west transit corridor is currently being reviewed as part of the New Silk Road. The line would probably be parallel to the conventional line to connect to the Russian Federation HSR line near Smolensk, and then through Orsha, Barysaw, Minsk, Baranavichy would reach Brest and connect to Polish section near Brest.

Table III–19 Existing and planned high-speed rail lines in Belarus

Transport corridor	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opening or putting into operation	Comments
Border RU – Orsha – Minsk – Brest – Border PL	600	300*	New	N/A	* approx.

Source: own study.

Figure III–34 Target high-speed rail network in Belarus with complementary sections



Source: Own work.

Advancement of work on rail connections between Belarus and TER States

In 2017, Belarus started discussions with the China Rail Construction Corporation (CRCC) on the possible construction of a high-speed rail link across its territory between the Russian Federation and Poland. No further progress has been made since.

3. Proposed design of HSR corridors and connections in the TER area

3.1 Conclusions about the current consistency of high-speed rail programs in TER States

Summarising the review of projects in TER and neighbouring States, it can be noted that most HSR projects currently implemented or planned in TER States are located in the transport corridors designated in the 1990s. The most advanced projects (preparation and implementation – see section II-1 nad II-7) are in the Central Europe region (Austria, Czechia, Hungary, Poland, and Slovakia). Joint international projects have been developed for more than 10 years and have now reached the phase of initial feasibility studies. In Austria, implementation of projects is well advanced, while international agreements are facilitating the development of across borders.

The planning process in the Balkan region is not very advanced with limited focus on international links. The highest level of advancement in the area has been achieved in Greece and Serbia, where the modernisation of the Belgrade – Hungary border line to the speed of 200 km/h has begun.

A high level of investment in high-speed lines can be observed in Turkey. At present, the high-speed line network is almost 1,200 km long. As mentioned previously, other lines and connections are also in the planning phase.

In the Eastern European region, progress is being made only in the Russian Federation focused on the east-west axis line as part of the Europe – China corridor. Additionally, adaptation works on the existing conventional lines Moscow – Sankt Petersburg – Finland to speeds of 200-250 km/h have been accompanied by the purchase of new rolling stock.

3.2 The structure of system corridors

The high-speed projects identified in the TER region create a multi-directional network system. It extends beyond the existing corridors (TINA) and EU Regulations 1315/2013 and 473/2014 and 758/2016, which do not cover all TER States. In this structure, corridors can be distinguished as being along the north-south and east-west axes. The dominant corridor in terms of the number of connections, as a result of its length is the north-south corridor which reflects the historical and geographical conditions for the development of the rail network in the regions following the directions of economic activity. The possible high-speed corridors have, however, slightly different patterns due to them:

- Introducing new quality connections reflecting the flow of people between major agglomerations
- Being focused on achieving short travel times between the largest number of agglomerations
- Being based on a system of urban rail nodes and connected to them through passenger distribution systems.

For this reason, the identification of particular corridors is important for assessing the passenger flows and transport organization which for the purpose of this study is:

1. North-South corridor: from Poland via Czechia, Slovakia/Austria, Hungary, Serbia, Bulgaria/Northern Macedonia to Greece and Turkey
2. North corridor (East-West): from Germany and Poland via Belarus to Russian Federation and further towards China
3. Middle corridor (Danube): from Austria and Switzerland and from Germany and Czechia via Slovakia and Hungary to Romania and Ukraine

4. Southern corridor (East-West): from Italy and France via Slovenia, Croatia to Hungary with a branch towards Turkey
5. Baltic corridor: from Germany, Czechia and Poland (Warsaw) via Lithuania, Latvia and Estonia to Finland
6. Southern corridor: East – West (Istanbul – Iran) from Istanbul to Iran and the Caucasus States
7. Carpathian corridor: from Poland via Slovakia, Hungary to Romania.

3.3 Characteristics of the corridors

3.3.1 North-South corridor

It is the longest corridor with a length of about 3000 km. This corridor closely follows corridor VII of the TINA network and TEN-T Baltic – Adriatic. It runs through 10 States and crosses three other corridors, running through and connecting 10 capitals and over 20 agglomerations with populations of more than 500,000 inhabitants. The corridor runs through varying terrain which affects the various geometric parameters of the lines and their maximum speeds. Most of the corridor is still in the planning stage in terms of higher speeds with the only section of line with maximum speed of at least 200 km/h in Turkey and Poland. As stated previously, there are no plans for high-speed lines in Bulgaria and Northern Macedonia, therefore these sections can be treated as supplementary lines to the HSR system. On the other hand, because the planning processes for these lines have not yet been finalised, it is advisable to analyse the possibility of their modernisation to a speed of at least 200 km/h.

The corridor would take the following route:

1. From Gdańsk to Warsaw on a new high-speed line (CMK North) – the new line, being an extension of the current CMK line (South). This line runs westwards from Warsaw serving the planned central airport in Poland. Until the construction of the new line, the current line may be used (when upgraded to a speed of 200 km/h). In the area of Grodzisk Mazowiecki an intersection with the planned high-speed line Warsaw – Łódź – Poznań/Wrocław is planned.

2. From Warsaw to Katowice and Cracow on the existing high-speed line (CMK South), where the maximum speed will be increased in the coming years to at least 250 km/h. Its southern part is planned to be extended southwards to Katowice and Cracow, as key rail hubs in Poland and urban centres inhabited by more than one million people. To the West, the line is connected to the high-speed line Berlin – Poznań – Łódź and the Opoczno node.

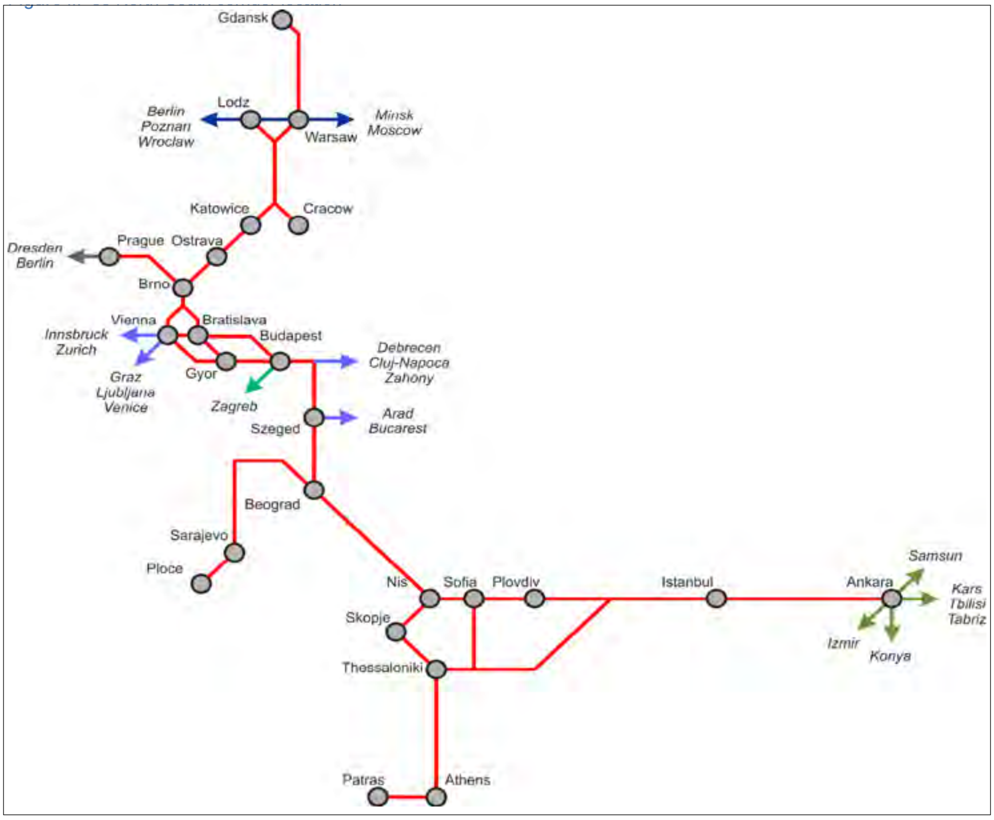
3. From Katowice to the PL/CZ border and further to Bohumin, a new, shorter, line with a maximum speed of 300 km/h is planned. Currently, cross-border traffic is carried out on conventional lines with constantly improved parameters since 2016.

4. From Bohumin to Ostrava and then to Brno, a new high-speed line with a maximum speed of 350 km/h is to be constructed. The Prerov – Brno section will be constructed in the second phase (until then the existing section will be modernised to 200 km/h). To the south from Brno, at the Brzecław junction, the line will be split into the section running via Vienna and the other one running via Bratislava. A new high-speed line from Brno to Prague and Dresden is planned. It will be connected to the corridor from the west – including the capital of Czechia and Saxony (Dresden).

5. From Vienna and from Bratislava to Budapest – the high-speed rail node is planned to go east and south – to the border with Serbia and on to Belgrade. Ultimately, a new high-speed line is planned from Budapest to the border. In the first stage, the modernisation of the existing line to the speed of 160-200 km/h is planned.

6. The planning works for the modernisation of the existing Belgrade – Sofia line on the section from Belgrade to the border with Bulgaria are underway. In the south of Serbia, in the Nis node, the corridor splits into two branches – the western one runs across Northern Macedonia and Skopje, and the east via Sofia. In Bulgaria, it is planned to modernise the existing lines.
7. From Belgrade to the west and then to the south there is also a branch leading to Sarajevo and then southwards to the port of Ploce. In Croatia and Serbia, the rail service runs on conventional lines, while in Bosnia and Herzegovina – the rail lines will have been modernised to 200 km/h.
8. Next, the corridor splits into two directions: to the south to serve Greece and to the south-east to Turkey. The line to Turkey runs from Sofia via Plovdiv to the border city of Edirne. The lines to Greece run from Sofia and Skopje to the south and merge in the region of Thessaloniki.
9. In Greece, the corridor runs along the new Thessaloniki – Athens line with an operating speed of between 130 and 200 km/h. Then, the corridor runs from Athens westwards via Piraeus to the port city of Patra. As mentioned previously, most of this line has already been or will soon be constructed – except for the final section of Rio – Patra.
10. In Turkey, the corridor runs through planned high-speed lines. From the Bulgarian border, the corridor runs to Istanbul, where it crosses the Bosporus Strait through the Marmaray Tunnel and enters the Asian part of Turkey. Then it runs along the existing high-speed line to Ankara through İzmit and Eskişehir. This line has branches on high-speed lines to Izmir, Antalya by Konya and the Black Sea port of Samsun.
11. To the east of Ankara, the corridor continues as the planned high-speed line to the city of Kars, near the border with Armenia, and then via Azerbaijan to the city of Tabriz in Iran.

Figure III–35 North-South corridor location



Source: Own work.

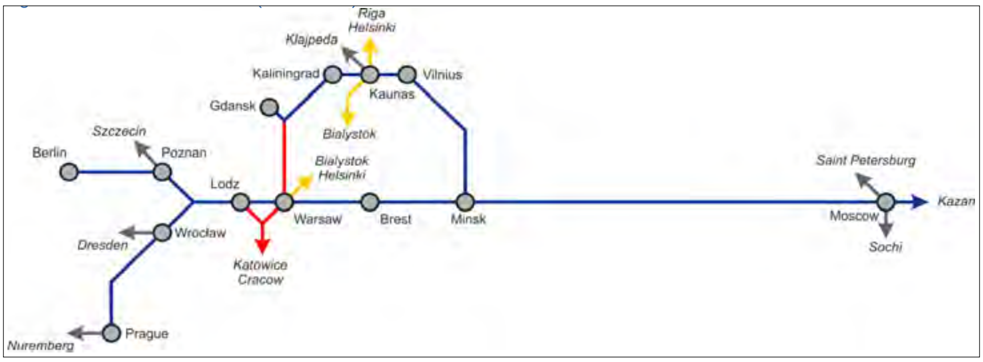
3.3.2 North corridor (East – West)

The corridor runs mostly in lowland terrain which allows for very high maximum speeds planned on the lines (350 km/h). It connects urban centres located in the Central and Eastern European Plain, and mountain terrains of Czechia and Germany. Due to the relatively easy conditions, the corridor is almost entirely planned as a newly constructed high-speed rail line adapted to the speed of 300-350 km/h. Its task is not only to integrate the Central and Eastern European States, but also to have the intercontinental function being part of the so-called "The New Silk Road". It connects six States: Belarus, Czechia, Germany, Lithuania, Poland and Russian Federation. Currently, feasibility studies or preliminary feasibility studies have been completed for the majority of the line sections.

The corridor would be the following:

1. The line would start in Berlin, Germany with interconnections to Dresden (via the line to Wrocław, PL) and Munich (via the line to Pilzno and Prague, CZ). The Dresden – Wrocław and Munich – the Czech border lines are conventional, modernised lines.
2. In Czechia, the corridor runs from the German border (Furt im Wald) via Pilzno, Prague to the border with Poland. The Czech-Polish border passage remains the subject of study. Due to the natural barrier of the Sudetes mountains, it requires a deviation of the line westwards (crossing the border near the Izerski Foothills) or eastwards. Depending on the option, this will mean the route running through Liberec or through Hradec Kralove.
3. In Poland, both branches of the corridor – from Berlin and Poznań, as well as from Prague and Wrocław – merge in the area of the urban complex of Ostrów Wielkopolski and Kalisz. The corridor then runs through Łódź and Warsaw (including the planned central international intermodal hub airport CPK with dedicated railway station) and heads to the border with Belarus in Terespol/Brest.
4. In Belarus, the corridor runs from Brest via Minsk and Orsha towards Smolensk, where a new high-speed line will need to be planned. It is assumed that from Brest the line will have 1,520 mm track gauge, and thus relevant gauge change solutions are required.
5. The separate branch serves as a conventional line from Gdansk in Poland to Kaliningrad in Russian Federation and then eastwards to Kaunas in Lithuania where there will be the Rail Baltica node, the line runs to Vilnius via the new high-speed line, and then from Vilnius to Minsk on the existing track. In Minsk the branch joins the main branch of the corridor.
6. After crossing the Belarusian-Russian Federation border, the corridor will run through Smolensk to Moscow where it will join the national line to Nizhny Novgorod and Kazan, and then through Kazakhstan to China.

Figure III–36 North corridor route (East – West)



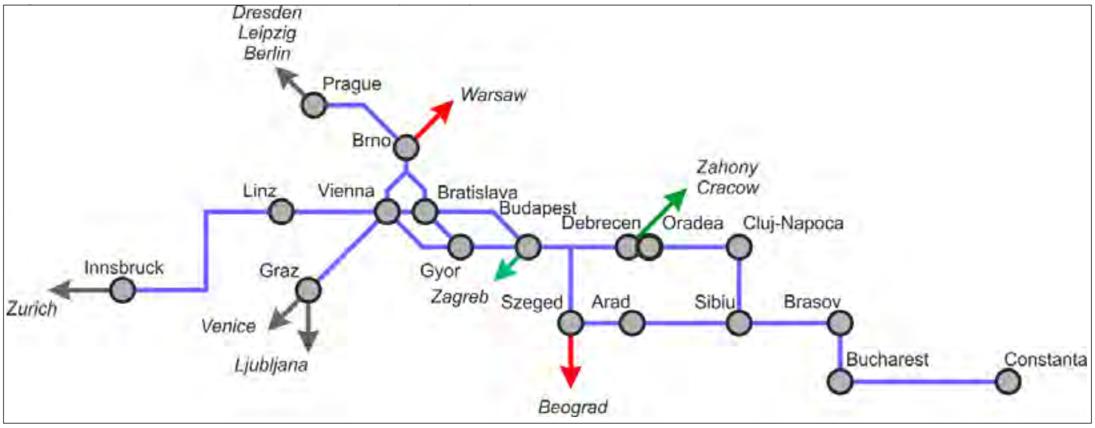
Source: Own work.

3.3.3 Middle corridor (Danube)

This corridor is a latitudinal link between the States running along the Danube, the Alps, the Sudetes and the Carpathian Mountains. It has many sections in common with the Rhine-Danube TEN-T corridor. Due to the topography along this corridor, the maximum speeds and line parameters differ on individual sections – starting from conventional lines through completely modernised ones with the speed of 160-230 km/h up to high-speed line sections. Most of this corridor remains incomplete with only some sections in Austria operational. The route of the corridor would be:

1. From the west side, the corridor has three branches. The north originates from Germany – Nurnberg and Dresden, starts in Prague and then runs through Czechia on the axis of Prague – Brno. From Brno, the corridor runs southwards to Vienna and Bratislava. The middle branch leads through the Alps from Innsbruck via Linz to Vienna. It is connected to a conventional line from Zurich. The southern branch, running from Italy and Slovenia, leads from Klagenfurt via Graz to Vienna.
2. From Vienna, the corridor runs east to the city of Györ in Hungary where it joins the lines from Bratislava, proceeding then to Budapest.
3. The corridor branches east from Budapest. The northern section serves the east part of Hungary and the Hungarian-Romanian border. Finally, the corridor reaches the border of Hungary, Slovakia and Ukraine in the Čierna nad Tisou and Tchop.
4. The southern section runs along a common line towards Serbia and Romania, and then through Szeged to Arad in Romania.
5. In Romania, the high-speed lines are currently limited to the section from Arad via Timisoara, Sibiu, Braşov to Bucharest. The Debrecen – Oradea – Cluj-Napoca – Sibiu line will therefore be considered as an auxiliary line. The last section is the line connects Bucharest to Constanta at the Black Sea.

Figure III–37 Location of the Middle corridor (Danube)



Source: Own work.

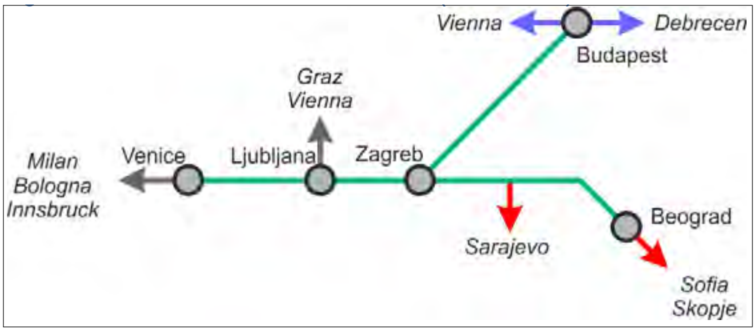
3.3.4 Southern corridor (East-West)

The southern corridor links the areas located on the south side of the Alps and the Carpathians. These regions have differentiated landform and levels of investment. The corridor includes high-speed lines and modernised conventional lines. Some parts of these conventional lines can be included in high-speed construction projects in the future.

The corridor runs as follows:

1. It begins in Italy where it crosses the entire north of the country to Venice.
2. East of Venice, the corridor heads to the port of Trieste and enters Slovenia, where it goes to the capital, Ljubljana where a high-speed line going from Trieste via Ljubljana to the Croatian border is planned.
3. In Croatia, the corridor utilizes conventional lines connecting the Slovenian border to Zagreb. At this point, the corridor splits into two branches.
4. The northern branch leads from Zagreb to Budapest, where it joins the Danube corridor. In Hungary, the construction of a high-speed line is planned from the Croatian border to Budapest.
5. The southern branch runs along the modernised conventional lines to Belgrade in Serbia, where it joins the north-south corridor.

Figure III–38 Location of the South corridor (East – West)



Source: Own work.

3.3.5 Baltic corridor

This corridor would extend from Poland to the north-east of the Baltic Sea. It runs mainly in low-lying terrain, however, there are sections with varied terrain and changing geological conditions. The main natural obstacles to construction work in the corridor are water courses and straits. It is a corridor that links large urban centres, but it also runs through low-density areas and one with different track gauges.

The route of the corridor would be:

1. The corridor starts in Germany (Berlin), Czechia (Prague) and crossing Poland by several paths (Cracow, Katowice, Poznan, Wroclaw, Łódź) and passes through Warsaw.
2. The line then runs north-east, following the modernised conventional line to Bialystok, and then north-west – to Ełk. From Ełk to the border with Lithuania, it runs on a planned new high-speed line being part of the Rail Baltica project.
3. The corridor would then follow the route of Rail Baltica through Kaunas, Riga to Tallinn (LT, LV, EE).
4. In Kaunas, there is a branch to Vilnius. There is also a connection to Gdansk – Kaliningrad – Minsk section of the North Corridor.
5. From Tallinn there is a planned undersea tunnel which will run to Helsinki. Currently, no rail transport is possible in this section.
6. In the Helsinki metropolitan area, there is a change in the gauge to 1,524 mm, and travel can be continued to Turku in the west, Tampere, Oulu and Kirkenes in the north and St. Petersburg in the east.

Figure III–39 Location of Baltic corridor

Source: Own work.

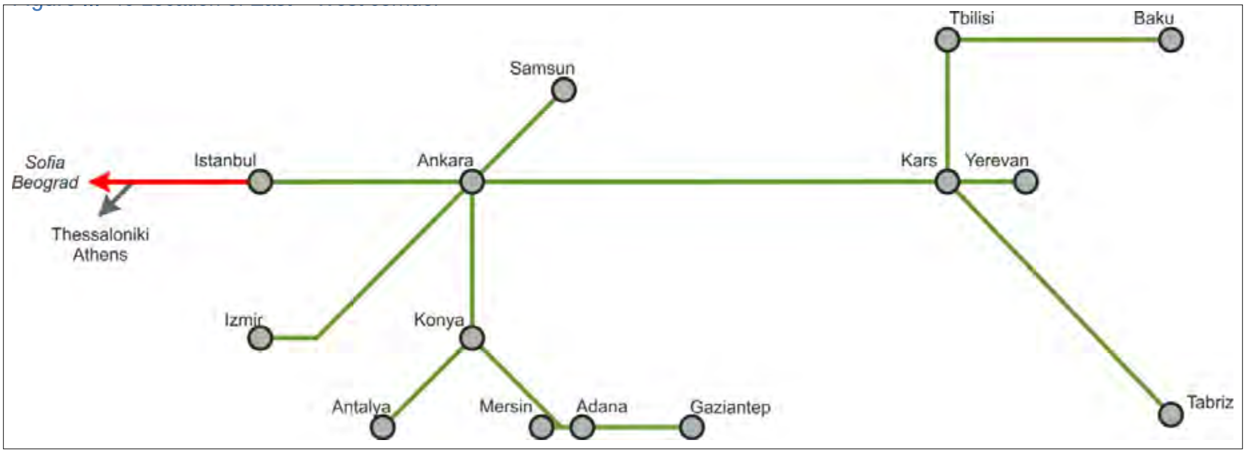
3.3.6 Southern East – West (Istanbul – Iran) corridor

This corridor would start in Turkey and continue to the eastern border and then to Iran, Georgia and Azerbaijan. It runs in some parts in mountainous terrain. It consists of sections adapted to different speeds, which is influenced by terrain conditions.

The corridor runs as follows:

1. It begins in Istanbul where it connects to the main north-south corridor and line from Greece.
2. Then the corridor runs along the main trunk line connecting the two Turkish largest metropolitan cities, Istanbul and Ankara.
3. The Ankara junction is the beginning for the branches to Samsun, Konya, İzmir and to the system of cities Mersin – Adana – Gaziantep.
4. The corridor continues through Central Anatolia Region in the eastern direction to the border city Kars.
5. From Kars, the routes would proceed to Georgia and Azerbaijan (new conventional line), Armenia (existing conventional line – border currently closed) and Iran (planned high-speed line).

Figure III–40 Location of East – West corridor



Source: Own work.
Note: the connection to Yerevan is not currently possible due to the closed border.

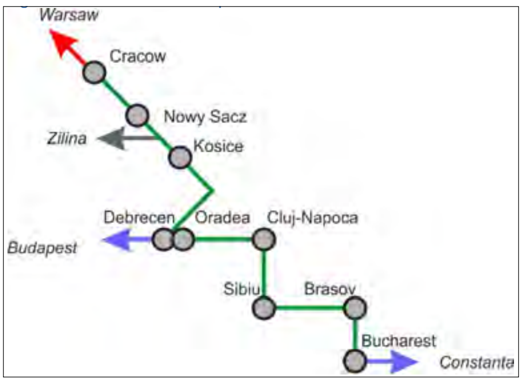
3.3.7 Carpathian corridor

The Carpathian corridor is a complementary route to the main N-S corridor. A large part of the corridor crosses the hilly area of the Carpathian Mountains, which limits possible routing solutions also limiting the use of full high-speed lines limits.

The route of the corridor is as follows:

1. The corridor begins in Cracow (Poland) where it connects to the North-South corridor running from Central and Western Poland.
2. Then the corridor enters the Beskid Mountains, crossing the Polish-Slovakian border in Muszyna/Plavec.
3. It then proceeds through Slovakia, passes Kosice to reach the Slovakian/Hungarian border. Then the route runs towards Debrecen.
4. From Debrecen the corridor runs south-east to the Romanian city of Oradea.
5. From Oradea the corridor runs eastwards entering the Romanian Carpathian Mountains. After reaching Cluj-Napoca it turns south to Sibiu.
6. In Sibiu the corridor again turns to the east and enters the main Romanian high-speed line to Bucharest via Brasov. From there, there is a connection to the seaport of Constanta (Black Sea).

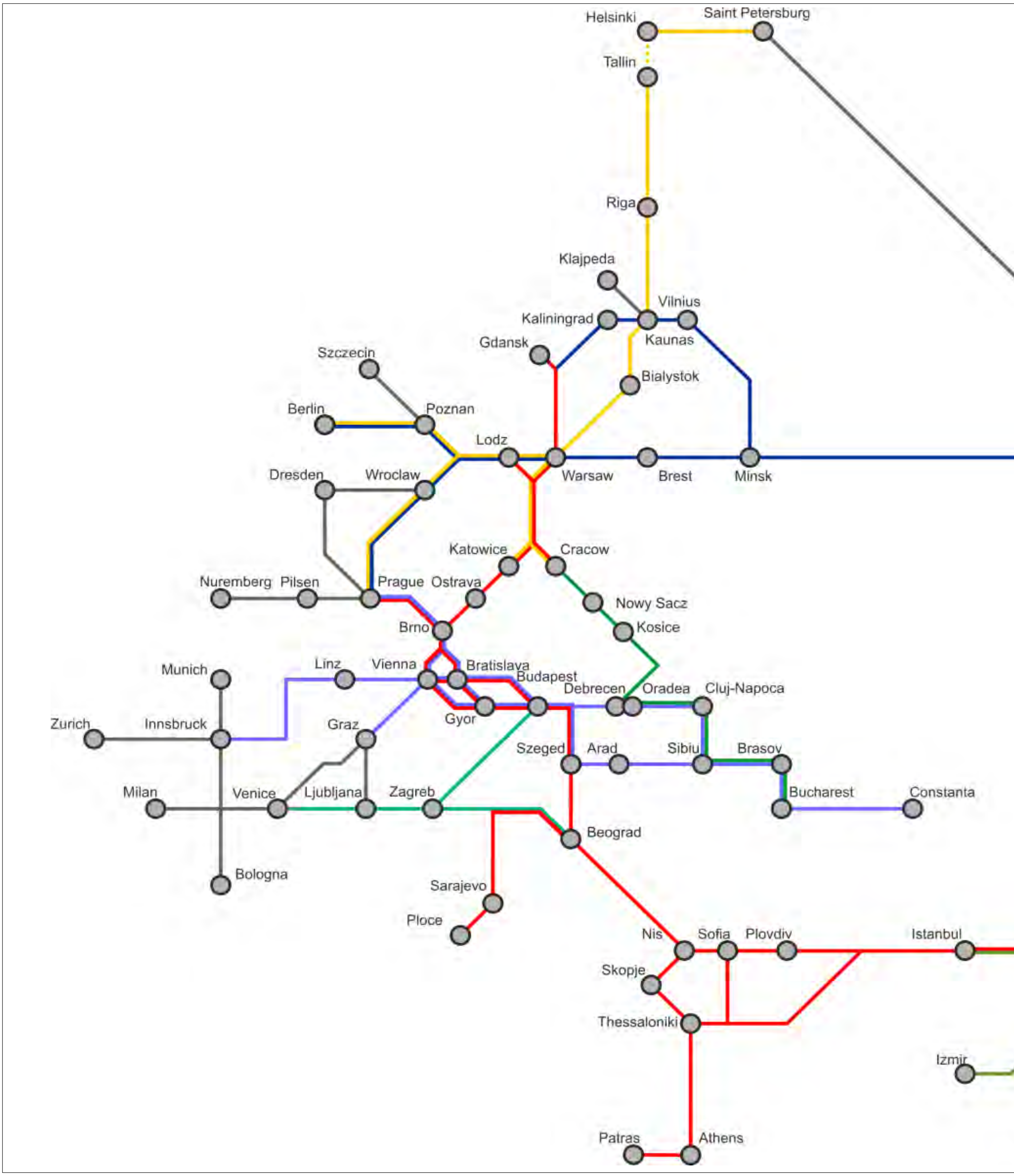
Figure III–41 Location of Carpathian corridor



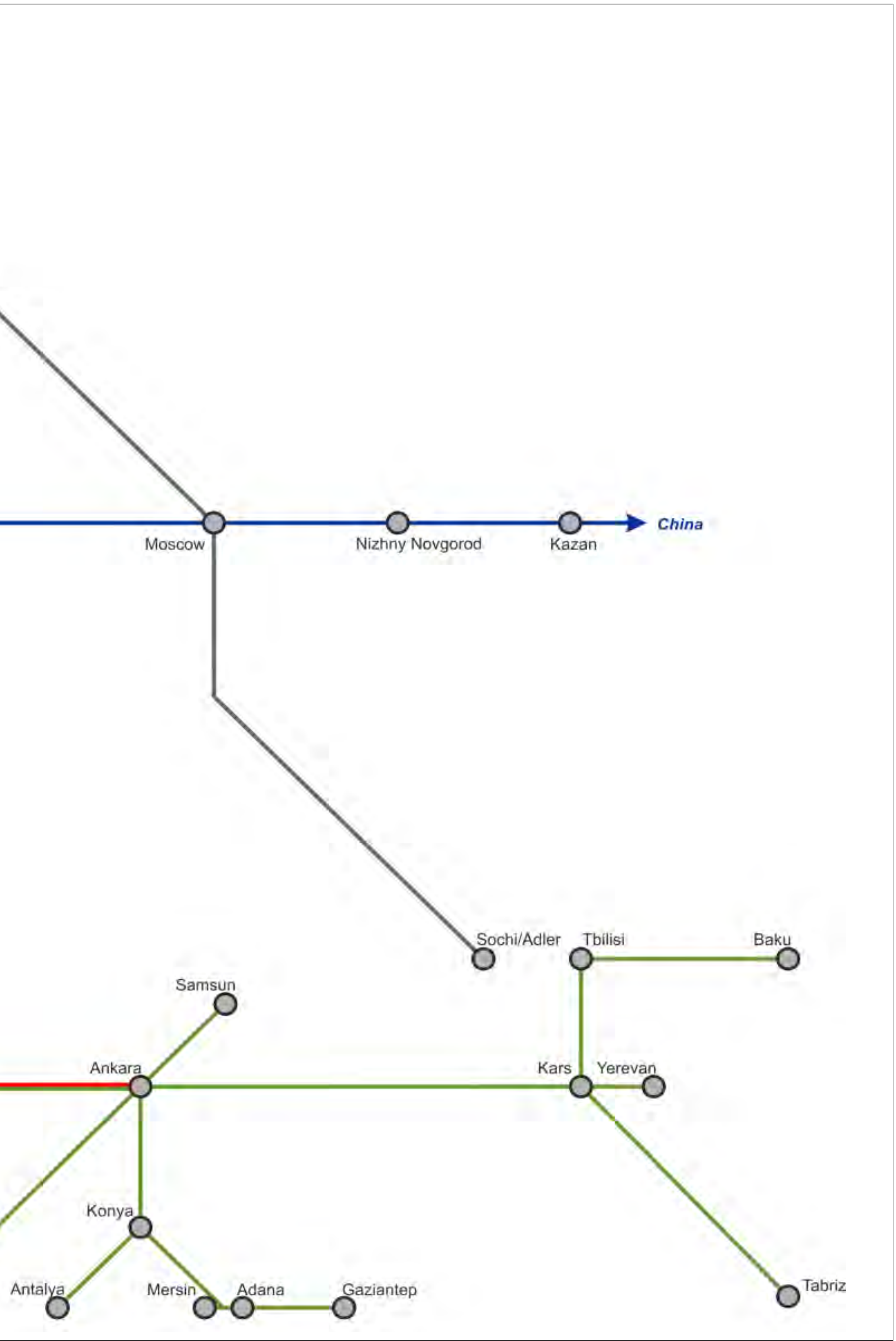
Source: Own work.

The combined network is shown in figure III-42 below.

Figure III–42 Network of TER HSR corridors



Source: Own work.
Note: the connection to Yerevan is not currently possible due to the closed border.



China
Moscow
Nizhny Novgorod
Kazan
Sochi/Adler
Tbilisi
Baku
Samsun
Ankara
Kars
Yerevan
Konya
Antalya
Mersin
Adana
Gaziantep
Tabriz

4. Missing links and other inefficiencies

4.1 General

One of the main concerns for this network is the system of international connections, where the journey times between the major cities, and, in particular, between the capital cities are not competitive compared to air transport. In many cases, road transport is faster than rail and the number of connections is limited or non existent as a result of investment decisions aimed at focusing on the construction of motorways and modernisation of roads, whereas parallel rail lines remained limited and do not creating suitable network being without major modernisation. The problem appears especially in mountainous areas where the geometry of the existing lines (curves and inclines) limits the possibility of increasing the maximum speed and creating significant increase of construction/operational/maintenance costs.

Further improvement of average commercial speed will be possible if the process of rail network modernisation is continued or accelerated. This means construction of new sections capable of running at competitive (higher) speeds. Without necessary investments, rail transport will remain not compete with to other means of transport. Competitive speeds will also allow for an increased number of connections, which is also important from the passenger's point of view.

The TER HSR Project provides the opportunity to create fast international rail connections also for cargo transport – supporting trade on international traffic. This can be done only after the following challenges eliminating:

- Missing links by constructing new lines or at least modernising the conventional lines to higher speeds, as complementary lines
- Bottlenecks or at least reduce their impact on commercial speed
- Other inefficiencies, for example linked to different gauges.

4.2 Proposals of conventional complementary lines

The plan for the TER HSR system presented is limited to declarations of particular TER States which, in some cases, are also supported by the European Union. However, such plans are not in place in each of the TER States. This fact has been taken into consideration while developing transport corridors.

In order to maintain the coherence of the network and ensure its functionality it is important to allow for a supplementary network, which would be composed of conventional lines with improved parameters, increased to at least 160 km/h, as a link between high-speed lines. Examples of such links are shown in table III-20.

Table III–20 Proposal of conventional lines complementing high-speed lines

TER HSR Corridor	Country	Connecting line
North – South	Serbia, North Macedonia, Greece	Belgrade – Nis – Skopje – Thessaloniki
North – South	Serbia, Bulgaria, Greece	Nis – Sofia – Thessaloniki
North – South	Bulgaria, Turkey	Sofia – Plovdiv – Kapıkule (BG/TR Border)
North – South	Greece, Turkey	(Thessaloniki) – Xanthi – EL/TR border
Southern	Slovenia, Austria	Ljubljana – SI/AT border
Southern	Croatia	SI/CR border – Zagreb – CR/HU border
Southern	Croatia, Serbia	Zagreb – Indija – (Belgrade)
Carpathian	Poland, Slovakia, Hungary	Cracow – Kosice – Miskolc
North	Lithuania, Russian Federation, Poland	Kaunas – Kaliningrad – Gdansk

Source: Own study.

In the very long-term perspective these lines would be replaced by high-speed lines. The analysis indicates that without further investments it will not be possible to establish an effective network of high-speed connections.

4.3 Proposals for the missing HS lines within the main network

The most striking example of a missing link is the east-west line through Belarus, connecting the Russian Federation and Poland. Due to the large distance covered, this line should be a HS line with the speed ranging between 300 and 350 km/h. The project may prove necessary in the framework of plans to create a high-speed Europe-Asia line.

Table III–21 Proposal of conventional lines complementing high-speed lines but requiring support also from outside TEN-T network

TER HSR Corridor	Country	Connecting line
North	Russian Federation, Belarus, Poland	Smolensk – Minsk – Brest – Warszawa

Source: Own study based on data in section III-5.3.

4.4 Border crossing bottlenecks

Border crossings are currently significant bottlenecks in the system of international high-speed connections in the TER region resulting from:

- Traction change (different systems of power supply etc.)
- Gauge change
- Low technical level of cross-border sections
- Lack of network continuity and the necessity to use long bypasses
- Passport controls.

Examples of such sections are presented in table III-22.

Table III–22 Bottlenecks in TER HSR

TER HSR Corridor	State	Connecting line
North	Poland, Germany	Poznań – Berlin
Middle	Czechia, Germany	Pilsen – Nuremberg
North-South	Greece, Turkey	Thessaloniki – İstanbul
Carpathian	Slovakia, Hungary, Romania	Kosice – Debrecen – Oradea
North	Belarus, Poland	Brest
North	Lithuania	Kaunas
North	Lithuania	Vilnius
North	Russian Federation, Poland	Kaliningrad
North	Finland, Estonia	Helsinki – Vantaa

Source: Own study.

4.5 Conclusion

The main challenges in the TER region are low speeds of operation and missing links. There is also another problem related to the small number of daily connections between major cities that make it even more difficult to compete with private car transport.

The construction of a high-speed rail network is necessary to ensure the competitiveness of rail in this region. It is, however, possible to establish a mix of high-speed and conventional, well maintained sections, as the high-speed and conventional lines are based on the same technical solutions. The conventional sections should be minimal and could be later replaced by high-speed lines when economically justified by increased traffic.

There is also a problem with the incoherence of the rail network, especially due to different track gauges and other systemic differences of rail systems among neighbouring States around Europe and beyond.

This cannot be easily solved but it can be minimised by means of automatic variable gauge system both on infrastructure and rolling stock. The differences in traction systems or lack of electrification at borders is something that is surmountable given current technologies in multi-system electric locomotives and electric multiple units.

In general – overcoming these challenges is very complicated and extremely expensive, so it will require substantial political support.

5. Possible connection and extension of TER HSR network to other regions

5.1 Technical possibilities

The rapid development of high-speed technology has enabled the implementation of projects over longer distances which, according to UIC,[67] can now be efficient on distances up to 1,200 km. Furthermore, examples from China have shown that distances above 2,000 km can also be effective as shown on the following lines:

1. Beijing West – Hong Kong West Kowloon, time travel 8 h 58m, distance 2,185 km, average commercial speed 242 km/h
2. Kunming – Beijing, travel time 13 h, distance 2,760 km, average commercial speed 212 km.

It is clear though that very few passengers would cover the entire journey as usually journeys over 5 hours make air travel more competitive, where the air option is available, and most journeys would be between the intermediate stops or between the terminals and the intermediate stops.

The development of high-speed connections over considerable distances is conditioned by the construction of high-performance rail lines with maximum speeds of up to 350 or even 400 km/h. Rolling stock would also need to have variable gauge solutions to run from China to Europe for example to allow for the switch to and from the 1,435 mm track gauge. Currently, the transport of containers on this route (currently the only service along the entire route) requires transhipment at border stations for both systems. So, to support the HSR possibilities there should be a network of intermodal hubs developed – close to the borders.

Another feature that increases attractiveness of travelling by HSR is the possibility to run high-speed night trains over very long distances. This possibility requires very close and challenging cooperation among rail lines administrations/managers (timetables monitored on-line) – in optimal circumstances – coordinated on the international level.

5.2 Transcontinental rail transport

From a geographical point of view, it seems natural to develop high-speed connections from TER States to the Asian continent. However, very large distances (Europe through the Russian Federation to China is about 10,000 km) are a barrier to the transcontinental HSRs development. The travel time of this route, assuming an average commercial speed of 250 km/h, would be about 40 hours, which would be uncompetitive in relation to air transport. However, using this route might be attractive to passengers traveling on individual sections. The economic efficiency of the line will increase and thus its construction would be justified if freight trains were also operating on these lines. The travel time of freight trains is already highly attractive compared to sea and air transport. This section sets out the possible corridors.

In April 2019 the twenty-first EU-China Summit took place in Brussels focusing on the development of transport connections between Europe and Asia, where a strong emphasis was placed on strengthening synergies between China's Belt and Road Initiative and the EU's Trans-European Transport Network

[67] Resolution of UIC "Operating high-speed lines: in search of efficient solutions. Round-table on good practice share and international benchmark", Paris, 31 January 2019.

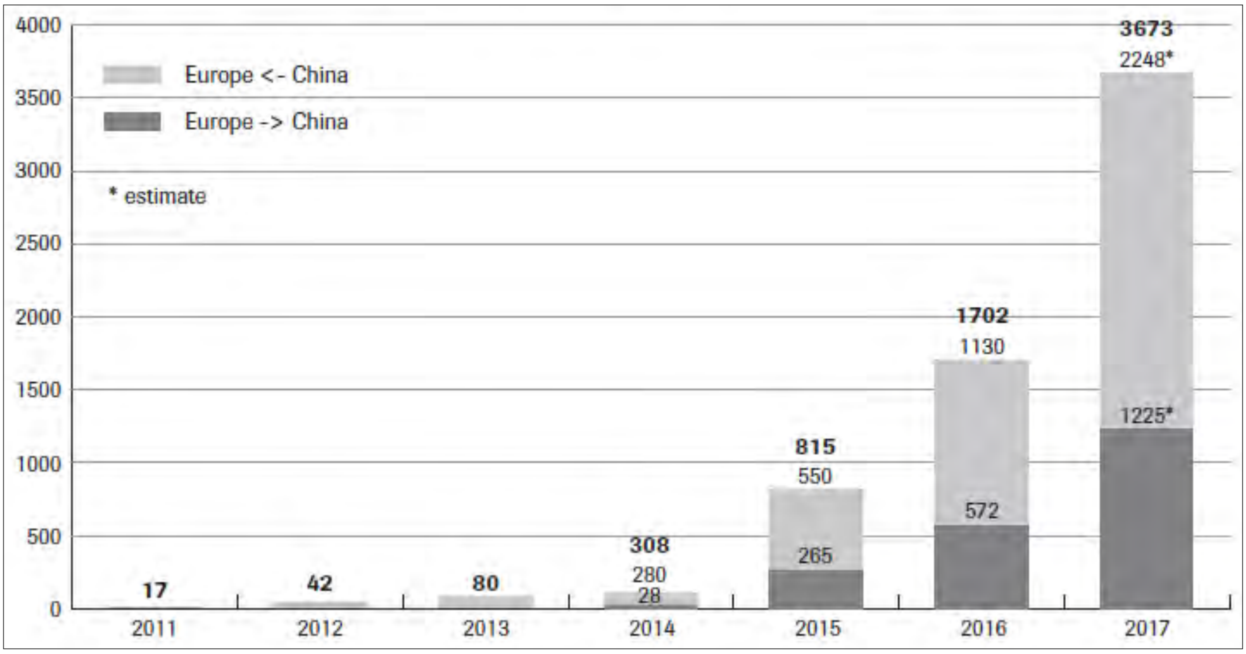
policy, promoting sustainable development and infrastructure. It was agreed to undertake a joint study on rail-based, sustainable and comprehensive transport corridors between the EU and China. The study will analyse the current state of corridors between China and Europe, analyse their problems, propose the most sustainable corridors and, as a result, key projects related to them. All directly interested States will be consulted at the stage of implementation of the study. There are no results of this study yet.

5.3 Western Europe – Russian Federation – China corridor

Now it seems that the corridor from Western Europe to China is optimal for high-speed train traffic. It is currently the shortest distance for the transport of goods (containers) from China to Europe with the highest growth. This would be an extension to North Corridor (East – West) through Poland, Belarus, Russian Federation and Kazakhstan identified in the previous section III-3.3.2.

The number of containers handled at Małaszewice station (PL – the EU border with Belarus) has doubled annually in recent years and one of the main problems is insufficient capacity on the line (figure III-43).

Figure III–43 Container transport on the Europe – China route



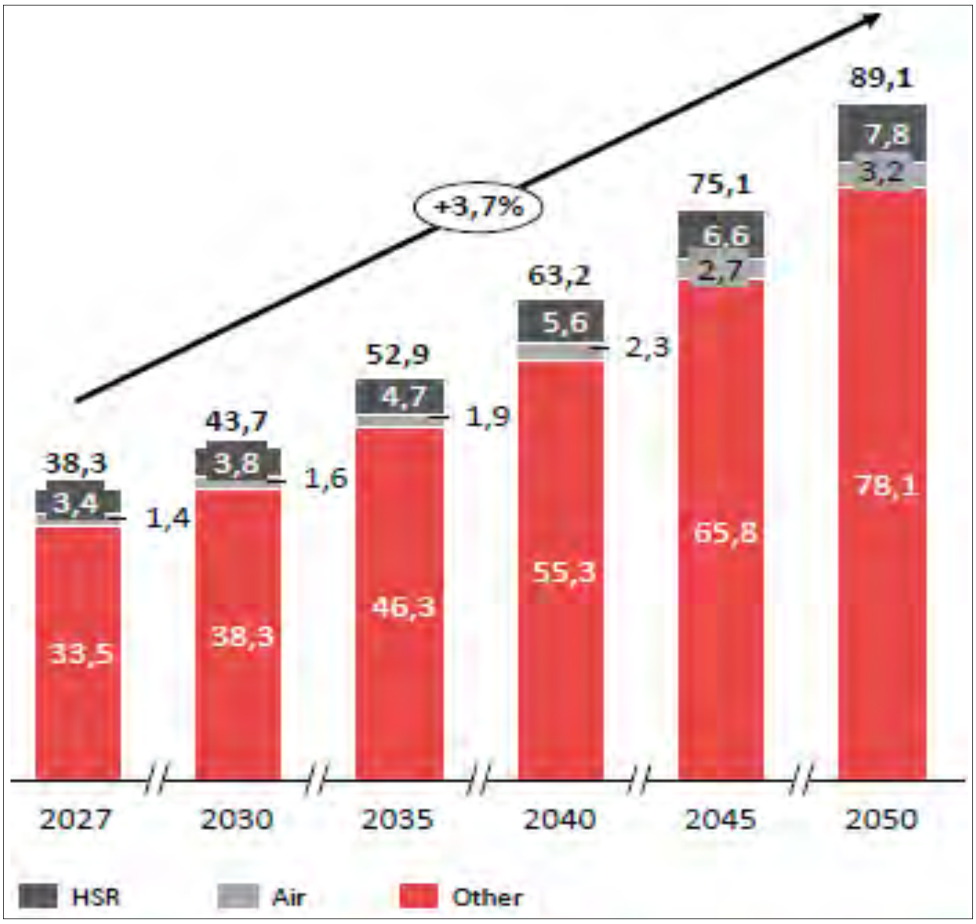
Source: J. Jakóbowski, K. Popławski, M. Kaczmarski *The Silk Railroad. The EU-China rail connections: background, actors, interests*. Centre for Eastern Studies. Warszawa, 2018.

The concept of a high-speed passenger-freight corridor was presented by the Russian Federation Railways at the UIC forum of the Intercity & High-Speed Committee in 2017. A preliminary feasibility study of the project was commissioned by the government of the Russian Federation and prepared by the OJSC High-Speed Railways, a subsidiary of the OJSC Russian Federation Railways, PricewaterhouseCoopers and Infrastructure Economics Centre.

The corridor concept is based on the combination of two existing and well-developed HSR systems – the European Union's and China's. The national rail systems of Belarus, Russian Federation and Kazakhstan are located between these two systems. Details of the development of these networks have been set out in previous sections.

From the technical point of view, the main task would be to integrate these systems into one transport corridor in order to achieve the appropriate economies of scale. For rail systems in individual States, such a corridor would result in an increase in both international and domestic transport. The pre-2020 high growth of transport between Europe and Asia results in high trade forecasts justifying the construction of this corridor.[68]

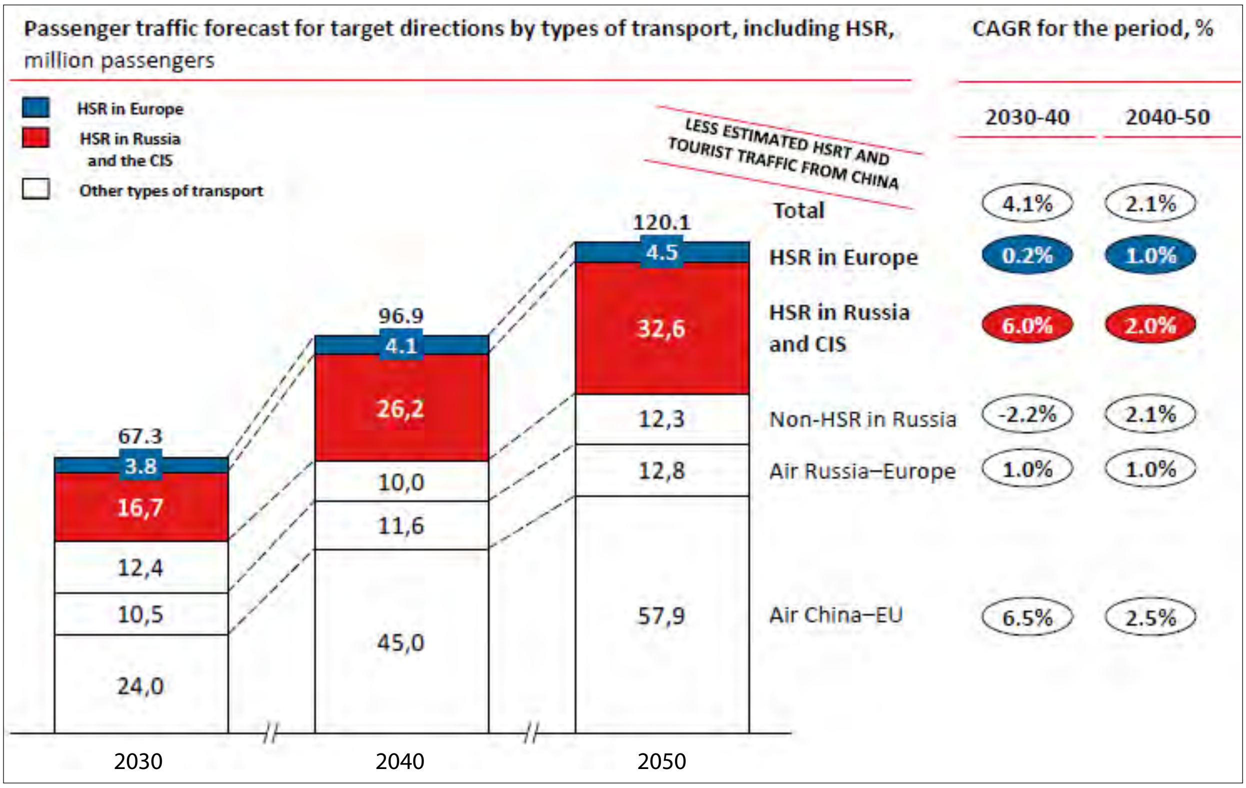
Figure III–44 China–EU cargo traffic forecast by type of transport, 2027–2050, [mln tons]



Source: High Speed Rail (HSR). EuroAsia Project. Presentation on UIC Intercity & High-Speed Committee, London, 17 September 2017.

[68] *High Speed Rail (HSR). EuroAsia Project. Presentation on UIC Intercity & High Speed Committee*, London, 17 September 2017.

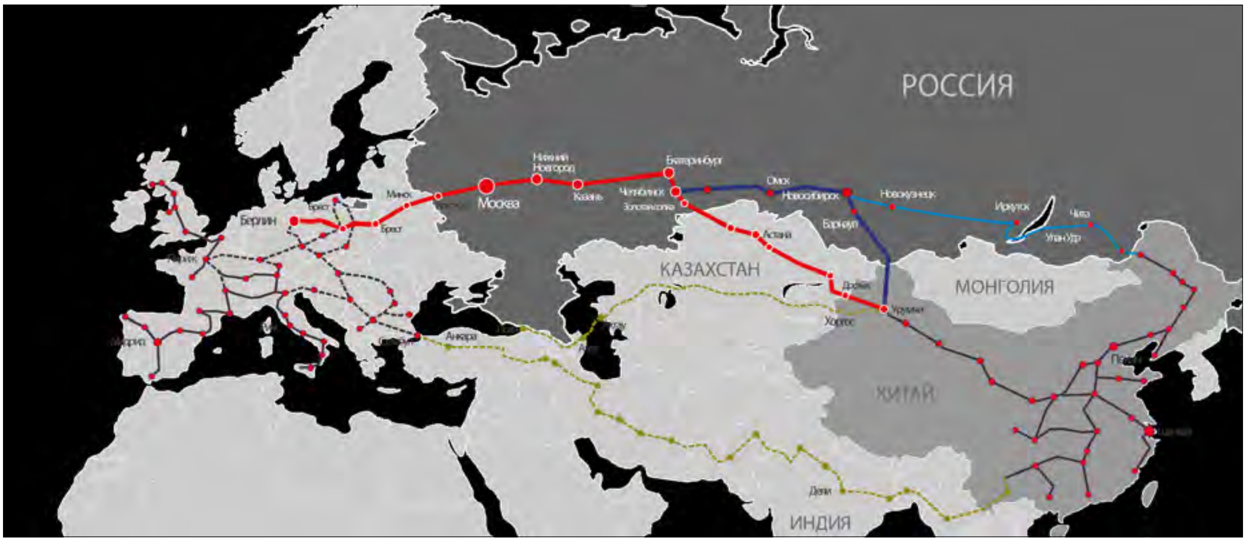
Figure III–45 Passenger traffic forecast for target directions by types of transport, including HSR, [million passengers]



Source: High Speed Rail (HSR). EuroAsia Project. Presentation on UIC Intercity & High-Speed Committee, London, 17 September 2017.

The route of the new corridor is presented in figure III-46.

Figure III–46 EuroAsia corridor route



Source: High Speed Rail (HSR). EuroAsia Project. Presentation at the UIC Intercity & High-Speed Committee, London, 17 September 2017.

The total length of the line will be about 9,500 km, including 6,700 km of newly constructed lines, of which 2,300 km in the Russian Federation. As a result, the world's largest HSR network with a length of more than 50,000 km will be created by connecting transport systems from Asia, Russian Federation and the European Union.

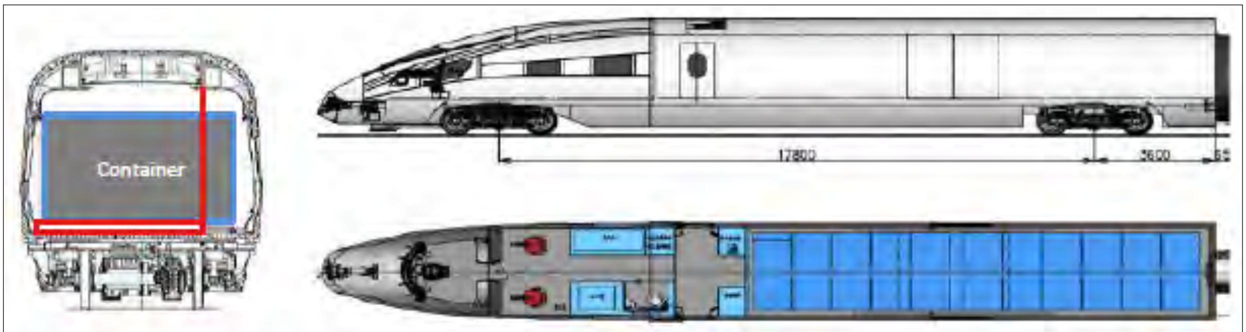
The total capital expenditure on the project of 7.08 trillion roubles in the prices of Q2'2017 for the Brest – Dostyk section (7.84 trillion roubles, considering China), including 3.58 trillion roubles in the prices of Q2'2017 for construction on the territory of the Russian Federation.

Two types of rolling stock are proposed to operate the Eurasia line:

1. For passenger services with speeds of up to 350 km/h
2. For freight transport with speeds ranging between 250 and 300 km/h.

The freight rolling stock to be operated on this line has never been operated before. It is to be constructed on the basis of technical solutions used for high-speed passenger trains with adapted interiors to transport containers. The construction of trains is to enable fast and automated loading operations. The assumed length of the train is approx. 400 m (16 wagons) and the load capacity – 600 t.

Figure III–47 High-speed freight rolling stock concept



Source: High Speed Rail (HSR). EuroAsia Project. Presentation on UIC Intercity & High-Speed Committee, London, 17 September 2017.

The traffic would be managed so that the maximum capacity possible would be used to fit both passenger and freight high-speed services.

5.4 Balkans – Turkey – Iran and further to China and India via Pakistan corridor

HSR network development in Turkey makes it possible to establish fast rail connections for both passenger and freight transport in the Balkans – Turkey – Iran corridor. This would be an extension to Southern East – West Corridor identified in the previous section 3.3.6. The rapid development of the rail network in Iran, including the construction of HSL, makes it possible to extend the corridor eastwards:

1. To China via Kazakhstan (Almaty and then to Urumqi in China)
2. From Tehran to Pakistan (Islamabad and then to India, Delhi).

However, while the technical standards adopted for part of the corridor in Turkey and Iran can accommodate high-speed services, the rail line from Iran to Kazakhstan existing since 2014, is characterised by lower parameters. The length of this line is 925 km, including 140 km in Kazakhstan and 85 km in Iran. This corridor is primarily important for freight traffic. The Iranian HSL section is to reach Mashhad. In Kazakhstan, a new Turkmen line will connect to the planned HSL Eurasia in Almaty.[69]

[69] S. Li, *High Speed Rails – Case of China*., "Regional EST Training Courseat United Nations University. ITDP China February 26, 2018".

Figure III–48 China – Iran rail corridor

Source: High Speed Rails – Case of China. Regional EST Training Course at United Nations University. *Shanshan Li, Vice Country Director, ITDP China Feb 26, 2018*.

For the route to Pakistan, the current state of infrastructure does not allow the launch of high-speed trains. There are no plans to modernise the existing line or build a new one. The presented concept on the basis of the quoted source materials requires further studies in the field of technical possibilities of its implementation, economic profitability and political conditions.

5.5 Rail Baltica corridor via Finland to Arctic Sea

The construction of HSL Rail Baltica (planned commissioning date 2026) and plans for the construction of the tunnel under the Gulf of Finland will establish a corridor for fast rail connections from Central Europe to Finland. The construction of the northern HSL will also enable northern Finland to be covered by a HSR network. The construction of the so-called Arctic Rail through Lapland to the planned seaport in Kirkenes is aimed to serve the so-called north-eastern sea route from East Asia via the Arctic Sea.

The proposed new rail link as part of the intermodal chain in Europe-Asia transport was presented at the Rail Baltica Forum in 2019 (see figure III-48). Its implementation may be possible in the near future as the Arctic warms and the Arctic Sea ice retreats. The project may be attractive for railways and may shorten the time of cargo transportation, especially on the Asia-Central Europe route. This would be an extension to the TER HSR Baltic Corridor identified in the section 3.3.5.

Figure III–49 Rail corridor Rail Baltica – Arctic Sea

Source: Rail Baltica and National Transportation Infrastructure Development in Finland. Sabina Lindström. Rail Baltica Forum. Vilnius, 2019.

6. Multimodal solutions

6.1 Background

For any railway system to be effective, it is essential to ensure good connections with other modes of transport through good multimodal solutions (intended as the carriage of passengers or freight, or both, using two or more modes of transport).[70]

Multimodal transport solutions can contribute to the improvement of the general effectiveness of transport through reduced unit costs, which are caused by the usage of the most efficient mode of transport on every stage of travel. It is also a more sustainable transport option.[71]

Modal split for TER States is still highly dependent on road transport as shown in table III-27 and figure III-51.[72] The highest for passenger rail (although still low) are seen in Austria (11.5 per cent) Slovakia (9.5 per cent), Hungary (9 per cent) and Czechia (8 per cent).

While the participation of HSR in western Europe calculated in passenger kilometres amounts to 28 per cent (2016) for all the rail systems, in TER States it is much lower with the highest share in Czechia (8 per cent – 0.7 billion pkm) and Poland (7.5 per cent – 1.44 billion pkm).

Table III–23 Share [%] of passenger rail in modal split for the planned TER HSR network

Country	Passenger Cars	Buses & Coaches	Trains	Tram & Metro
Austria	72.60	9.60	11.40	6.50
Bulgaria	79.60	17.20	2.00	1.10
Croatia	83.30	12.10	2.60	1.90
Czechia	66.50	15.40	8.00	0.40
Estonia	79.50	17.70	2.00	0.80
Greece	80.80	16.90	1.00	1.30
Hungary	66.50	20.90	9.00	3.60
Lithuania	89.90	9.10	1.00	0.00
Poland	77.20	13.90	7.30	1.60
Romania	75.00	14.70	3.90	6.40
Slovakia	74.20	15.70	9.30	0.80
Slovenia	86.30	11.80	2.00	0.00
Armenia	na	na	na	na
Belarus	na	na	na	na
Bosnia and Herzegovina	na	na	na	na
Georgia	na	na	na	na
Montenegro	95.80	2.40	1.80	0.00
North Macedonia	85.90	13.10	1.00	0.00
Russian Federation	na	na	na	na
Serbia	74.90	22.70	1.10	1.20
Turkey	na	na	na	na

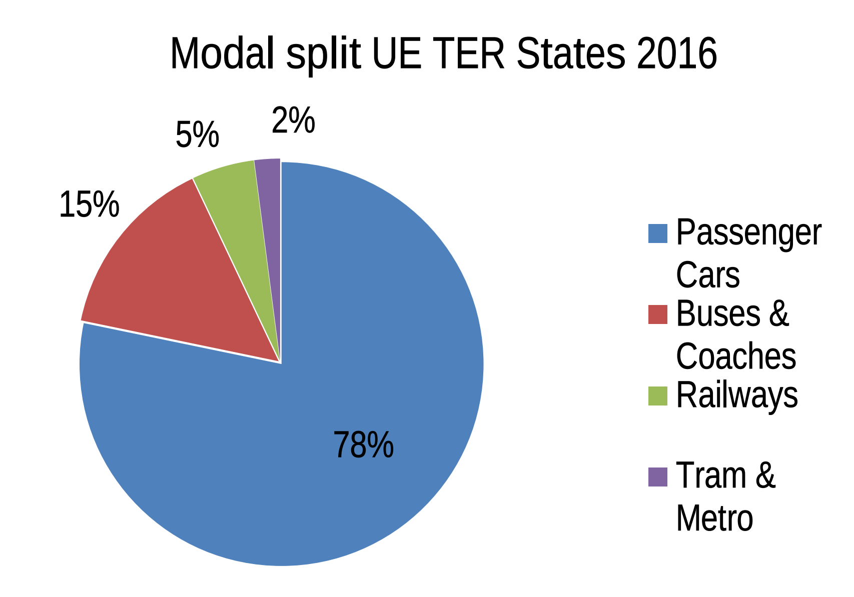
Source: EC EU Transport in figures. Statistical Pocketbook 2018.

70 Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU, Article 3 p. n) (OJ L 348, 20.12.2013, p. 1).

71 EU, *White Book COM (2011) 144*, Brussels.

72 Data available only for a subset of TER States.

Figure III–50 Share of rails modal split for the area of planned TER HSR network



Source: EC EU Transport in figures. Statistical Pocketbook 2018.

6.2 Node structure development

6.2.1 Definition of a transport node

A transport node is a place in which at least three transport routes converge - roads (road node), rail lines (rail node), tram lines (tram node) or air corridors (airport), and inland waterway and sea routes (river and seaports).

Nodes play a crucial role in the development of transport systems ensuring their coherence allowing for integrated interchanges, equipped with the necessary infrastructure for passengers, including parking lots, ticket offices and information systems. These nodes need to be designed to ensure the highest possible value added for users as well as minimise congestion and inefficiencies.

An "urban node" is defined in Regulation (EU) No. 1315/2013 as an urban area where transport infrastructure of the TEN-T network, such as ports, including passenger terminals, airports, rail stations, logistic platforms and freight terminals, are connected to other parts of the infrastructure for regional and local transport. While this is an EU definition, it can also be used in the wider TER region and beyond.

While developing transport networks in urban nodes, focus should be on ensuring:

a) Mutual connections between rail, road, air and, in some cases, inland waterways and sea infrastructure both for passengers and freight;

b) Appropriate connections between particular rail stations, ports, roads and airports of a complex network within a given urban node;

c) Flexible connections among infrastructure of the main network, infrastructure of regional and local traffic, also freight shipment in urban areas, together with logistics consolidation and distribution centres.

Point (c) enables effective inclusion of the regions in transport systems (national and international).

The main role of urban nodes depends on:

- Origin and/or destination of the majority of long-distance trips
- Location of major transport nodes (ports, airports and other terminals)
- Interfaces of long-distance and local/regional transport
- Reservation of sufficient space and access to the intermodal transport terminals as well as specific equipment suitable for logistic operations operated by the node.

Urban node structures are polycentric and are not defined by administrative boundaries. They are functional areas that include the hinterland of cities and peri-urban areas with flexible boundaries depending on local, regional and European development. Every transport infrastructure, enterprise, human resource and administrative level are part of the node.

6.2.2 Node development possibilities

One of the most significant elements of infrastructure which has an influence on the efficiency of the high-speed rail systems are rail nodes. Solutions approved during planning have an impact not only on the accessibility of rail services but also commercial speeds of trains and their journey times.

Usually, new high-speed lines are included in existing rail nodes, often using existing stations. It is very convenient from the point of view of a passenger, who can make use of a new service in the current location of the station. However, including a new line in an old, often 19th-century node leads to lower speeds on a relatively long section. Old stations may also have limitations in terms of interchange possibilities.

Therefore, the construction of new high-speed lines and their inclusion in the city requires in-depth urban studies, which will enable the achievement of optimized solutions.

The main issues that should be considered in the feasibility studies for urban nodes should take into accouint urban development plans, in particular regarding environmental protection. When carrying out such a study, individual responses should be formulated for each of the following questions:

- Does the location of the existing main station serve the current and future needs of a city/region?
- Does the new function of a multimodal station require overall reorganization e.g. underground localisation, multilevel structure or only modernisation of the existing infrastructure?
- Is further urban restructuring needed?
- How to include regional and local rail systems into the service of the main HSR station?
- How to solve the problem of efficient access to the station by means of individual modes of transport remaining the priority for public transport?
- How to optimise the transfer time passenger from one mode of transport to another?
- How does the station interact with the surrounding urban structure of a city/region?

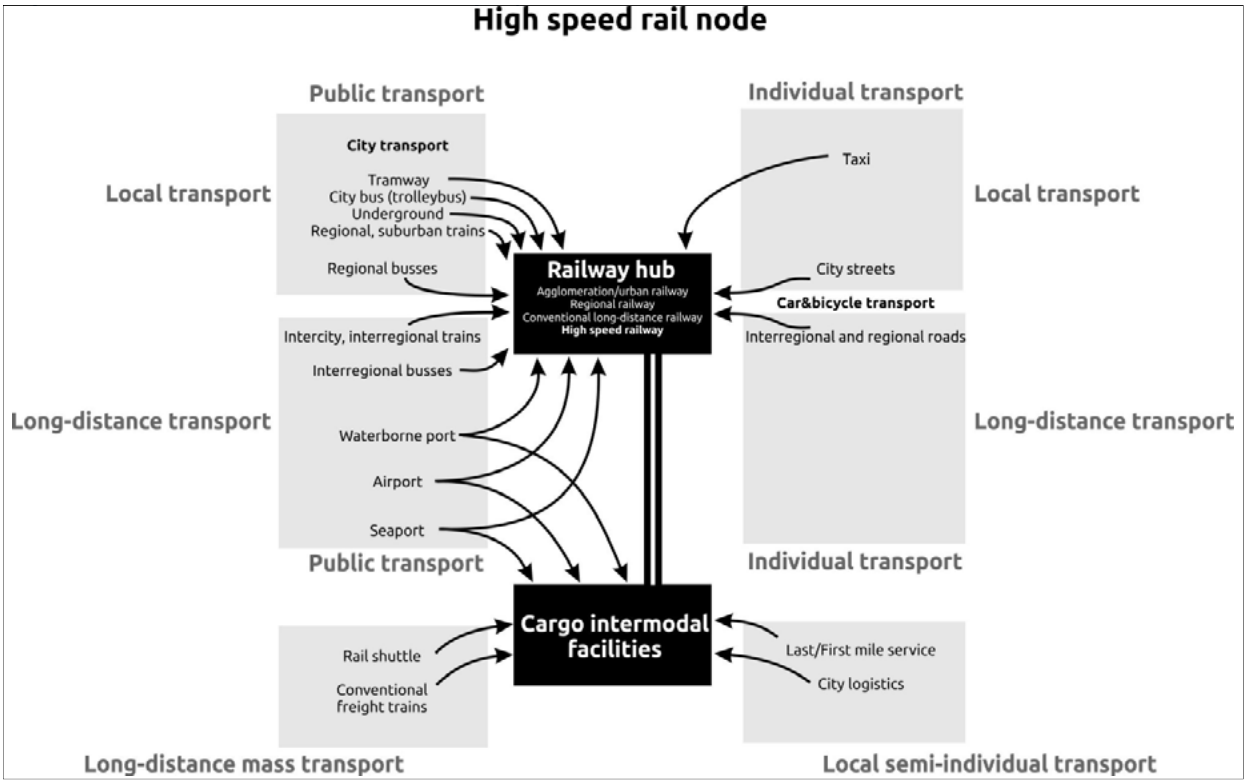
The development of the node takes several years and consists of several stages, including public consultations, based on best practice legal regulations, guidelines and reports, in particular those developed by UIC (see section 6.3.2).

6.2.3 Structure of the rail node

A HSR node should allows for as many intermodal connections as possible primarily as high-speed stations themselves are rarely the origin or final destinations of a journey. Therefore, efficient connections to other modes is essential, including buses, trolleybuses, trams, metro, local and regional trains for access to the agglomeration and other rail services or ports and airports for long distance intermodal services. Furthermore, appropriate connections should be considered for individual modes of transport such as the private car, bicycle, scooter or a taxi.

A hub could be regarded as the core component of a node. Its role is to integrate all the possible means of transport and their transhipment in one spatially limited area. All interchanges should be within a set of buildings or within short walking distance where necessary with supporting infrastructure such as lifts, ramps, moving walkways, etc. The functional structure of such a hub is shown in figure III-50. However, concentration of all the means of transport in one place is not always possible. Main rail stations are usually located in the city centres. Sea and waterborne ports might be separated from the city structure. Airports are usually far from city centres due to noise and located even several dozen kilometres from the city. In that case connection between them and the central hub located in the city centre has to be provided by local trains, buses, trams, etc. Efficient logistics should be assured in all nodes, especially those that include rail operations.

Figure III–51 The functional structure of the high-speed rail node



Source: Own study.

6.3 Requirements for nodes

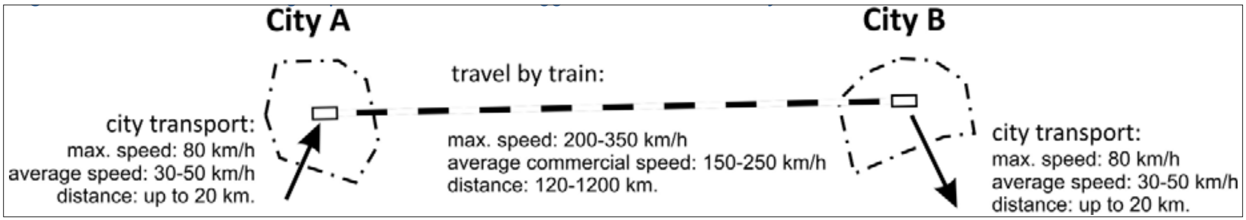
6.3.1 Travel time considerations

When considering the requirements for nodes, door-to-door travel time considerations are key and include travel time:

- To the origin station
- By HS train to the destination station
- To the final destination.

Therefore, travel time to, from and at the station plays a key role in the overall travel time. For medium-sized agglomerations (about one million inhabitants), based on best practice, the average travel time of a resident to a station can be estimated at about 30 minutes. At the same time, an additional 15 minutes should be added for station time (purchase of a ticket, taking a seat on the train and the so-called time reserve for unforeseen events calculated by travellers).

Figure III–52 Elements of high-speed train travel for agglomeration with nearly 1 million inhabitants



Source: own study.

The travel time to the trunk mode of transport differs for each mode. For car journeys, it can usually be omitted (although recent experiences show that some people spend as much as 20 minutes finding a parking place at destination or have to walk significantly from their parking place to their final destination). For air transport, the travel time to the airport can be even longer than the flight itself (this is often the case for many European flights). Dedicated rail services have been introduced at airports to reduce these transit times where possible.

In the case of the use of high-speed lines for cargo transport, the location of intermodal terminals and access to them needs to be defined. Due to the nuisance of the freight process and the high occupancy of the area, the terminals are located outside cities. In such a case, the train will reach the terminal via a siding. Such a solution has been adopted for the transport system using high-speed line in Italy.

6.3.2 Standards and the best practices

Adjusting existing rail nodes to allow for high-speed operations can be the most expensive part of the construction of a high-speed line. For this reason, the final solutions for node design should be the subject of individual feasibility studies based on best practices. The main guidelines for the development of an efficient node are found in the documents set out in table III-24.

Table III–24 Legislative documents and studies in the scope of good practices within the requirements for rail nodes

Name of document	Status of document	What about?
EU TSI PRM	EU Regulation 1300/2015	Accessibility of rail infrastructure and vehicles for passengers with limited mobility
EU TSI INF	EU Regulation 1301/2015	Legal requirements for rail infrastructure
UIC 140 Leaflet **Accessibility to station in Europe**	UIC recommendation	Station overview and station layout. Station access. In-station area.
UIC 180 Leaflet **Classification of Rail Passenger Station**	UIC recommendation	Classification criteria depending on the scale of traffic and the method of station service

Table III–24 Legislative documents and studies in the scope of good practices within the requirements for rail nodes (continued)

Name of document	Status of document	What about?
UIC 406 Leaflet **Capacity**	UIC recommendation	Calculation of capacity of rail lines and nodes
High Speed and the City I, 2010	UIC Study (the best practice)	Solution for rail nodes, station for high-speed rail, connection with other transport modes
High speed and the City II, 2014	UIC Study (the best practice)	Solution for rail nodes, station for high-speed rail, connection with other transport modes
High speed and the City III **Comparison nad conclusion of UIC Studies High speed and the City I & II**	UIC Study (the best practice)	Solution for rail nodes, station for high-speed rail, connection with other transport modes
Station for High Speed Systems: Toolbox for the design and/or renovation of major interchanges	UIC Study (the best practice and recommendation)	Guidelines for designing, modernisation and construction of rail hubs

Source: UIC, and EU regulation.

6.4 List of proposed multimodal nodes

The list below sets out the main modes for the network identified in chapter III, section 3.3.

6.4.1 Austria (AT)

Node: Enns	Category: TEN-T Core	Number of habitants: 9,812 (2018)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Linz Airport located 15 km from the city; number of passengers – 465,798 (2018); no rail link to the city	
Sea port	x	
Waterborne port	TEN-T Core; Port of Enns/Ennshafen located 2111.83 river kilometre, right bank of the Danube river; Cargo: dry bulk, break bulk, high and heavy cargo, petroleum products refined, RoRo cargo, liquid bulk, moisture sensible break bulk, containers	
Local public transport	Bus, rail (Linz urban area network)	

Node: Graz	Category: TEN-T Core	Number of habitants: 222,326 (2018)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Graz Airport located 9,3 km from the centre of Graz (in Abtissendorf), number of passengers – 1,030,929 (2018), rail link to city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, trolleybus, rail (urban area+region), funicular	

Node: Innsbruck	Category: TEN-T Core	Number of habitants: 132,110 (2017)
Rail-road system	TEN-T Core	
Airport	Innsbruck Airport/Kranebitten Airport located 4 km from the city centre; number of passengers – 1,092,547 (2017); No rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, suburban tram, rail (urban area+region), funicular	

Node: Linz – Wels	Category: TEN-T Core	Number of habitants: 181,162 (2018) + 16,857 WELS (2018)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Linz Airport located 12 km from the city; number of passengers – 465,798 (2018); No rail link to the city.	
Sea port	x	
Waterborne port	TEN-T Comprehensive; Linz Port located 2124 – 2128 river kilometre, right bank of the Danube river; Cargo dry bulk, break bulk, petroleum products refined, RoRo cargo, high and heavy cargo, containers Passengers: passengers harbour cruise (3 x per day in V-IX); Danube cruises	
Local public transport	Bus, tram, rail (urban area+region)	

Node: Vienna	Category: TEN-T Core	Number of habitants: 1,691,468 (2018)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Vienna International Airport/Vienna-Schwechat located 18 km from centre of city (in Schwechat); number of passengers – 27,037,349 (2018), rail link to city	
Sea port	x	
Waterborne port	TEN-T Core; Port of Vienna consists of several major areas: Port of Freudenau, Port of Albern, Port of Lobau, the Viennamarina, and DDSG Port Vienna; located 1920 river kilometre right bank of the Danube river; Cargo: 12 million tons of cargo on 1650 ships. The car terminal handles 72 thousand vehicles, and the 60 thousand square meter container terminal handles 323 thousand TEUs of containerised cargo Passengers: over 300 thousand passengers per year	
Local public transport	Bus, tram, suburban tram, rail (urban area+region), underground	

6.4.2 Armenia (AR)

Node: Yerevan	Category: TEN-T Core	Number of habitants: 1,093,485 (2018)
Rail-road system	TEN-T Core	
Airport	TEN-T Core Zvartnots International Airport located 15 km from centre of Yerevan in Zvartnots, number of passengers – 2,690,727 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, trolleybus, underground	

6.4.3 Belarus (BY)

Node: Brest	Category: TEN-T Core	Number of habitants:347,576 (2018)
Rail-road system	TEN-T Core;	
Airport	Brest Airport number of passengers – 400,197 (2018)	
Sea port	x	
Waterborne port	Port of Brest; Bug river	
Local public transport	Bus, trolleybus	

Node: Minsk	Category: TEN-T Core	Number of habitants: 1,995,000 (2018)
Rail-road system	TEN-T Core	
Airport	TEN-T Core Minsk National Airport located 42 km from the city; number of passengers – 4,536,644 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, trolleybus, underground	

Node: Orsha	Category: TEN-T Core	Number of habitants: 115,052 (2018)
Rail-road system	TEN-T Core	
Airport	x	
Sea port	x	
Waterborne port	x	
Local public transport	Bus	

Belarus Republic has around 1,600km of waterways, with transport along such rivers as the Dnipro, Pripyat, Biarezina, Zachodniaja Dzvina, Sož, Nioman, and the Dniaproŭska-Buhski kanal.

6.4.4 Bosnia and Herzegovina (BA)

Node: Mostar	Category: TEN-T Core	Number of habitants: 105,448 (2012)
Rail-road system	TEN-T Core	
Airport	Non-TEN-T Mostar International Airport located 6 km from the city (in Ortiješ); number of passengers – 28,463 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus	

Node: Ploce (HR)*	Category: TEN-T Comprehensive	Number of habitants: 10,135 (2011)
Rail-road system	TEN-T Core for road, TEN-T Comprehensive for rail	
Airport	x	
Sea port	TEN-T Comprehensive Port of Ploce 20,420 TEU; number of passengers: 146,000	
Waterborne port	x	
Local public transport	-	

* The Port of Ploce is a final point of the rail line Doboj – Sarajevo – border HR/BA – Ploce with no connection to the Croatian rail network. Located on the territory of Croatia as a node it serves strongly the Bosnia and Herzegovina. Due to that fact it is mentioned twice in the document.

Node: Sarajevo	Category: TEN-T Core	Number of habitants: 300,855 (2012)
Rail-road system	TEN-T Core	
Airport	Sarajevo International Airport/Butmir Airport located 12 km from the city (in Butmir); number of passengers – 1,046,635 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, trolleybus, cable car, funicular	

6.4.5 Bulgaria (BG)

Node: Plovdiv	Category: TEN-T Core	Number of habitants: 343,424 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Plovdiv Airport/Krumovo Airport located 12 km from the city centre; number of passengers – 133,397 (2018); no direct rail link to the city (Mavrudovo train station is situated three km from airport)	
Sea port	x	
Waterborne port	x	
Local public transport	Bus	

Node: Sofia	Category: TEN-T Core	Number of habitants:1,236,047 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Sofia Airport located 10 km from the city centre; number of passengers – 6,962,040 (2018); metro link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, trolleybus, metro, regional rail	

6.4.6 Croatia (HR)

Node: Zagreb	Category: TEN-T Core	Number of habitants: 802,701 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Franjo Tuđman Airport Zagreb located 17 km from the city (in Velika Gorica); number of passengers – 3,336,310 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, regional rail	

Node: Ploce (HR)*	Category: TEN-T Comprehensive	Number of habitants: 10,135 (2011)
Rail-road system	TEN-T Core for road, TEN-T Comprehensive for rail	
Airport	x	
Sea port	TEN-T Comprehensive Port of Ploce 20,420 TEU; number of passengers: 146,000	
Waterborne port	x	
Local public transport	-	

* The Port of Ploce is a final point of the rail line Doboj – Sarajevo – border HR/BA – Ploce with no connection to the Croatian rail network. Located on the territory of Croatia as a node it serves strongly the Bosnia and Herzegovina. Due to that fact it is mentioned twice in the document.

6.4.7 Czechia (CZ)

Node: Brno	Category: TEN-T Core	Number of habitants: 379,527 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Brno-Tuřany located 7,5 km on South-East; number of passengers – 500,725 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, trolleybus, regional rail	

Node: Ostrava	Category: TEN-T Core	Number of habitants: 290,450 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Leos Janacek Ostrava Airport located 20 km from the city centre (n. Mošnov); number of passengers – 258,223 (2016); rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, trolleybus, regional rail	

Node: Prague	Category: TEN-T Core	Number of habitants: 1,294,513 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Václav Havel Airport Prague located 12 km from the city centre; number of passengers – 16,797,006 (2018); no rail link to the city (CD bus – Airport Express, connects Terminal 1 with Prague hlavní nádraží)	
Sea port	x	
Waterborne port	TEN-T Core; Prague Holešovice located Left bank of the Vltava river, in the 46.6-49.3 river kilometre; Cargo: tranship of bulk materials	
	TEN-T Comprehensive; Praha Liben marina	
	TEN-T Comprehensive; Prague Radotín located Left bank of the Berounka river, in the 1st river kilometre; tranship of bulk materials but in the future any character of cargo port. WILL BE SPORT AND RECREATION AREA	
	TEN-T Comprehensive; Prague Smíchov located left bank of the Vltava river in the 57.24-55.54 river kilometre; Cargo tranship of bulk materials	
Local public transport	Bus, tram, trolleybus, underground, urban area and regional rail, river ferries, funicular	

6.4.8 Estonia (EE)

Node: Tallinn	Category: TEN-T Core	Number of habitants: 426,538
Rail-road system	TEN-T Core	
Airport	TEN-T Core: Tallin Airport (TLL); 5 km from the city centre; 3,007,644 passengers; direct tram service	
Sea port	TEN-T Core; Old City Harbour – only passenger port with 10,619 passengers in 2018; the most popular destination is Helsinki (8,797) and Stockholm (1,009); four shipping companies offer ferry to: (1) Helsinki and Mariehamn (Tallink, Eckerö Line, Viking Line); Mon-12; Tue-14, Wed-13; Thu-13; Fri-13; Sat-13, Sun-13 2) Stockholm (Tallink); Mon-2; Tue-1; Wed-1; Thu-1; Fri-1; Sat-1; Sun-1 3) St. Petersburg (Moby SPL) – 13 per month (generally every two days). Regular cruise ships – 339 from 27 April to 19 October 2019. No rail link to the city (in plan Rail Baltica station)	
	TEN-T Core; Muuga Harbour (in Maardu) – cargo port with 20–30 million tons cargo per year and container volume 251,738 TEU's (2013); Regular container line: (1) Hamburg – St. Petersburg – Rauma – Hamburg – Muuga – Helsinki – Hamburg (1 x week); (2) Muuga – Rauma – Hamburg – Bremerhaven – Gdynia – Klaipeda – Riia – Muuga (1 x week); (3) Muuga – Antwerp – Bremerhaven – Oslo/Copenhagen/Aarhus – Riga (1 x week)	
	TEN-T Core; Paljassaare Harbour – cargo port. In total cargo ports in Tallin – 20,608 th t (2018)	
Waterborne port	x	
Local public transport	us, tram, trolleybus, urban area and regional rail	

6.4.9 Georgia (GE)

Node: Tbilisi	Category: TEN-T Core	Number of habitants: 1,108,717 (2014)
Rail-road system	TEN-T Core	
Airport	TEN-T Core Shota Rustaveli Tbilisi International Airport located 17 km from the city; number of passengers – 3,808,619 (2018);	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, underground, funicular	

6.4.10 Greece (EL)

Node: Athína	Category: TEN-T Core	Number of habitants: 664,046 (2011)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Athens International Airport "Elefthérios Venizélos" located 25 km from the city centre (in Spata); number of passengers – 24,135,736 (2018); rail and underground connection	
Sea port	TEN-T Core; Port of Piraeus containers 4,9 million TEU's (2018) Passengers generally 59,123,432 (2017), Inc.: domestic passengers – 35,521,123; Ferry passengers – 28,432,342; Foreign passengers – 11,213,321. Year – Round destinations: (1) Saronic Gulf (10 dest.; 3 companies: Hellenic Seaways, ANES, Saronic Ferries); (2) Crete, Kythera and Antikythera (6 dest; 4 companies: ANEK Lines, Blue Star Ferries, Minoan Lines, TBA); (3) Cyclades (20 dest.; 7 companies: Hellenic Seaways, Blue Star Ferries, Seajets, Zante Ferries, Aegean Speed Lines, ANEK Lines, Superfast Ferries)	
Waterborne port	x	
Local public transport	Bus, tram, underground, urban and regional rail, funicular	

Node: Patras	Category: TEN-T Core	Number of habitants: 166,446 (2011)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Patras Araxos Airport, 182,129 passengers (2018); no rail connection	
Sea port	TEN-T Core; 260,000 passengers (2017); Companies: Anek-Superfast Consortium (AU), Grimaldi Lines (GR), Levante Ferries Group (LF), Minoan Lines (H.Q.) (ML)	
Waterborne port	x	
Local public transport	Bus, urban and regional rail	

Node: Thessaloniki	Category: TEN-T Core	Number of habitants: 315,196 (2011)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Thessaloniki International Airport "Macedonia" located 13 km from the city centre; number of passengers – 6,689,193 (2018); No rail link to the city	
Sea port	TEN-T Core; Port of Thessaloniki: Cargo port: Cargo 3,755,102 tonnes (2017) Container 424,500 TEU's (2017) Passengers: 180,755 (2010); 2 companies: Golden Star Ferries, Seajets	
Waterborne port	x	

6.4.11 Hungary (HU)

Node: Budapest	Category: TEN-T Core	Number of habitants: 1,752,704 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Budapest Ferenc Liszt International Airport located 16 km from the city centre; number of passengers – 14,867,491 (2018); rail link to the city	
Sea port	x	
Waterborne port	TEN-T Core; Port of Csepel located 4 km south-southeast of downtown Budapest, Left bank of the Danube river; Cargo 273.8 th tons (2007) inc. agricultural products, iron and metal; container terminal Direct rail-waterway transport link	
Local public transport	Bus, tram, underground, urban and regional rail, river ferries, funicular	

Node: Debrecen	Category: TEN-T Comprehensive	Number of habitants: 201,981
Rail-road system	TEN-T Core for rail; TEN-Comprehensive for roads	
Airport	TEN-T Comprehensive; Debrecen International Airport located 5 km from the city centre; number of passengers – 381,391 (2018); rail link to the city only used for freight traffic	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, regional rail	

Node: Győr	Category: TEN-T Core	Number of habitants: 129,301
Rail-road system	TEN-T Core	
Airport	Non-TEN-T international airport Győr-Pér; no regular flights	
Sea port	x	
Waterborne port	TEN-T Comprehensive; Györ-Gönyü Port located 1,794 river kilometre, right bank of the Danube river; Cargo dry bulk, break bulk, high and heavy cargo, petroleum products refined, RoRo, Container Direct rail-waterway transport link	
Local public transport	Bus, tram, regional rail	

6.4.12 Lithuania (LT)

Node: Kaunas	Category: TEN-T Core	Number of habitants: 292,691 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Kaunas International Airport located 14 km from the city (in Karmėlava town); number of passengers – 1,011,067 (2018); no rail link to the city	
Sea port	x	
Waterborne port	Non-TEN-T port	
Local public transport	Bus, trolleybus, funicular	

Node: Vilnius	Category: TEN-T Core	Number of habitants: 545,280 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Vilnius Airport located 7 km from the city centre; number of passengers – 4,922,949 (2018); rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, trolleybus, funicular	

6.4.13 North Macedonia (MK)

Node: Skopje	Category: TEN-T Core	Number of habitants: 467,257 (2002); greater 506,926
Rail-road system	TEN-T Core	
Airport	TEN-T Core Skopje International Airport located 15 km from the city centre (in Petrovec); number of passengers – 2,158,258 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus	

6.4.14 Poland (PL)

Node: Gdańsk, Gdynia, Sopot	Category: TEN-T Core	Number of habitants: 582,205 (2017) + 246,306 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Gdańsk-Rębiechowo Lech Wałęsa, located 10 km from Gdańsk City centre; Number of passengers: 4,980,647 (2018); rail link to both Gdańsk and Gdynia	
Sea port	TEN-T Core: Gdańsk, Gdynia Seaports: Gdańsk Cargo 49,032,234 t (2018), containers 1,948,974 TEU's (2018); Passengers 148,294 (2018); Gdynia Cargo 23,491,000 t (2018), containers 803,871 TEU's (2018); Passengers 460,231 (2018)	
Waterborne port	x	
Local public transport	Bus, tram (Gdansk only), trolleybus (Gdynia only), rail (urban + regional), funicular (Gdynia)	

Node: Katowice	Category: TEN-T Core	Number of habitants: 296,262 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Katowice Airport/Katowice – Pyrzowice Airport located 30 km from Katowice, in Pyrzowice village; number of passengers – 4,838,149 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	B	

Node: Kraków	Category: TEN-T Core	Number of habitants: 767,348 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; John Paul II International Airport Kraków-Balice located 11 km from the city centre (in Balice); number of passengers – 6,769,369 (2018); rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, rail (urban area+region)	

Node: Łódź	Category: TEN-T Core	Number of habitants: 690,422 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Lodz Władysław Reymont Airport/Lodz-Lublinek Airport located 6 km from the city centre; number of passengers – 217,426 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, rail (urban + regional)	

Node: Ostrów – Kalisz	Category: TEN-T Comprehensive	Number of habitants: 72,364 (2017) + 98,306 (2017)
Rail-road system	TEN-T Core for rail, TEN-T Comprehensive for roads	
Airport	x	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, rail (regional)	

Node: Poznań	Category: TEN-T Core	Number of habitants: 538,633 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Poznań–Ławica Henryk Wieniawski Airport located 5 km from the city centre; number of passengers – 2,476,304 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, rail (urban area + region)	

Node: Szczecin, Świnoujście	Category: TEN-T Core	Number of habitants: 403,833 (2017) + 41,032 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Solidarity Szczecin–Goleniów Airport located 46 km from Szczecin (in Goleniow); number of passengers – 598,971 (2018); rail link to the city	
Sea port	TEN-T Core: Szczecin and Świnoujście Seaports; Cargo 24,113,000 tonnes (2016), containers 90,869 TEU's (2016); Passengers 930,022 (2007) TEN-T Comprehensive: Police Seaport Cargo 1,534,500 tonnes	
Waterborne port	TEN-T Core; Szczecin Port, Świnoujście Port, TEN-T Comprehensive: Police	
Local public transport	Bus, tram, rail (regional)	

Node: Warszawa	Category: TEN-T Core	Number of habitants: 1,764,615 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Warsaw Frederic Chopin Airport/Warsaw-Okecie Airport located 10 km from city centre; number of passengers – 17,755,500 (2018); rail link to the city New airport is planned in 2030 perspective on west from Warsaw (30 km). Estimated number of passengers 40 mln in the first stage. Preparatory steps going on – selected strategic advisor, etc.	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, underground, rail (urban + regional)	

Node: Wrocław	Category: TEN-T Core	Number of habitants: 638,586 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Wrocław – Strachowice; number of passengers – 3,293,948 (2018); no rail link	
Sea port	x	
Waterborne port	Non-TEN-T port, extensive use	
Local public transport	Bus, tram, rail (urban area + region), cableway	

6.4.15 Romania (RO)

Node: Brașov	Category: TEN-T Comprehensive	Number of habitants: 289,878 (2017)
Rail-road system	TEN-T Comprehensive for roads, TEN-T Core for rail	
Airport	Non-TEN-T airport under construction	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, trolleybus, rail (regional)	

Node: București	Category: TEN-T Core	Number of habitants: 2,112,483 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Bucharest Henri Coandă International Airport located 16,5 km from the city centre (in Otopeni); number of passengers – 13,824,830 (2018); rail link to the city	
Sea port	x	
Waterborne port	TEN-T Comprehensive; 1 Decembrie Port (part of Danube-Bucharest Canal), Arges River	
	TEN-T Comprehensive; Glina Port (part of Danube-Bucharest Canal); Dambovita River	
Local public transport	Bus, tram, trolleybus, underground, rail (regional)	

Node: Constanța	Category: TEN-T Core	Number of habitants: 283,782 (2011)
Rail-road system	TEN-T Core	
Airport	TEN-T Comprehensive; Mihail Kogălniceanu Airport located 26 km from the city; number of passengers – 129,235 (2018); no rail link to the city	
Sea port	TEN-T Core; Port of Constantza; Cargo 61,303,774 t (2018), containers 668,016 TEU's (2018); passengers 69,910 pass. (2014); 3,150 (2017) Passenger see-going ship 95 (2014), 37 (2015) 17(2016) 13(2017) 11(2018); Ro-Ro/ferry: NEPTUNE SHIPPING LINES offers: Constantza – Borusan – Fos-sur-Mer – Sete – Barcelona – Tanger – Malaga – Vigo – Setubal – Valencia – Pireu – Yenikoy – Borusan – Constantza 20 Cruise ships: 24 March 2019 – 29 October 2019;	
Waterborne port	the Corridor IV (rail and road) and Corridor VII – Danube (inland waterway)	
Local public transport	Bus, tramway	

Node: Sibiu	Category: TEN-T Comprehensive	Number of habitants: 147,245 (2011)
Rail-road system	TEN-T Core for road, TEN-T Comprehensive for rail	
Airport	TEN-T Comprehensive; Sibiu International Airport located 3 km from the city centre; number of passengers – 673,657 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus	

6.4.16 Russian Federation (RU)

Node: Kaliningrad	Category: Non-TEN-T	Number of habitants: 482,433 (2018)
Rail-road system	Main rail lines and road to Kaunas (LT) & Elbląg (PL)	
Airport	Kaliningrad-Chrabrowo; 2,149,413 passengers (2018); no rail link	
Sea port	Port Kaliningrad; Cargo 14,052 th t (2018), containers 276,429 TEU's (2018)	
Waterborne port	Kaliningrad River Port	
Local public transport	Bus, trolleybus, tramway	

Node: Kazan	Category: Non-TEN-T	Number of habitants: 1,112,673 (2006)
Rail-road system	Rail Moscow – Kazan – Yekaterinburg; Roads: Moscow, Perm, Ufa,	
Airport	Kazan International Airport located 25 km from the city; number of passengers – 3,141,776 (2018); rail link to the city	
Sea port	x	
Waterborne port	Kazan River Port Cargo and passenger	
Local public transport	Bus, tramway, underground, regional and urban area rail	

Node: Moscow	Category: Non-TEN-T	Number of habitants: 10,425,075 (2006)
Rail-road system	Main rail and roadways in different directions	
Airport	Sheremetyevo International Airport located 29 km from the city centre (in Khimki); number of passengers – 45,348,150 (2018); rail link to the city	
	Moscow Domodedovo Airport located 42 km from the city centre (in Domodedovo; number of passengers – 29,403,704 (2018); rail link to the city	
	Vnukovo International Airport located 28 km from the city centre; number of passengers – 21,478,486 (2018); rail link to the city	
	Zhukovsky International Airport/Ramenskoye Airport/Zhukovsky Airfield located 36 km from the city centre (in Zhukovsky); number of passengers – 1,161,633 (2018); rail link to the city	
Sea port	x	
Waterborne port	Port of Moscow (2 terminals) passenger & freight	
Local public transport	Bus, trolleybus, tramway, underground, urban, suburban & regional rail	

Node: Nizhny Novgorod	Category: Non-TEN-T	Number of habitants: 1,283,553 (2006)
Rail-road system	Moscow – Kazan routes	
Airport	Nizhny Novgorod International Airport/Strigino Airport located 14 km from the city centre; number of passengers – 1,134,534 (2018); no rail link to the city	
Sea port	x	
Waterborne port	Port of Nizhny Novgorod	
Local public transport	Bus, trolleybus, tramway, underground, urban & regional rail, cableway	

Node: Sankt Petersburg	Category: Non-TEN-T	Number of habitants: 4,580,620 (2006)
Rail-road system	Main rail and roadways in different directions incl. Finland & Estonia	
Airport	Pulkovo Airport/Fyodor Dostoyevsky International Airport located 23 km from the city; number of passengers – 18,123,064 (2018); no rail link to the cityTrain station "Airport" is 15 minutes' walk from Pulkovo 2.	
Sea port	Port of Saint-Petersburg; Cargo 59,325, th t (2018), 2,130,721TEU's (2018)	
Waterborne port	Port of Saint Petersburg	
Local public transport	Bus, trolleybus, tramway, underground, suburban & regional rail	

Node: Sochi	Category: Non-TEN-T	Number of habitants: 443,644 (2018)
Rail-road system	Routes to Krasnodar and Sukhumi	
Airport	Sochi International Airport/Sochi Adler International Airport located 28 km from the city centre; number of passengers – 6,343,869 (2018); rail link to the city	
Sea port	Port of Sochi;	
Waterborne port	x	
Local public transport	Bus, regional rail, cableway, funicular	

6.4.17 Serbia (RS)

Node: Belgrade	Category: TEN-T Core	Number of habitants: 1,659,440 (2011)
Rail-road system	TEN-T Core	
Airport	TEN-T Core Belgrade Nikola Tesla Airport located 18 km from the city centre (in Surčin); number of passengers – 5,641,105 (2018); no rail link to the city	
Sea port	x	
Waterborne port	TEN-T Core Port of Belgrade located 1168 river kilometre, right bank of the Danube river; Cargo: dry bulk, break bulk, high and heavy cargo, moisture sensible break bulk, containers	
Local public transport	Bus, trolleybus, tramway, urban, suburban & regional rail	

Node: Niš	Category: TEN-T Core	Number of habitants: 260,237 (2011)
Rail-road system	TEN-T Core	
Airport	Niš Constantine the Great Airport located 4 km from the city centre, number of passengers – 351,582 (2018); no rail link to the city	
Sea port	x	
Waterborne port		
Local public transport	Bus	

6.4.18 Slovakia (SK)

Node: Bratislava	Category: TEN-T Core	Number of habitants: 425,923 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; M. R. Štefánik Airport/Bratislava Airport/Bratislava-Ivanka located nine km from the city centre; number of passengers – 2,292,712 (2018); no rail link to the city	
Sea port	x	
Waterborne port	TEN-T Core; Port of Bratislava located 1867 river kilometre, left bank of the Danube river; Cargo: dry bulk, break bulk, high & heavy cargo, petroleum products refined, RoRo cargo, crude oil, containers. The container terminal is direct and regular connections by rail for containers going to Melnik, Bremerhaven, and Budapest	
Local public transport	Bus, tramway, trolleybus, suburban & regional rail	

Node: Košice	Category: TEN-T Core	Number of habitants: 239,141 (2017)
Rail-road system	TEN-T Core;	
Airport	TEN-T Comprehensive; Košice International Airport located 6 km from the city centre; number of passengers – 542,026 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tramway, trolleybus, regional rail	

6.4.19 Slovenia (SI)

Node: Ljubljana	Category: TEN-T Core	Number of habitants: 288,919 (2017)
Rail-road system	TEN-T Core	
Airport	TEN-T Core; Ljubljana Jože Pučnik Airport located 24 km from the city centre (in Brnik); number of passengers – 1,812,411 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, funicular, regional rail	

6.4.20 Turkey (TR)

Node: Ankara	Category: TEN-T Comprehensive	Number of habitants: 5,503,985 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	TEN-T Comprehensive Ankara Esenboğa Airport located 28 km from the city; number of passengers – 22.980.247 (2019); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram, underground, suburban and regional rail	

Node: Antalya	Category: TEN-T Comprehensive	Number of habitants: 2,426,356 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	TEN-T Comprehensive Antalya Airport located 13 km from the city; number of passengers – 14.623.793 (2019); tram link to the city	
Sea port	TEN-T Comprehensive – Cruise passengers 161,636 (2012)	
Waterborne port	x	
Local public transport	Bus, tram	

Node: İstanbul	Category: TEN-T Comprehensive	Number of habitants: 15,067,724 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	TEN-T Comprehensive İstanbul Airport located 35 km from the city centre (in triangle: Yeniköy – Tayakadın – Akpınar); All scheduled commercial passenger flights were transferred from İstanbul Atatürk Airport to İstanbul Airport on 6 April 2019; Number of passengers 27.158.473 (2019);; no rail link to the city. Atatürk Airport number of passengers 8.356.453 (2019), rail link to the city TEN-T Comprehensive İstanbul Sabiha Gökçen International Airport located 32 km from the city centre; number of passengers – 45.960.494 (2019); no rail link to the city	
Sea port	TEN-T Comprehensive Port of İstanbul (Karaköy, Istanbul); İDO İstanbul: passenger; number of passengers 460,427 (2007); Cruise passengers 599,477 (2012) TEN-T Comprehensive İgsaş İstanbul Gübre Sanayii A.Ş.; Cargo port: D. bulk, G. cargo, Fertilizer, Ammonia.	
Waterborne port	x	
Local public transport	Bus, tram, underground, suburban & regional rail, funicular, cableway	

Node: İzmir	Category: TEN-T Comprehensive	Number of habitants: 4,320,519 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	TEN-T Comprehensive Izmir Adnan Menderes Airport located 18 km from the city centre; number of passengers – 18.802.020 (2019); rail link to the city	
Sea port	Port of Izmir; Container, G.cargo, Ro-Ro, D.bulk Total freight handled 8.405.917 ton (2019)	
Waterborne port	x	
Local public transport	Bus, tram, underground, suburban and regional rail	

Node: Kars	Category: TEN-T Comprehensive	Number of habitants: 288,878 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	TEN-T Comprehensive Kars Harakani Airport located 6 km from the city; number of passengers – 577,562 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus	

Node: Konya	Category: TEN-T Comprehensive	Number of habitants: 2,205,609 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	Konya Airport located 18 km from the city; number of passengers – 1,160,885 (2018); no rail link to the city	
Sea port	x	
Waterborne port	x	
Local public transport	Bus, tram	

Node: Samsun	Category:	Number of habitants: 1,335,716 (2018)
Rail-road system	TEN-T Comprehensive	
Airport	TEN-T Comprehensive Samsun Çarşamba Airport located 24 km from the city; number of passengers – 1.735,522 (2018)	
Sea port	TEN-T Comprehensive Port of Samsun; Container, G. cargo, D.bulk, Ro-Ro; Total freight handled 11.150.996 ton (2019)	
Waterborne port	x	
Local public transport	Bus, tram	

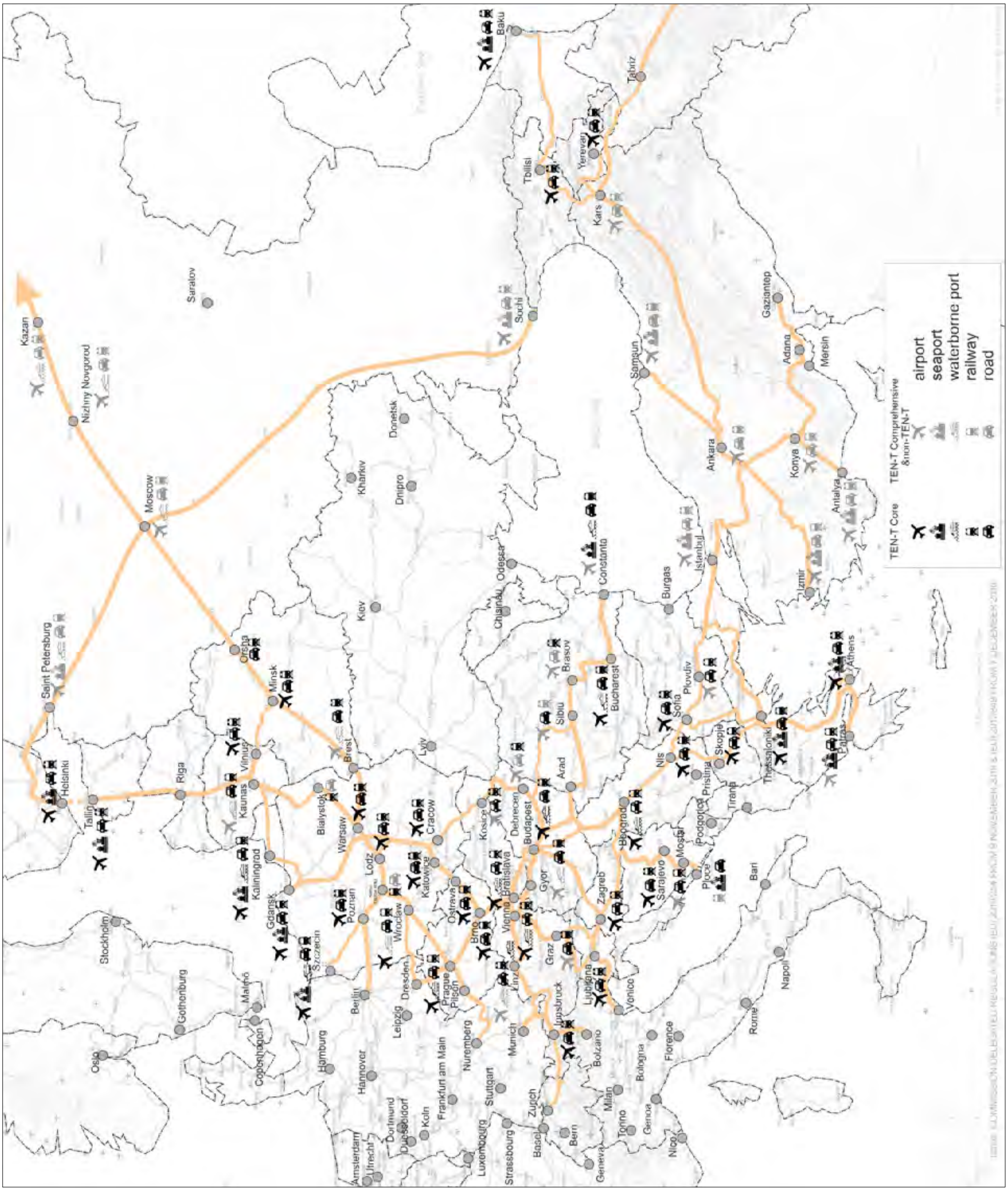
6.4.21 Finland (FI)

Node: Helsinki	Category:	Number of habitants: 635,181 (2017)
Rail-road system	TEN-T Core	
Airport	Helsinki -Vantaa International Airport located 17 km from the city (in Vantaa); number of passengers – 20,848,838 (2018); rail link to the city	
Sea port	TEN-T Core; Port of Helsinki – several locations; Cargo 14,714,657 t (2018), containers 509,532 TEU’s (2018); Passengers 11,558,745 (2018)	
Waterborne port	x	
Local public transport	Bus, tramway, underground, urban, suburban & regional rail, local ferries	

6.5 TER HSR Network of nodes

The location of the TER HSR nodes is set out in figure III-53 with an identification of the other modes that the node serves. The description of nodes in section 6.4 shows that each of them has at least terminals for road transport, most of them also for air cargo handling, and some have connections to seaports and inland waterway ports.

Figure III–53 Location of TER HSR nodes



Source: Own work.

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IV. Conditions for the implementation of Master Plan

1. TER HSR implementation costs and expected results

1.1 Cost of construction, maintenance and operations of recommended HSR TER

1.1.1 Methodology for estimating investment cost

The costs of constructing high-speed lines and modernising the line for high-speed parameters were estimated by two methods per km of double track line.

1. As per the feasibility studies identified in the examples of 6 lines planned for construction in Part II-7.
2. As per available data from:
   - The length of lines according to questionnaires compiled with the participation of Country Coordinators.
   - Estimated cost of one km considering the assumptions of average investment costs.

Statistics for the length of the line has been prepared on the basis of questionnaires for every country according to:

- New lines planned for construction,
- Lines planned for modernisation to high-speed line parameters.

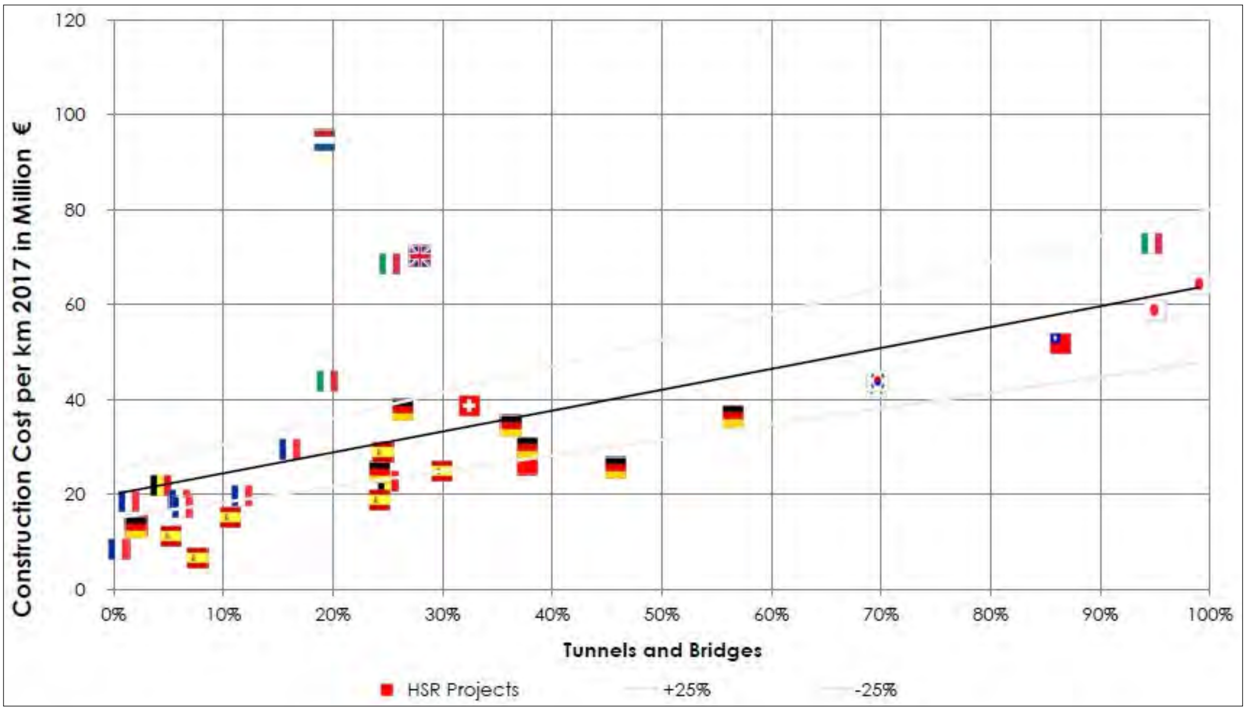
For new lines the following indicators have been assumed:

- Average cost of construction of one km in a lowland terrain €15 million and in a mountainous area €30 million,
- Average cost of modernisation of one km in depending of the type of terrain – €10-12 million.

The estimation is based on UIC data. The cost of constructing a line increases gradually as terrain becomes more difficult to pass, which leads to, for example, the need to build tunnels. This reliance is shown in figure IV-1 which sets out the costs of constructing one km of railway in different projects across Europe.[73]

[73] M. Meyer, Deutsche Bahn., *Efficiency in High-Speed rail – How to evaluate and how to achieve?*, "UIC Workshop Operating High-Speed lines: in search of efficient solutions.UIC Paris, 31 January 2019".

Figure IV–1 **Dependence of constructing lines on terrain conditions**
Efficiency in the construction of HS lines – worldwide HS line project overview



Source: Efficiency in High-Speed rail – How to evaluate and how to achieve? UIC Workshop Operating High-Speed lines: in search of efficient solutions. Matthias Meyer, Deutsche Bahn. UIC Paris, 31 January 2019.

The figure shows that there is a linear relationship between costs and difficulty of terrain. The majority of the examples used in the analysis are within +/-25 per cent of this value. There are, however, some exceptions:

- The HSL Zuid in the Netherlands constructed in difficult geological conditions and highly urbanised surroundings;
- In Italy; lines in urbanised area requiring major reconstruction of surrounding infrastructure, including roads as well as ancillary construction costs;
- In the United Kingdom of Great Britain and Northern Ireland; HS1 constructed in a highly urbanised area with a very high cost of land acquisition; the costs of the newly constructed HS2 are expected to be even higher.

Analyses of existing high-speed projects in CEE States show that their costs will not be significantly different from the average in Europe.

1.1.2 Costs of building and modernising the lines in individual TER States

Based on these averages, the estimated cost of high-speed projects in the TER region are set out in table IV-1 below.

Table IV–1 Estimation of the building and modernising cost of the lines in TER and TER neighbouring States

Country	Lines in operations [km]	Lines under construction [km]	New lines planned		Lines for modernisation planned		Total cost	Comments
			Length [km]	Cost [mEUR]	Length [km]	Cost [mEUR]	Cost [mEUR]	
Armenia	-	-	-	-	-	-	-	
Austria	204	281	110	3 300	182	2 184	5 484	E
Bosnia and Herzegovina	-	-	-	-	385	9,875	9,875	E
Bulgaria	-	-	-	-	-	-	-	
Croatia	-	-	-	-	-	-	-	
Czechia	-	-	798	22 500	103	-	22 500	FS
Georgia	-	-	-	-	-	-	-	
Greece	471	150	234	7 020	-	-	7 020	E
Lithuania	-	-	367	2 474	-	-	2 474	FS
North Macedonia	-	-	-	-	-	-	-	
Poland	224	-	1 590	19 780	-	-	19 780	FS
Romania	-	-	810	24 300	-	-	24 300	E
Russian Federation	807	-	5 093	84 170 +60 400	1 319	2 480	86 650 +60 400	FS, E
Serbia	-	183	-	-	240	2.190	2 190	FS, E
Slovakia	-		-	-	337	4 014	4 014	E
Slovenia	-	-	185	5 550	-	-	5 550	E
Turkey	588		7208	40 000			40 000	FS
Hungary	-	-	968	14 520	50	500	15 020	E
Belarus	-		600	15 000	-	-	15 000	E
Rail Baltica Incl. LT	-	-	848	5 788	-	-	5 788	FS
Total	**2 719**	**614**	**23 796**	**302 278**	**2 370**	**19 053**	**321 331**	

Source: Country Questionnaires, Country Feasibility Studies, UIC Studies.
Sources of estimation: FS – under feasibility studies, E – under estimation with method of average cost of construction/modernisation per km.
Non-TER States key for coherence of HSR TER network have also been included.

According to the table above, the following conclusions can be drawn from construction across the TER region:

- **23,844** km of lines are planned for construction with the total cost of €**302,278** million
- **2,370** km of lines are planned for modernisation to high-speed parameters with the total cost of €**19,053** million
- Total cost of the investment €**321,331** million
- Total average cost per year in 2050 will be €**10,710** million.

1.1.3 Maintenance and operational costs

According to UIC data,[74] the maintenance cost of one km of line in Europe is €90k per year. The lowest costs have been estimated for Rail Baltica in its Feasibility Study (see section II-7.2.3) where maintenance and operating costs will be €70.7 million (81k per km) in 2030, including technical maintenance of €58.9 million (€67.7k per km). It should be considered that intensive traffic of heavy freight trains is anticipated on the line, which also increases the cost of maintaining the line.

Given the averaging in section 1.1.2 above, the estimated maintenance and operating costs are likely to be the following:

- Maintenance cost €80k per km per year: €2,093 million
- Operating cost €15k per km per year: €392,5 million.

Investment costs per corridor using data from table IV-1 are presented in table IV-2. As some corridors overlap, the total costs for corridors are higher than the total costs listed in table IV-1.

Table IV–2 Estimation of the building and modernising cost of the TER HSR corridors in TER and TER neighbouring States

Corridor	Length [km]	Investment cost [mEUR]	Maintenance cost [mEUR]	Operating cost [mEUR]
North–South corridor: from Poland via Czechia, Slovakia/Austria, Hungary, Serbia, Bulgaria/ Northern Macedonia to Greece and Turkey	5 952	43.773	473.6	88.5
North corridor (East-West): from Germany and Poland via Belarus to Russian Federation and further towards China	4 337	46.241	346.9	65.1
Middle corridor (Danube): from Austria and Switzerland and from Germany and Czechia via Slovakia and Hungary to Romania and Ukraine	3 204	44.945	256.3	48.1
Southern corridor (East-West): from Italy via Slovenia, Croatia to Hungary with a branch towards Turkey	942	9.000	75.3	14.1
Baltic Corridor: from Germany, Czechia and Poland (Warsaw) via Lithuania, Latvia and Estonia to Finland	2 591	21.985	203.3	38.1
Southern: East – West (Istanbul – Iran) from Istanbul to Iran and the Caucasus state	3 100	15.100	248.0	46.5
Carpathian Corridor: from Poland via Slovakia, Hungary to Romania	1 118	11.256	89.4	16.7

The creation of corridors may be and even should be, stages in the long term, according to the assumptions also adopted for the TEN-T network until 2030 and 2050. The costs of their construction, even with the use of lines modernised up to 200-230 km/h, are very high.

74 Reports of the High-Speed Rail Hast Track 2018 – Periodically published.

1.1.4 Risk of investment delays

The average time to complete a high-speed line, from concept to commissioning is usually about 10 years. Multi-stage investments last up to 20 years or even longer. The initial processes of investment planning and consultation are also long-lasting ones, especially for international projects. The role of this stage is particularly important because the decisions taken at this time are crucial for planning the entire investment and may be difficult to modify.

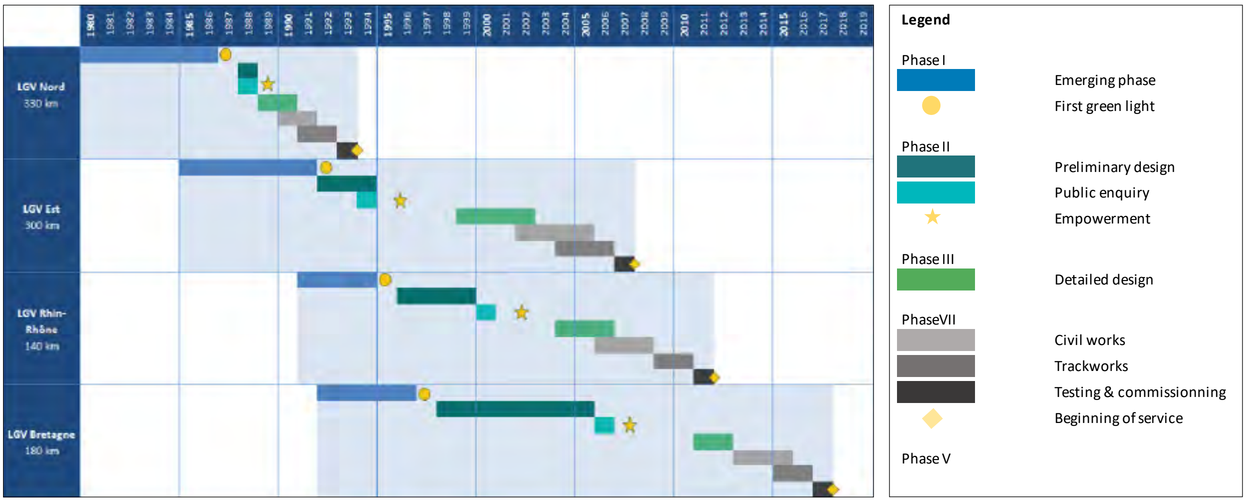
The preparation and implementation procedures for HSR projects are now largely standardised and have been included as part of UIC's work in two handbooks:

- High Speed Railway System Implementation Handbook, UIC Paris 2017
- High speed service Start up Handbook, UIC Paris 2018.

The second publication also includes recommendations for the preparation of the high-speed passenger transport operation.

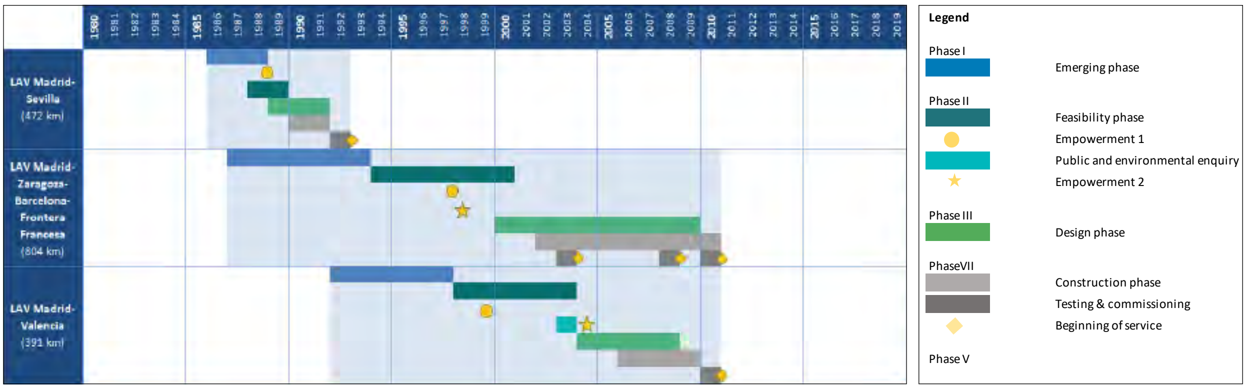
The examples of actual investment implementation schedules on high-speed lines in France and Spain are shown in figures IV-2 and IV-3.

Figure IV–2 Examples of actual investment implementation schedule on high-speed lines in France



Source: High Speed Rail System Implementation Handbook, UIC Paris 2017.

Figure IV–3 **Examples of actual investment implementation schedule on high-speed lines in Spain**



Source: High Speed Rail System Implementation Handbook, UIC Paris 2017.

The preparation and construction of the Madrid – Seville line project was exceptionally short (figure IV-3) due to the fact that the investment process considered earlier works on the conventional line planned at this site.

Implementation delays often increase overall costs. Sample data on pre-planned investment costs and their final value for selected high-speed lines is summarised in table IV-3.

Table IV–3 **Changes in costs of the high-speed line construction within long-term investments**

Audited line	Total length (km)	Total cost (mEUR)	Initial estimated cost (mEUR)	Actual cost overrun (%)	Initial construction cost per km (mEUR)	Final completion cost per km (mEUR)
Berlin – Munich	671	14 682	8 337	76.1	12.4	21.9
Stuttgart – Munich	267	13 273	1 838	622.1	6.9	49.7
Rhin – Rhone	138	2 588	2 053	26.1	14.9	18.8
LGV Est Europeenne	406	6 712	5 238	28.1	12.9	16.5
Madrid – Barcelona – French Border	797	12 109	8 740	38.5	11.0	15.2
Eje Atlantico	165	2 596	2 055	26.3	12.5	15.7
Madrid – Leon	345	5 415	4 062	33.3	11.8	15.7

Source: Special report 19/2018 "A European high-speed rail network: not a reality but an ineffective patchwork". European Court of Auditors. Luxemburg 2018. All figures are expressed in nominal terms.

The highest cost overruns were identified in the report for the Stuttgart - Munich line which resulted from many factors, such as the need to increase the scope of works beyond those planned in the feasibility study or the costs of extending the investment time. There is a slight deviation from the initial assumptions for projects in Spain and France. This is due to the financial regime for the implementation of projects from the EU funds and high quality of preparation of feasibility studies and technical documentation.

The above-mentioned examples and effects of the long-term investment process in high-speed lines should be considered when assessing the risk of implementing a TER HSR. This risk can be reduced by adopting appropriate planning methodologies and organizational structures that limit the emergence of such risks both at a national and international level.

1.1.5 Summary

The total estimated cost of constructing a HSR network in TER States are around €313 billion, including almost €14 billion for the modernisation of existing lines to high-speed standards. These estimates were made on the basis of feasibility studies for projects and, where data was missing, were based on estimates considering the average construction cost of one km of line. Approximately €10.5 billion investments per year for the entire region would be required to 2050 to implement all the identified projects. These are base approximation that do not account for cost increases from delays or changes in scope.

It should be noted that projects for the modernisation of lines to high-speed standards represent a small proportion compared to the value of projects for the construction of new high-speed lines. This shows that the desired option for the region is the construction of new lines rather than the modernisation of existing ones.

Maintenance and operational costs of the planned high-speed lines in TER States are estimated at about €3 billion per year.

1.2 Expected revenues

1.2.1 Sources of revenue

Revenues from the operation of high-speed lines should be analysed from the point of view of the rail organization model. The dominant model in Europe is the separation of transport activities from the management of rail infrastructure. This model is binding in EU States (Directive 2012/34) but has also been transferred to States cooperating with the EU, including acceding States. On average, access charges for the use of high-speed rail infrastructure represent about 30 per cent of railway undertakings' costs.

1.2.2 Revenues of railway undertakings

HSR is usually operated on a commercial footing in Europe. Fares are based on market principles and analysis has shown that (appendix 2) high-speed operators can maximise fares due to large time savings. The average fare for existing high-speed services in Europe oscillates around a dozen eurocents per km. These values are similar to the results assumed in feasibility studies in TER States.

Examples given in part III-7.3 for high-speed trains currently operated in TER States indicate that revenues earned by carriers per passenger kilometre (pkm) range from five eurocents (Turkey) to 10 eurocents (Poland).

The level of fares depends on a number of local factors including the structure of the financing of infrastructure investments (scale of external financing sources) and the operating costs of the carrier (including staff costs). The operating plan for the rail line is also important: for example, if there are other categories of trains in operation, such as freight or local passenger trains, which may have an effect on charges for the use of rail infrastructure.

The EBITDA to revenue ratio for HSR operators is usually above 10 per cent, for example, for SNCF it is 14.1 per cent (2018) and for DB it is 9.2 per cent (2018). In Italy, the private HSR operator has achieved results of 34.2 per cent (2017) and 26.6 per cent (2016) with an average revenue per passenger of more than seven eurocents.

There is no analogous data for freight transport due to the very small share in the use on high-speed lines. The current high-speed freight train traffic also limits the use of short line sections, which account for a small share of the total freight route. Further studies in this area are currently being undertaken by UIC.

1.3 Cost-benefits analysis

1.3.1 General rules

Three indicators are usually used to assess the economic efficiency of infrastructure investments in rail transport i.e.

- Economic net present value (ENPV)
- Economic rate of return (ERR)
- Benefit/Cost (B/C) ratio in economic assessment.

The efficiency criterion requires the ENPV value to be greater than zero, and the ERR value should be greater than social discount rate (SDR value 3,5-5 per cent) and B/C greater than one (see appendix 2). The calculation of these indicators is the subject of feasibility studies conducted for individual projects. The content of feasibility studies and the principles of economic analyses are set out in the appendix V-4. UIC paramenters are widely used in these analyses while EU guidelines are used in projects co-financed by EU funds.[75]

1.3.2 Results of Cost Benefits Analysis for projects in TER States

The analysis of the questionnaires submitted by TER country coordinators shows that, for the majority of high-speed rail projects implemented and planned in the region, an economic assessment has been carried out to assess the legitimacy of planned projects.

Table IV-3 summarizes the economic data for these projects in each country, i.e. ERR and B/C, if such indicator has been calculated.

In Czechia and Turkey, the table lists indicators for two projects (also discussed in more detail in the chapter II-7.2). For the remaining projects in these States listed in tables III-3 and III-13, these indicators are currently being updated as part of the selection procedure for investment options. In other States, i.e. Hungary, Bosnia and Herzegovina, advanced feasibility studies are underway. In Poland, the feasibility study (the phase wherethe most favourable option was selected) for the Rail Baltica from Białystok to Ełk (modernisation of the existing line of up to 200 km/h) and the construction of a new line from Ełk to the PL/LT border (250 km/h) are about to be completed. Due to the almost identical volume of transport on both sides of the border, the same indicators can also be used on the Polish side as in section PL/LT – Tallinn.

[75] UIC, *High Speed Railway System Implementation Handbook, Paris 2017; EC, Guide to Cost-Benefit Analysis of Investment Projects*, Bruxelles 2014.

Projects at an advanced stage in the investment process have not been included in the comparison. Their assessment will be possible after the completion of the investment and the verification of costs and benefits.

Table IV–4 Economical rates for TER HSR projects

Project	ERR [%]	B/C
Belgrade – RS/HU border (RS)	5.5	-
Prague – Dresden (CZ, DE)	7.3	-
Halikali – Kapikule (TR)	8.6	1.67
Rail Baltica (LT, LV, EE, PL)	6.32	1.19
Warszawa – Łódź – Poznań/Wrocław (PL)	6.3	1.2
Wrocław – PL/CZ border (Prague)	5.4	-
Poznań – PL/DE border (Berlin)	4.6	-
Warszawa – Katowice-Ostrawa/Kraków (PL, CZ)	6.7-9.1*	1.7-2.3*
Moscow – Nizhny Novgorod – Kazan (RU)	14.3	-
Yekaterinburg – Chelyabinsk (RU)	18.2	-
Kazan – Yekaterinburg (RU)	11.0	-
Moscow – Tula (RU)	12.1	-
Moscow – Smolensk – Krasnoye (border RU/BY)	9.6	-
Moscow – St. Petersburg (RU)	10.0	-
Moscow – Adler (Sochi) RU)	10.0	-

* Depending of the section.
Source: TER States questionnaires (extended) and Feasibility Studies.

No economic analyses have been identified for the following projects in the concept stage:
- Smolensk – Minsk – Warsaw (in Poland only feasibility study in 1993)
- Budapest – Bucharest – Constanta
- Warsaw – Gdansk (new line).

Economic analyses carried out for the Venice – Trieste – Ljubljana – Zagreb showed an insufficient level of economic efficiency.

A simplified CBA analysis was carried out for the three projects listed in appendix 3 which describes the methodology used in accordance with the guidelines for projects financed from EU funds. Due to the fact that for the analysed projects there are no full feasibility studies, which would be the basis for economic analyses, the so-called partially inverted analysis was used. Calculations were done on the basis of data obtained using the index method in comparison with other high-speed rail projects in Europe or according to estimates for similar investments in a given region. At the final stage of the analysis, the question is formulated about the minimum volume of passenger services in high-speed trains necessary to obtain a key economic ERR higher than the social discount rate (SDR). The number of passengers required in the calculations should be assessed in terms of the reality of the assumed goal. If reaching this number of passengers is unrealistic, one should think about whether it is possible to develop an operational plan for the analysed line, which would either increase the number of passengers on high-speed trains or indicate other sources of transport volumes. This may be, for example, the introduction of regional trains or freight trains on selected sections of the line (if it is technically possible).

In this analysis, except for the lines of the Russian Federation and Rail Baltica in LT, LV, EE (data in aggregate for both types of traffic), the introduction of freight traffic was not assessed.

This methodology was used in feasibility studies for the construction of the Poznan – PL/DE border (Berlin) and the Wroclaw – PL/CZ border (Prague) high-speed lines. The estimated revenues from high-speed trains however proved to be too low to achieve the required economic indicators. So, with the participation of regional authorities, a program was introduced to allow the line to be used by regional express trains and partly freight traffic, making the project viable (data in the table IV-4).

In the three projects analysed, only the Warsaw – Gdansk line would reach the required number of passengers on high-speed trains. For the Smolensk – Minsk – Warsaw and Budapest – Bucharest – Constanta lines, the number of passengers required on high-speed trains would require running more than three pairs of trains per hour. However, intensive and profitable freight traffic may be possible for the Smolensk – Minsk – Warsaw line. For the extension of this line through the Russian Federation (Smolensk – Moscow), the feasibility study showed a high ERR (9.6 per cent) which points to the possibility that accepting similar assumptions will achieve similar results. A more detailed analysis involving stakeholders is required for the Budapest – Bucharest – Constanta line (see appendix 2).

It can be seen therefore that the operational plan for the planned high-speed line is the key to its economic success. Some seemingly economically unjustified projects may be financially effective after analysing and optimising the business plans. It seems evident that, at this stage, economic viability may be achieved only by combining freight transport with passenger services for part of the HSR operations.

1.3.3 Conclusions

The results of the economic efficiency assessment presented in table IV-4 show that the benefits of launching the HSR system are aligned with planned investment expenditure. This is demonstrated by the relatively high values of the ERR indicators. B/C ratios are also greater than one. The fact that the indicators are satisfactory and provide grounds for making investment decisions is indicated by the assessment of these indicators in table IV-5.

Table IV–5 Interpretation of the B/C ratio according to the UK Department of Transport

Interpretation	B/C indicator
Weak	< 1,0
Low	1,0 – 1,5
Medium	1,5 – 2,0
High	2,0 – 4,0
Very high	> 4,0

Source: The Economic Case for HS2: Value for Money Statement. HS2 Ltd for Department for Transport.

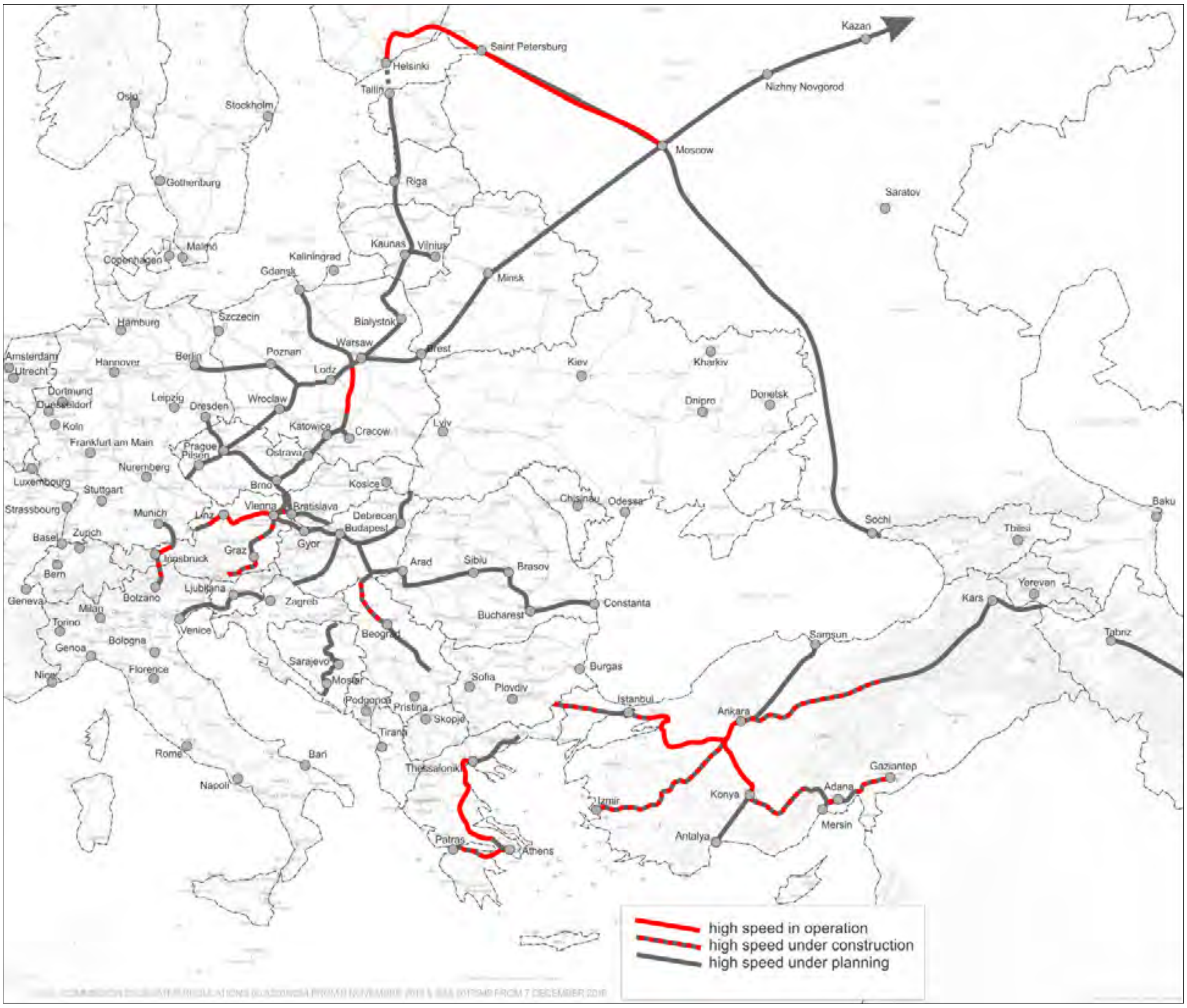
Economic efficiency indicators are highly sensitive to changes in investment spending. However, the sensitivity analysis carried out in the analysed feasibility studies for TER States shows that the increase in investment expenditure may not lead to economic inefficiency. It is therefore necessary to include a reserve for unforeseen expenses, allowing for an adequate rate of return on capital engaged, in particular private capital. Moreover, the analysis should assume various scenarios of investment realisation, from optimistic to pessimistic, assuming risk in the investment process.

2. Proposal of TER network implementation

2.1 The current HSR network in TER States and development plans

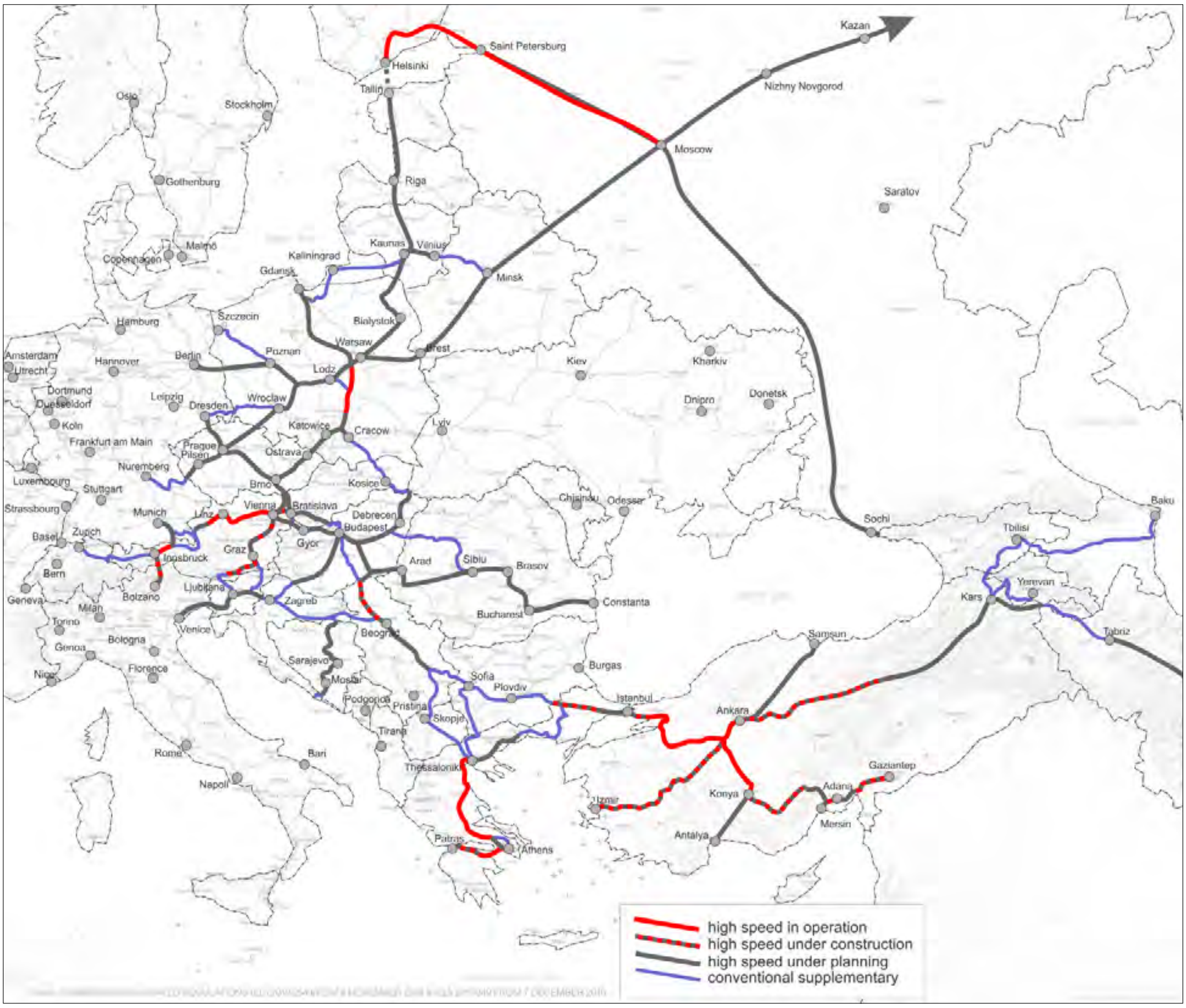
The level of development of the high-speed network across the TER region has been set out in detail in previous chapters and are summarized in figure IV-4 which identifies the completed lines with maximum speed of at least 200 km/h which are under construction/modernisation or planned for construction/modernisation. In addition, figure IV-5 shows the current state of the implementation of TER HSR network, considering, the so-called complementary lines. These additional conventional lines, with improved technical parameters, allows for the creation of a network of fast rail connections across the TER region. It is assumed that these supplementary lines would be replaced by high-speed lines in future.

Figure IV–4 Current state of the implementation of TER network divided into lines in operation, under construction or modernisation and the planned ones



Source: Own work.

Figure IV–5 Current state of the implementation of TER network together with complementary lines divided into lines in operation, under construction or modernisation and the planned ones



Source: Own work.

2.2 Development of a schedule for the implementation of TER HSR network

2.2.1 Conditions

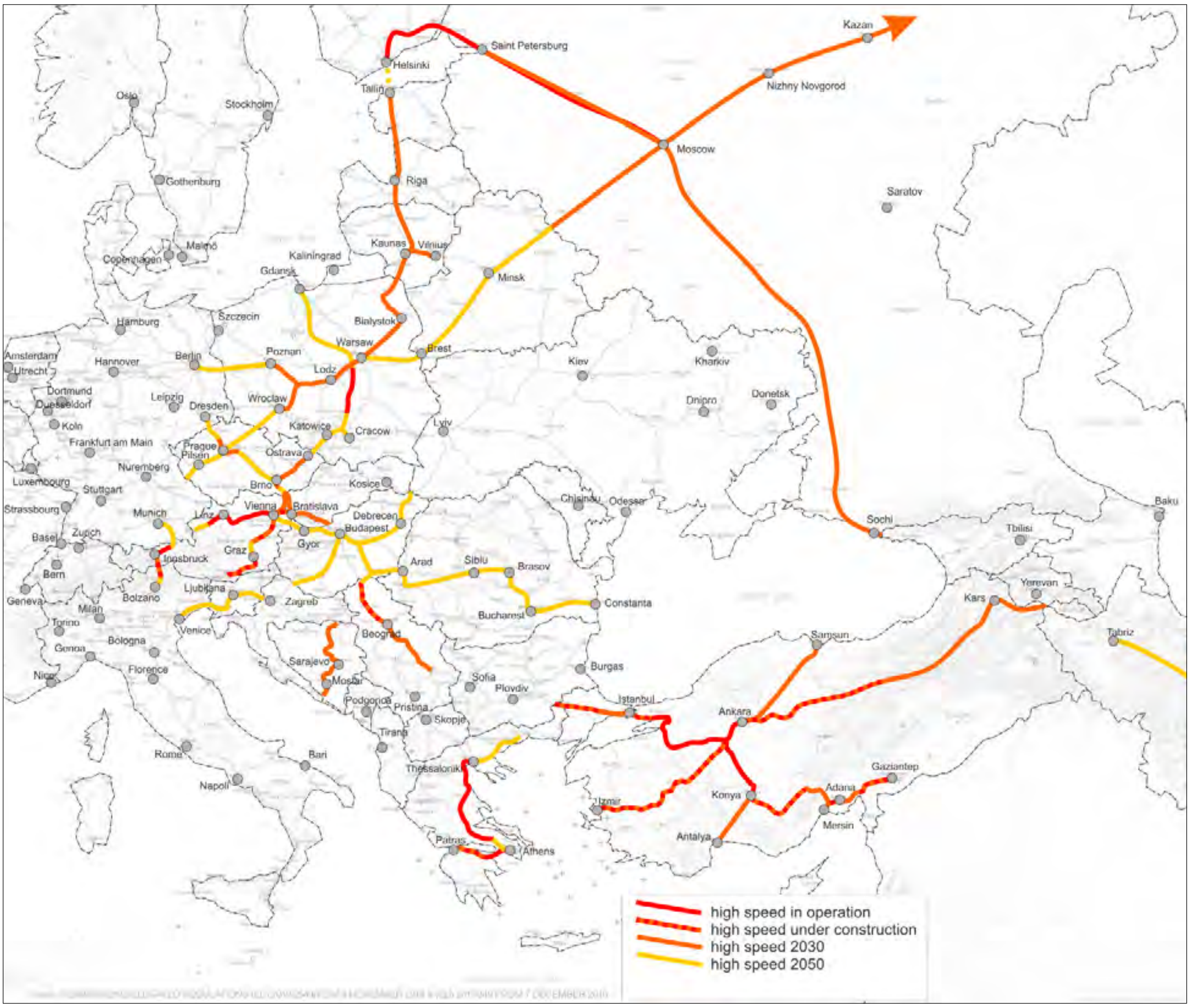
A number of factors should be considered when preparing an implementation plan for the TER HSR network as they determine the sequence of investments. There are also a number of factors that may affect the schedule to accelerate the implementation of investments.

2.2.2 National development plans

The final derived TER HSR network in 2030 and 2050 is based on data obtained from questionnaires provided by Country Coordinators as shown in figure IV-6.

In the TER region, several line sections are high-speed lines, modernised to a speed above 160 km/h and newly constructed in accordance with the standard for high-speed lines as set out in previous chapters.

Figure IV–6 **Comparison of current and planned investments in the period of 2030-2050 according to national plans**



Source: Own work.

2.3 The role of corridors as a tool to consolidate and accelerate HSR projects

Building on the analysis in 2.1 above, figure IV-7 identifies those sections of the network that are expected to be completed by 2030 (in darker shading) those sections which will be constructed by 2050 or have not yet been scheduled (in lighter shades of the same colours). The figure shows that none of the corridors is planned to be completed by 2030, and the most problematic sections are the cross-border and outlying sections. In some cases, the problem results from a lack of decision or the construction of high-speed lines being postponed after 2030.

For the purpose of analysis, the following four criteria of the most urgent corridors have been identified:

1) The highest population density within TER region

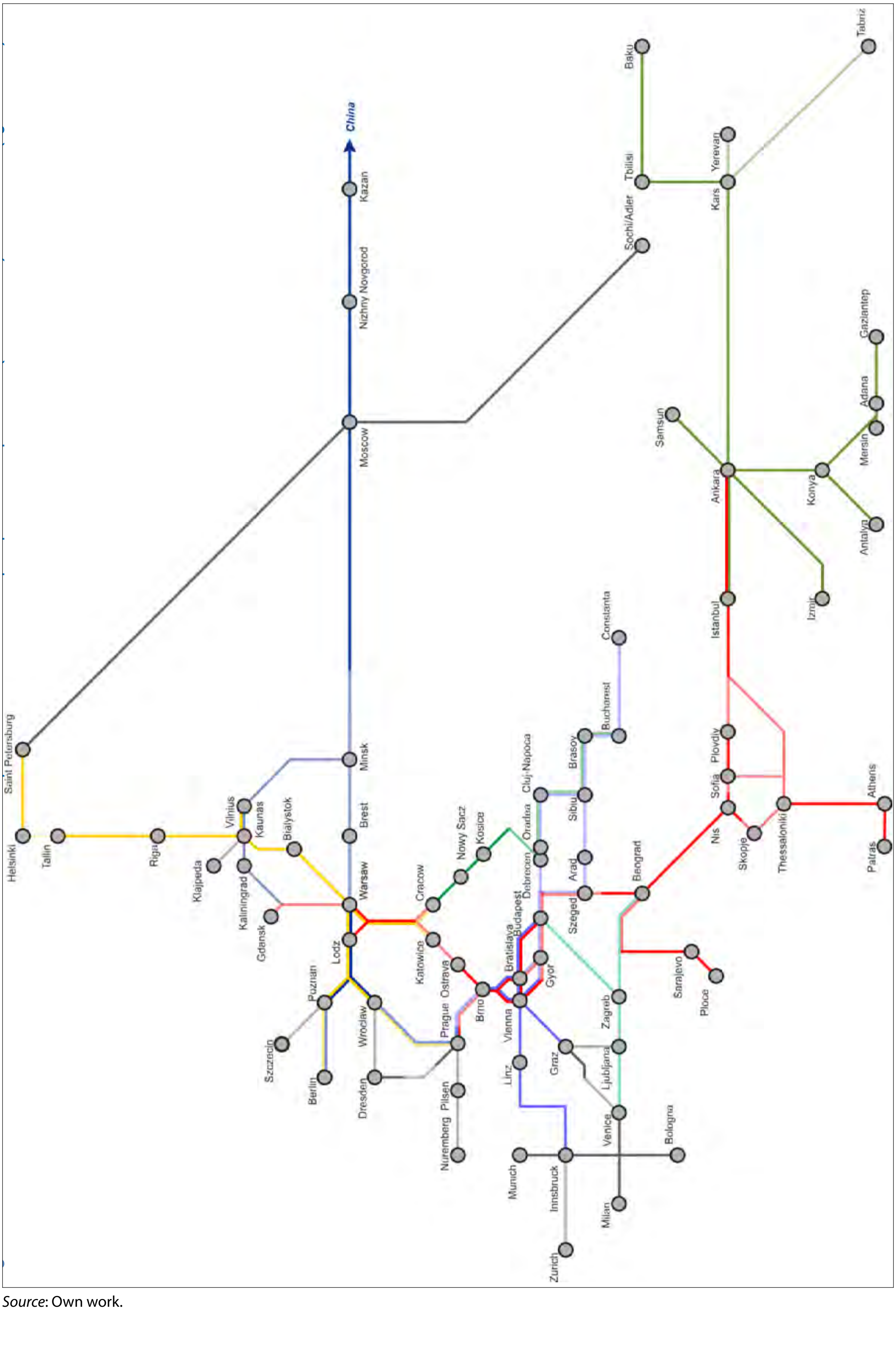
In the TER region, southern Poland, eastern Czechia, northern-eastern Austria, western Slovakia and northern Hungary are the most densely populated regions. Density of population is more than 200 and in urban areas – 500 people per km². This is followed by the slightly less densly populated areas in the middle Poland (triangle cutting in the coast of the Gdansk Bay), western Czechia, southern Austria, central and northern Serbia and the foothills of the Carpathian Mountains in various States. In addition, in the area of low average population density there are isolated urban centres which are usually connected to major cities having a population of 10 or more million inhabitants, such as Moscow and Istanbul.

Figure IV-8 is based on UIC research and shows population density in Europe. It also covers most of the Russian Federation's European part and Turkey. It has been prepared for the smallest municipal administration units. The map includes high-speed lines already in service, planned for construction by 2030 and by 2050 and conventional supplementary lines that will support the service of HSR TER nodes and link high-speed lines in areas with a smaller number of passengers or in areas where topographical conditions are difficult.

From the point of view of the population distribution it would be beneficial to start investments in the lines situated in the Polish – Czech, Czech – Austrian and Austrian – Hungarian borderlands. As such construction of the lines Cracow/Katowice – Ostrava – Brno, Brno – Vienna, Vienna – Budapest, Vienna – Bratislava, Vienna– Graz – Klagenfurt, Subotica – Belgrade – Nis should be the priorities. The region between Bucharest and Brasov in Romania is also densely populated. Despite a relatively low population density in the areas between the cities, the Lodz and Warsaw line has a high population potential arising from a relative proximity of two large cities.

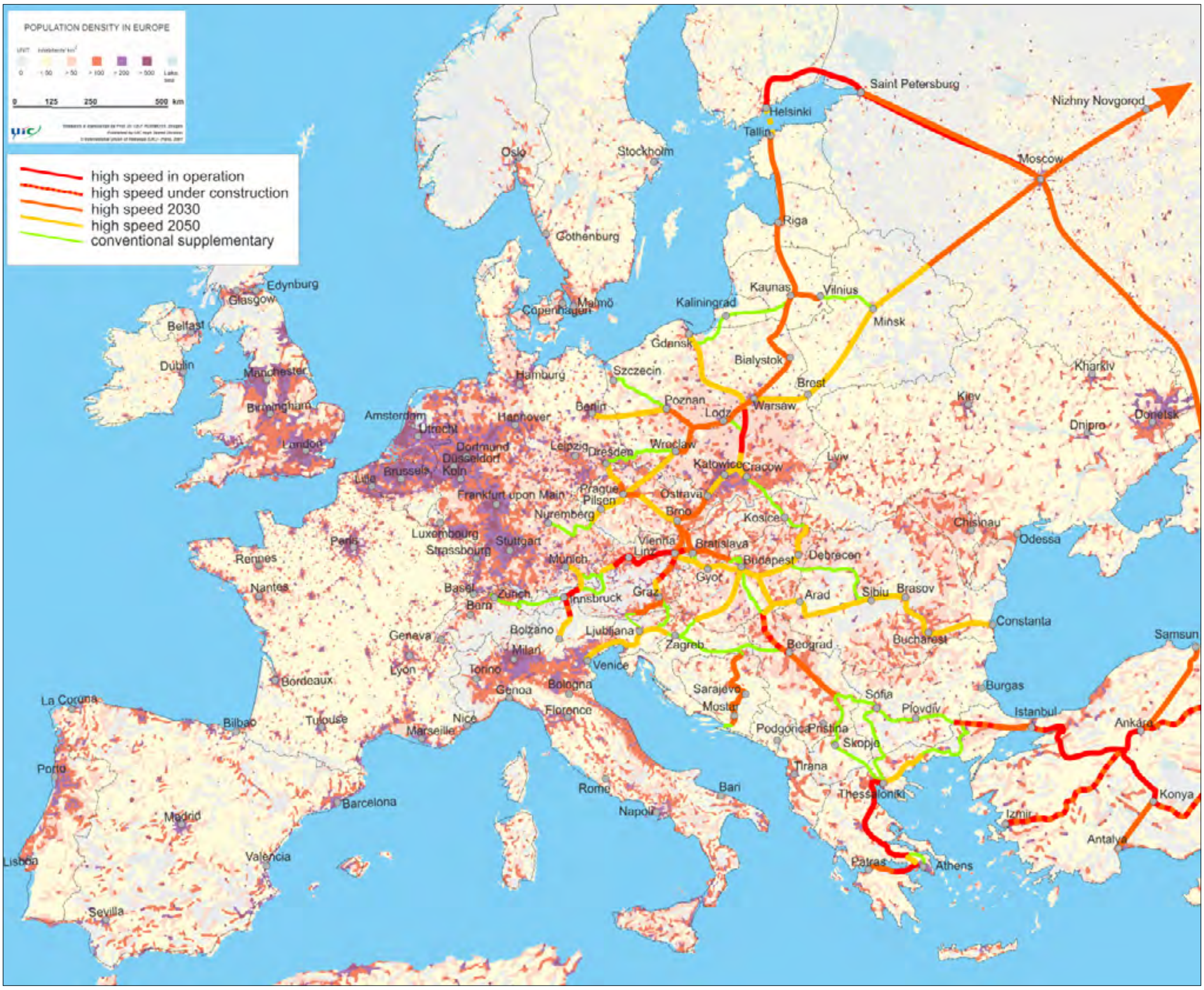
In addition, Moscow and Istanbul which are served by high-speed lines, have a big population potential. On the other hand, the characteristics of the lines serving the cities is completely different. Due to their dominant position and significant distance to other large urban centres these lines primarily run through less populated areas and will be distinguished by significant length with infrequent network of stops. Areas between Moscow and Kazan and those situated to the south of Moscow along the line to Sochi are more populated. Areas along the line towards Minsk and Saint Petersburg are less populated, although, simultaneously, these two cities alone have big population potential. A similar situation exists in Turkey where, despite low population density, large urban centres are densely populated. Eight Turkish cities have a population exceeding one million inhabitants, and a few more are close to reach the number. Priority lines due to the high population density are marked in figure IV-9.

Figure IV–7 **Corridors of TER HSR network with indicated completion of the lines in the perspective of up to 2030 (dark colours) and to 2050 (light colours)**



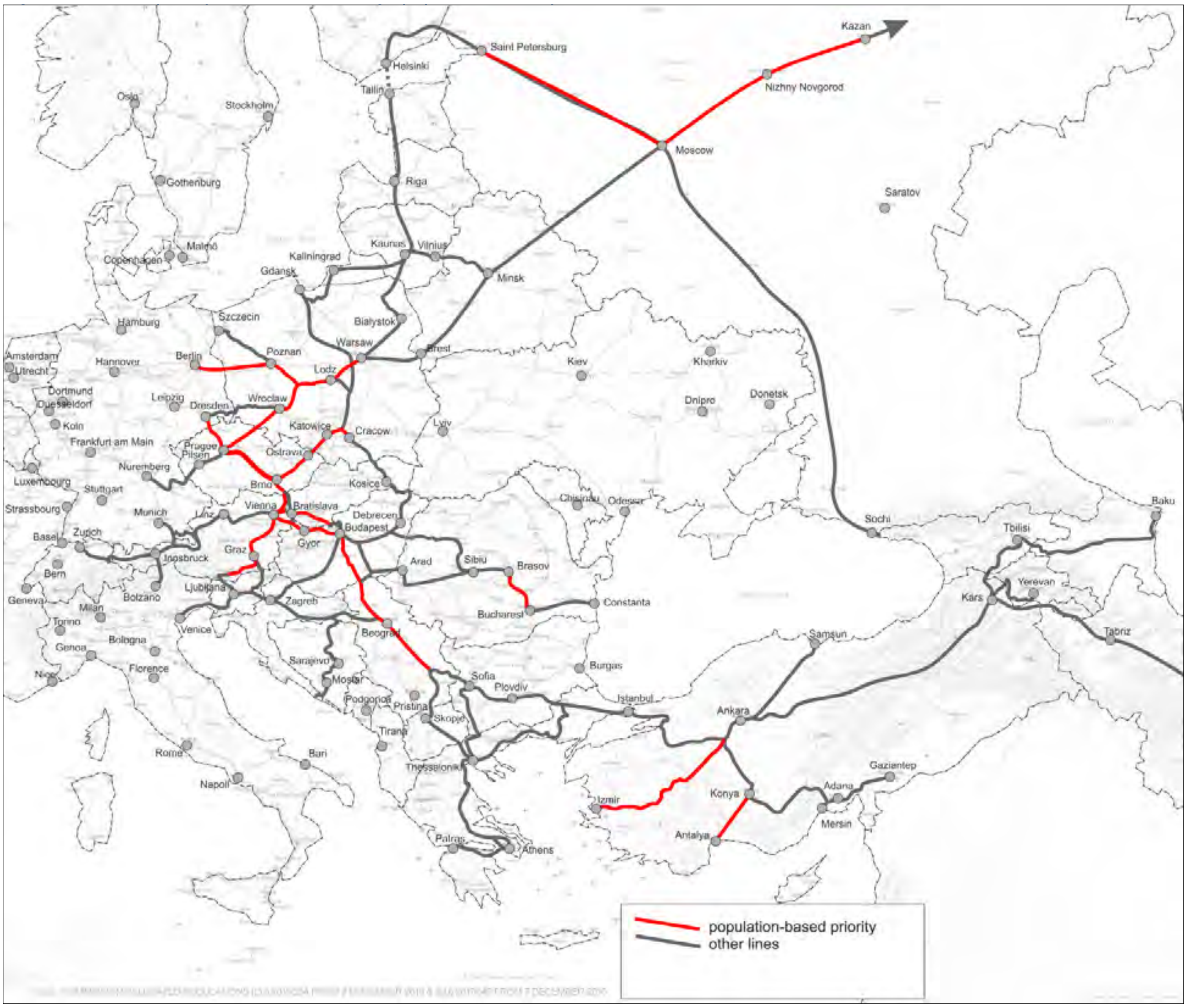
Source: Own work.

Figure IV–8 High speed lines vs. population density with indicated completion in the perspective of up to 2030 and 2050



Source: Own work.

Figure IV–9 TER priority lines due to the high population density



Source: Own work.

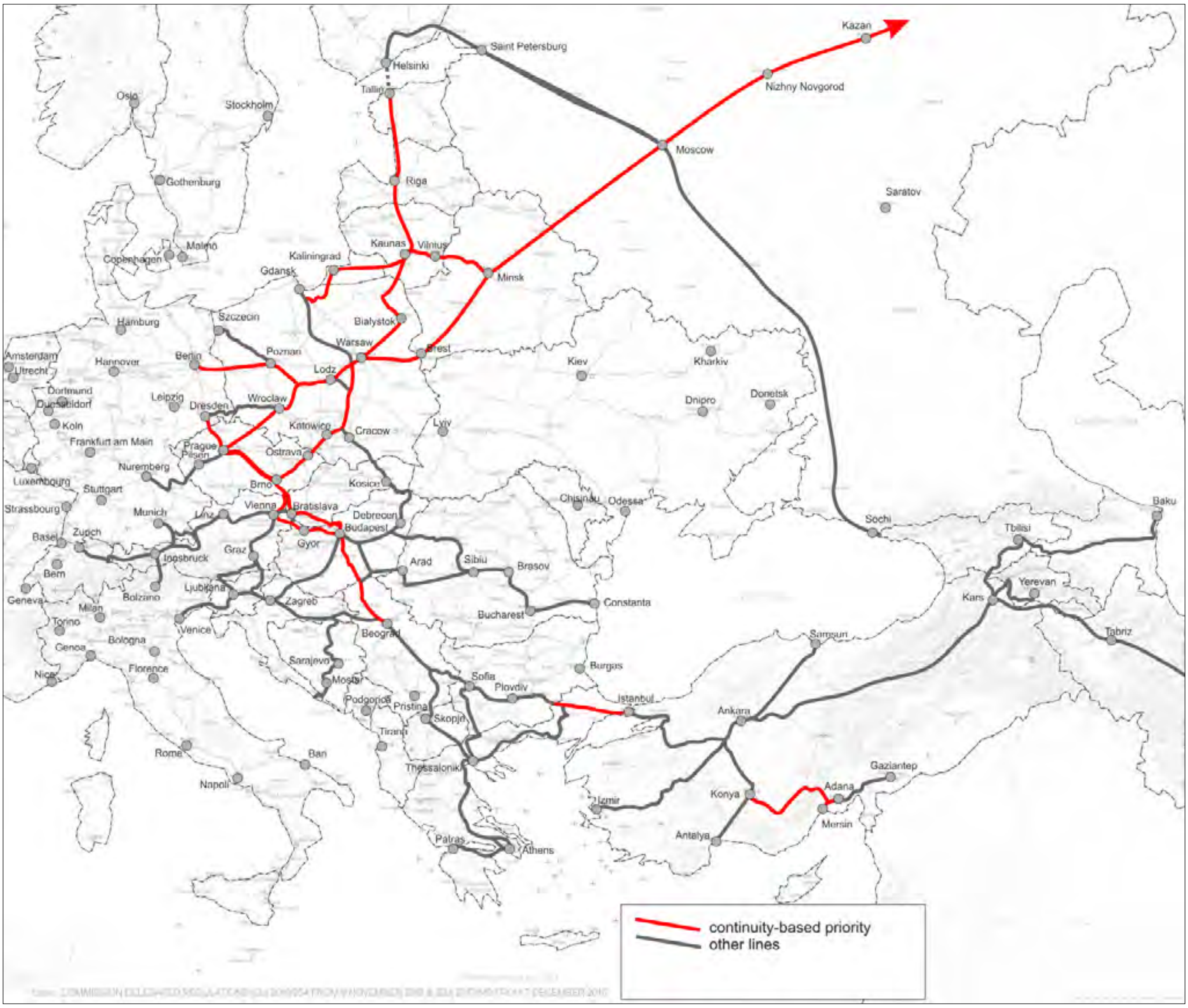
2) Possibility of quick consolidation of the most important transport corridors

None of the planned corridors has been completed nor will be completed by 2030 as some lines have been planned for construction of upgrade post-2030 and others involve cross-border sections which require more extensive negotation. The best and most efficient way to consolidate high-speed lines into one TER network is to implement corridors by all involved States.

In the norther corridor in the East-West Axis there are no sections with substandard travel conditions therefore, consolidation, the maintenance of good parameters and subsequent modernisation is possible. It is also a corridor with very heavy traffic as far as passenger and freight transport are concerned and is also the main corridor for cargo traffic in the China – Western Europe Axis (figure IV-10).

In the north-south corridor from Poland to Czechia, Slovakia, Austria and Hungary the high-speed projects can be consolidated at the same time.

Figure IV–10 TER lines by continuity-based priority



Source: Own work.

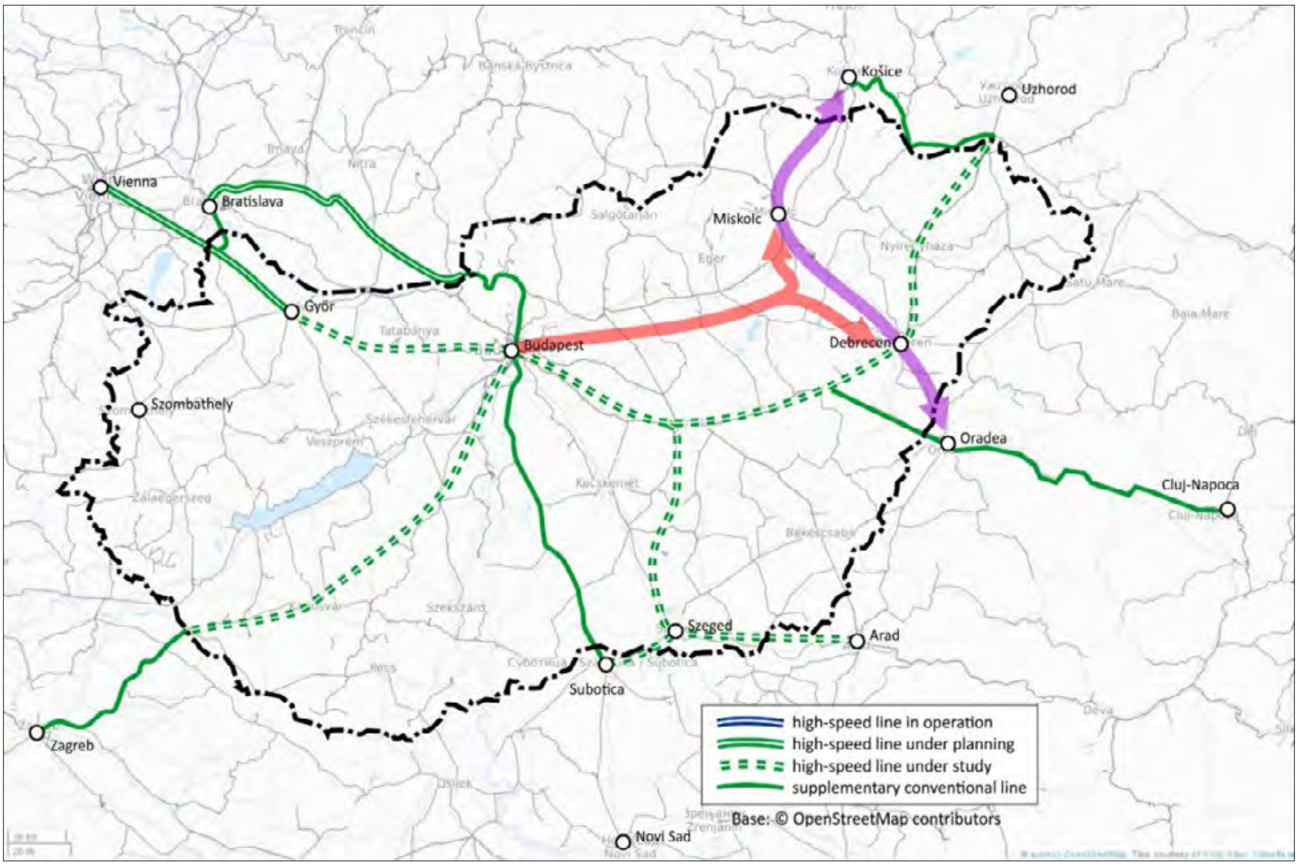
3) Elimination of the major gaps in the TER HSR network

Currently the railway network in TER States remains highly fragmented. Even if physically connected, its track width, traction, gauge, load capacity and operation speeds are not homogeneous. Full standardisation is neither necessary nor realistic (e.g. different operating speeds) but suitable steps should be adopted to eliminate those barriers that are creating bottlenecks.

- Polish-Lithuanian border area: the current projected network in 2030 probably may not be sufficient to meet the expected potential of the corridor.
- The Gulf of Finland: The natural barrier of the Gulf of Finland is expected to be eliminated with the construction of the undersea tunnel explained in previous chapters to be completed by 2050.
- The Carpathian Mountains, Polish-Slovakian border: Currently only single track and with low operating speed, the existing network constrains the development of the corridor and requires modernisation.

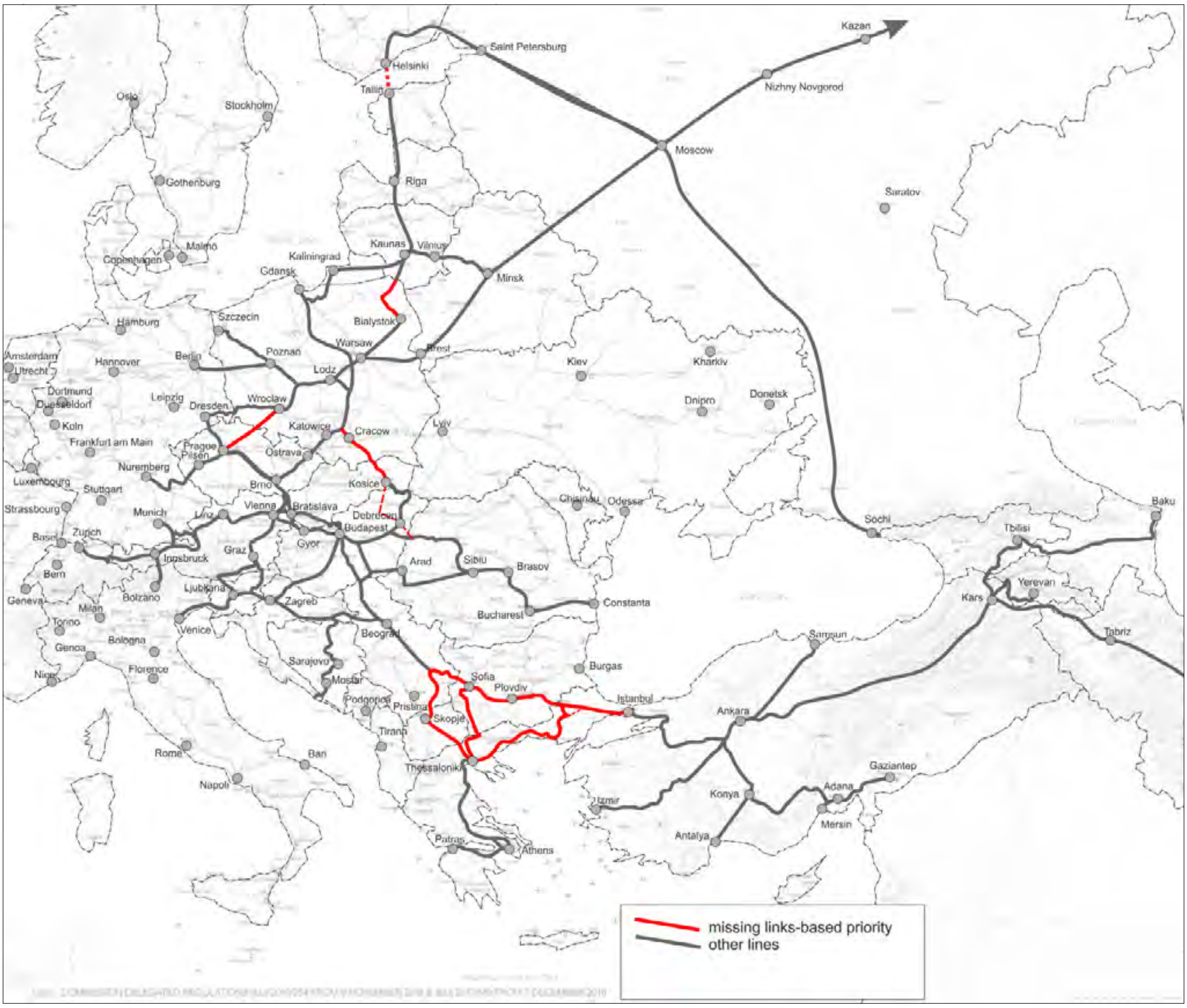
- Sudety Mountains, Polish-Czech border: The current border crossing does not provide enough capacity, the construction of a new high-speed line after 2030 would improve the connectivity here.
- Slovakian-Hungarian-Romanian border area: The current network has significant limitations and the construction of a new line between Slovakia and Hungary would alleviate this as identified in figure IV-11 below.
- Turkish, Greek, Bulgarian, Serbian and North Macedonian region: A number of investments are underway to increase speeds in this area but there are a number of missing links as set out in figure IV-12 below.

Figure IV–11 Planned HSR network in Hungary with potential directions of service



Source: Own work on board © OpenStreetMap contributors.

Figure IV–12 TER lines with missing links-based priority



Source: Own work.

4) Increase the competitiveness of rail services

A comparison of travel times by car and train – currently as well as after potential modernisations – indicates the areas that require construction of high-speed lines. Analysis of travel time in the network of corridors has been carried out in figures IV-13 to figure IV-16 below. Figure IV-13 below shows the travel time by road between each node, figure IV-14 shows the current travel time between each node by rail and figure IV-15 shows the new travel times by rail following the investments highlighted throughout the study. Importantly, figure IV-15 identifies where there will be improvements of significance. Finally, figure IV-16 below shows where the investments need to be concentrated to improve the competitiveness of rail.

Planning and construction of HSR lines should consider that only road transport can fulfil the requirements of door-to-door delivery. As a consequence, there is a strong requirement for other transport modes to shorten journey times as much as possible below the values of road transport otherwise the potential advantage of rail transport will disappear.

In mountainous regions rail service competitiveness is reduced. In areas of Turkey, Greece, Bulgaria, Serbia and North Macedonia travel times between particular network nodes by car are almost twice as fast as by rail, with the exception of the areas where HSR is already present. If no investments are made in railways, the disadvantage will be compounded. The largest modal shift can be achieved with the introduction of HSR services. Turkey is the example here, the introduction of high-speed lines has reduced travel times to well below the current travel time by road transport. This is also true for projects in Romania.

In Austria, Czechia and Hungary travel times by road and rail transport are similar and the planned modernisation on the border of Austria, Czechia, Slovakia and Hungary to high-speed standards will not significantly shorten the travel time unless new lines are built with operating speeds of more than 250 km/h. A similar situation can be observed in Slovenia and on the Ljubljana – Trieste line.

On lines predominantly on flat terrain such as in the Russian Federation, Belarus and Poland rail is more competitive when compared to road transport, although local differences can be observed. On modernised sections, from Warsaw to Gdansk, Katowice, Cracow (PL) or on the route from Moscow to Saint Petersburg (RU) rail transport dominates over road transport. Simultaneously, there are cases like Lodz – Poznan, Lodz – Wroclaw (PL), or Warsaw – Bialystok – Kaunas (PL/LT), where road transport is much faster. On these routes this trend may only be reversed by the construction of well-equipped high-speed line with appropriate transhipments nodes. As per the mountainous regions set out above, road transport is currently faster than rail transport, particularly on the following lines: Katowice – Brno (PL/CZ), Wroclaw – Prague (PL/CZ), Wroclaw – Dresden (PL/DE), Prague – Dresden and Prague – Nuremberg (CZ/DE).

The Baltic States also face low competitiveness of the rail sector. The current travel times, if indicated, remain significantly longer than road transport. The construction of Rail Baltica line is expected to reverse the trend.

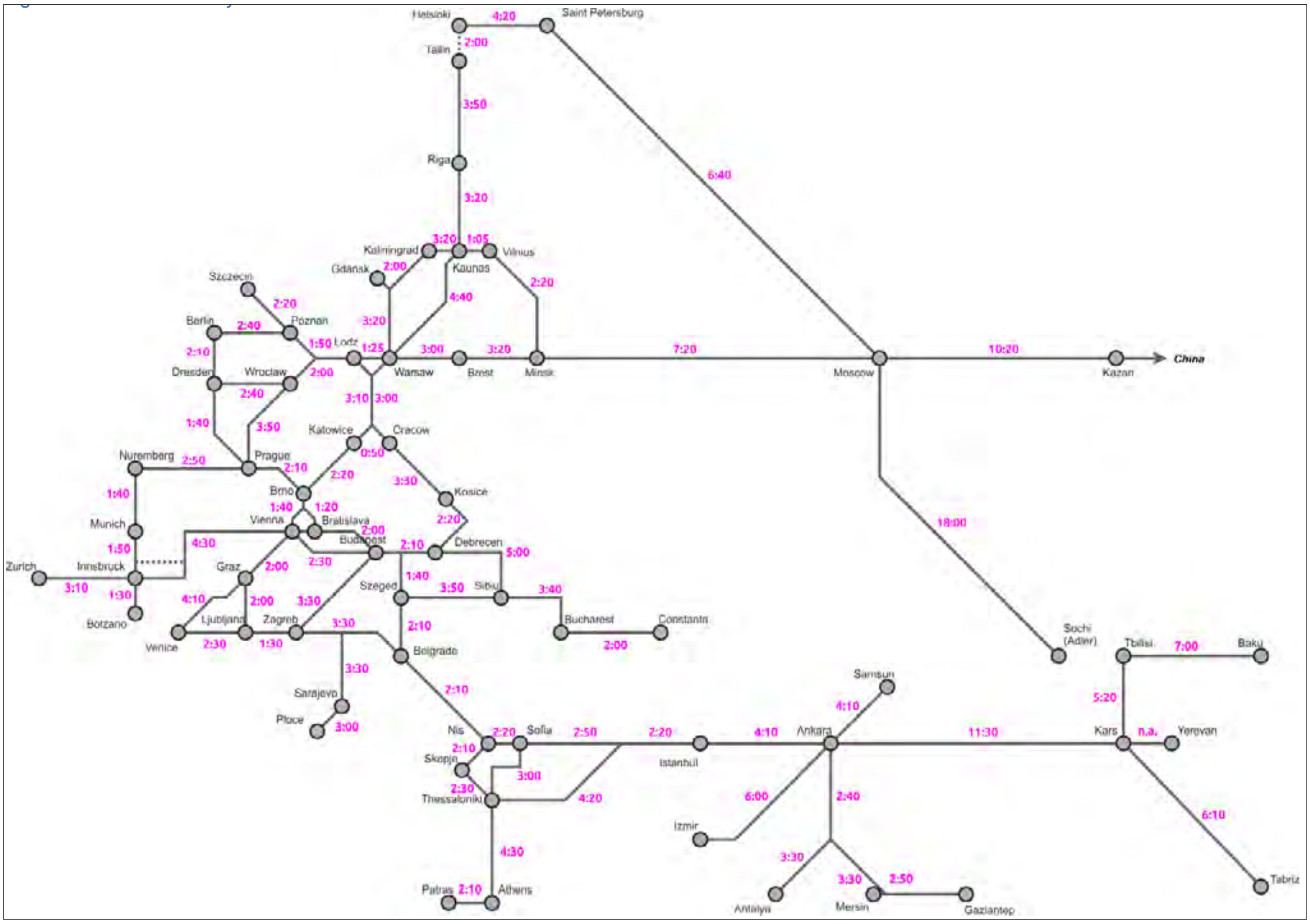
The effectiveness of the railway network should be measured not only from the point of view of its technical parameters, but also through comparison to the other means of transport. Rail may be competitive when compared to air transport mainly at the small and medium distances; however, it will be strongly affected by the variable network of the air connections. Rail competitiveness compared to road transport will be an important factor also for the longer distances in the case of high-speed lines. It will be affected by the rail schedules and connection density, while the availability of road connections is almost uninterrupted. On the other hand, it may be assumed that within the TER network rail traffic will be dense enough to make waiting time at the nodes almost negligible. The potential volume of individual freight delivery could be the only justification for supporting rail transport.

Comparison of the current travelling times between the TER nodes by train and by individual car indicates as well the sections where the means of transport are more or less equal, those, where the train is the faster option and those where the car gives definitively better travelling time (table IV-6). When comparing those results to the possible travelling times that might be achieved after the planned investments one can see where the predominant position might be achieved. Next, the simulation of the possible travel times for the sections where the investments have not been planned yet, could suggest what kind of investments will be necessary to consider optional gain the supremacy.

The list of sections, where rail transport is significantly slower than car and will be much faster than road transport provided the investments are done, includes:

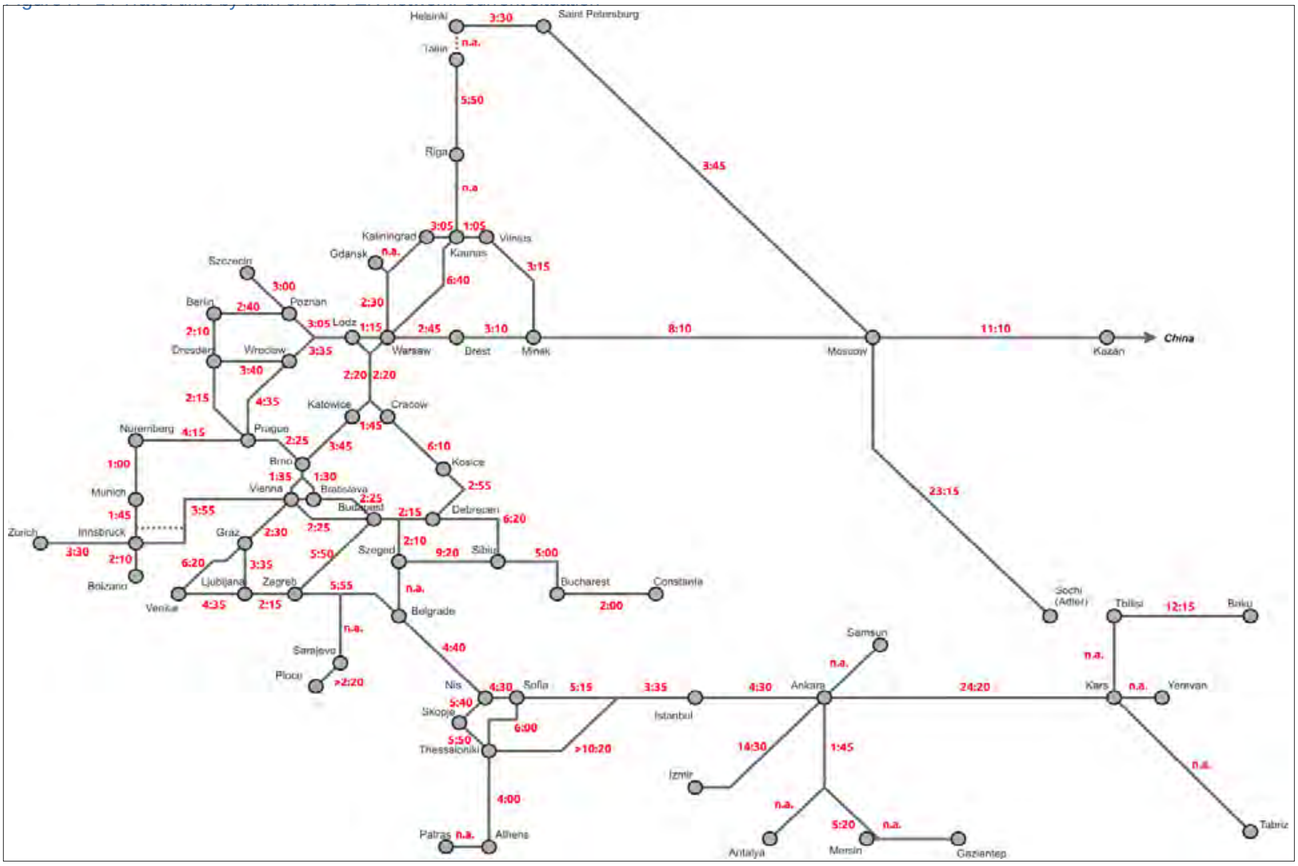
1. The whole Rail Baltica route (EE, LV, LT and PL). The poor competitiveness of the rail transport is a result of the low design speed of the existing tracks and weak maintenance in comparison with a relatively well-developed road infrastructure.
2. Sections crossing the mountain ranges on the borders between Poland as well as Germany and Czechia as well as Slovakia. Poor competitiveness of the rail is a result of insufficient technical parameters of the railways and, partially, poor maintenance of the tracks, especially on the bordering sections.
3. The section between Warsaw, Lodz, Poznan and Wroclaw (PL). A result of the relatively well-developed highways network and historically conditioned shortages in the railway network of central Poland. (II World War extremely extensive destructions).
4. Sections on the mountainous areas of Balkan States as well as Romania and Greece. Very low competitiveness of the rail transport is a result of a poor geometrical parameters of the railway lines designed in the difficult terrain and also, in many cases, poor maintenance of the track. It is worth to stress that the road network is also not very developed one, so the railway would become competitive even with the maximum speed of only 160-200 km/h as long as the road network is not strongly upgraded.
5. Sections connecting Budapest (HU) to Serbia and Romania, where the technical condition is not sufficient.
6. Sections in the area of Turkey, where the technical parameters of railroads are not satisfactory because of difficult terrain conditions. This does not refer to the already existing high-speed sections.

Figure IV–13 Travel time by car on the TER-network. Current situation



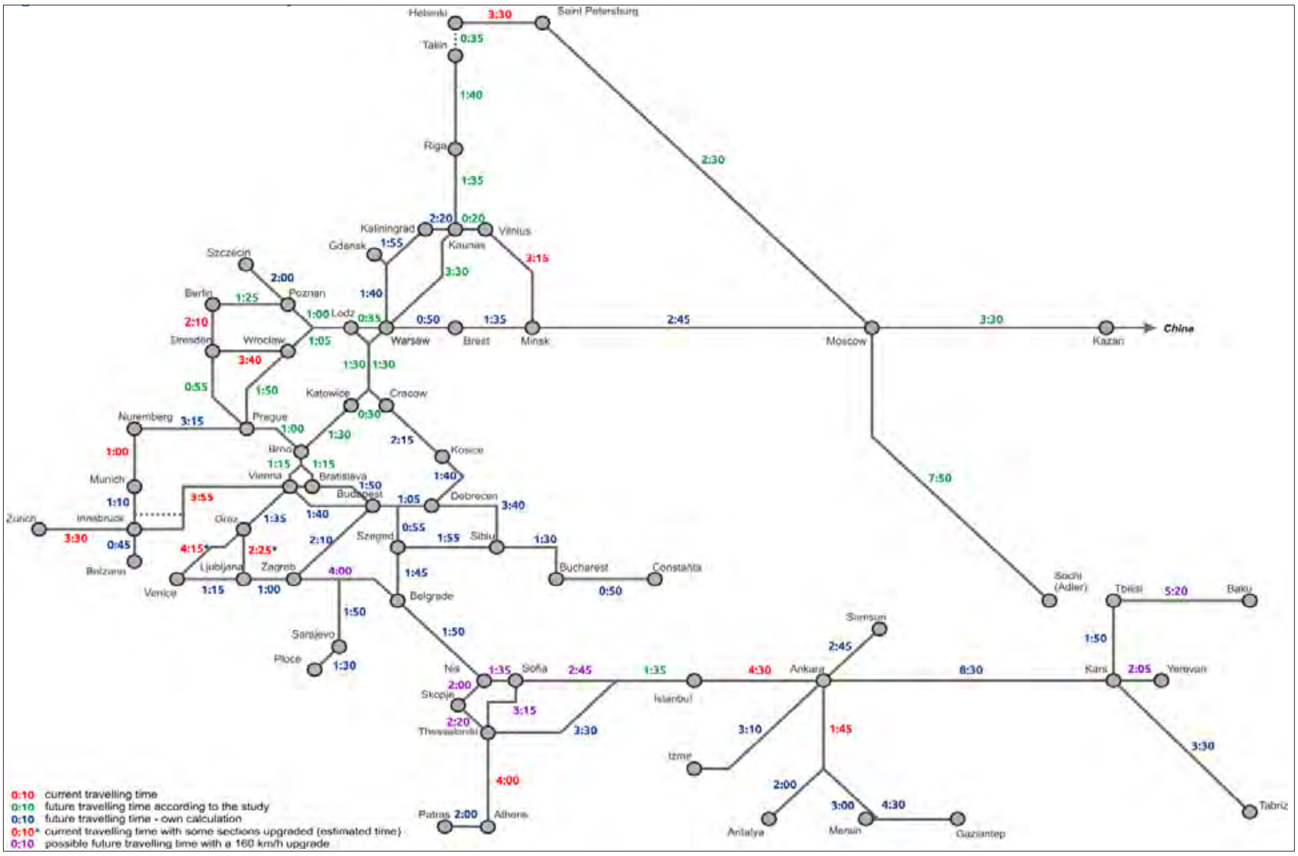
Source: Own work based on Google Maps road planner.

Figure IV–14 Travel time by train on the TER-network. Current situation



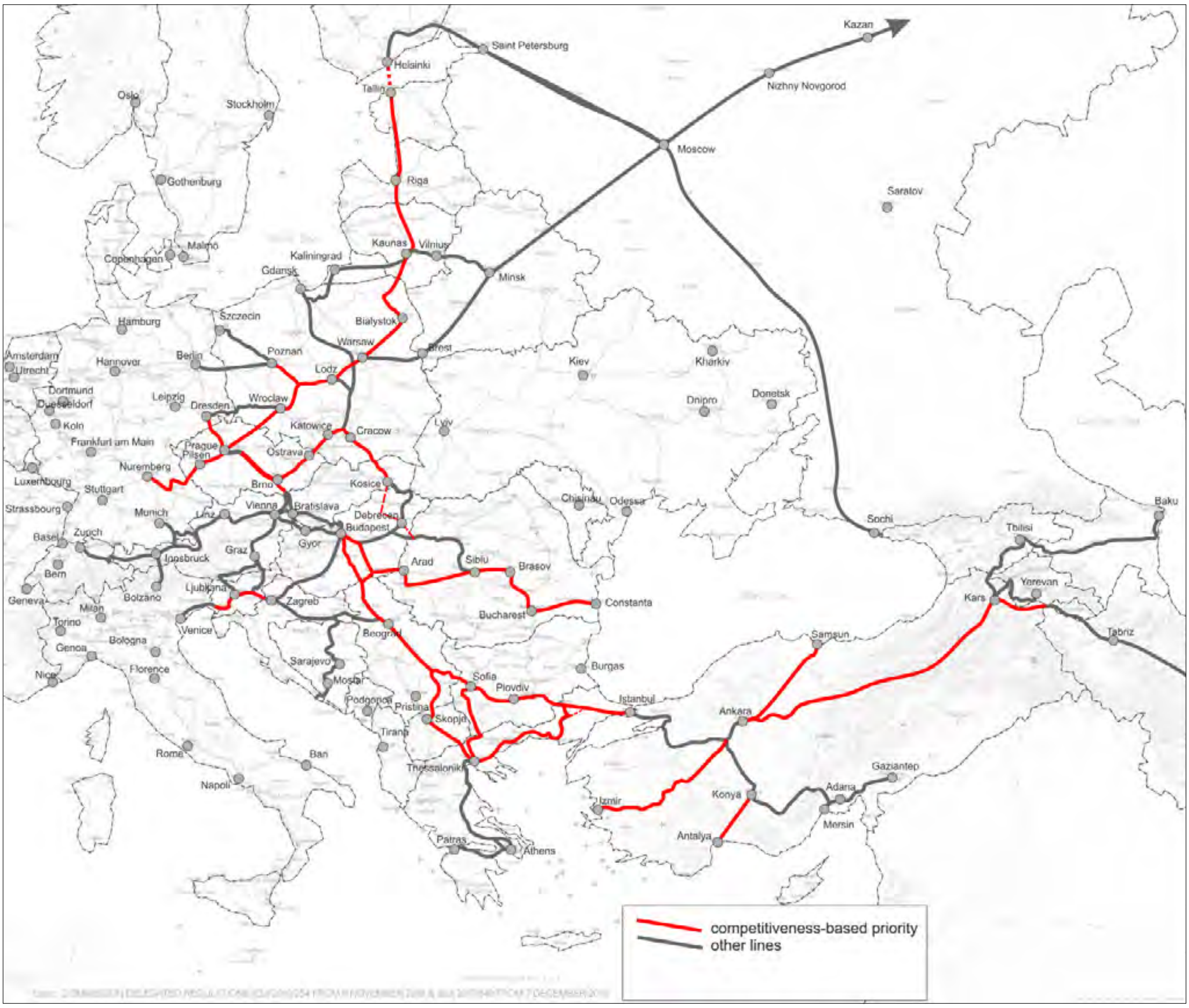
Source: Own work based on carriers' schedules.

Figure IV–15 Future travel time by train on the TER-network



Source: Own work based on timetables, studies and own calculations.

Figure IV–16 HSR lines with the competitiveness-based priority (accordingly Figure IV 13-15.



Source: Own work.

2.4 Conclusions

Two matrices with travel times between the nodes in the northern and southern parts of the network have been prepared for the area of TER. The travel times have been estimated for the completed TER network, taking into consideration the fact that all the supplementary, conventional lines would be upgraded to the speed of 160 km/h. This assumption may go beyond the currently approved modernisation plans. Routing of particular connections has been made along the planned TER network, each time with the highest speed possible. Where the connection beyond the TER network is faster, the relevant travel times have been identified. The actual routing of trains may differ from the estimated one. To some extent, also the travel times may vary due to the number and length of train stops at the stations, where the train scheduling at longer non-stop sections may ensure shorter times than the ones specified in the table IV-5 and IV-6.

The findings concerning travel times have been grouped according to the length of the trip. The travel times of up to 1.5 h have been classified as the first group, covering such things as commuting and refer to areas such as the Czech-German border, Polish-Czech border, Slovenian-Italian border and also between neighbouring network nodes in the Baltic States and Finland. Also, the area of a common international labour market at the borders of Czechia, Austria, Slovakia and Hungary as well as observed development of mutually interpenetrating labour market between Poland and Germany would develop significantly.

The second group includes travel times ranging between 1.5 and 3-3.5 hours which covers one day business trips and occasional leisure trips. In case of the TER network, the area where such trips are possible is very much leaning to international movements. Such a situation may occur in:

- The Baltic States;
- Czechia, Germany, and Poland;
- Eastern Austria, Hungary and Slovakia; or
- Bosnia and Herzegovina, Hungary and Serbia.

The northern subregion covering Austria, Belarus, Czechia, Poland and Slovakia could serve as an example here. The middle subregion represented by Austria, Croatia, Hungary, Romania, Serbia and Slovakia and the southern subregion will include the European part of Bulgaria, Northern Greece and Turkey. For these regions air transport remains strong, however, rail travel could be equally popular.

Table IV–6 Travel times between major cities in Central and Eastern Europe

	Prague	Brno	Bratislava	Budapest	Vienna	Warszaw	Poznań	Katowice	Wroclaw	Vilnius
Prague		01:00	02:15	03:55	02:15	03:30	02:50	02:30	01:50	07:20
Brno			01:15	02:55	01:15	03:00	03:50	01:30	02:50	06:50
Bratislava				01:50	00:30	04:15	05:05	02:45	04:05	08:05
Budapest					01:40	05:55	06:45	04:25	05:45	09:45
Vienna						04:15	05:05	02:45	04:05	08:05
Warszaw							01:35	01:30	01:35	03:50
Poznan								02:30	01:00	05:25
Katowice									2:35*	05:20
Wroclaw										05:30
Vilnius										
Minsk										
Moscow										
Kaliningrad										
Belgrade										
Bucharest										
Zagreb										
Ljubljana										
Berlin										
Munich										
Dresden										
Riga										

* 2:15 on the direct, conventional route; ** 3:25 on the direct, conventional route; *** via Erfurt, away from the TER network.
Source: Own work.

Marks

1:15 Quick Business trip – Travel time shorter than approx. 1 h 30

3,00 One-day trip – Travel time of more than 1 h 30 and less than approx. 3 h

4,20 Long trip – Travel time of more than 3 h and less than 5-6 h

Minsk	Moscow	Kaliningrad	Belgrade	Bucharest	Zagreb	Ljubljana	Berlin	Munich	Dresden	Riga
05:55	08:40	06:50	06:35	08:15	06:05	06:15	03:05	04:15	00:55	08:35
05:25	08:10	06:20	05:35	07:15	05:05	05:15	04:05	05:05	01:55	08:05
06:40	09:25	07:35	04:30	06:10	04:00	04:30	05:20	04:20	03:10	09:20
08:20	11:05	09:15	02:40	04:20	02:10	03:10	07:00	05:30	04:50	11:00
06:40	09:25	07:35	04:20	06:00	03:50	04:00	05:20	03:50	03:10	09:20
02:25	05:10	03:20	08:35	10:15	08:05	08:15	03:00	07:45	04:25	05:05
04:00	06:45	04:55	08:45	11:15	08:55	09:05	01:25	07:05	03:45	06:40
03:55	06:40	04:50	07:15	08:45	06:35	06:45	03:55	06:35	03:25	06:35
04:05	06:50	04:00	08:25	10:05	07:55	08:05	02:25	06:05	02:45**	06:45
03:15	06:00	02:40	12:25	14:05	11:55	12:05	06:50	11:35	08:15	01:55
	02:45	05:55	11:00	12:40	10:30	10:40	05:25	10:10	06:50	05:10
		08:40	13:45	15:25	13:15	13:25	08:10	12:55	09:35	07:55
			11:55	13:35	11:25	11:35	06:20	11:05	07:45	03:55
				05:10	04:00	05:00	09:40	08:10	07:30	13:40
					06:30	07:30	11:20	09:50	09:10	15:20
						01:00	09:10	07:40	07:00	13:10
							09:10***	04:40	07:10	13:20
								4:30***	02:10	08:05
									04:35***	12:50
										09:30

Table IV–7 Travel times between major cities in South-East Europe

	Belgrade	Sofia	Skopje	Thessaloniki	Athens	Istanbul	Ankara	Zagreb	Ljubljana	Sarajevo
Belgrade		03:25	03:50	05:50	09:50	07:45	12:15	04:00	05:00	03:35
Sofia			03:35	03:15	07:15	04:20	08:50	07:25	08:25	07:00
Skopje				02:20	06:20	07:25	11:55	07:50	08:50	07:25
Thessaloniki					04:00	05:05	09:35	10:10	11:10	09:45
Athens						09:05	13:35	14:10	15:10	13:45
Istanbul							04:30	11:45	12:45	11:20
Ankara								16:15	17:15	15:50
Zagreb									01:00	04:05
Ljubljana										05:05
Sarajevo										
Mostar										
Budapest										
Vienna										
Venice										
Munich										
Prague										
Bratislava										

Source: Own work.

Marks

1:15 Quick Business trip – Travel time shorter than approx. 1 h 30

3,00 One-day trip – Travel time of more than 1 h 30 and less than approx. 3 h

4,20 Long trip – Travel time of more than 3 h and less than 5-6 h

Mostar	Budapest	Vienna	Venice	Munich	Prague	Bratislava
04:35	02:40	04:20	06:15	08:10	06:45	04:30
08:00	06:05	07:45	09:40	11:35	10:10	07:55
08:25	06:30	08:10	10:05	12:00	10:25	08:20
10:45	08:50	10:30	12:25	14:20	12:45	10:40
14:45	12:50	14:30	16:25	18:20	16:45	14:40
12:20	10:25	12:05	15:15	15:55	14:20	12:15
16:50	14:55	16:30	19:45	20:25	18:55	16:40
05:05	02:10	03:50	02:15	05:40	06:05	04:00
06:05	03:10	04:00	01:15	04:40	06:15	04:30
01:00	06:15	07:55	06:20	08:15	10:10	08:05
	07:15	08:55	07:20	09:15	11:10	09:05
		01:40	04:25	05:30	03:55	01:50
			05:50	03:50	02:15	00:30
				03:25	08:05	06:20
					04:15	04:20
						02:15

3. Proposed actions for the implementation of TER HSR Master Plan

3.1 Proposed recommended TER HSR network implementation methodology

Corridor approach

The TER HSR network identified in previous chapters is very extensive and covers over half of the European continent. It consists of about 25,000 km and covers 15 TER States (with different levels of development and different stage of investment process) together with connections to neighbouring non-TER States. The implementation of such a project is therefore complex, expensive and time-consuming. For this reason, it has been suggested to adopt a corridor approach.

A transport corridor is a generally linear area that is defined by one or more modes of transportation like railways, motorways or public transit which share a common course. Development often occurs around transportation corridors because they carry so many people, creating linear agglomerations. This methodology was applied to the creation of the Cretan corridors and the TEN-T priority corridors (see also UN report Effective Transit Transport Corridor Development and Management: Report on Best Practices (2020).

It should also be considered that a significant part of the TER HSR network recommended is currently in various stages of planning and, in some cases, even in construction or operation. The integration of all projects is therefore a great challenge, not only from a financial, but also organizational point of view. For this reason, a corridor approach that allows concentration of actions to achieve measurable effects as soon as possible is justified.

In section III-3 the following main corridors were identified:

1. North-South corridor: from Poland via Czechia, Slovakia/Austria, Hungary, Serbia/Bulgaria, Northern Macedonia to Greece and Turkey
2. North corridor (East-West): from Germany and Poland via Belarus to Russian Federation and further towards China
3. Middle corridor (Danube): from Austria and Switzerland and from Germany and Czechia via Slovakia and Hungary to Romania and Ukraine
4. Southern corridor (East-West): from Italy via Slovenia, Croatia to Hungary with a branch towards Turkey
5. Baltic corridor: from Germany and Poland (Warsaw) via Lithuania, Latvia and Estonia to Finland with a branch to Czechia
6. Southern: East – West (Istanbul – Iran) from Istanbul to Iran and the Caucasus States
7. Carpathian corridor: from Poland via Slovakia, Hungary to Romania.

These corridors are to be supplemented by a number of nodes as identified in figure III-6 (chapter III).

Freight network based on the TER HSR network

To date, experiences in high-speed line services indicate that it is advisable to use HSR also for freight trains on high-speed lines and this will lower the breakeven point for passenger traffic as well as increase the average speed of freight movements across the network. However, as it is not possible to run freight trains on every high-speed line (lack of capacity, the need to bypass urban nodes) it is necessary to analyse existing conditions and develop operational plans for a dedicated freight HSR network.

The development of the TER HSR freight network requires further in-depth studies on individual sections of high-speed lines. It is necessary to identify restrictions on capacity for selected lines. In future feasibility studies for new lines dedicated for freight traffic, key technical focus should be on:

- The longitudinal slope of the line profile (recommended for freight traffic between 12 and 15 per mil)
- Station track length (recommended 740-1,050 m or longer)
- The location of passing loops and connections with conventional lines.

3.2 Proposed development of an action plan for the implementation of the TER HSR project

Implementation of the TER HSR project requires an action plan that would include tasks to be undertaken by proper policy and decision makers. The most important of them should include:

1) Completion of ongoing feasibility studies or development of missing ones

Examples of completed feasibility studies are given in chapter III-4. There are a significant number of such studies but there is still a large group of projects that are either at the stage of the initial feasibility study or the conceptual stage. Their preparation should be a priority, but the coordination with existing advanced projects should be taken into consideration.

Presently, the majority of key projects have complete feasibility studies. Some of the feasibility studies are still underway and expected to be completed within the next three years. All feasibility studies for the entire TER HSR should be completed within five years.

2) Integration of projects within a corridor

In order to establish a HSR corridor, existing projects must be **integrated**. Design works on high-speed lines that have been carried out so far should be analysed against the possibility of achieving the highest possible consistency. It is not excluded that there will be a need for partial revision of already advanced projects to achieve synergies within corridors and the entire TER HSR network.

It is also advisable to **standardise technical parameters** of the newly-constructed and modernised high-speed lines so that they would form routes with maximum continuous performance parameters, in particular in terms of maximum speed, for long-distance trains. This would make it possible to obtain travel times that would be attractive for travellers and competitive compared to other long-distance means of transport.

The integration of projects within the TER HSR network should take place in two stages. The **first** stage should cover existing, under construction and planned lines with completed feasibility studies and the definition of the framework requirements for new projects that would ensure further development and better integration of the network. This task would be an action plan to be implemented within one year. Quick implementation of this task is also required in the context of the planned modernisation of the TEN-T network (2022) and would allow for the effective integration of both networks. The **second** stage of TER network integration would be a long-term process that would end with the completion of the last missing feasibility studies of the TER network lines and thus last approximately five years.

3) Identification of the TER HSR network to be made suitable for freight

At the stage of the preliminary analysis, it appears that the introduction of high-speed freight traffic in TER States is possible on a large scale and can have significant effects. This is due to the conditions associated with large, attainable freight distances and a dense network of industrial and logistics centres. Several potential corridors for this type of transport have been identified in previous chapters.

It is recommended that the possibilities of efficient freight transport be considered at the planning stage of high-speed line construction.

4) **Preparation of financial plans**

Such plans are necessary to raise funds for projects and to plan the investment process, as well as to develop operational plans at various levels (lines, corridor).

The financial plan should also be drawn up in two stages.

The **first** stage (about one year) would be aimed at making estimates based on current feasibility studies and, in the absence of them, using the indicator method.

The **second** stage would consist of a further and continuous adjustment of the estimates as the subsequent studies were completed, and the updates already made.

5) **Proposed development of the TER HSR network implementation schedule**

In chapter IV-2, completion deadlines of 2030 and 2050 were recommended for investments in the TER HSR network. These deadlines are in line with the TEN-T implementation schedule, which for EU States would ensure consistency in the implementation of TER and TEN-T network developments as recommended in the financial plans requiring EU support. In order to coordinate the implementation of the TER HSR network, the schedule of implementation should be detailed to 5-year periods starting from 2025.

Table IV–8 Development of action plan

Action	Time for action
Completion of incomplete feasibility studies or development of missing ones	3-5 years
Integration of projects within corridors	1st stage (preliminary) – one year 2nd stage – 5 years
Determination of TER HSR freight transport sections	1 year (initial study)
Preparation of financial plans	1st stage (preliminary) – one year 2nd stage (detailed plans) – permanently
Development of the TER HSR network implementation schedule	2030 for the basic network 2050 for the completed network

Source: Own study.

3.3 Institutional support

Significant institutional support is needed to implement the TER HSR project due to its scale and long-term nature. This support should involve internal coordination within the TER project and cooperation with other entities.

A project-coordinating organizational unit is proposed to be established at UNECE level with the following structure:

1) TER HSR Steering Committee (Representatives of TER States)
2) Coordinators for each of the corridors (together with TER HSR nodes)
3) Funding consultancy unit (Financial Consultant/Coordinator)
4) Technical consultancy unit (Technical Consultant/Coordinator).

The scope of activities and tasks to be carried out by the recommended units is presented in table IV-8 and the organizational chart in figure IV-17.

For this to be accepted a number of issues will need to be addressed, including the role of UNECE and how the unit would be organized, run and funded. It is also recommended to establish permanent cooperation between the TER HSR Steering Committee and the following international organizations and institutions:

- UIC – International Union of Railways
- OSJD – Organisation for Cooperation of Railways
- OTIF – Intergovernmental Organisation for International Carriage by Rail
- ERA – European Union Agency for Railways (as a member or observer).

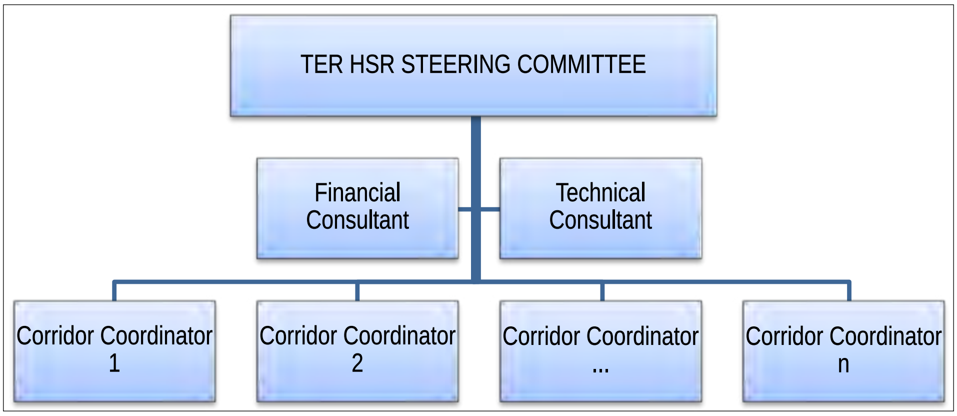
The recommended form of cooperation is a long-term agreement which enables long-term cooperation planning as well as the possibility of *ad hoc* consultations without the need, each time, to sign contracts.

Table IV–9 Proposed organizational structure for the TER HSR project support

Name	Activities	Tasks
TER HSR Steering Committee	Coordination of TER activities and cooperation with external entities (e.g. international organizations)	Developing an action plan for the TER HSR implementation Ongoing supervision over the work schedule implementation; Corrective actions in case of changes and threats to the plan implementation (permanently)
Corridor coordinator	Coordination regarding the individual TER HSR corridor	Developing a TER HSR corridor action plan Ongoing supervision over the work schedule implementation; Corrective actions in case of changes and threats to the plan implementation
Financial Consultant	Financial consulting	Support in investment financing plan; Support in fund raising;
Technical Consultant	Technical consulting	Support in preparing missing technical documents; Support in the ongoing solving of technical problems

Source: Own study.

Figure IV–17 Organizational chart of TER HSR network implementation support functions



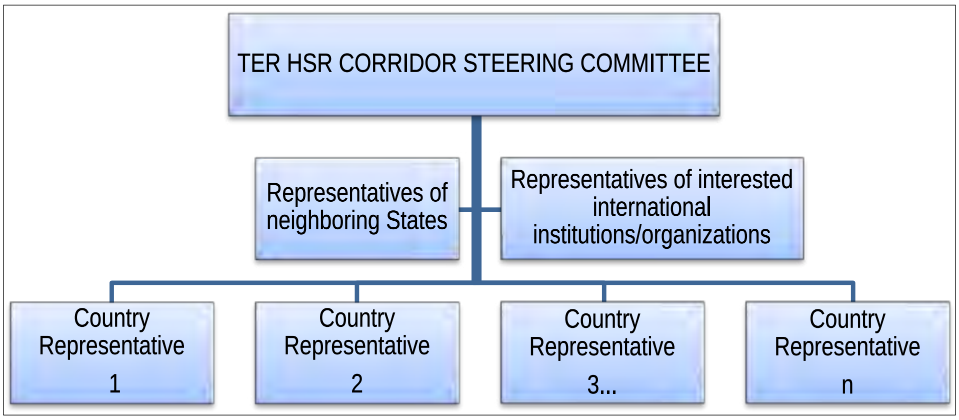
Source: Own study.

The TER HSR Steering Committee structure is recommended for each level of corridor. It consists of the following bodies:

1) Corridor coordinator
2) Representatives of TER States – National Coordinators
3) Other bodies involved for the special needs of each corridor:
    - Represent neighbouring States socially and economically affected by the construction of the corridor
    - Representatives of interested international institutions/organizations for which the corridor remains within the area of responsibility.

The involvement of these bodies in the preparation and implementation process in the creation of corridors could help to remove institutional obstacles to the achievement of goals, for example by coordinating strategies and development plans for transport networks with neighbouring States and at a European level.

Figure IV–18 Organizational chart of TER HSR network implementation support functions – Single Corridor Level



Source: Own study.

3.4 Conclusions

Proposed actions that should be taken to implement the TER HSR project can be divided into two stages:

- Preparatory
- Construction works.

The preparation phase is very important because of the need for rapid integration of already implemented or planned high-speed projects. The number of projects prepared in TER States is already very significant and some of them are implemented within the framework of cooperation also between TER States. For methodological reasons, this phase should be divided into two stages:

- Stage 1: preliminary studies and analysis, identifying main assumptions and directions of actions (corridors, including for freight using high-speed lines) and estimating implementation costs. It is advisable for stage 1 to take one year until the decision to start works.
- Stage 2: completion of feasibility studies (or at least initial preliminary feasibility studies). A realistic deadline for this case up to five years since the beginning of the Stage 1.

The construction phase, according to the assumptions set out above revolves around two phases: 2030 (for projects already started) and 2050 for other projects.

The work on the preparation of the HSR network project for the entire TER region requires international institutional support in which UNECE can play an important role. Financing this work requires the involvement of own resources of the States interested in the project as well as support from international organisations.

This remains a preliminary proposal which is of a framework nature where the organisational structure will require further detailing and negotiation, and which will need a solid legal basis. In particular it requires a negotiated division of competences and clear principles for its financing to implement projects, especially on cross-border sections, effectively.

4. Possibilities and potential sources of funding for the proposed links within the TER HSR Master Plan

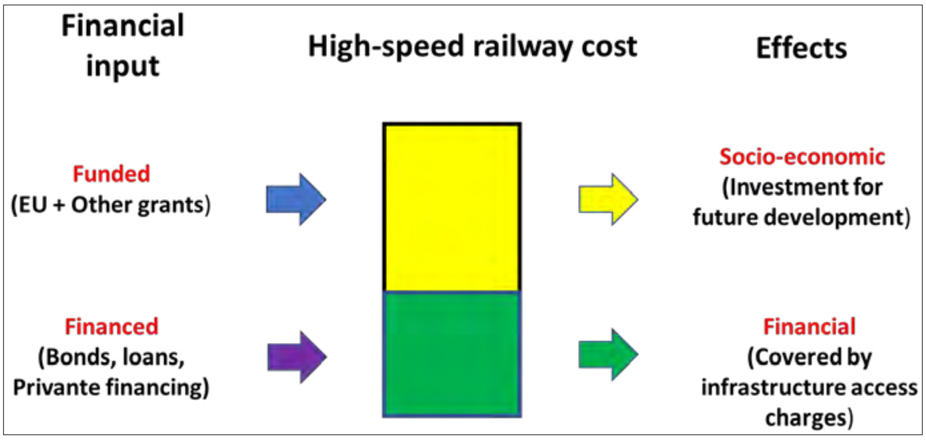
4.1 Costs of TER HSR construction versus available resources

4.1.1 Identification of the scale

The investment cost of construction of the 26,000 km of the TER HSR is estimated at being around €321 billion. Based on the analysis in the part IV-1.1.2-3, the required funds for this investment should be divided into two parts:

- A loan to cover part of the investment
- Direct financial support to cover a gap between an investment cost and forecasted revenue.

Figure IV–19 Financing mechanism for high-speed rail investment



Source: Own study.

Analyses of projects implemented so far and planned for implementation indicate that the gap requiring financing, can vary from several dozen per cent of the project value, reaching up to 85 per cent (the case of construction of the new Rail Baltica line). The need to use such significant resources requires the use of a rational financing model. In recent years, the preferred models were changing according to type, value and a way of financing of the project. In the first period of HSR development, the mixed model which combined public and private funding has become the most popular solution. At the same time, the first high-speed lines were built with a high return on investment (e.g. the line Paris-Lyon) – see appendix 2.

The evolution in the method of financing the construction of high-speed lines in France (appendix 2) is significant – from self-financing investments to the participation of local governments and EU funds. The last of the lines commissioned were financed under PPP according to various models. The need to avoid increasing the public deficit has an impact on the financing method.

Due to the high capital intensity of infrastructure investments, the financing of HSR construction requires that funds are taken from different sources. Based on experience acquired during implementation of multiple infrastructure projects, a solution of combining multiple funding sources is applied in order to maximise the effectiveness. Regardless of the choice of financing method, it is necessary to guarantee the financial sustainability of the project (some best practice in appendix 2).

4.1.2 Infrastructure investment management models

There are two main railway sector organization models:

- One in which infrastructure is separated from service (transportation);
- One that exists as a single enterprise managing both infrastructure and operations.

In the prevailing majority of European States (the EU and non-EU members) a functional separation of railway carriers from infrastructure managers applies. This type of market organization affects infrastructure investment planning. With this approach, the investor is the infrastructure manager and the operators are its customer. The standard scheme of planning, financing and subsequent operation is as follows:

- The operator determines its forward-looking transport needs in terms of the required travel times and other technical and operational parameters allowing a competitive transport to be offered;
- The infrastructure manager, which is usually the investor, carries out investment planning, provides funding and, after the end of the investment process, makes it available to carriers;
- The operator using the infrastructure pays an access charge to the infrastructure manager.

The main problem related to the financing of rail investments is the application process for the necessary funds. Usually, the infrastructure manager is a state-owned entity that may use state budget resources. However, the possibility to obtain budgetary funds is limited, so it is required to raise funds from external sources. When various forms of public-private partnership are used to finance infrastructure investments, the presented management structure is modified as a result of third-party entities involved in the process of management, operation or maintenance.

If the railway is an integrated entity combining investment activities, infrastructure management and transport activities, the management structure of the new rail line is simplified.

Government bodies in individual States are also actively involved in the decision-making processes regarding HSR investments, financing and the organization of the transport market. This commitment results from both the scale of the investment and its importance for the country's economic development.

In the case of investments implemented as international projects, these projects are managed under the supervision of their funding institutions. An example is the investment in the TEN-T corridors. Each of these corridors has a Coordinator appointed by the European Commission.[76] In addition, specific entities may be established to implement selected cross-country projects. An example of such an entity is Rail Baltica AS which manages the implementation of the project as identified in previous chapters.

4.1.3 Financial possibilities for States

TER States are in a diverse financial situation. Next to States with high revenues and expenditures, there are States with very low incomes. Considering the capital intensity of rail infrastructure investments, even in the richest States, financing investments only from own funds can be insufficient. Only a few States have a balanced budget. Table IV-9 shows the key economic indicators for the TER States.

[76] *Regulation (EU) No 1316/2013 of the European Parliament and of the Council of 11 December 2013 establishing the Connecting Europe Facility, amending Regulation (EU) No 913/2010 and repealing Regulations (EC) No 680/2007 and (EC) No 67/2010*, OJ EU L 348 20.12.2013 2013.

Table IV–10 Basic data on transport expenditure of TER and TER neighbouring States

Country	Total domestic expenditure		Transport investment 2017 [EUR]	Final consumption of households [millions of US$] PPS of 2017	Share of consumption of households on transport [%] 2016
	2017 [mUS$] at prices and PPPs of 2017	Growth 2017/2019 [%]			
Armenia	31 428	34.0	96 062 388*	22 480	na
Austria	458 300	38.5	1 969 000 000*	237 654	11.9
Belarus	176 325	16.5	na	96 578	na
Bosnia and Herzegovina	55 118	27.2	na	35 821	na
Bulgaria	142 800	25.2	554 248 901*	89 036	14.0
Croatia	106 019	18.5	259 096 511	60 950	13.8
Czechia	372 493	34.4	1 557 020 876	188 446	9.8
Estonia	42 329	62.6	211 000 000	21 581	11.3
Georgia	44 702	55.7	355 019 768	23 980	na
Greece	310 501	-16.1	4 328 334 821	202 698	13.5
Hungary	260 558	31.2	1 838 262 374	135 936	12.4
Latvia	55 036	49.9	248 000 000	31 988	11.7
Lithuania	91 427	56.7	394 000 000	58 347	15.1
North Macedonia	36 239	32.0	na	20 676	
Poland	1 090 585	47.3	3 719 897 564	654 353	12.1
Romania	532 017	47.5	2 865 814 554*	324 519	11.4
Russian Federation	na	Na	11 854 391 389	na	na
Serbia	12 2981	18.2	771 532 574	80 349	na
Slovakia	170 615	35.4	982 022 000	96 436	7.5
Slovenia	67 443	22.6	220 000 000	38 705	15.9
Turkey	na	na	7 871 354 394	na	na

*2016

Sources: UNECE Statistical Database https://w3.unece.org [access 12 October 2019]; https://appsso.eurostat.ec.europa.eu [access 3 October 2019]; EC Transport in figures. Statistical Pocketbooks 2011-2018 [access 3 October 2019].

The information in the table above shows that there is a strong correlation between expenditure on financing transport infrastructure investments and the level of budget revenues and GDP. At this level of development of States and regions, infrastructure is a necessary but not sufficient condition for creating stable economic growth. In addition, these regions use widely used and easily available technologies.

Infrastructure investments are conducive to short-term employment growth, contributing to the improvement of the residents' quality of life and an increase well-being. In the long run, however, it is necessary to focus on an investment-driven economy that is conducive to improving productivity and efficiency. In particular, these investments should promote the creation of a knowledge economy which requires significant expenditure on research and development. An excessive focus on infrastructure investments, especially in States with a low GDP level, may cause a long-term reduction of the development possibilities of the economy. Therefore, it is preferable to apply non-budgetary sources of financing to finance high-speed lines. This does not mean that national governments should not directly participate in financing the construction of high-speed lines. The scope of budget financing should, however, consider other investment needs, including improvement of the economy's innovativeness.

In all the States analysed as part of this study, it is therefore necessary to use different sources of capital for HSR investment. For instance, the low-income States will need to be provided with grant funding. This approach is not only an expression of social solidarity, but it is equally important for the sustainable development of the whole of Europe. Nowadays, the existing disproportions in the level of development of States and regions constitute a barrier to harmonious development, posing a threat to the creation of a high level of competitiveness in Europe.

4.1.4 Funding versus financing

Infrastructure projects may be:

- **Funded**, implying that funds are not expected to be recovered
- **Financed**, mostly by private sources, and in this case capital recovery is expected.

A predominant portion of world transport infrastructure is public or heavily impacted by the public sector. This encompasses various forms of involvement, from direct ownership and management, to a regulatory framework that defines operational and safety standards.

Transportation infrastructure was previously considered to be a public good, which was not operating or being managed by market forces. Transportation infrastructure was placed under the management of public authorities. The advent of PPPs has allowed for private finance to be introduced into the railways.

4.2 Public funds for HSR

4.2.1 Categories of public funds

There are two main categories of public funds used for HSR:

a) Accumulated public funds;

b) Government borrowing.

Accumulated funds are broadly derived from consolidated tax revenue, or infrastructure levies, while public sector borrowing includes general bonds, infrastructure bonds, infrastructure revenue bonds, or public trading enterprise borrowing. The most common form of public sector borrowing is by issuing long-term bonds. There are multiple types of issuing government bonds.[77, 78]

A traditional way of financing infrastructure investment is based on the usage of national budget funds. However, due to the widespread limitation of these resources, they are also funded by regional and possibly local governments. In principle, in both cases these funds come from: taxes, fees, revenues, borrowing, and printing money.

The same is true for EU grants and funds from international financing institutions (IFIs) such as: EBRD, EIB and other funds. In further assessment we have separated budget funding from EU, IFIs, and other sources.

A completely different category but related to public funds are various forms of joint public-private initiatives. In this case they are funded/financed jointly by private and public sectors under sophisticated legal arrangements. They are also addressed separately further in this chapter.

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[77] D. Dutzik, J. Scheider, and P. Baxandall, *High-Speed Rail: Public, private or both? Assessing the Promise, Prospects and Pitfalls of Public-Private Partnerships*, US PIRG Education Fund 2011.

[78] L. Henn, K. Sloan, and N. Douglas, *European case study on the Financing of High Speed Rail*, "Australasian Transport Research Forum 2013 Proceedings, 2-4 October 2013", Brisbane, Australia 2013, http://www.patrec.org/atrf.aspx.

4.2.2 Full public funding

A model of **full public financing** entails government financing total capital costs and assuming the role of long-term developer and owner. This has been the most popular model for raising HSR capital to date. Public financing can be direct or through a combination of direct government support and finance by national railway companies.[79] As an example, in the beginning of its development, most European and Japanese high-speed railways were built using this form of funding.

In some cases, the regions were also involved in the financing of construction of HSRs. The development of new high-speed lines which is followed by including a region in its network, has a crucial role for the territory and constitutes an added value to public spending.

As an example, the HS2 line is built using full public funding in the United Kingdom of Great Britain and Ireland. The full public funding model is also used in China (30,000 high-speed lines have been built so far), although one of the last lines built in this country uses PPP financing. High-speed lines will be/are built using full public funding in Turkey and in Russian Federation, but a PPP model is foreseen for some projects.

4.2.3 EU matching funds (national budgets)

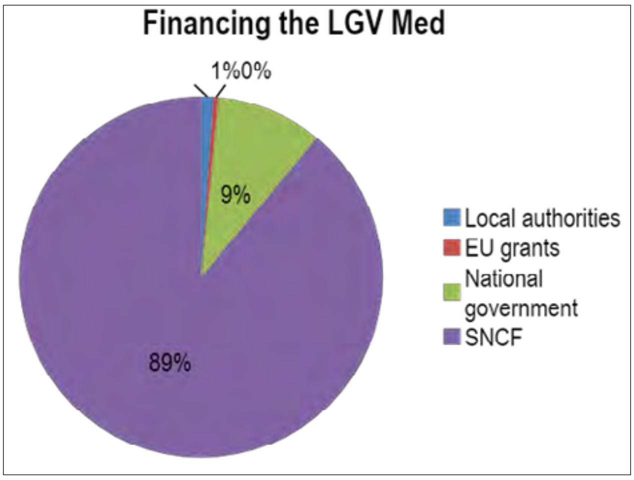
The beneficiary of EU funds must match these funds with domestic funds when using these funds for investment. Matching funds may be raised by bond financing, loans obtained from commercial banks, loans from IFIs, capital within the framework of public-private partnerships.

As a principle infrastructure is funded by national budgets. The development of new high-speed lines more often uses regional funding. Including a region where the HSR network has a crucial role for that region and constitutes an added value to its citizens and economic development. Therefore, regions more often seek to participate in funding HSR projects.

Examples of the structure of financing high-speed lines, including regions in France, are presented in figures IV-21 and IV-22. The financial support of the regions was also important in the construction of two further high-speed extensions of LGV Atlantique to Bordeaux and Rennes. However, those lines have been financed on a public-private partnership basis.

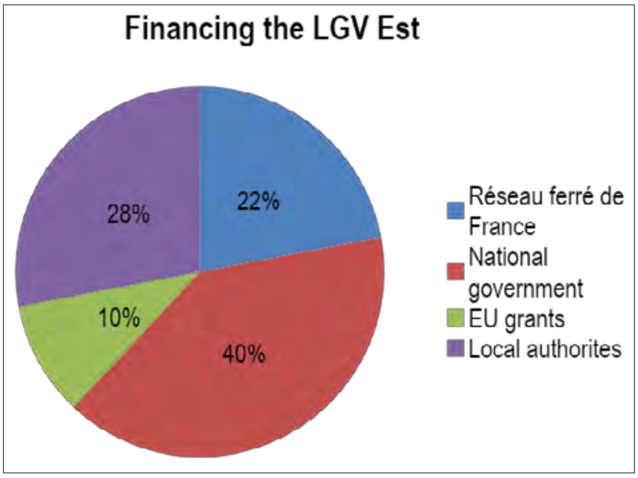
[79] L. Henn, K. Sloan, and N. Douglas, "European case study on the Financing of High Speed Rail", op. cit.

Figure IV–20 Funding HSR LGV Med. by source of funds (2001)



Source: L. Henn, K. Sloan, N. Douglas, European case study on the Financing of High-Speed Rail, Australasian Transport Research Forum 2013 Proceedings, 2-4 October 2013, Brisbane, Australia, http://www.patrec.org/atrf.aspx.

Figure IV–21 Funding HSR LGV Est., by source of funds (2008)



Source: L. Henn, K. Sloan, N. Douglas, European case study on the Financing of High-Speed Rail, Australasian Transport Research Forum 2013 Proceedings, 2-4 October 2013, Brisbane, Australia, http://www.patrec.org/atrf.aspx.

4.3 Funding from the EU sources

4.3.1 General remarks and needs for new funding rules

EU funds are the main source of assistance in funding railway infrastructure in Europe. These funds are also available to the pre-accession and the EU neighbouring States whose socioeconomic development is in the interest of the Member States of the Union. The initial analysis presented below focused on options for assigning the European Union funds to HSR focused on the period after 2020. This is because the majority, and in practical terms all funds for the 2014-2020 EU budget have already been allocated under the existing allocation schemes. HSR stakeholders have stated that there is an urgent need to improve the funding and financing system by developing schemes consistent with the character and specificity of HSR investments. The reforms must ensure a stable and logical support to the system of the HSR across Europe and not fragmented through national projects.

The EU funds are increasingly important in financing infrastructure investments in Europe. This applies in particular to the new Member States of the European Union, whose accession took place in 2004, 2007 and in 2013 – a total of 13 States that also belong to the TER area. In these States, the level of transport infrastructure development is much lower than in the EU-15 States. In an effort to level out development disparities, the European Union funds support the construction and modernization of infrastructure, including rail investments. The European Regional Development Fund and Cohesion Fund play a particularly important role in financing.

The list of funds in the 2007-2013 and 2014-2020 budget perspectives is presented in table IV-10. They show that in the 2008-2013 period their value amounted to €259 billion and in the years 2014-2020 it will amount to €632 billion. They are currently the largest sources of financial support in the world. Their significance is even greater, considering that the projects financed from them must still have local additional financial support, as a result of which the total value of implemented projects is even higher.

Table IV–11 **Distribution of the EU funds in 2007-2013 and 2014-2020 among the EU-28 member States by individual funds [million EUR]**

Community States	Financial perspective												
	2007-2013					2014-2020							
	EFRR	EFS	FS	Total	Share [%]	EFRR	EFS	FS	EFRROW	EFMR	YEI	Total	Share [%]
Austria	9 362.75	498.19	0.00	9 860.94	3.80	2 073.00	876.00	0.00	7 698.00	14.00	0.00	10 661.00	1.69
Belgium	869.21	828.89	0.00	1 698.09	0.65	2 331.00	2 174.00	0.00	1 326.00	69.00	189.00	6 089.00	0.96
Bulgaria	2 073.20	969.53	1 324.95	4 367.67	1.68	4 179.00	1 721.00	2 680.00	2 912.00	114.00	120.00	11 726.00	1.85
Croatia	186.37	44.00	145.33	375.70	0.14	5 084.00	1 664.00	2 953.00	2 383.00	344.00	220.00	12 649.00	2.00
Cyprus	246.49	108.29	161.31	516.10	0.20	353.00	134.00	347.00	243.00	53.00	39.00	1 170.00	0.19
Czechia	8 682.99	2 449.03	5 347.33	16 479.35	6.34	17 421.00	4 203.00	7 228.00	3 771.00	41.00	30.00	32 693.00	5.17
Denmark	205.72	205.98	0.00	411.71	0.16	399.00	411.00	0.00	1 199.00	308.00	0.00	2 317.00	0.37
Estonia	1 680.95	371.94	1 089.66	3 142.56	1.21	2 459.00	682.00	1 515.00	994.00	129.00	0.00	5 779.00	0.91
Finland	856.01	567.33	0.00	1 423.34	0.55	1 584.00	1 037.00	0.00	5 674.00	141.00	0.00	8 435.00	1.33
France	5 661.32	4 101.01	0.00	9 762.33	3.76	17 566.00	9 810.00	0.00	16 675.00	774.00	1 118.00	45 943.00	7.27
Germany	13 231.40	7 980.94	0.00	21 212.34	8.17	17 717.00	12 540.00	0.00	14 122.00	286.00	0.00	44 665.00	7.06
Greece	13 231.40	7 980.74	0.00	17 841.67	6.87	10 971.00	5 039.00	3 842.00	5 832.00	521.00	574.00	26 780.00	4.24
Hungary	9 640.92	2 664.73	6 130.62	18 436.27	7.10	12 612.00	5 611.00	7 089.00	4 177.00	52.00	108.00	29 650.00	4.69
Ireland	311.75	286.84	0.00	598.60	0.23	822.00	953.00	0.00	3 922.00	239.00	204.00	6 140.00	0.97
Italy	12 302.20	5 405.15	0.00	17 707.35	6.82	33 519.00	17 465.00	0.00	20 913.00	979.00	2 288.00	75 165.00	11.89
Latvia	1 908.96	430.49	1 103.14	3 442.59	1.33	2 825.00	717.00	1 588.00	1 532.00	183.00	63.00	6 907.00	1.09
Lithuania	3 183.61	976.89	2 189.97	6 350.48	2.44	4 119.00	1 289.00	2 410.00	2 028.00	82.00	69.00	9 997.00	1.58
Luxemburg	21.38	20.93	0.00	42.32	0.02	48.00	40.00	0.00	368.00	0.00	0.00	456.00	0.07
Malta	331.47	77.76	207.28	616.51	0.24	477.00	132.00	256.00	130.00	29.00	0.00	1 024.00	0.16
Netherlands	696.88	641.68	0.00	1 338.57	0.52	1 372.00	1 031.00	0.00	1 271.00	129.00	0.00	3 803.00	0.60

Table IV–11 Distribution of the EU funds in 2007-2013 and 2014-2020 among the EU-28 member States by individual funds [million EUR] (continued)

Community States	Financial perspective												
	2007-2013					2014-2020							
	EFRR	EFS	FS	Total	Share [%]	EFRR	EFS	FS	EFRROW	EFMR	YEI	Total	Share [%]
Poland	30 590.30	8 728.09	17 958.43	57 276.81	22.05	47 502.00	15 203.00	27 304.00	13 612.00	711.00	585.00	104 916.00	16.59
Portugal	10 497.90	6 507.58	2 818.91	19 824.39	7.63	14 899.00	8 817.00	3 367.00	4 972.00	508.00	486.00	33 048.00	5.23
Romania	5 156.21	1 628.19	3 946.89	10 731.29	4.13	12 952.00	5 434.00	8 159.00	9 645.00	223.00	329.00	36 742.00	5.81
Slovakia	3 349.50	1 032.67	2 244.59	6 626.76	2.55	9 700.00	2 461.00	5 010.00	2 099.00	21.00	228.00	19 520.00	3.09
Slovenia	1 777.26	667.25	906.86	3 351.37	1.29	1 824.00	898.00	1 075.00	1 107.00	33.00	21.00	4 958.00	0.78
Spain	16 567.89	5 409.97	3 222.01	25 199.87	9.70	29 267.00	10 246.00	0.00	12 278.00	1 558.00	2 964.00	56 313.00	8.91
Sweden	839.79	621.84	0.00	1 461.64	0.56	1 896.00	1 440.00	0.00	4 411.00	173.00	132.00	8 053.00	1.27
United Kingdom	4 071.49	3 150.46	0.00	7 221.95	2.78	10 339.00	8 692.00	0.00	6 775.00	310.00	578.00	26 695.00	4.22
Total	147 069.95	60 444.84	52 255.78	259 770.56	100.00	266 310.00	120 720.00	74 823.00	152 069.00	8 024.00	10 345.00	632 294.00	100.00

Source: Own study based on https://cohesiondata.ec.europa.eu/overview [access 11 August 2019].

The new rules for the EU transport spending should guarantee that taxpayers' money go towards sustainable projects and are distributed by logical and effective funding schemes. The discussions on new rules for the EU transport spending are ongoing. They will be concluded during 2020, before the new EU budget is approved. There is a tendency to insist that only projects which protect the environment and biodiversity while delivering measurable steps towards a low-carbon, climate-resilient and resource-efficient economy should be supported. It has been advocated that the rules on the EU transport funds ensure that cleaner projects are prioritized. Although, this direction is in principle justified, there are many other factors which must be considered to build logically constructed the EU transport systems (including the HSR).

Up to 2013, the rules for spending the EU funds on transport projects did not encourage sustainable and greener projects. They failed to properly consider the resulting impacts on emissions of greenhouse gases, air pollutants, noise, land use, habitats and biodiversity. There was no real incentive to ensure sustainable finance, in the meaning that that it would support sustainable projects. It was often argued that because the loan's share of the TEN-T (Trans-European Transport Network) budget was earmarked for rail projects, that would be enough to ensure the sustainability of transport investments. This assumption is wrong. It resulted in spending from cohesion funds being concentrated on the road sector. Also, a systemic approach to building the EU transport infrastructure did not exist. As a result, much of the €13 bn that the EU spent on transport annually (ca. € 1bn per year from the TEN-T budget and €12 bn per year from cohesion funds for poorer regions) was assigned to environmentally questionable projects such as regional airport developments or extensive network of roads that were needed for connectivity. Almost 50 per cent of the EU investment in transport projects went to roads and aviation.

The EU pledged to spend at least 20 per cent of the approximately €1 trillion budget for 2014-2020 on climate protection and adaptation goals. It is still unclear how this may be accomplished. Plus, it is impossible to decipher from the current data and information, how transport spending will be structured.

In the existing EU spending legislation and other rules and guidelines, there are indicative (very long) lists of projects annexed to the TEN-T Guidelines and CEF regulation. These lists were pre-negotiated between the Commission and national governments and indicate national political priorities. The lists were subsequently expanded by member States during a political process and argument with an objective to maximize the EU funds for their constituencies. Although being on the priority list is no guarantee of receiving funds, but projects which are not in the list will not be eligible for funding at all.

4.3.2 EU Investment Plan 2014

The EU Infrastructure Investment Plan creates a framework establishing the scope of possible reforms of funding and financing of EU infrastructure, including on HSR. For all practical purposes, any proposals for improving the EU system for HSR investments funding and financing must be in accord with the EU Infrastructure Investment Plan. Obviously other concepts may also be developed but applying them in reality may be much more difficult.

4.3.3 The EU Multi-annual Financial Framework 2021-2027

The European Commission has put forward ambitious yet realistic proposals for a modern EU budget which reflects rapid developments in innovation, the economy, the environment and geopolitics, amongst others. The Commission is putting forward modern, clearer and simpler EU financial rules that ensure the EU budget delivers on the issues that matter to Europeans.[80] Multiannual Financial Framework 2021–2027 is presented in document COM/2018/321 final.[81]

The Multiannual Financial Framework for 2021-2027 has several instruments and funds planned to co-finance infrastructure investments. These include in particular:

- InvestEU
- Connecting Europe Facility
- European Regional Development Fund and Cohesion Fund.

4.3.4 The InvestEU

The InvestEU Fund is the Union's new investment instrument. It provides an EU guarantee with a view to mobilising public and private financing in the form of loans, guarantees, equity or other market-based instruments, for strategic investments in support of EU internal policies. It builds on the successful implementation during the current period 2014-2020 of the European Fund for Strategic Investments and other financial instruments. The InvestEU Fund aims at mobilising investment within the EU to support political priorities and to contribute to the integration of European capital markets and the strengthening of the Single Market. It will target many different investment areas including promoting sustainable infrastructure.

80 *EU budget for the future*: https://ec.europa.eu/commission/priorities/democratic-change/future-europe/eu-budget-future_en, n.d.

81 *Communication from the Commission to the European Parliament, the Council, the European Central Bank, the European Economic and Social Committee, the Committee of the Regions, and the European Investment Bank An Investment Plan for Europe*., op. cit.

Table IV–12 Proposed budget allocation for 2021-2027, current prices, in millions of €

Subject	Budgetary guarantee	Mobilised investment (estimates)
Sustainable infrastructure	11 500	185 000
Research and innovation	11 250	200 000
Social investment and skills	4 000	50 000
Small and Medium-sized enterprises	11 250	215 000
Total	38 000	650 000

Source: Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions *A Modern Budget for a Union that Protects, Empowers and Defends the Multiannual Financial Framework for 2021-2027*, COM/2018/321 final.

4.3.5 The Connecting Europe Facility

The Connecting Europe Facility supports investment in cross-border infrastructures in the transport, energy and digital sectors. At the core of the Single Market lies the guarantee that goods, capital, services and labour can freely move from one member State to the other. However, gaps still exist between member States and regions which fragment the EU and impede the smooth functioning of the Single Market as have been identified in earlier chapters in relation to some TER States.

The Facility is designed to foster investment in the trans-European networks. The Facility also provides the opportunity to deploy technologies developed at the EU level and in particular through the EU Research and Innovation Framework Programmes, boosting their market uptake and ensuring that the trans-European networks use the most advanced available equipment.

The Connecting Europe Facility supports investment and cooperation to develop infrastructure in the transport, energy and digital sectors and connects the EU and its regions. It further aligns with the policy objectives of decarbonisation and digitisation of the European economy. This means for transport it aims at completing both layers of the European network for all transport modes: the strategic backbone (i.e. the core network) by 2030 and its more extensive layer (i.e. the comprehensive network) by 2050. It also supports the deployment of European traffic management systems for air transport and railways, and helps the EU transition towards connected, sustainable, inclusive, safe and secure mobility. It contributes to the decarbonisation of transport, for example by constituting a European network of charging infrastructure and for alternative fuels or prioritisation of environmentally friendly transport modes.

Trans-European transport networks projects will continue to be financed from the Cohesion Fund via both shared management and the direct implementation mode under the Connecting Europe Facility. €11 billion of the Cohesion Fund will be transferred to the Connecting Europe Facility for this purpose. Synergies will be ensured with the LIFE programme for Environmental and Climate Action, in particular through LIFE strategic integrated projects, to optimise the uptake of funds supporting environmental investments.

4.3.6 The EU Structural and Investment Funds

European Structural and Investment Funds also complement each other to deliver on infrastructure investment. For instance, in the transport sector, the Facility concentrates on the trans-European network, notably on the cross-border corridors, while the European Regional Development Fund and Cohesion Fund will prioritise transport projects with a national, regional and urban focus. The programme can support the deployment of innovative technologies developed within **Horizon Europe** whilst the latter support upstream technology development. Building on the positive experience in the current period, a contribution from the Cohesion Fund will be made available to the Transport strand, in direct management. In addition, funding from the Defence cluster will be made available to the Transport strand as well to ensure that transport infrastructures of strategic importance are suitable for military mobility needs.

Table IV–13 Proposed budget allocation for 2021-2027

Figures in current prices	EUR million
Total envelope for 2021-2027	42 265
Digital	3 000
Energy	8 650
Transport	30 615
of which:	
General envelope	12 830
Contribution from Cohesion Fund	11 285
Support for Military Mobility	6 500

Source: Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions *A Modern Budget for a Union that Protects, Empowers and Defends The Multiannual Financial Framework for 2021-2027*, COM/2018/321 final.

4.3.7 The European Regional Development Fund and Cohesion Fund

The European Regional Development Fund (ERDF) and the Cohesion Fund (CF) support the economic, social and territorial cohesion of the European Union. They contribute to reducing disparities that still exist between European regions and States. In particular, the ERDF contributes to structural adjustment and economic transition, while the CF focuses on investments in environment and transport infrastructure. Together with the European Social Fund, they form the funding sources for the European Union's cohesion policy.

Economic and social disparities vary significantly between EU regions and hamper the harmonious development of the Union. On the basis of Article 174 of the Treaty on the Functioning of the European Union, the Union aims to reduce disparities between the levels of development of its regions and to support the development of the least favoured regions. Cohesion policy is both an expression of solidarity among Europeans, and the main investment policy of the EU. Fostering economic convergence for the least developed regions through the ERDF and the CF strengthens the Single Market and creates opportunities for workers, consumers and companies across the whole Union.

The ERDF and the CF support development by co-financing investment in research and innovation; climate change and environment; business support to small businesses; services of general economic interest; telecommunications, energy and transport infrastructure; health, education, culture and social infrastructure; sustainable urban development and smart villages. Evidence exists that only limited parts of these investments would happen without the two Funds, even in more developed member States and regions. In addition, they would not benefit from the framework that is put in place for the Funds, including multiannual programming, the partnership principle and the establishment of smart specialisation strategies.

The ERDF also provides funding for a high-profile element of European added value – the INTERREG programmes, which support cross-border, transnational and interregional co-operation across Europe and enable member States and regions to work together across borders to address common challenges.

It is anticipated that the **European Regional Development Fund and Cohesion Fund** over the 2021-2027 period, will help member States reduce their economic, social and territorial disparities thanks to interventions focused on five objectives:

- **A smarter Europe**: to promote competitiveness, digital transformation, entrepreneurship and innovation (including inclusive growth and social enterprises), and enhance the business environment as a part of industrial adaptation to the challenges of globalisation, circular economy and climate change;
- **A greener carbon free Europe: clean and fair energy transition**, to enhance energy efficiency; to support transition to low-carbon economy; to stimulate renewable energy; to support innovative use of low-carbon technologies, to support green and blue investment, including in sustainable natural resource management, circular economy, climate adaptation and mitigation;
- **A more connected Europe: mobility, energy and regional ICT connectivity** to develop regional networks and systems to promote sustainable transport, smart energy grids and high-speed digital access in order to enhance regional, local and cross-border connectivity, including security;
- **A more social Europe: implementing the principles of the European Pillar of Social Rights**, in particular life-long learning, education and training infrastructure as well as health, culture and social infrastructure;
- **A Europe closer to citizens: sustainable and integrated development**, through local initiatives to foster growth and socioeconomic local development of urban, rural and coastal areas.

The Funds are implemented in partnership with the Member States and their regions through shared management. These partnerships involve a strong mobilisation of national, regional and local stakeholders, as well as civil society. This ensures ownership of objectives and achievements and brings Europe closer to its citizens. They also contribute to the strengthening of national, regional and local administrations.

4.3.8 Procedural improvements

It is anticipated that a simplified and more effective approach to delivery will be a key element of the proposed new Regulations with the following changes as from 2021:

- Reduced administrative burden through synergies and the alignment of implementing rules across funds, increased cross reliance on audits and the possibility to roll-over existing management and control systems;
- Differentiated implementation via lighter management and control systems for programmes with good track records;
- Flexibility in the form of a mid-term review to adjust, if necessary, the priorities of the last programming years to address emerging priorities, take stock of progress in addressing investment-related guidance issued alongside the Country-Specific Recommendations and performance;
- Increased use of financial instruments including through a voluntary participation in the new InvestEU Fund;
- A focus on results rather than costs.

Higher national co-financing will help increase ownership on the ground as well as the impact of the policy. A more stable and predictable payment profile over the period are expected to be achieved. Considering the importance of commitments remaining to be paid out from the 2014-2020 period, the pre-financing rate will be lowered. Reintroducing the n+2 rule will also lead to better financial management and a faster start to the programming period.

In order to maximise the impact of cohesion policy, physical investments need to be accompanied by soft measures, including upskilling of the labour force. To this end, programmes may combine the European Social Fund+, ERDF and CF support.

Allocation of funds. The relative per capita gross domestic product will remain the predominant criterion for the allocation of funds, while other factors such as unemployment, climate change and the reception/integration of migrants will also be considered.

Funds management. There will be common rules for all shared management funds (the Common Provisions Regulation) which will cover the following funds: the ERF, the CF; the European Social Fund+, the European Agricultural Fund for Rural Development, the European Maritime and Fisheries Fund, the Asylum and Migration Fund, the Internal Security Fund and the Integrated Border Management Fund. This will create a convergence of rules that will enhance coherence and synergies among these Funds.

The ERDF and the CF will be more closely aligned with the **European Semester of economic policy coordination**, which will also reinforce its regional dimension. Through the European Semester process the Commission and the Member States (notably through their National Reform Programmes) will ensure coordination and complementarity of financing from cohesion policy funds and the new **Reform Support Programme** with regard to the support to structural reforms.

The **Trans-European transport networks projects** will continue to be financed from the CF via both shared management and the direct implementation mode under the **Connecting Europe Facility (CEF)**. €11 billion of the CF will be transferred to the CEF for this purpose.

Cohesion policy will increase its concentration on innovation. Complementarities with the **Erasmus+** and the **Horizon Europe** will also be reinforced through an alignment of relevant rules, a reinforcement of the "seal of excellence" mechanisms and a dedicated ex-ante conditionality. Further development of the smart specialisation strategy concept will continue.

Table IV–14 Proposed budget allocation for 2021-2027

Figures in current prices	EUR million
Total envelope for 2021-2027	273 000
of which:	
European Regional Development Fund	226 308
of which:	
Investment for growth and jobs	215 172
European territorial cooperation	9 500
Outermost regions and sparsely populated areas	1 637
Cohesion Fund	46 692
of which contribution to CEF Transport	11 285

Source: Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions *A Modern Budget for a Union that Protects, Empowers and Defends the Multiannual Financial Framework for 2021-2027*, COM/2018/321 final.

4.3.9 Conclusions

Grants alone cannot address the significant investment gaps. They can be efficiently complemented by financial instruments, which have a leverage effect and are closer to the market. On a voluntary basis, Member States will be able to transfer a part of their Cohesion Policy resources to the new, centrally managed **InvestEU fund**, to access the guarantee provided by the EU budget. Combining grants and financial instruments is made easier and the new framework also includes special provisions to attract more private capital.

The financing from the European structural funds will continue to be important. The forecasted funds for the implementation of infrastructure transport investments in the Multiannual Financial Framework for 2021-2027 may be insufficient for the implementation of all investment programs. The potential support from the EU funds and instruments will have to be supplemented with national funds. Considering the presented assessment of budget revenues and expenses, it can be assumed that in many TER States it will be necessary to look for extra-budgetary means for financing investments, including those related to the construction of high-speed railway lines. In particular, it will be necessary to use private capital but also the capital market financial instruments should also be an important source of financing.

The use of private capital and funds obtained on the financial market will require guaranteeing an adequate level of revenues for the infrastructure manager. They will come from both infrastructure access charges and budget subsidies. In total, these two sources should ensure a sufficient level of funds for maintaining infrastructure in technical efficiency as well as related to the operation of financial instruments obtained to cover investment outlays (loan repayment, redemption of bonds, etc.). In case of use of private capital as part of a public-private partnership, it will also be necessary to ensure its adequate return.

The cost estimation for the implementation of the necessary investments and the subsequent costs of line operation and maintenance was made in Part IV-1.1.

4.4 Funding for non-EU States

4.4.1 Instrument for Pre-Accession Assistance

The Instrument for Pre-accession Assistance supports candidate States and potential candidates on their path to fulfilling the accession criteria. It is positioned in the context of the Western Balkans Strategy and reflects the developments in the relations with Turkey.

Supporting the enlargement of the EU is by its very nature a task best pursued at EU level. Granting pre-accession assistance under one single instrument on the basis of a single set of criteria is more efficient than granting assistance from multiple sources – including the national budgets of the Member States – following different procedures and priorities. In addition, the EU's political influence and leverage allows it to engage national authorities with greater authority and legal certainty than individual Member States. The Instrument complements the enlargement policy of the Union by supporting political and economic reforms, including as regards EU values and the respect for the rule of law and the proper functioning of institutions ensuring sound financial management in candidate States/potential candidates and is used proactively to advance negotiations with beneficiary governments towards fulfilling the Copenhagen criteria, as well as the conditionality of the Stabilisation and Association Agreements.

The Instrument for Pre-accession Assistance contributes to the broader European objectives of ensuring stability, security and prosperity in the immediate neighbourhood of the Union. Proximity between Member States and beneficiaries and the corresponding need for coordination also ensures that support given to beneficiaries helps the EU to reach its own objectives in terms of sustainable economic growth, migration, security, energy supply, transport, the environment and climate change.

The instrument will be shaped around the following key priorities: Rule of Law, fundamental rights and migration – this will include strengthening security cooperation, the fight against radicalisation and against organised crime, as well as supporting an integrated migration policy including border management; the EU policies and acquis; Socio-Economic development; Investments for growth; Reconciliation, good neighbourly relations and Regional and cross-border cooperation. These objectives follow on from those pursued under the predecessor programme. Proposed budget allocation for 2021-2027 is €14,500 million.

4.4.2 Eastern Partnership

In order to improve the connectivity and contribute to economic growth in the States of Eastern Partnership (EaP),[82] the European Commission and the World Bank have prepared an investment program focusing on railway networks, as well as defines the priorities in Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine. In addition, in the program framework, there are investments in 4,800 km railway lines, six ports and 11 logistic centres.

In a wider context, the EaP also supports delivery on key global policy goals set by the UN 2030 Sustainable Development Goals and the Paris Agreement on Climate Change.

The overall framework guiding relations between the EU and its six Eastern Partners is provided by the relevant bilateral agreements, such as the Association Agreements, as well as the Association Agendas and the Partnership Priorities and the EaP 20 Deliverables for 2020 aligned along the four key priority areas.

Furthermore, there are two types of priority projects: short-term which have to be finalized until 2020 and long-term project which aim the improvement of transport connections until 2030.

To ensure a broadly streamlined approach, the new multi-annual assistance frameworks for the period 2017/2018-2020 are being designed in an inclusive manner between the EU, its Member States and the six Partner States to act as a work plans guiding the actions until 2020, supporting delivering under existing commitments, and allowing for an easier monitoring of progress. Supporting the comprehensive approach by the EU towards its Eastern partners is the European Neighbourhood Instrument, which is the key EU financial instrument for cooperation with the EaP States during the period of 2014-2020. After 10 years of close cooperation, the joint work of all partners is not finished. A broad and inclusive structured consultation process to reflect on the future strategic direction of the Eastern Partnership and a new – post 2020 – generation of deliverables is now open. Currently no high-speed projects financed from these funds.

4.5 Funding/Financing by IFIs

4.5.1 International Finance Institutions (IFIs) involved in EU projects funding

The European Bank for Reconstruction and Development, the EIB and the World Bank are particularly important in granting loans for financing infrastructure investments because of their preferential terms.

[82] *Eastern Partnership (EaP) Summit Brussels*, November 2017.

The European Bank for Reconstruction and Development. The projects that are being implemented contribute to the creation of an open market economy, while supporting sustainable and inclusive growth. The EBRD offers loans, guarantees, equity investment and advisory services. The most suitable tool will depend on the objectives of the project and on various other factors. The bank supports projects that make a significant contribution to sustainable growth and employment in Europe and beyond.

The European Investment Bank. The EIB provide loans starting from €25 mln to public sector entities to finance a single large investment project or investment programme, aligned with one or more priorities of the EIB. Flexible loans to finance an investment programme which usually start from €100 mln and consist of smaller projects. The loan is arranged to have pre-defined objectives, aligned with one or more priorities of the EIB.[83] One of the EIB's instruments is the called the Project Bond Credit Enhancement aimed at investments in the TEN-T.[84]

As an example, EIB provided a loan of €400 million for the HSL Zuid project in the Netherlands.[85]

The World Bank Group is one of the world's largest sources of funding and knowledge for developing States.

The World Bank has financed some 2,600 km of high-speed rail in China to date. Building on analysis and experience gained through this work and relevant Chinese studies. Two Chinese high-speed rail (HSR) projects supported by the World Bank loans – the Nanning-Guangzhou (Nanguang) and Guiyang-Guangzhou (Guiguang) – began operations in late December 2014. The services have connected the peripheral provinces of Guangxi and Guizhou to the economically advanced province of Guangdong.

4.6 The Silk Road Fund (and associated funds)

The Silk Road Fund is a state-owned investment fund of the Chinese government to foster increased investment in States along the One Belt, One Road, which is an economic development initiative. The Chinese government pledged 40 billion US dollar for the creation of the investment fund established on 29 December 2014. Its four shareholders are: State Administration of Foreign Exchange (65 per cent), China Investment Corporation (15 per cent), Export-Import Bank of China (15 per cent) and China Development Bank (5 per cent).[86]

China has signed a cooperation document on the Belt and Road initiative with 126 States and 29 international organizations. In terms of **infrastructure construction**, China and the States along the Belt and Road have carried out effective cooperation in ports, **railways**, highways, power stations, aviation and telecommunications. **The Belt & Road Initiative (BRI)** is a development strategy announced in 2013 covering six land corridors, one maritime corridor, and more recently an Arctic "Ice Silk Road". The BRI now extends to more than 71 States; together they comprise up to 65 per cent of the world's population and make up 40 per cent of global GDP as of 2017. The BRI is evolving towards a more rigorous investment policy, including:

- More diverse projects;
- More investments in manufacturing and trade, along with softer investments in tourism and culture;
- A stronger focus on less risky regions and more profitable projects;
- Greater inclusion of local as well as international players in projects; and
- A more transparent definition of the framework of the initiative, of the rules of access to financing, and of the settlement of disputes.[87]

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83 *European Investment Bank*, n.d., https://www.eib.org/en/about/index.htm.

84 *European Investment Bank*, n.d., http://www.eib.org/en/products/blending/project-bonds/index.htm.

85 Ibid.

86 *Silk Road Fund's 1st investment makes China's words into practice*, "Xinhua News Agency", n.d.

87 *Eurobiz.cn*, n.d., https://www.eurobiz.com.cn/the-belt-road-initiative-scope-of-projects-and-financing-issues/.

The goal is to improve infrastructure access and interconnectivity between participating BRI States, making trade faster and easier, and this is being done through large-scale construction of roads, rails and port facilities. These are aimed at removing barriers and bottlenecks in core international transportation corridors and promoting connectivity of infrastructure facilities.

Access to Silk Road Funds has specific requirements and condition to fulfil.

4.7 Commercial borrowing

4.7.1 Bank loans

Bank loans are among the most flexible forms of investment financing. However, the loan is subject to the bank's decision. Such a decision is based on the borrower's creditworthiness assessment. In the case of such banks as European Bank for Reconstruction and Development, EIB or World Bank, the compliance of the project with the bank's financing objectives (e.g. sustainable development, anti-exclusion, combating poverty, etc.) is considered. The cost of credit at these banks is much lower than at commercial banks.

The cost of credit is usually the sum of Interbank Offered Rate and the bank's profit margin. Interbank Offered Rate is the rate of interest charged on short-term loans made between banks. Its amount is set for different currencies. For loans granted in EUR, EURIBOR (Euro Interbank Offer Rate) is used, and for US$, EUR, CHF, GBP, JPY – LIBOR (London Interbank Offered Rate). Currently, these rates are negative. Therefore, with low banks' profit margin, the interest rate on loans may be 0 per cent.

In the case of infrastructure investments requiring the involvement of large capital and a long loan repayment period, it is necessary to secure it. It usually takes the form of state guarantees.

4.7.2 Bond financing

Bond financing allows the borrower to access debt directly from individuals and institutions, rather than using commercial lenders as intermediaries. The issuer (the borrower) sells the bonds to the investors. The lead manager helps the issuer to market the bonds. Rating agencies will assess the riskiness of the project and assign a credit rating to the bonds which will signal to bond purchasers the attractiveness of the investment and the price they should pay.

Bond financing generally provides lower borrowing costs, if the credit rating for the project is sufficiently strong. Rating agencies may be consulted when structuring the project to maximise the credit rating for the project.

Bond financing provides a number of benefits to projects including lower interest rates, longer maturity (which can be very helpful given the duration of most of these projects) and more liquidity. Bond financing has seen limited usage for initial project financing, but is commonly used for refinancing, once construction risks have been largely mitigated.

The *project bond* initiative would support the financing of specific projects in the area of transport, energy and communications infrastructure, that can help lay the foundations for sustainable future growth and employment.

Projects will need to meet basic standards of bankability for project finance transactions, including:

- An appropriate allocation of risks between the private and public sector that is consistent with international best practice;
- An adequate investment, legal and regulatory framework, including strong and respected contractual and property rights, minimal appropriation risk, predictable government policy and regulation; and
- A revenue stream that can be forecasted with some degree of accuracy and, to the extent comprised of government payments, is backed by credit-worthy entities.

Private sector bonds, frequently called corporate bonds, are bonds that companies issue to investors to raise funds for projects. Both public and private companies issue private sector bonds. For investors, private sector bonds vary widely in their characteristics, such as their credit ratings, maturities and yields.

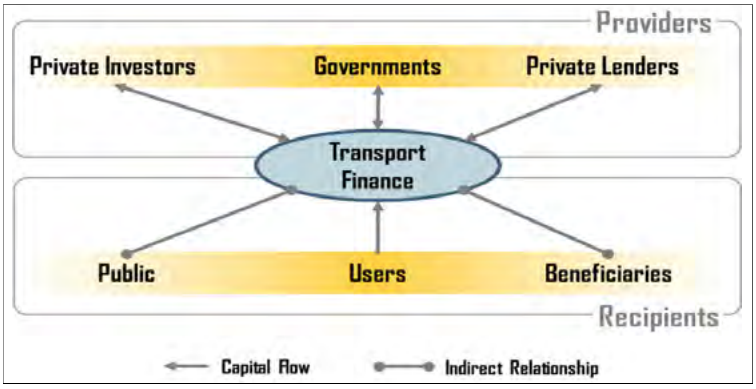
4.8 Private financing

4.8.1 When private funds can necessary

Contemporary transportation infrastructure financing is facing the following challenges:

- **Lack of funding**. Transport funding initiatives are generally **not sufficient for maintaining and improving the performance** of transport systems. This was a major driver behind privatization and deregulation in the passenger and freight transport industries worldwide. The infrastructure financing model is gaining momentum.
- **Divergence of purpose**. Transport finance initiatives should be designed to **promote productivity gains**, such as increased accessibility, capacity and performance. Many investment projects are politically instead of commercially driven, which creates a divergence in the purpose of transportation.
- **Uncertainty in outcome**. Transport finance initiatives differ in their **probable impacts on transport system performance**. This underlines the difficulty of assessing multiplying effects linked with specific infrastructure investment projects.
- **Time frame misalignment**. There is often a misalignment between the **time range of the infrastructure project** and the **time range of the financing**. This underlines the paradigm between the long-term character of infrastructure and the short-term perspective prevailing in finance.[88]

Figure IV–22 Transport finance scheme



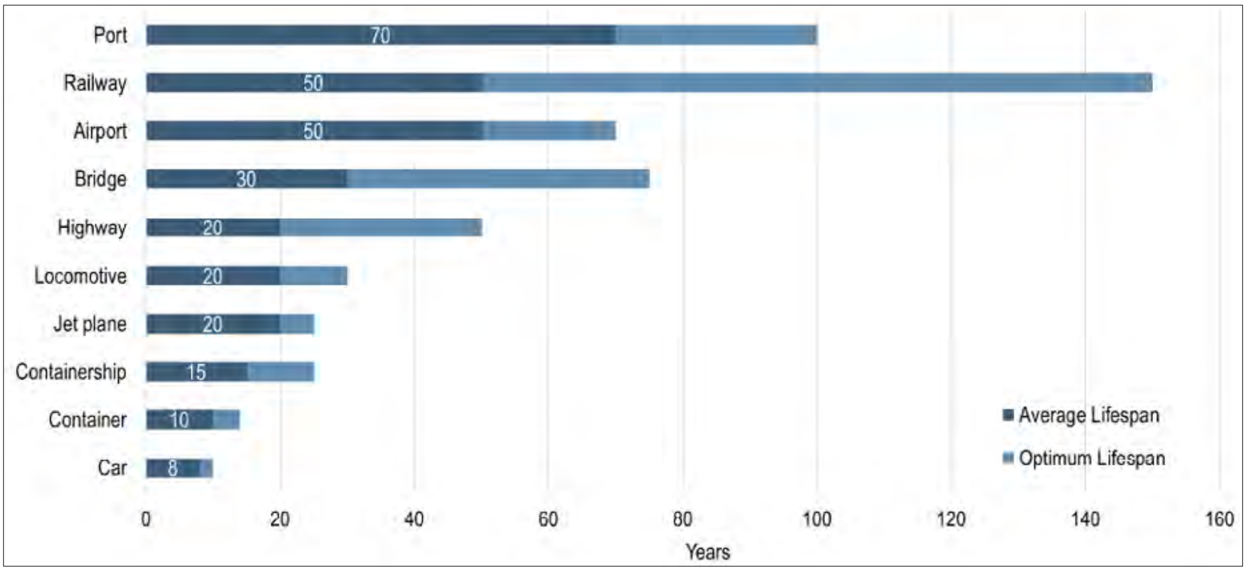
Source: JP. Rodrigue with B. Slack, C. Comtois, and others, The Financing of Transportation Infrastructure, in: The Geography of Transport Systems, e-version, https://transportgeography.org/?page_id=8689 [Access: 1 October 2019].

[88] J. Rodrigue et al., *The Financing of Transportation Infrastructure*, "The Geography of Transport Systems", n.d., p. [Accessed: 1 October 2019].

Figure IV-23 shows the lifespan expectancy of transport infrastructure assets. It shows that investments in railway have particularly long-term service life. It should be emphasized that comparing with the other transport sectors the **optimal** lifespan of railway assets reaches up to 150 years. Unfortunately, this benefit is not reflected in the **average** lifespan of the assets of the railway sector. Most of the railway infrastructure in Europe was built before the First World War.

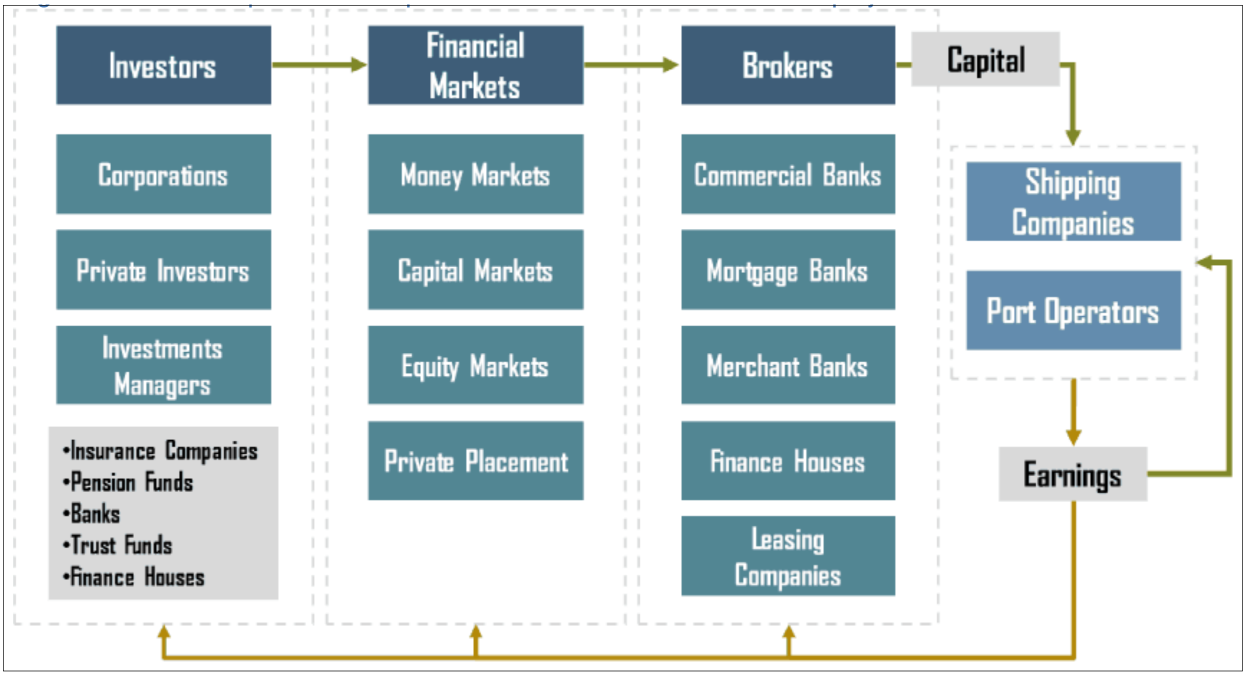
It is crucial to emphasize that in case of railway sector the **average** lifespan of assets is at the very low level. It reaches only **one third of optimum** lifespan, not the longest one, but optimal. Simple comparison with other transport sectors of such measure proves extremely low efficiency of railway assets management. These reliable data have to be treated with the highest caution as a serious warning and an indication for urgent improvements. In such circumstances hopes for financial investments in the railway sector, particularly from private investors, may prove illusory. Institutional investors will not accept such indicators with understanding.

Figure IV–23 Lifespan (Life Cycle) of Main Transport Asset



Source: JP. Rodrigue with B. Slack, C. Comtois, and others, The Financing of Transportation Infrastructure, in: The Geography of Transport Systems, e-version, https://transportgeography.org/?page_id=8689 [Access: 1 October 2019].

Figure IV–24 Participants of transport finance transactions in maritime projects



Source: Prepared based on JP. Rodrigue with B. Slack, C. Comtois, and others, The Financing of Transportation Infrastructure, in: The Geography of Transport Systems, e-version, https://transportgeography.org/?page_id=8689 [Accessed: 1 October 2019]. Adapted from Stopford, M. (1997 & 2009) Maritime Economics, 2nd & 3rd edition, London: Routledge.

4.8.2 Privatisation and Financing Models

Once privatisation is considered by a public entity, an important issue concerns which form it will take. There are several options ranging from a complete sale of the infrastructure to a management contract where the public sector retains ownership and a share of the revenues. Three forms of privatization are particularly dominant.

- **Sale or concession agreement (lease) of existing facilities**. Divesture is part of a political agenda which began with deregulation. As discussed before, budget relief is sought because of mismanagement; the public sector is essentially forced to sell or lease some of its infrastructures. For a sale, the infrastructure is transferred on a freehold basis with the requirement that it will be used for its initial purpose, unless another agreement was negotiated and in this case the outcome is an abandonment of the infrastructure. This is the case when an infrastructure is obsolete, and it is more suitable to build a new one at another more suitable site. For a concession agreement, it commonly takes the form of a long-term lease with the requirement that the concessionaire maintains, upgrade and build infrastructure and equipment.

- **Concessions for new projects**. Tap new sources of capital outside conventional public funding. It can take place in the context of fiscal restraints or as a way to experiment with a more limited form of privatization since existing assets remain untouched. It also confers the advantage of getting the latest technical and managerial expertise for the infrastructure project.

- **Management contract**. While ownership remains public, management is given to a private operator, commonly through a bidding process. This strategy has been particularly popular in the terminal operation business as many rail and maritime terminals are managed by private operators who do not own the facilities but have long term leases. The outcome commonly involves efficiency improvements and public revenue from the lease.

Concessions are a **simple and fair** strategy involving a bidding process, which underlines the importance to have it take place in a transparent and open manner. This is particularly relevant in the current context as retirement funds, sovereign wealth funds, investment banks and other financial institutions are increasingly involved in the funding of transportation infrastructure. A lack of transparency can be perceived negatively by the general public and can transform a simple transaction into a complex political process side-tracked by special interest groups. Since some concessions are set over long time periods (50-75 years), they bring the issue of **changing market conditions** that may force a renegotiation of the contract. It is next to impossible to foresee long term market changes and traffic levels, so a provision for renegotiation should be considered in concession agreements. Again, this renegotiation can be subject to controversy and public debate, particularly if performed in an un-transparent manner.

Due to their nature and function, several other forms of privatization can be established for intermodal freight terminals. Considering that intermodal terminals have an intensive use of equipment; leasing agreements are an important dimension of privatization and of the strategies of existing private infrastructure operators.

4.8.3 Conclusion on limitations of Private Capital

Even if public and private actors have established institutional and finance arrangements, many have been hard pressed to meet the demands imposed by growing volumes of passengers and freight traffic. Shifts in regional and global patterns of trade patterns associated with trade agreements and globalization have also created pressures to develop infrastructures supporting global supply chains.

A challenge resides in identifying the respective roles and competencies of the public and private sectors, which varies substantially depending on the concerned mode. Although a level of privatization is commonly perceived as a desirable outcome for the efficient use and operation of transportation infrastructures, privatization comes with limitations. In some instances, privatization can be unsuccessful. The main reasons are linked with the private contractor unable to **honour the commitments** (which is rare) or the **new cost structure** is perceived to be unfair by users since the privatized infrastructure now offers market pricing (more common). If customers are used to low and subsidized costs, they will not well respond to market prices, particularly if they are not introduced in an incremental manner. Although private initiatives commonly result in efficiency gains, private capital involves many limitations concerning capital costs and the issue of domestic versus foreign capital:

- **Capital costs**. Nominal costs for private capital are often higher than for public debt, since the latter is guaranteed by the full faith in the credit of the state. This can create a moral hazard as the capital costs and their risks are transferred to the public in terms of guarantees to cover operating costs (cross-subsidy) or bail-outs in case of default. This process is very common in a variety of public enterprises which is spite of acute losses operate on the assumption that their financial shortfalls will be covered by the state. Thus, depending on the size and capitalization of a transport operator, capital costs can be higher than for a public counterpart.

- **Domestic vs. foreign finance**. Local private capital markets can be very limited, particularly in developing States. Transportation assets are also so substantial that they are only accessible to the largest equity firms. Modern transportation infrastructure projects are easily beyond the range of local and regional governments. Finance can thus be tapped from foreign markets. Fluctuations in exchange rates can also be a significant risk factor, but if a currency is undervalued (debased), investments can pour in to take advantage of the discount to capture valuable and revenue generating assets.

4.9 Private–Public Partnerships

4.9.1 PPP in HSR projects

High Speed Rail (HSR) and Public-Private Partnerships (PPP) have been studied intensively in recent decades. There is a global trend encouraging the financing public works via PPP, but the markets do not show extensive enthusiasm towards this concept. One contributing factor in the popularity of PPP is its capability to harness the innovative capability and capital of the private sector. Many States plan to implement HSR systems in the coming decades. However, HSR implementation is consistently hampered by government budgetary deficits. The provision of HSR service requires a huge capital investment for its construction. Instead of the traditional public procurement method, PPP is increasingly practiced because it minimizes the financial deficit incurred for major infrastructure projects. Hence, PPP is a possible solution for realizing the HSR as it has been successfully implemented in other infrastructure sectors, (including Energy, Telecommunications, Transport and Water facilities).

States which have applied PPP in HSR, (e.g., France, Portugal and Spain) encounter challenges. The major challenges include drafting attractive tender documentation in the pre-contract stage and implementing contract management in the post-contract stage. The Taiwan High Speed Rail (THSR) is the first HSR project completed using a PPP scheme, namely BOT. Although operations are successfully and safely underway, the franchised company is facing financial bankruptcy due to its limited ridership and over-optimistic forecasts. Therefore it is important to understand: a) Are PPP lessons learned from general infrastructure projects applicable in HSR PPP projects?; b) What are the main differences between PPP-based HSR projects and PPP-based general infrastructure projects?; c) What factors should PPP experts consider when applying the experience obtained in general infrastructure projects to HSR.

4.9.2 PPP assumptions

The term PPP is defined as an arrangement under which a public authority grants a long-term contract (with a duration typically exceeding 20 years) to a private sector partner for the design, financing, construction or refurbishment, operation, maintenance of rail facilities and the provision of related services. The term "public authority" may include a government department or a statutory provider of transport services. Under the terms of these contracts, the private sector partner will raise private capital to pay for the new facilities, which in most cases will be repaid by a lease, rental fee, or service concession from the public authority, provided the facilities and services are made available and meet a specified outcome standard.

PPPs in rail cover capital investment in rail infrastructure, and often railway stations, that are funded using primarily commercial finance repaid over a long-term concession period.

Rail PPPs can help governments tackle development needs by bringing sustainable investment, replicable processes and expertise to complex rail systems. There are many different models of PPP in the rail sector worldwide. The challenge for governments developing rail PPPs is to ensure consistency between the project delivery strategy and programme, and the achievement of the Sustainable Development Goals (SDGs).

There are a number of examples of PPPs in the rail sector (Appendix 4). The PPP models for rail can be adapted to suit the circumstances of a particular project and desired outcome, and the benefits that can be achieved by flexible application of the model.

4.9.3 Issues related to PPP application to infrastructure projects

One of the objections to PPPs is that private sector financing costs are higher than the government's cost of debt, and hence PPPs are more expensive to finance than traditional public procurement. Thus, the argument goes, PPPs will deliver overall cost benefits only where the private sector is able to generate substantial efficiencies in operations. One means of overcoming the problems created by uncertainty around future outcomes is to build other outcome sharing mechanisms – dependent terms and risk – into the contracts. However, this can make the contract increasingly complex and has led to the criticism that the transaction costs associated with PPP contracts (including costs of specification, tendering and agreeing contracts) have been high. Problems with the bidding process have also showed that PPPs have failed to overcome some of the problems of bidding that are associated with traditional procurement methods.

A criticism of transport infrastructure projects has been that private sector companies have systematically underestimated the costs that will be involved in delivering these projects or overestimated the demand for the finished product. In PPPs, this has led to overbidding in the form of inflated traffic and revenue forecasts.[89]

Our experience indicates too, that PPPs have been highly controversial as funding tools, largely over concerns that the public return on investment is lower than returns for the private funder. It is closely related to concepts such as privatization and the contracting out of government services. The lack of a shared understanding of what a PPP is makes the process of evaluating whether PPPs have been successful complex. Evidence of PPP performance in terms of VfM and efficiency, for example, is mixed and often unavailable. Common themes of PPPs are the sharing of risk and the development of innovation.

The effectiveness of PPPs as cost-saving or innovation-producing ventures has been called into question by numerous studies. A common problem with PPP projects is that private investors obtained a rate of return that was higher than the government's bond rate, even though most or all of the income risk associated with the project was borne by the public sector

For examples of PPP in HSR projects see appendix 4.

4.10 Conclusions

At the end of a day, in each and every human activity there are financial challenges, based on trust among business partners, who calculate risks, collect funds and invest them to achieve profits. This is true also for railway business, including HSR investments.

Before starting considerations how to gain money for HSR investments, there is an obvious requirement to convince potential investor that proposed investment is a reliable one, which will guarantee profits in investment's period. Preparing SWOT analysis or any other financial analysis, special efforts should be done to limit the WEAK sides of the planned project. As it was proved above, the serious challenge for the railway sector is its efficiency – extremely low **average** lifespan of assets versus **optimal** one for the sector. Therefore, the basic conclusion for the all HSR plans is to take immediate actions to improve this situation - assets management. Then after significant improvements of these challenges there might be a perspective to start looking for potential investors.

89 J. Chou et al., *Critical factors and risk allocation for PPP policy: Comparison between HSR and general infrastructure projects*, "Transport Policy 22/2012", n.d.

The other conclusions presented below will have to follow this basic requirement achieved first.

Grants alone cannot address significant investment gaps. They need to be efficiently complemented by financial instruments, which have a leverage effect and are closer to the market. On a voluntary basis, Member States will be able to transfer a part of their Cohesion Policy resources to the new, centrally managed **InvestEU fund**, to access the guarantee provided by the EU budget. Combining grants and financial instruments is made easier and the new framework also includes special provisions to attract more private capital. The objective is to set realistic but ambitious targets for structural public spending to ensure that contribution of the structural funds really does add value. As a rule, average annual spending in real terms should not be less than in the previous programming period.

So, there is a simple message of limitation – the EU Member States and some neighbouring States only may consider possible financing of the TER projects from the EU sources.

The forecasted funds for the implementation of infrastructure transport investments in the Multiannual Financial Framework for 2021-2027 will be insufficient for the implementation of all investment programs. The potential support from European Union funds and instruments will have to be supplemented with national funds. Considering the funds available, it can be assumed that in many TER States it will be necessary to look for extra-budgetary means for financing investments, including those related to the construction of high-speed railway lines. In particular, it will be necessary to use private capital but also the capital market financial instruments should also be an important source of financing.

The use of private capital and funds obtained on the financial market will require guaranteeing an adequate level of revenues for the infrastructure manager. They will come from both infrastructure access charges and budget subsidies. In total, these two sources should ensure a sufficient level of funds for maintaining infrastructure in technical efficiency as well as related to the operation of financial instruments obtained to cover investment outlays (loan repayment, redemption of bonds, etc.). In case of use of private capital as part of a public-private partnership, it will also be necessary to ensure its adequate return.

There is an open basic question – will all Non-EU States be able to encourage private capital to invest in the HSR lines on their territories? The answer in post-Covid-19 environment might be not optimistic, however it is not so simple and may have some new opportunities.

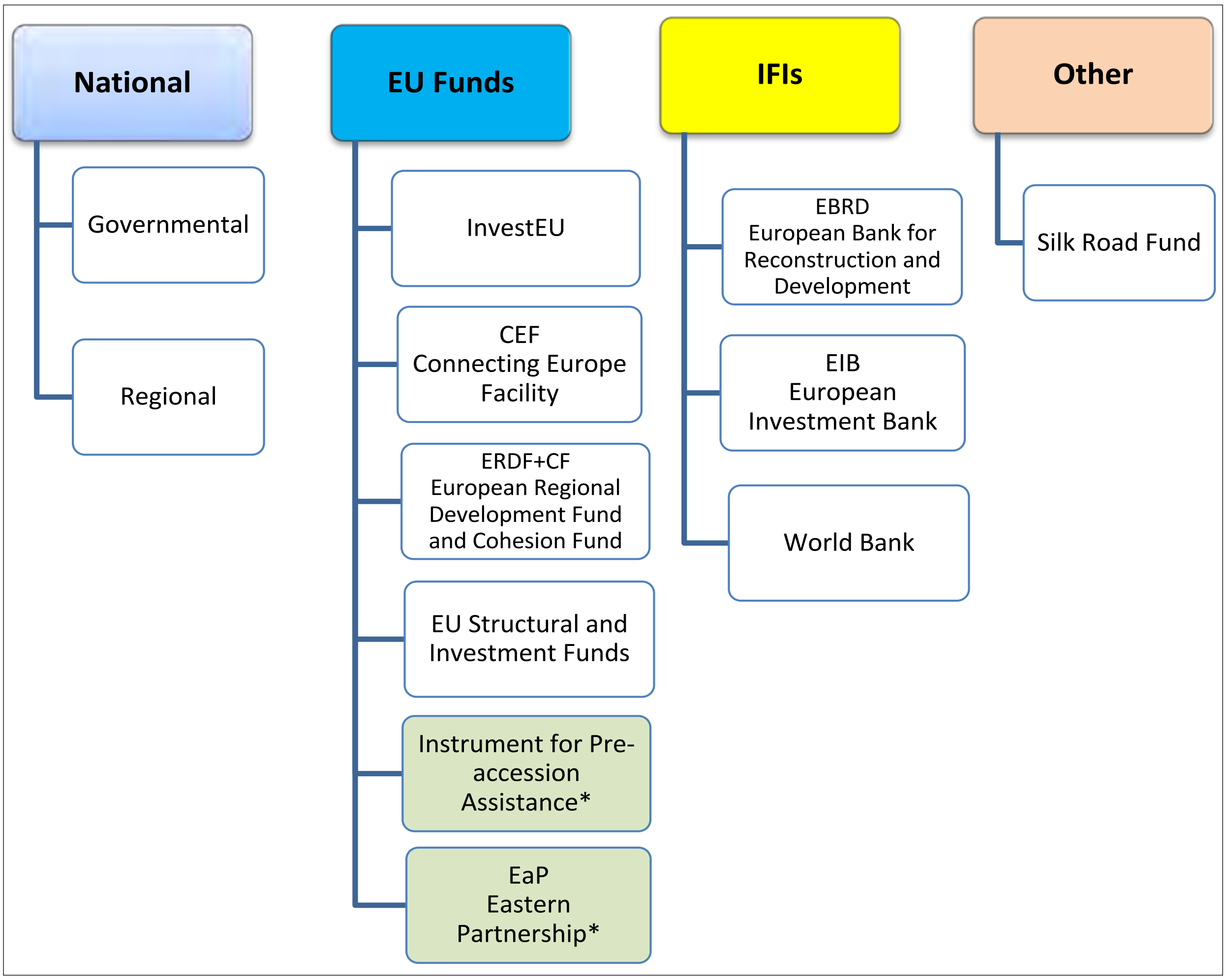
Generally, the mechanism for financing high-speed lines in Europe is based on assembly from available sources, with the share of funds from these sources depending on the type of project and its market environment.

High speed rail projects implemented so far in the world from the point of view of their financing can be divided into groups:

- Fully financed from public funds.
- Partly from public funds and partly from other sources.

  This is the most popular model now. The part not financed from public funds consists of loans, bonds and other sources, which during the operation of the line is repaid by the infrastructure manager from the revenues obtained from fees paid for the use of the line by railway carriers as well as from other sources such as station revenues, advertisements, etc.
- Entirely other funding sources than public.

Figure IV–25 Public financing of high-speed railway projects



* UE Funds available for non-EU States.
Source: Own study.

The EU objective to triple HSR network by 2030 is unlikely to be achieved. One of the most important stumbling blocks is lack of effective funding and financing system which would be in synch with the ambitious EU objectives.

The growth of the HSR system in Europe is not only slower than expected but also uneven. There is a significant difference in the development of HSR in Western and Central and Eastern Europe, and also non-member States considered for the HSR system. There are significant funds for the development and enhancement of infrastructure in Europe. The problem is in their practical availability and application to the specialized infrastructure programs like HSR. As the analysis in this document shows, the current system of infrastructure funding is highly decentralized, and focused on individual projects selected by national governments. HSR projects have to compete for funding and financing with other transport projects supported by the identified sources according to national, and continental priorities and objectives. The criteria and procedures for selecting proposed projects is not uniform and differ among States.

Very interesting conclusion are included in the Special Report of European Court of Auditors: A European high-speed rail network: not a reality but an ineffective patchwork. The current approach to HSR funding and financing is based on national decisions on prioritizing infrastructure projects. Since 2000, the EU has invested €23.7 billion in high-speed rail infrastructure, but at the same time there is no realistic long-term EU plan for high-speed rail, but an ineffective patchwork of national lines not well linked.

Such examples are also presented in the TER HSR Study. In order to effectively raise funds for the construction of high-speed rail systems, the rail sector needs to prepare its own effective action plan to demonstrate to decision makers at national and international level the benefits of such systems. They cannot be limited only to the direct goals of increasing the number of passengers or freight loads transported. Reliably attainable global goals should be identified, e.g. climate protection by shifting freight from "dirty" means of transport to rail. As a significant part of the funds for the construction of high-speed rail systems will come from non-returnable funds, it is important to identify additional social and economic benefits that are achievable by social goals. The advantageous feature of high-speed transport is their self-sufficiency at the operational level and no need for permanent subsidies from national and regional budgets. Also, investment financing plans should be attractive and credible, which requires high-quality feasibility studies. Building a coherent and efficient operationally and financially across Europe is therefore a key issue.

There are no miraculous funds to finance the construction of high-speed lines and uniform recipes for financial assembly. The best practices presented in the Study require implementation within the framework of individual feasibility studies for each project, considering local conditions.

V. Conclusions and recommendations

1. The current state of development of high-speed long-distance connections in TER States

The rapid development of high-speed rail (HSR) networks has been observed worldwide in recent years.

In the TER region, the railway network is unevenly developed, and the quality of infrastructure has remarkable potential for improvement in some areas. The development of an HSR network would significantly improve the competitiveness of rail travel; both for the benefit of the environment and socioeconomic development.

The most advanced implementation of HSR technology at present can be observed in Austria, where it is estimated that the planned network will be completed by 2030. This network consists of new lines with a maximum speed of 250 km/h, and modernised lines with a maximum speed of 230 km/h.

In Poland, a section of the CMK line between Warsaw and Katowice with a length of approximately 224 km is currently in operation. The maximum speed at the time of writing is 200 km/h. Further modernisation of the line is performed to ensure higher speeds in the near future.

In Russian Federation, on the line between Moscow and St. Petersburg, trains can reach speeds of up to 250 km/h. Between St. Petersburg and the Finnish border, the modernised line allows high-speed trains from St. Petersburg to Helsinki to run at a maximum service speed of 200 km/h.

In Turkey, an HSR network is currently under construction. However, on two lines in operation – Ankara to Konya, and Ankara to Istanbul – the maximum service speed is 250 km/h. Both lines served 8.2 million passengers in 2018, indicating an increase of 20.34 per cent compared with 2015.

In general, however, long-distance HSR service is underfunded within the TER region.

Low service speeds on the lines and unmodernised sections in border regions are the most pressing difficulties. Subsequently, there is a low number of daily connections between major cities, which makes it even more challenging to compete with road transport. This applies in particular to Southeast Europe. There is also an issue with inconsistency within the rail network. In order to ensure the competitiveness of rail travel in the TER region, it is necessary to establish a more comprehensive HSR network.

In most TER States, plans have already been developed to build new high-speed lines, and to upgrade existing lines to high-speed parameters. Some of these projects are already in the process of being implemented.

Turkey has demonstrated a high level of commitment to HSR construction projects – there is 588 km of track already in operation, and a further 7,208 km planned.

Rail Baltica, which runs from the Polish-Lithuanian border to Tallinn, Estonia, will probably be commissioned in 2027, and reach a final length of 848 km. On the Polish side of Rail Baltica, a 379 km section running from Warsaw to the Polish-Lithuanian border will be modernised to increase speeds of up to 200 km/h, incorporating the Warsaw-Białystok and Białystok-Ełk routes, in addition to a section of the Ełk-Białystok route as a new line, with a maximum speed of 250 km/h. Feasibility studies are currently being finalised for these sections. The total length of the Rail Baltica route between Warsaw and Tallinn will be 1,158 km.

Feasibility studies on the construction of HSR lines in Czechia, Poland, and Russian Federation have been completed or are in progress. The lowest level of preparation is in the Balkan region, of which some States have not yet commenced development.

2. Transport potential in the TER region

In Central Europe, a concentric settlement structure dominates at the level of individual States. The exception is Poland, which exists in a polycentric settlement structure. However, at the subregional level, polycentric settlement structures are much more common. It is therefore possible to create an efficient railway network based on high-speed lines that connect most cities across the region directly, without the need to concentrate international traffic in capital cities After expensive and long-lasting investments in multidirectional rail connection system in the region could be highly effective and in large area countries, sometimes more attractive than air travel. The current rail network in Central Europe requires major adjustment to achieve this goal, particularly in Poland, Czechia, and the Baltic States. It is a positive development that projects for the new HSR network have been launched and are already being implemented as planned in neighbouring States. The introduced and being developed connection with China through the freight corridor crossing Germany, Poland, Belarus and then Russian Federation, the HSR connections concept is strongly efficient with positive perspectives. For the wider region, however, there are structural deficiencies in less-populated areas.

South-East Europe also has a polycentric structure on a regional scale, with a large number of medium-sized cities. However, due to geographical limitations, the rail network does not connect these cities in a satisfactorily direct manner. Overcoming natural barriers in the form of high mountain ranges requires the construction of expensive new lines. Importantly, the region is characterised by a relatively low population, and therefore fails to generate large passenger flows.

In Eastern Europe, the concentric system dominates, with Moscow serving as the centre of the region. Despite the network's orientation towards the Russian Federation capital, a banding pattern can be observed along the railways leading to it. The planned network of HSR lines will handle these bands to a significant extent, in particular in the Urals, and towards Poland via Belarus. However, due to the very long distances involved, these lines should have high maximum speeds of up to 400 km/h.

In Turkey, despite the fact that Istanbul and Ankara dominate other cities in terms of population, and both are connected to the main transport axis with a high-speed line, the remaining large and medium-sized cities are relatively evenly distributed throughout the country. The key objective should be the expansion of the HSR network eastwards to the borders with Iran and other States. This demands the construction of high-speed lines. However, it should be noted that long distances are a barrier to the popularity of railways in this region, and that some passenger traffic can be served more efficiently by air travel. As HSR lines can also be utilized for fast freight traffic, new economic prospects on the Asia-Europe axis will likely emerge, regardless.

The characteristics of the settlement structure and the size of the population are factors that support the development of an HSR system that meets the socioeconomic needs of the region. A polycentric settlement structure at the scale of the entire region, with a large number of relatively large cities as multimodal nodes is a particularly favourable condition. The construction of HSR lines can strengthen this structure for the benefit of the whole region's economy.

The existing rail network is relatively dense and is well-integrated into the settlement structure. Some gaps exist in the network, and there are sections that fail to comply with modern technical and construction standards. Nevertheless, the high density of the network allows, in most cases, for the progressive development of HSR networks. Where geographical and environmental conditions allow, partial use of the conventional network for the implementation of HSR connections is possible.

3. Technical standards and legislation

Rail transport is subject to national legislation within each country, which defines the basic elements of the railway system, and specifies the minimum requirements in terms of safety and interoperability, both in infrastructure and in rolling stock. Additionally, European Union (EU) legislation applies to its member States and is also being implemented in pre-accession candidate States. The legal systems of the remaining States in Europe may be subject to the provisions of the Convention concerning International Carriage by Rail (COTIF) and/or Organization for Cooperation between Railways (THE OSJD) regulations. These legislative systems are non-contradictory in terms of basic requirements. The number of mandatory technical criteria for HSR systems has increased significantly compared to those set out in the European Agreement on Main International Railway Lines (AGC) of 1985 (revised 2019). Significant progress has been made over the last 35 years in the field of high-speed rail, in the number of specification requirements, and in terms of safety.

For the purposes of this study, the following rules were adopted:

- Compliance with the technical recommendations of the International Railway Solutions (IRS) framework published by UIC;
- Compliance with the International Governmental Organisation for International Carriage by Rail (OTIF) regulations and, in individual cases, with other regulations at the regional level where justified by the need for internal interoperability;
- Full compliance with the EU legal system and THE OSJD standards where applicable;
- Full alignment with the AGC.

The requirements set out in the EU Technical Specifications for Interoperability (TSI) only apply to issues that promote the interoperability of the railway system in Europe. The purpose of TSI is to define the minimum values of the most relevant parameters. Entities planning the construction and operation of HSR networks may wish to impose stricter parameters.

In addition to those parameters, a set of so-called functional parameters that are relevant to rolling stock manufacturers and railway operators are used. To a large extent, they are based on the standardisation activities of the UIC, which are codified in UIC leaflets, and then into IRS documents. Adoption of these solutions is non-mandatory, but they offer the most extensive set of successful guidelines available to the public. In addition, they are being developed constantly by the UIC and its members, delivering new universal solutions on a global scale.

In practice, the parameters set out in accordance with TSI standards, including the UIC IRS, (such as platform length) are used worldwide. The procedures for the placing of systems and equipment in service are also adopted from TSI. The largest producers are located within the EU and produce mainly for the EU market.

4. Technology and operation

Signalling and communication

Analysis of developments in the field of telecommunications and signalling systems suggest that a major technological leap is imminent, and that a host of new solutions concerning the automation of rail traffic and advancement of IT applications will soon become feasible.

Based on the work of the UIC, the concept of the Future Mobile Radio Communication System (FRMCS) system, which utilizes 5G technology has been developed. The implementation of this system, as well as the migration of the currently-used GSM-R (2G) system to FRMCS will open new possibilities for the development of traffic control systems and the introduction of Automatic Train Operation (ATO) systems. The initial tests of the system in Europe have been successful.

In the field of satellite navigation, rapid development of applications for the rail industry should be expected, based on Galileo for EU and associated States, and the Global Navigation Satellite System (GLONASS) for the Russian Federation and the Commonwealth of Independent States (CIS).

This will be reflected in the development of rail traffic control, and the management and maintenance of infrastructure and rolling stock.

In the field of traffic control systems, there has been an increase in European Railway Traffic Management System (ERTMS) applications in Europe in recent years. ERTMS Level 2 has been selected as the traffic management system in the EU States, and this selection has been mimicked by EU pre-accession candidates and other cooperating States. Further impetus for the application of such systems should come from the implementation of ERTMS Level 3 with ATO generation 1/2 (GoA 1/2) elements in the specification TSI under development as part of the TSI 2022 project. The traffic control system will serve as a key component of future HSR lines.

Maintenance

The maintenance of railway lines should be performed by the Infrastructure Manager, in house or via outsourcing, depending on appropriate technical and economic analyses. The outsourcing option may, from the economic and organizational perspective, be attractive to smaller rail networks, in which technical equipment and maintenance comprise a relatively high share of the total costs.

Condition-based maintenance is recommended to allow cost optimisation, but requires extensive experience of the relevant entities, or the transfer of appropriate technology, from manufacturers, for instance; a long-lasting process, which ultimately results in the increased safety and economic efficiency of rail traffic. The operation of such systems requires large transfers of data, which is only feasible with the use of 5G technology. RAM and life-cycle cost (LCC) analysis should be conducted during the maintenance of operations. These methods should be considered at the stage of feasibility testing.

Thanking the UNECE Inland Transport Committee (ITC) works and legal arrangements the supply industry is in the process of unifying a number of processes in the field of railway maintenance across Europe. This is also happening in Asia, which will facilitate interoperability. The unification and globalisation of technical solutions in the field of telecommunications and traffic control should enable the development of the rail industry.

Maximum speed

The designation of the maximum speeds for newly-built and modernised lines should result from assessment of the required journey time to achieve competitiveness and economic efficiency in relation to other modes of transport, specifically air travel. The analyses indicate that a journey time of 90 minutes by train makes it almost entirely competitive with air travel. In turn, a trip lasting three hours makes it possible to travel there and back the same day, which is especially desirable for business travellers. As the travel time lengthens, the competitiveness of rail transport declines in relation to air travel, depending on the local conditions. Optimal trip times should account for the fact that the TER HSR network will be used by international traffic: while the obtained travel times may be satisfactory from a national perspective, the expectations are higher internationally.

This leads to the general conclusion that network operators must strive to shorten trip times as far as possible, allowing for the technical conditions in the field influencing maximum speeds. Currently, the highest legally codified speed is 350 km/h, and this is soon likely to be increased to 400 km/h. Increasing maximum speeds has a non-linear effect on journey times. For this reason, for the distances between stations in Europe, the maximum speed for new lines is assumed to be in the range of 300-350 km/h. Trains purchased or planned for purchase in Europe typically have a maximum speed of 300-320 km/h. In practice, due to local geographic limitations, it is unfeasible to achieve such high-speeds, and for individual sections of the line, the maximum speed may be lower. For modernised lines, the technical and economic barriers limit maximum speeds to the range of 200-250 km/h, and in some sections below 200 km/h.

The HSR lines planned for construction in the TER region and neighbouring States most probably will be built for maximum speeds of at least 250 km/h. The planned lines in Czechia and Poland will have maximum speeds of 350 km/h, so that both networks remain consistent with each other in terms of operation. In Austria, new lines are being constructed for maximum speeds of 250 km/h, and existing ones are being modernised to accommodate maximum speeds ranging from 200-230 km/h. In Slovakia, short complementary sections are being upgraded to maximum speeds of 200 km/h. In Hungary, studies are being conducted on the construction of a line from Budapest towards the Austrian border as part of the target TEN-T network, and one option proposed assumes a maximum speed of 300 km/h. These investments will enable the creation of an attractive international network across Central Europe including the expected link from Vienna via Czechia and Poland to the Baltic

A maximum speed of 250 km/h in Turkey, and 350 km/h in the Russian Federation is planned. The Rail Baltica line from Warsaw to Tallinn will have a maximum speed of 250 km/h for new sections, and 200 km/h for modernised sections within Poland.

Modernised lines are usually planned to reach maximum speeds of 200 km/h (in Czechia, Serbia, Slovakia and Poland).

The examples mentioned above demonstrate that generally, very high maximum speeds on new and modernised lines are assumed. As some HSR projects in the TER States remain in the study phase, efforts should be made to ensure that their entire length, especially for new lines, have the highest possible speeds, and reach beyond 300 km/h.

Types of traffic

The technical and operational possibilities of using HSR lines are applicable to various types of traffic including freight one. The selection of HSR service must also consider how it will interact with other service types, regardless of whether it is planned to operate on a dedicated line. From a legal perspective, there are no obstacles to operating different types of train on the same high-speed line. Many HSR systems with mixed traffic solutions are already in operation around the world. Their design solutions prove adequate for local needs.

The use of high-speed lines by local or long-distance passenger transport allows conventional rolling stock to operate in cases where the capacity of the high-speed lines allows the introduction of trains with lower speeds.

High-speed lines may also be used for freight traffic according policy decisions and local capacities. There is currently no generally applicable legislation or guidelines for this type of traffic. Freight transport on high-speed lines can be undertaken by two types of rolling stock:

- Conventional: hauled by locomotives with a maximum speed of 160 km/h (but typically 120 km/h);
- High-speed special construction trains (currently operating in Italy).

The introduction of freight traffic on HSR lines is only feasible if adequate balance of capacity reserve is present on those lines.

The benefits of operating freight trains on a high-speed line include shorter delivery times, which encourages trade expansion and create a new market for time-sensitive deliveries by rail and possess the potential to gain market share from air transport in express parcel delivery, particularly on transcontinental routes.

5. Planning the TER HSR network

Summary of HSR projects in the TER States and neighbouring States

The ongoing HSR projects in the TER States are presented in figure 1. The map includes high-speed lines in operation, under construction, planned, and supplementary conventional lines connecting high-speed lines into a single network for fast passenger and freight trains.

A summary of the length of lines in operation, under construction, and those planned, as well as the estimated cost is presented in table 1. The sources of estimation are feasibility studies and calculation by the method of average cost of construction or modernisation per km, based on UIC analyses. The cost of constructing a line increases gradually with the interference with geographical conditions, which demands the construction of tunnels, viaducts, and bridges.

Non-TER States' key points for consistency within the HSR TER network have also been listed.

Table V–1 Estimation of the construction and modernisation cost of the lines in TER States and neighbouring States

Country	Lines in operation [km]	Lines under construction [km]	New lines planned		Lines for modernisation planned		Total cost	Comments
			Length [km]	Cost [mEUR]	Length [km]	Cost [mEUR]	Cost [mEUR]	
Armenia	-	-	-	-	-	-	-	
Austria	204	281	110	3.300	182	2.184	5.484	E
Belarus	-		600	15.000	-	-	15.000	E
Bosnia and Herzegovina	-	-	-	-	385	4.620	4.620	E
Bulgaria	-	-	-	-	-	-	-	
Croatia	-	-	-	-	-	-	-	
Czechia	-	-	798	22.500	103	-	22.500	FS
Georgia	-	-	-	-	-	-	-	
Greece	471	150	234	7.020	-	-	7.020	E
Hungary	-	-	968	14.520	50	500	15.020	E
Lithuania	-	-	367	2.474	-	-	2.474	FS
North Macedonia	-	-	-	-	-	-	-	
Poland	224	-	1,590	19.780	-	-	19.780	FS
Romania	-	-	810	24.300	-	-	24.300	E
Russian Federation	807	-	5,093	84.170 +60.400*	1,319	2.480	86.650 +60.400*	FS, E
Serbia	-	183	-	-	240	2.190	2.190	FS, E
Slovakia	-		-	-	337	4.014	4.014	E
Slovenia	-	-	185	5.550	-	-	5.550	E
Turkey	588		7,208	40.000			40.000	FS
Rail Baltica Incl. LT	-	-	848	5.788	-	-	5.788	FS
Total	**2,719**	**614**	**23,796**	**302.278**	**2,323**	**13,798**	**313.126**	

* Long-term projects
Source: Compilation of Feasibility study questionnaires.
Sources of estimation: FS – feasibility studies, E – estimation by method of average cost of construction/modernisation per km.

The HSR corridors in the TER network

The ongoing projects in the TER and neighbouring States will allow the development of HSR systems in a corridor approach, in which:

- Main line sections are distinguished by the maximum achievable speeds under local conditions;
- Additional sections, including those modernised to operate at speeds of 200 km/h (or more);
- Conventional lines with enhanced technical parameters, which constitute links between sections of high-speed lines.

With this approach, the average service speed should range between 160 km/h and 250 km/h. Higher service speeds require a larger share of high-speed lines allowing 300-350 km/h, or a lower share of feeder lines. Higher average service speed is expected to:

- Enable the trip times required to achieve economic efficiency of the HSR network by creating an environment that enables the required population mobility and freight transhipments;
- Ensure the competitiveness of rail in relation to other means of transport – in particular air travel – over distances of 120-1,200 km, and longer in specified cases.[90]

Most of the high-speed line projects being implemented or planned in the TER States are located in the transport corridors designated in the 1990s – the Cretan, Helsinki, and TINA corridors.

The high-speed projects proposed in the TER region should create a multi-directional network system.

The following key corridors have been determined for the purposes of this study:

1. North to South corridor: from Poland via Czechia, Slovakia, Austria, Hungary, Serbia, Bulgaria, and North Macedonia to Greece and Turkey
2. North corridor (East to West): from Germany and Poland to Russian Federation via Belarus, and further towards China
3. Middle corridor (the Danube): from Austria and Switzerland and from Germany and Czechia via Slovakia and Hungary to Romania and Ukraine
4. Southern corridor (East to West): from France and Italy via Slovenia, Croatia to Hungary with a branch towards Turkey and eastwards
5. Baltic Corridor: from Germany, Czechia and Poland (Warsaw) via Lithuania, Latvia, and Estonia to Finland
6. Southern: (East to West) from Turkey (Istanbul) to Iran and the Caucasus
7. Carpathian Corridor: from Poland to Romania, via Slovakia and Hungary.

Figure 2 illustrates the proposed network corridors for the entire TER area.

In accordance with the assumptions adopted in this study, the TER HSR Network consists of high-speed lines that are in operation, under construction, or planned, along with supplementary conventional lines connecting high-speed lines into a single network for fast passenger and freight trains.

Multimodal nodes

One of the most significant elements of transport infrastructure which influences the efficiency of the HSR systems, aside from functioning to ensure an appropriate level of multimodality, is the presence rail nodes. Solutions approved during planning have an impact not only on the accessibility of rail services, but also the commercial speeds of trains and their trip times.

The location of the proposed TER HSR nodes is illustrated in figure 3, which also identifies the other modes that each node serves.

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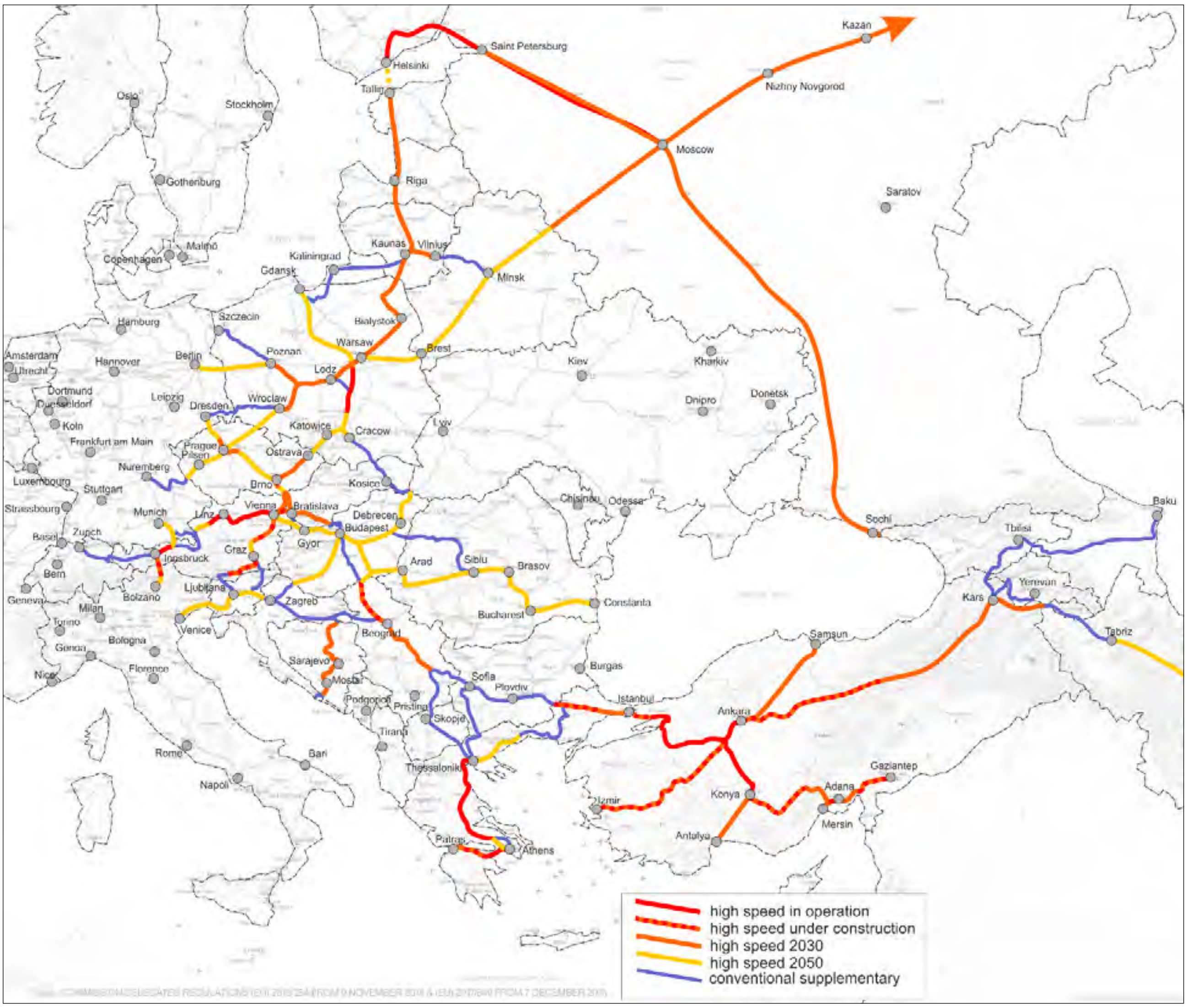
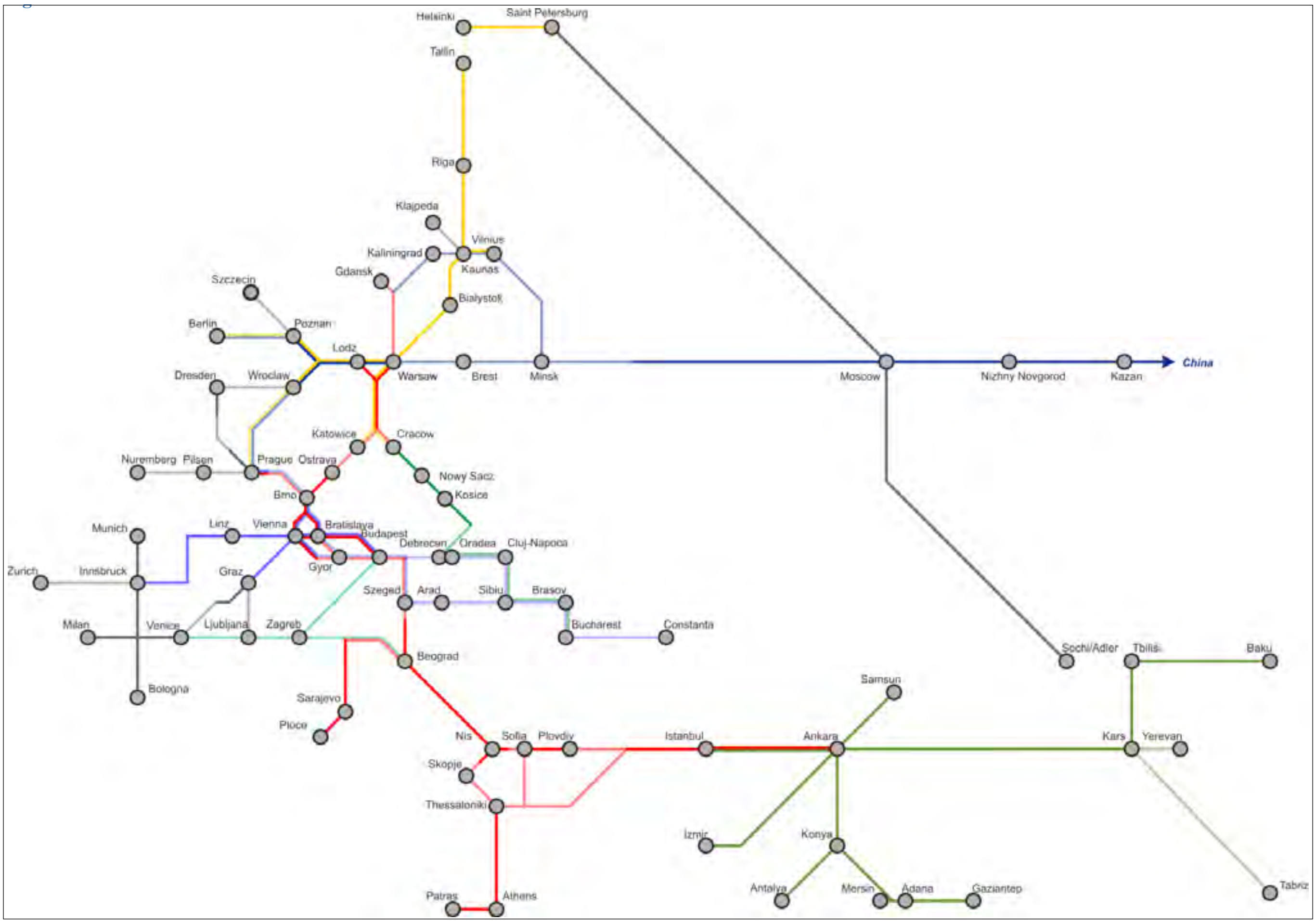
[90] *Resolution of the UIC, Operating high-speed lines: in search of efficient solutions. Round-table on good practice share and international benchmark*, Paris, 31 January 2019.

Figure V–1 Proposed HSR projects in TER States and complementary conventional lines



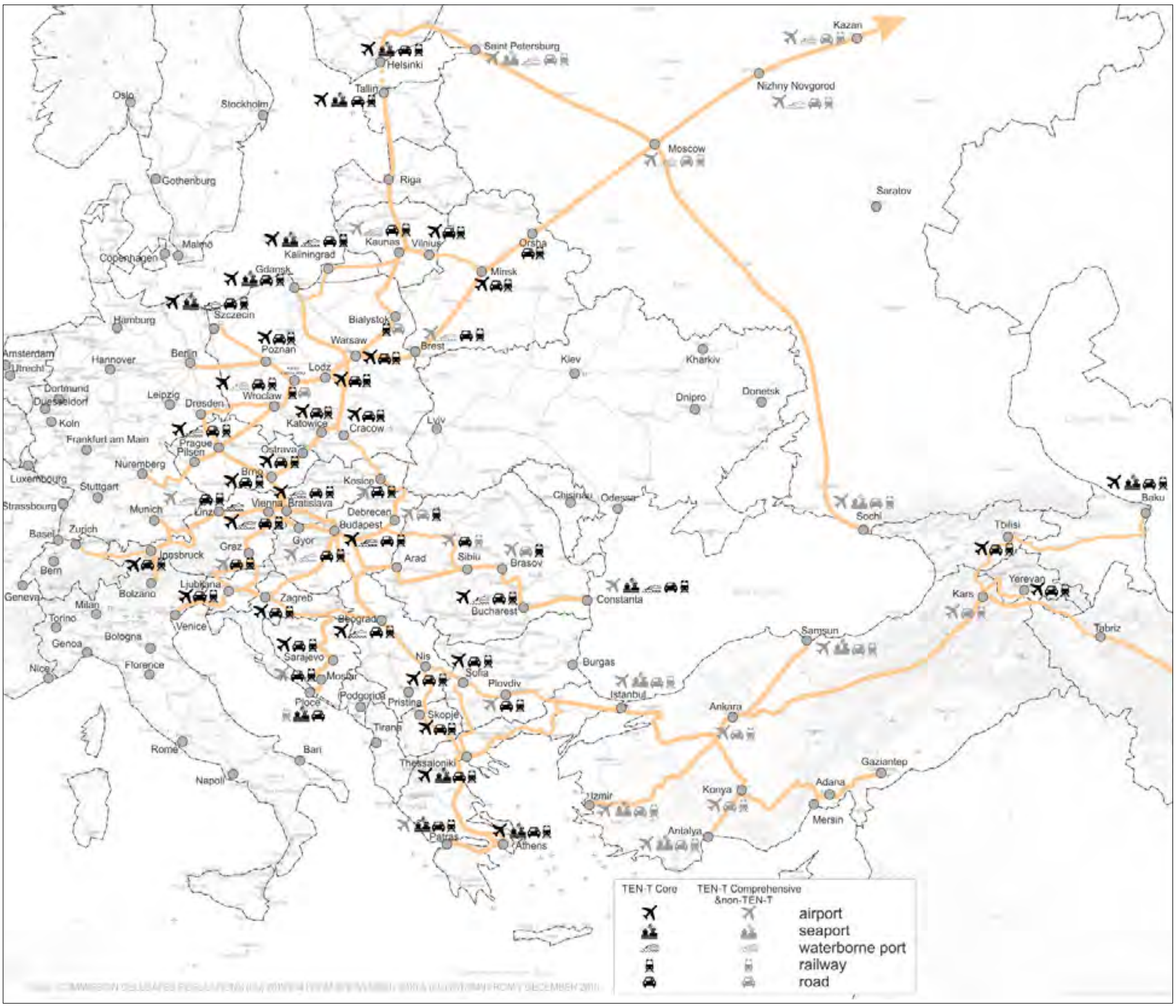
Source: The authors' own research.

Figure V–2 Network of TER HSR corridors



Source: The authors' own research.

Figure V–3 Location of TER HSR nodes



Source: The authors' own research.

6. Financing

The HSR construction, operations and maintenance costs

The Master Plan Study indicates that the network proposed above for the TER region as a whole will:

- Consist of about **23,844 km** of new lines at a cost of **€302.3 billion**
- Be supplemented by about **2,370 km** of lines planned for modernisation to high-speed parameters at a cost of about **€19.05 billion**
- Reach the total cost of about **€321.3 billion**
- Impose a total average cost per year of about **€10.7 billion** until 2050.

These calculations represent current estimates and are subject to change over time. It should be noted that the costs of some investments might increase during implementation process, as demonstrated by experience from the HSR projects already undertaken in Europe. It should also be noted that investments in the modernisation of existing lines to HSR parameters represent a relatively small share of total investments (4.1 per cent), in comparison with the construction of new lines. This is the result of an assessment of the condition of existing rail infrastructure, as described in this report, which highlights that the cost of upgrading existing lines to high-speed parameters would be so high that the construction of new lines is often the only viable option.

According to the UIC analysis, in Europe the maintenance average cost for one km of the line will be €90,000 per year.

The lowest costs identified in the finalised feasibility studies have been estimated for Rail Baltica and will amount to €70.7 million (€81,000 per km) in 2030, including €58.9 million (€67,700 per km) for technical maintenance. It should be noted that intensive traffic of heavy freight trains is anticipated on the line, which will increase its maintenance costs.

For the purposes of analysis of new projects in the TER region, an average between the values given above can be established:

- Maintenance cost: €80,000 per km per year: €2,093 million
- Operating cost: €15,000 per km per year: €392,5 million.

These estimates represent credible financial projections. Approximately €10.5 billion in investment per year for the TER region would be required by 2050 to implement all of the projects proposed what makes in total about €315 bln in 2050. These calculations should consider the possibility of cost increases caused by inflation and many more factors which are challenging to estimate reliably over such a long period. In addition, it should be noted that the costs of some investments may increase during implementation, as demonstrated by experience from the HSR projects already completed in Europe.

It should also be noted that investments in the modernisation of existing lines represent a relatively minor share of total investments (4.1 per cent), in comparison with the construction of new lines. This demonstrates that the solution to the transport problems of the TER region lies in the construction of new lines, rather than the modernisation of existing ones. This is the result of a real assessment of the condition of existing rail infrastructure. Most of it was designed in the nineteenth century, and even following modernisation, will fail to meet high-speed requirements.

The maintenance and operating costs of the planned high-speed lines in the TER States are estimated to be approximately €2.5 billion per year. The economic analyses conducted in this study demonstrate that these costs can be cover by the revenues of rail carriers. Such carriers are also able to incur a significant portion of the cost of investing in high-speed lines. However, in all identified cases, the carriers' expected revenues were insufficient to cover the total investment costs of the projects. If the financial analysis is followed by an economic analysis that accounts for all revenues, including indirect ones deriving from socioeconomic effects, investments in HSR are profitable over the long-term. Rail carriers will gain new opportunities and will be able to generate profit.

This conclusion is consistent with analysis of the financial performance of railway companies, both in Western Europe and in China. The activities of HSR system operators are unlikely to require support from central and regional budgets.

Investment costs per corridor are presented in table V–2. Because some corridors overlap, the total costs for corridors are higher than those listed in table V–1.

Table V–2 **Estimation of the construction and modernisation costs of TER HSR corridors in TER and neighbouring States**

Corridor	Length [km]	Investment cost [mEUR]	Maintenance cost [mEUR]	Operating cost [mEUR]
North-South corridor: from Poland via Czechia, Slovakia/Austria, Hungary, Serbia, Bulgaria and North Macedonia to Greece and Turkey	5 952	42.773	473.6	88.5
North corridor (East-West): from Germany and Poland via Belarus to Russian Federation and further towards China	4 337	46.241	346.9	65.1
Middle corridor (Danube): from Austria and Switzerland, and from Germany and Czechia via Slovakia and Hungary to Romania and Ukraine	3 204	44.945	256.3	48.1
Southern corridor (East-West): from Italy via Slovenia, and Croatia to Hungary with a branch towards Turkey	942	9.000	75.3	14.1
Baltic corridor: from Germany, Czechia and Poland (Warsaw) via Lithuania, Latvia and Estonia to Finland	2 591	21.885	203.3	38.1
Southern: East-West (Turkey – Iran) from Istanbul to Iran and the Caucasus	3 100	15.100	248.0	46.5
Carpathian corridor: from Poland via Slovakia and Hungary to Romania	1 118	11.256	89.4	16.7

Evaluation of project effectiveness

The effectiveness of HSR projects can only be assessed on the basis of appropriate feasibility studies. Successful investment in HSR requires reliable analysis of transport potential, and the development of a transport system that ensures high economic efficiency.

The financial effectiveness analysis utilizes the cost-benefit analysis (CBA) method, which is commonly used and recommended by international institutions, including the World Bank and the EU. In simplified terms, this method involves reducing the assumed future costs and benefits of the planned project to current values, accounting for the changeable value of currency over time. The task of analyses based on the CBA method is to establish whether an undertaking assessed on the basis of established criteria will provide adequate benefit from the capital invested. This assessment is usually based on two indicators: net present value (NPV) and internal rate of return (IRR).

In financial analysis, the NPV and IRR are often referred to as the financial net present value (FNPV) and the financial rate of return (FRR). This is done to emphasise that the analysis focuses on the financial aspects of the venture. The efficiency criteria are an FNPV value greater than zero, and an FRR value greater than the adopted financial discount rate (FDR).

Infrastructure investments are often characterised by financial inefficiency. This indicates the need to have investments supported by public funds to an extent that covers the financial gap.

Where it is not prohibited by law, preparing a consolidated analysis, considering the cash flow of both the infrastructure manager and the HSR operator, might be the surest path to financial efficiency.

It should be supposed that the construction of transport networks, including that of HSR lines, will generate future profit from the socioeconomic development of States and regions. Meeting the financing needs of an HSR project, therefore, should be considered a long-term investment in the future, as should the development of road infrastructure.

The degree of co-financing in the HSR projects implemented in Europe to date has varied somewhat. The need for public funds to co-finance infrastructure projects is widespread in Europe.

In the TER region, an economic efficiency assessment at this stage is possible on the basis of the feasibility studies conducted. The highest proportion of co-financing (85 per cent) can be found in the Rail Baltica project (Poland, Lithuania, Latvia, and Estonia), which results not only from the specificity of the region, but also from the special importance of the project for the EU, which has ensured its financing by the Connecting Europe Facility (CEF) fund.

As part of this study, eight representative examples of investments in the TER States were analysed, and full feasibility studies were conducted for each.

The following indicators were chosen for the purpose of this study:

- ERR (economic rate of return)
- B/C (benefit/cost ratio) – this indicator is not available for every project.

Use of the ERR rate is justified by the fact that the FRR alone is too low to justify commencement of the investment. On the other hand, the social effects are so significant that they must be accounted for in the final calculation.

Review of the results of economic analyses in the feasibility studies for the planned sections of the TER HSR network demonstrates that the benefits of launching an HSR network are sufficient for the planned investment expenditure. The ERR indicators have relatively high values of more than 4.5 per cent. The B/C ratios in this case are also greater than one.

Sources of financing

According to general observation presented at the beginning of Conclusion part above, described condition, as the general one, should be utilised and applied especially in this part of the Report.

The sources of financing for investments in infrastructure might be:

- Funds granted from the public sector
- From private sector.

Only part of the investment may be covered by e.g. fees for the use of new infrastructure paid by railway carriers, depending on quality of railway assets management.

Investment in HSR in Europe is predominantly financed by public funds. This is due not only to the scale of the costs, but also to long payback periods.

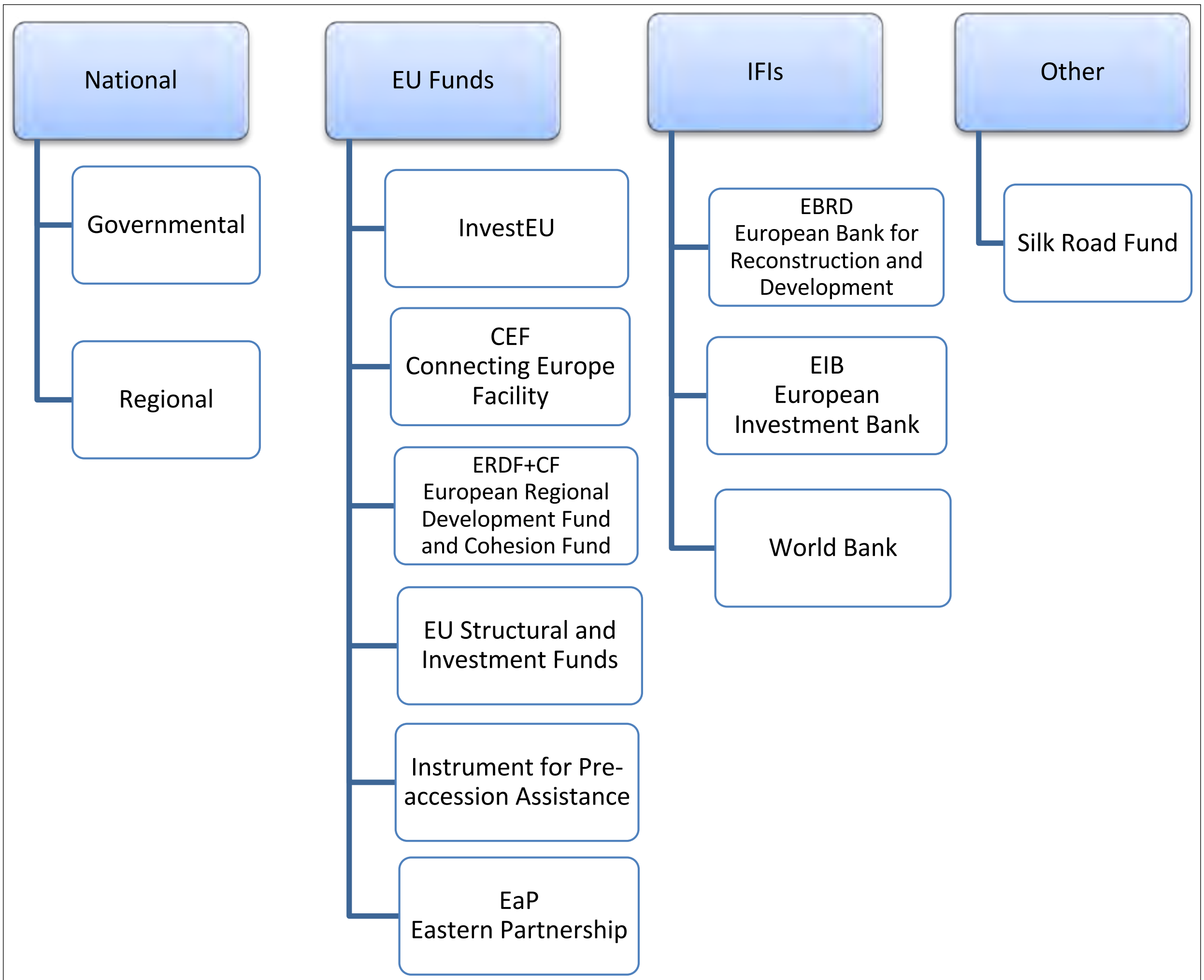
Major infrastructure investments can be financed by the EU – the world's largest fund providing *de facto* non-returnable aid for infrastructure investments. In addition to being utilized by the EU member States, the fund is also accessible to States embarking on the accession process, and neighbouring States whose development complements that of the EU.

Grants alone are unable to address major investment gaps. They must be efficiently complemented by financial instruments that enable a leverage effect.

Funding from European structural funds cannot replace the national expenditure of a member state. The European Commission establishes the level of eligible public (or equivalent) spending to be maintained throughout the programming period with each country, checking compliance both during and following completion.

Private capital may also be directly involved in the funding of public-private partnership (PPP) investments, which come in various forms.

Figure V–4 Public financing of HSR projects



Source: The authors' own research.

7. Socioeconomic aspects and the environmental impact of planned HSR network

Socioeconomic effects

When deciding whether to commence investments in HSR projects, not only should the immediate financial impact be considered, but also the country's long-term economic growth policy. he most frequently considered are the economic stimulation of regions resulting from improved accessibility and interregional economic connectivity; the need to adjust modal split; the development of tourism; support for industry and services related to transport construction; and the establishment of research and development facilities.

When the socioeconomic background is considered, the construction of HSR systems can lead to direct, indirect, and induced effects:

1. Direct effects (during construction and following the launch of transport services):
   - Creation of jobs
   - Shorter journey times
   - Improvements in safety
   - Improved reliability and comfort.

2. Indirect effects:
   - Changes in mobility
   - Improved capacity and safety of other means of transport.

3. Induced (wider) effects:
   - Relocation of enterprises
   - Accelerating the transformation of cities
   - Increased property values in the vicinity of HSR
   - Development of ancillary infrastructure for HSR
   - Network benefits for other modes of transport
   - Reduced environmental impact of transport
   - Impact on tourism
   - Influence on economic growth of the country and regions within it.

The factors identified above outline the potential socioeconomic effects of HSR investments, which can apply to all States with railway networks. The construction of HSR is widely viewed not only as a way of improving the overall performance of rail services, but also of stimulating a country's economic growth. Positive examples of such development policies can be observed in many TER States, as well as those beyond the region.

The role of high-speed rail in reducing the environmental impact of transport

Compared with other means of transport, HSR has the lowest negative impact on the environment, by several times – except for maritime and inland waterways transport.

In economic analyses, conducted as part of feasibility studies on the construction of HSR lines, external costs are considered, and act as a burden on the investment. Detailed environmental analyses are also required to ensure the routing of lines in a manner that ensures minimum environmental impact. These costs reduce the investment efficiency indicators. However, there are two key benefits that should be considered when assessing investments in HSR:

- The negative impact on the environment is the lowest of all means of transport;
- The construction of high-speed lines leads to the rerouting of some road and air traffic, which is associated with a reduction in the environmental impact of those means of transport and, globally, all transport, due to the shift from a more environmentally harmful form of transport to a less harmful one.

The arguments above should serve as an important factor in the decision-making process for all investments in transport.

However, the picture can be more complicated in this case. One can prove that there are indirect factors proving the HSR technology has its strong ecological limitation – extremely high use of electrical energy, this energy, up to now, is produced with the involvement of use of the fossil fuels. So, there are additional costs which significantly limit HSR efficiency and financial indicators, as well as ecological impacts.

8. Actions for the implementation of the TER HSR Master Plan

Corridor approach

For the purposes of the TER HSR implementation plan, the following criteria for identifying the most urgent corridors have been established:

1. **The highest population density within TER HSR**

   From the perspective of population distribution, it would be beneficial to commence investments in the lines crossing the Polish-Czech, Czech-Austrian, and Austrian-Hungarian borderlands. As such, construction of the Krakow/Katowice-Ostrava-Brno, Brno-Vienna, Vienna-Budapest, Vienna-Bratislava, Vienna-Graz-Klagenfurt, and Subotica-Belgrade-Nis lines should be priorities. The region between Bucharest and Brasov in Romania is also densely populated. Despite a relatively low population density in the areas between the cities, the Lodz-Warsaw line has a high population potential arising from the relative proximity of two major cities and above all – investments in new multimodal hub, big airport with railway station concentrating 12 new rail lines . In addition, Moscow and Istanbul, which are already served by high-speed lines, have significant population potential.

2. **Possibility of quick consolidation of key transport corridors**

   None of the planned corridors have been completed, nor will they before 2030. The problems arise from two fundamental factors. For some States, the construction of the HSR network has been scheduled for after 2030. Moreover, cross-border sections tend to be problematic, and are often treated as outlying sections. The most efficient method of consolidating high-speed lines into a single TER network is to implement corridors.

In the northern corridor in the East-West Axis (Germany – Poland – Belarus – Russian Federation), there are no sections with substandard conditions. Therefore, the maintenance of sufficient parameters and subsequent modernisation is feasible. The corridor experiences heavy passenger and freight traffic, and it is also the main corridor for cargo traffic in the China-Western Europe Axis.

In the north-south corridor from Poland to Czechia, Slovakia, Austria, Hungary, Serbia and Greece/ Turkey the high-speed projects can be consolidated simultaneously.

3. Elimination of existing major gaps in TER HSR network

The railway network within the TER States remains highly fragmented. Even if physically connected, its track width, traction, gauge, load capacity, and operation speeds vary. Full standardisation is neither necessary nor realistic even from financial point of view, but suitable steps should be taken to eliminate the barriers that create bottlenecks.

- The Polish-Lithuanian border area: the current network is developing to meet the requirements of the corridor.
- The Gulf of Finland: The natural barrier of the Gulf of Finland is expected to be eliminated with the construction of the undersea tunnel explained in previous chapters, which is to be completed by 2050.
- The Carpathian Mountains and the Polish-Slovakian border: Currently single-track and with low operating speed, the existing network is constraining the development of the corridor and is bilaterally discussed for its efficient modernisation.
- Sudetes Mountains, and the Polish-Czech border: The current border crossing allows inadequate capacity. The construction of a new high-speed line after 2030 would improve the situation.
- Slovakian-Hungarian-Romanian border area: The current network has significant limitations, and the construction of a new line between Slovakia and Hungary would alleviate this.
- Turkish, Greek, Bulgarian, Serbian, and North Macedonian region: A number of investments are underway to increase speeds in this area, but several missing links remain.

4. Increase the competitiveness of rail services

Comparison of travel times by car and by train – presently, as well as following the potential modernisations – highlights the areas that stand to benefit most from the construction of high-speed lines.

The competitiveness of rail travel is particularly limited in mountainous regions. In the area of Turkey, Bulgaria, and Serbia, journey times between particular network nodes by car are almost twice as short as those by rail (with the notable exception of areas where HSR is already present). If no investments are made in railways, this disadvantage will compound. The largest modal shift can be achieved via the introduction of HSR services. Turkey is a prime example of how the introduction of high-speed lines have reduced journey times to well below those of road transport. This is also true for projects in Romania.

In Austria, Czechia and Hungary, trip times by road and rail transport are comparable, and the planned modernisation on the border of Austria, Czechia, and Slovakia to high-speed standards will not significantly shorten journey times unless new lines are built with operating speeds of more than 250 km/h. A similar scenario can be observed in Slovenia, and on the Ljubljana-Trieste line (SI/IT).

On predominantly flat lines, such as those in Russian Federation, Belarus, and Poland, rail transport should be more competitive when compared with road transport, although local differences can be observed. On modernised sections, from Warsaw to Gdansk, Katowice and Krakow, or on the route from Moscow to Saint Petersburg, rail transport dominates over road transport. Simultaneously, there are the cases of Lodz-Poznan, Lodz-Wroclaw, or Warsaw-Bialystok-Kaunas, in which road transport is significantly faster. On these routes, the trend may only be reversed by the construction of high-speed lines. In the mountainous regions described above, road transport is currently faster than rail transport, particularly on the Katowice-Brno, Wroclaw-Prague, Wroclaw-Dresden, Prague-Dresden, and Prague-Nuremberg lines.

The effectiveness of a railway network should be measured not only from the perspective of its technical parameters, but also through comparison with other means of transport. Rail tends to be competitive with air travel over short distances. However, it is affected markedly by variations in the quality of air connections. The competitiveness of rail with road transport also becomes an important factor when considering longer distances. This will be affected by rail timetables and the density of the connections, while the accessibility of road connections is almost uninterrupted. Conversely, it may also be assumed that within the TER network, rail traffic is dense enough that waiting time at the nodes is almost negligible.

Comparison of the current journey times between the TER nodes by train and by car indicates the sections where the two means of transport are approximately equal, those where travelling by train is faster, and those where travelling by car is faster. When comparing those results to the journey times that might be achieved as a result of the planned investments, it can be deducted where it is realistic for rail services to compete. Next, the simulation of the possible journey times for the sections where investments have not yet been planned could suggest what investments will be necessary to achieve supremacy.

The following is a list of sections where rail transport is significantly slower than road transport at present, and has the potential to become faster than road transport, provided that the HSR projects are implemented:

- The entirety of the Rail Baltica route. The poor competitiveness of rail transport is a result of the low design speed of existing tracks, required gauge change (1,435 mm – PL/1,520 mm LT) and weak maintenance competing with relatively well-developed road infrastructure.
- Sections crossing the mountain ranges on the borders between Poland, Germany, and Czechia, as well as Slovakia. The poor competitiveness of rail is the result of insufficient technical parameters of the railways and, partially, poor maintenance of the tracks, especially on the border sections.
- The section between Warsaw, Lodz, Poznan, and Wroclaw. A result of the well-developed motorway network and historically conditioned shortages in the railway network of central Poland.
- Sections in the mountainous areas of Balkan States, as well as Romania and Greece. The very low competitiveness of rail transport is a result of poor geometrical parameters of the railway lines implemented in difficult terrain and in many cases, poor maintenance of the tracks. It is worth highlighting here that the road network is also rather underdeveloped, so rail transport would become competitive even with a maximum speed of 160-200 km/h, as long as the road network remains neglected.
- Sections connecting Budapest to Serbia and Romania, where the technical condition is insufficient.
- Sections in the territory of Turkey, where the technical parameters of railroads are unsatisfactory, owing to difficult geographical conditions. This statement excludes the existing high-speed sections.

Action plan for the implementation of the TER HSR project

Implementation of the TER HSR project requires an action plan which includes tasks to be undertaken following the approval of the TER HSR network. The most important of them include:

1. **Completion of ongoing feasibility studies and the development of missing ones**

   There is a significant number of such studies, but there remains a large group of projects that are either at the initial feasibility study stage, or at the conceptual stage. Their preparation should be included in further actions, and coordination with projects at an advanced stage should be taken into consideration.

   Presently, the majority of key projects have complete feasibility studies. Some feasibility studies are ongoing and are expected to be completed within three years. All feasibility studies for the TER HSR projected should be completed within five years.

2. **Integration of projects within the corridor**

   In order to establish an HSR corridor, existing projects must be integrated. Completed design work on high-speed lines should be analysed against the possibility of achieving the highest possible consistency. It is not unthinkable that partial revision will be required for advanced projects to achieve synergies, both within corridors and across the TER HSR network.

   Standardisation of the newly constructed and modernised high-speed lines is advisable, so that they form routes with the maximum continuous performance parameters, particularly in terms of maximum speed, for long-distance trains. This would make it possible to achieve journey times that are attractive to travellers and competitive compared to other means of long-distance transport.

   The integration of projects within the TER HSR network should occur in two stages:

   - The first stage should cover existing, under construction and planned lines with completed feasibility studies, and the definition of the framework requirements for new projects that would ensure further development and better integration of the network. This would entail the development of an action plan to be implemented within one year.
   - The second stage should be a long-term process, concluding with the completion of the final missing feasibility studies of the TER network lines, and thus lasting approximately five years.

3. **Identification of the TER HSR corridors to be made suitable for freight**

   At the stage of preliminary analysis, it appears that the introduction of high-speed freight traffic in the TER States is possible on a large scale and can have significant effects. This is due to the conditions associated with large, attainable freight distances, and a dense network of industrial centres. Several potential corridors for this type of transport have been identified in the Study.

   It is recommended that opportunities for efficient freight transport be accounted for at the planning stage of high-speed line construction.

4. **Preparation of financial plans**

   Such plans are necessary to raise funds for projects, and to plan the investment process, as well as developing operational plans at various levels (lines, corridors).

   The financial plan should also be designed in two stages. The first stage (approximately one year) would be aimed at establishing estimates based on current feasibility studies and, in the absence of such studies, utilizing the indicator method. The second stage would consist of further and continuous adjustment to the estimates as subsequent studies are completed, and updates made.

5. Development of the TER HSR network implementation schedule

The study recommends completion deadlines for investments in TER HSR network:

- By 2030
- By 2050.

These deadlines align with the TEN-T implementation schedule, which for EU States ensures consistency in the implementation of the TER and TEN-T networks recommended due to the financial plans requiring EU support.

In order to coordinate the implementation of the TER HSR network, the schedule of implementation should be detailed in five-year periods commencing from 2025.

Table V–3 Development of action plan

Action	Time for action
Completion of incomplete feasibility studies or development of missing ones	3-5 years
Integration of projects within corridors	First stage (preliminary) – 1 year Second stage – 5 years
Determination of TER HSR freight transport sections	One year (initial study)
Preparation of financial plans	First stage (preliminary) – 1 year Second stage (detailed plans) – permanently
Development of the TER HSR network implementation schedule	2030 for the basic network 2050 for the completed network

Source: The authors' own research.

Institutional support

Due to its scale and long-term nature, significant institutional support is required to implement the TER HSR project. This support should involve internal coordination within the TER, and cooperation with external entities. A project-coordinating organizational unit has been proposed at the UNECE level.

It is also recommended that permanent cooperation be established between the TER HSR Steering Committee and the international organizations and institutions involved in HSR projects.

Actions that should be taken to implement the TER TSR project can be divided into two stages:

- Preparation
- Construction work.

The preparation phase is paramount due to the need for rapid integration of high-speed projects already implemented or planned. The number of projects prepared in the TER States is already significant, and some of them are being implemented in cooperation between TER States. For methodological reasons, this phase should be divided into two stages:

- Stage 1: Preliminary studies and analysis, identifying the key assumptions and directions of action (corridors, including for freight using high-speed lines), and estimating implementation costs. It is advisable for stage 1 to last one year, or until the decision to commence works is finalised.
- Stage 2: Completion of feasibility studies (or at least preliminary feasibility studies). A realistic deadline in this case is up to five years from the commencement of stage 1.

The construction phase, according to the assumptions above, revolves around two deadlines: 2030 (for projects already commenced), and 2050 for all other projects.

Work on the preparation of an HSR network project for the entire TER region requires international institutional support, in which UNECE can play an important role. Financing this work requires the involvement of interested States' own resources, as well as support from international organizations.

9. Summary

Key findings

1. **High potential demand for passenger services in the TER region**

   The construction of an HSR network will significantly improve the mobility of the TER population. Construction of HSR at current socioeconomic development levels would have a positive impact on the region's sustainable growth and prevent excessive development of road and air transport as substitutes for an underdeveloped rail network. It is apparent that an efficient transport system in any country is crucial for the whole economy, and the development of HSR networks is increasingly becoming an essential component of such systems.

2. **Large number of planned HSR projects**

   A large number of HSR projects have already been considered and part of them in TER States. This will make it possible to close transport gaps across the region and create effective HSR corridors with a positive impact on the development of regional systems. The most significant network gaps exist in the Balkan region, but are also a feature in Central Europe, particularly concerning international connections. The planned HSR projects are expected to close these gaps.

3. **Impact on general competitiveness of rail travel**

   The analyses conducted in this study demonstrate that HSR significantly improves the competitiveness of rail travel when compared with air and road transport, particularly when the combination of journey time and cost for distances up to 800 km, and even in some cases up to 1,400 km, is considered.

4. **Financing of investments in the HSR network**

   It will be crucial to maximise the financing opportunities available, in particular from the EU and other international institutions, as well as from commercial banks, and from private capital through PPPs.

   Before thinking of strenuous search for money, there should be immediate actions towards **stopping losses** in the railway managements – extending the embarrassingly low level of railway assets managements reflected in the average lifespan of the assets three (3) times (!) lower than the optimal one. After finalising the corrective procedures there will be the time to re-gain the investors' market trust. Starting from improving its own management on different levels, including the financial one, will increase railways' own resources, increase the financial market indicators assessments and the sector's valuations, improve risk analysis – lowering risks levels - and finally be convincing for the investors to re-assess the sector's fundamentals. The procedures will be time consuming and probably costly, but it is crucial to start them as soon as possible. The time is flying. Then after the homework will be done it will be possible to look outside of the sector for additional funds – when really needed.

Recommendations

For TER States to reap the possible benefits of the HSR projects outlined in this report, a number of actions must be implemented:

1. **International coordination of HSR projects**

   The coordinated development of HSR projects must occur at international level. This could be achieved through the TER project and UNECE by the development of an HSR network in the form of a framework investment schedule, which will also ensure that priorities are optimised. This option has to be carefully analysed and agreed among different groups of decision-makers on different levels. Because of complicated international environment, the required necessary procedures might take several years. Expected solutions are of the highest political sensitivities

2. **Use of high-speed lines for freight transport**

   HSR lines should be used, at least partially, to establish an express freight network that will improve goods and trade turnover and then competitiveness, especially in international transport. During the whole procedures of discussing, planning, construction etc. in the construction of new lines, such opportunities should be provided for as early as possible the planning stage.

3. **Development of multimodal nodes/hubs**

   It is crucial to secure the development of efficient multimodal nodes/hubs, as these will also have a positive impact on the development of the TER region. The multimodal nodes would provide the opportunity to construct transport interchanges. The respective development plans should consider the position of the HSR network as the primary transport system of the future. How to define the requirements of these nodes could be considered within the TER project, or within the Working Party on Rail Transport.

APPENDIX 1

Questionnaire for Collection of Information and Data on TER States and their Railway Network

General comments

All TER States are kindly requested to supply the following data, which will be needed as a database for the new ***UNECE TER High-Speed Masterplan Phase 2***. With view to the tight schedule of this project, each TER member State is asked to complete the questionnaire and submit it electronically to Mr. Jan Raczynski (j.raczynski@infotransport.pl), not later than by 30 May 2019.

TER States are requested to inform about relevant **projects** (ongoing and future) and their parameters: new lines, upgrading of existing lines to higher speed and deliver documents with description these projects.

Please check information given in annex 1, correct and fulfil tables about the following existing and planned projects:

- New high-speed line with maximum speed at least 250 km/h
- Upgraded lines with maximum speed at least 200 km/h.

Documents should deliver data to recognise intended speed level, travel times, how many travellers are expected, etc.

Basically, forecasts should refer to 2030 and 2050.

In tables in the next annexes please list available documents as follows:

- **Annex 1** Data about existing, under building or planned in perspective 2030 or 2050
- **Annex 2** Agreements with neighbouring States on border crossing high-speed links
- **Annex 3** National (and/or regional) transport strategies included or not included high-speed projects
- **Annex 4** National (and/or regional) spatial development strategies.

Please deliver all mentioned documents on the one of the next ways:

- Links to its in public or other documents
- By mail in pdf format or links to download its by transfer website (e.g. We Transfer or others).

If documents are available in English, please deliver its at first.

Annex 1

Data on existing, in construction or planned in perspective 2030 or 2050

Notes:

For planned lines please add regarding information about studies on high-speed (feasibility studies, prefeasibility studies or relevant) and indicate whether project is a part of TEN-T network (only for EU States).

(Studies should indicate intended speed level, travelling times, if it is an upgrade or a new line parallel to an existing line or in a new relation, how many travellers are expected, economic effects etc.). If study is very large, please indicate only summary.

Transport corridor (between city and city)[91]	Length [km]	Max speed [km/h]	Status (modernised or new line)	Date of the line opened or year planned to put in operation	Source of financing the construction[92]	Estimated total cost	Links to download documents or information that it is attached in PDF

Annex 2

Agreements with neighbouring States on border crossing high-speed links

Title[93]	Subject/ Range	Parties of the Agreement	Period of validity	Links to download documents or information it is attached in PDF and other comments

Annex 3

Transport Strategies

National (and/or regional) transport strategies included or not included high-speed projects

Title[94]	National and/or regional level	Period of validity	Links to download documents or information it is attached in PDF and other comments

Annex 4

National Spatial Development Strategies

Title[95]	National and/or regional level	Period of validity	Links to download documents or information it is attached in PDF and other comments

91 Add as many rows as you need; different documents shown separately.

92 N–national, R-regional, EU – European, O – others. Combination possible (e.g. N+EU2007-2013).

93 Add as many rows as you need; stages of the investments completed in different programming periods shown separately.

94 Add as many rows as you need.

95 Add as many rows as you need.

APPENDIX 2

HSR implementation costs and expected results

1. Assessing the economic efficiency of HSR projects – practical examples

1.1 Methodology for the study and implementation of HSR projects

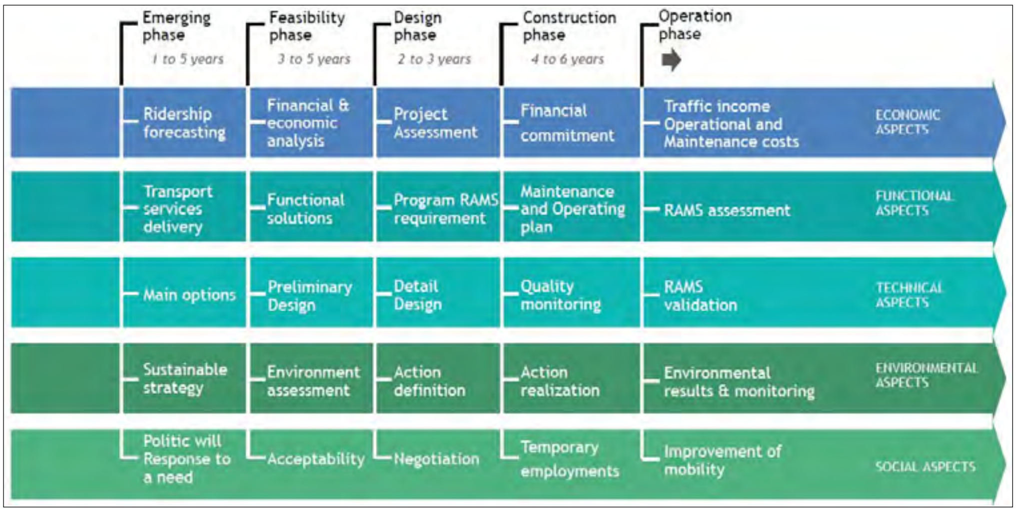
The most reliable way to evaluate HSR projects is to perform study work including technical, operational, financial and economic aspects. These projects require detailed analyses starting from technical and financial issues all the way to organizational issues.

Recommendations regarding such studies are the subject of UIC studies.[96] Activities should cover the following aspects:

- Economic studies based on transport forecasts aimed at estimating the costs and benefits of the project implementation,
- Functional aspects along with transport services delivery, RAMS requirement and assessment and also maintenance operating plan,
- Technical aspects
- Environmental aspects
- Social aspects.

These analyses should be carried out in all five project phases beginning from the emerging phase to the operational phase, where it is possible to evaluate the solutions adopted for the HSR system in operation. The entire process is set out in figure A2-1.

Figure A2–1 Action scheme for implementation of HSR system



Source: High Speed Railway System Implementation Handbook, UIC Paris 2017.

96 UIC, *High Speed Railway System Implementation Handbook*..., op. cit.

1.2 Financial analyses at individual stages of project preparation

Emerging phase

In the emerging phase, many variants of the route are usually considered. Therefore, it is important to select several variants for further, detailed analysis. A pre-feasibility study is usually performed at this stage. Multicriteria analysis can be used to evaluate variants in this study. This assessment should be based on clearly defined criteria. Their selection should enable the ranking of investment options according to the degree of achievement of project objectives.

In the prefeasibility study, it is possible to also use other instruments. A SWOT analysis (Strengths-Weaknesses-Opportunities-Threats), enabling identification of strengths and weaknesses of each investment variant as well as opportunities and threats of project implementation according to particular variants, may be particularly useful. This analysis should be used when the results of multicriteria analysis are not clear-cut.

Feasibility phase

The investment variants selected on the basis of multicriteria analysis in the emerging phase need to be put through a detailed cost-benefit analysis (CBA). This analysis should assess the position of:

- The infrastructure manager – as an entity incurring expenses related to the construction of new high-speed rail infrastructure and its maintenance and operation, as well as making it available to railway operators;
- The railway operator – as the entity providing HSR services.

A CBA can also be carried out from the point of view of the transport system as a whole. In this case, the analysis should also include the monetary implications of other entities.

The decision on whether to carry out the investment should be based on the direct economic impact as well as socio-economic aspects and should reply to 2 key questions:

- Whether the project is worth co-financing;
- Whether the project needs co-financing.[97]

The CBA should also allow the ranking of the assessed investment options. While the multi-criteria analysis in the emerging phase is usually performed with an accuracy of ±30 per cent. In the assessment of investment options in the feasibility study, accuracy is usually ±10 per cent.

An important element of the economic and financial assessment of projects in the feasibility study is potential sensitivity and risk analysis. An assessment of the financial sustainability of the project should also be carried out.

Design phase

In the design phase, the economic assessment should refer to detailed technical solutions adopted by designers (project assessment). The dynamic generation cost (DGC) method can be used at this stage. Its essence consists of the identification of investment costs and operational costs during the life cycle of the project. The criterion for choosing compared technical solutions is to minimize present value of dynamic generation cost.

97 T. Dyr, K. Ziółkowska, *The effectiveness and financing of the high-speed rail structure*, [in:] A. Żurkowski (ed.), High-Speed Rail in Poland. Advances and Perspectives, CRC Press, London 2018.

Construction phase

In the construction phase, economic aspects are primarily related to the assessment of financial commitment. The investor must be able to execute current liabilities in a timely manner. It is therefore important to plan liabilities in order to have optimal cash flow.

Operation phase

In the operation phase it is necessary to systematically analyse both traffic income and operational and maintenance costs. The results of these analyses should enable the creation of an appropriate policy regarding the financing of the maintenance of HSR infrastructure. They should also ensure an appropriate level of return on equity.

In this phase it would also be useful to perform *ex post* analyses. Further CBAs should be carried out using information about the actual volume of transport as well as traffic income, investment, operational and maintenance costs in order to compare the results with the forecasts prepared in the feasibility study. The conclusions of the analysis may improve the accuracy of *ex ante* analyses carried out in future projects.

1.3 Assessing investment effectiveness indicators

Multicriteria analysis

Multicriteria analysis should be the basic method of economic assessment of projects in the emerging phase. To ensure the validity of the conclusions, it is necessary to develop objective criteria for the assessment of the identified variants. These criteria can be both stimulant and de-stimulant. In addition, the criteria are expressed in different units. In this situation, their standardization is necessary. The following formulas are used in the analysis:

- For stimulants:

$$t_{ij} = \frac{x_{ij} - \bar{x}}{S_j}$$

- For de-stimulants:

$$t_{ij} = -\frac{x_{ij} - \bar{x}}{S_j}$$

- where:

  t_{ij} – standardized value of j-th index in i-th subdivision
  x_{ij} – value of j-th denominator in i-th subdivision
  $\bar{x}$ – the arithmetic means of j value
  S_j – standard deviation in distribution of characteristic xj.

Multicriteria analysis of investment options for high-speed line construction should consider at least the following main criteria:

- Investment outlays
- Changes in the market structure
- Socioeconomic benefits
- Environmental impact of the project
- Risk of project implementation.

For each of the above criteria, using heuristic methods, specific sub-criteria and criteria should be established, as well as their importance (weight) defined for achieving project goals. Heuristic methods are used in their identification. An example of the criteria used to assess the investment option for the construction of a high-speed line connecting urban agglomerations located in different States is shown in table A2-1. The specific feature of this investment is the presence of the cross-border sections.

Table A2–1 Sample criteria for assessing investment options for the construction of a high-speed line connecting agglomerations located in different States

Variable	Criterion weight	Sub criterion weight	Detailed criterion weight	Variable's type
Criterion 1: Investment outlays	0.25			
Total investment outlays [euro]			0.20	De-stimulants
Investment outlays on one km of line			0.30	De-stimulants
Investment outlays for one-minute shortening of travel time			0.50	De-stimulants
Criterion 2: Modal split changes	0.20			
Sub-criterion 2a: Modal split changes in the transport corridor		0.40		
Average transport performance of high-speed trains in the transport corridor [paskm/year]			0.30	Stimulants
Average transport performance taken from passenger cars [paskm/year]			0.20	Stimulants
Average transport performance taken from bus transport [paskm/year]			0.08	Stimulants
Average transport performance taken from air transport [paskm/year]			0.12	Stimulants
Average share of high-speed railways in the transport corridor [%]			0.30	Stimulants
Sub-criterion 2b: Modal split changes on cross-border sections		0.30		
Average transport performance of high-speed trains on cross-borders sections [paskm/year]			0.30	Stimulants
Average transport performance taken from passenger cars [paskm/year]			0.20	Stimulants
Average transport performance taken from bus transport [paskm/year]			0.08	Stimulants
Average transport performance taken from air transport [paskm/year]			0.12	Stimulants
Average share of high-speed railways on cross-border sections [%]			0.30	Stimulants
Sub-criterion 2c: Modal split changes on border sections		0.30		Stimulants
Average transport performance of railways on cross-borders sections [paskm/year]			0.30	Stimulants
Average transport performance taken from passenger cars [paskm/year]			0.25	Stimulants

Table A2–1 Sample criteria for assessing investment options for the construction of a high-speed line connecting agglomerations located in different States (continued)

Variable	Criterion weight	Sub criterion weight	Detailed criterion weight	Variable's type
Average transport performance taken from bus transport [paskm/year]			0.15	Stimulants
Average share of railways on border sections [%]			0.30	Stimulants
Criterion 3: Socio-economic benefits	0.30			
Sub-criterion 3a: Regional benefits		0.40		
Number of urban centres in the cross-border area covered by the high-speed rail system			0.10	Stimulants
Number of inhabitants of cities and agglomerations located in the cross-border area covered by the high-speed rail system			0.30	Stimulants
Number of inhabitants of cities and agglomerations located in the cross-border area covered by the high-speed rail system			0.10	Stimulants
Shortening the travel time of 1 passenger in border transport [min]			0.50	Stimulants
Sub-criterion 3b: Added value for the European Union		0.60		Stimulants
Average savings in travel time and time in cargo transport [PLN/year]			0.40	Stimulants
Average cost savings of climate change [PLN/year]			0.15	Stimulants
Average benefits from improved security [PLN/year]			0.15	Stimulants
Average cost savings of air pollution [PLN/year]			0.15	Stimulants
The amount of operational work taken over from road transport in freight transport [vehicle/km]			0.15	Stimulants
Criterion 4. Impact of the project on the natural environment	0.10			
Noise impact			0.15	De-stimulants
Collisions with monuments			0.10	De-stimulants
Impact on protected areas (excluding Natura 2000 areas)			0.10	De-stimulants
Impact on Natura 2000 areas			0.25	De-stimulants
Impact on migration corridors			0.15	De-stimulants
Collisions with buildings			0.15	De-stimulants
Impact on the soil and water			0.10	De-stimulants
Criterion 5. Risk of project implementation	0.15			
Demand risk			0.13	De-stimulants
Design risk			0.09	De-stimulants
Administrative risk			0.04	De-stimulants
Risk related to the land acquisition			0.09	De-stimulants

Table A2–1 Sample criteria for assessing investment options for the construction of a high-speed line connecting agglomerations located in different States (continued)

Variable	Criterion weight	Sub criterion weight	Detailed criterion weight	Variable's type
Regulatory risk			0.09	De-stimulants
Financial risk			0.13	De-stimulants
Risk of capacity limitations			0.17	De-stimulants
Risk of inability to further development and staging			0.09	De-stimulants
Risk of deterioration of the offer and decrease in demand during the implementation of the investment			0.17	De-stimulants

Source: Own study.

The criteria in the table above should consider the specifics of the project. In either case it is necessary to adjust both the set of criteria and the weights assigned to those criteria. Considering the identified criteria and the values and weights assigned to them, synthetic measures can be calculated for individual variants according to the formula:

$$T_i = \sum_{j=1}^{k} t_{ij} \cdot w_j$$

where:

T_i – A synthetic measure for the *i-th* variant

t_{ij} – Standardized value of the *j-th* criterion in the *i-th* variant

w_j – Weight of *j-th* criterion.

The criterion for ranking investment options is to maximize the value of the synthetic measure T_i. For further, detailed analysis, variants with a relatively high synthetic T_i value should be selected. Variants with a high level of risk and failing to achieve the project's objectives should be rejected.

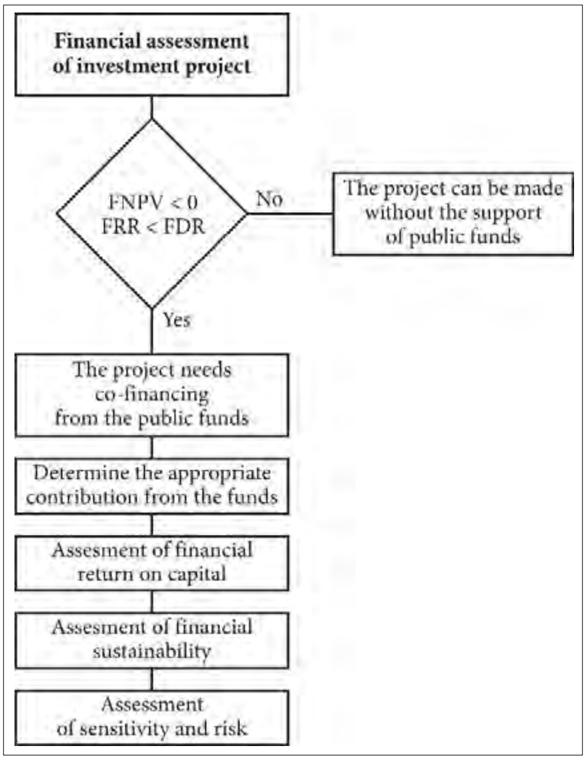
Cost–benefit analysis

The CBA results are of key importance in the decision-making process for high-speed lines. It has a dual character. In the first dimension, it is carried out from the investor's point of view (financial analysis). The second additionally includes costs and benefits in the project environment (economic analysis). Its elements are:

- The Economic Net Present Value (ENPV), Economic Rate of Return (ERR) and B/C ratio in economic assessment;
- The Financial Net Present Value (FNPV) and Financial Rate of Return (FRR) in financial assessment.

The primary purpose of the financial analysis is to examine whether the project is financially effective and, on that basis, make a statement, whether it requires funding from public funds and to determine the funding level. Investments which demonstrate the financial effectiveness do not require public support. It is possible to obtain funds for their realization on the capital market. Financially ineffective projects can be funded partially from EU funds or from other public funds. However, these projects must achieve economic effectiveness. Figure A2-2 illustrates the financial assessment of infrastructure projects regarding high-speed line construction.

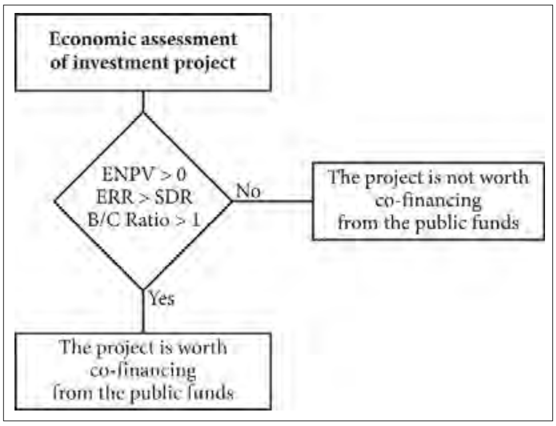
Figure A2–2 **The financial assessment process for HSR investment projects**



Source: Own study.

The public nature of transport infrastructure investment as a result of them generating external positive effects is a fundamental element of the economic assessment. It enables the identification of actions which are socially valuable and should be carried out, as they bring external benefits, contributing to a region's development. The process for the economic analysis is presented on figure A2-3.

Figure A2–3 **The economic assessment process for HSR investment projects**



Source: Own study.

Table A2-2 below shows the aspects of the financial assessment that need to be carries out to ensure the financial fitness of HSR investment projects.

Table A2–2 **The structure of the financial assessment for the investment project in railway transport**

Financial Assessment	**Defining the time horizon**	
	The cash flow forecasting	The forecasting of total investment costs
		The forecasting of total operating costs
		The forecasting of total revenues
		The forecasting of residual value
		The forecasting of other cash flows (outflows and inflows)
	Defining the financial discount rate	
	The calculation of the financial project performance indicators	
	The calculation of the co-financing rate	
	The setting of the sources of financing	
	Assessment of the financial sustainability	
	Assessment of financial performance and risk	

Source: Own study.

Table A2-3 below shows the aspects of the economic assessment that need to be carries out to ensure the economic sustainability of HSR investment projects.

Table A2–3 **The structure of the economic assessment for the investment project in railway transport**

Economic Assessment	**Defining the time horizon**	
	The cash flow forecasting	The forecasting of total investment costs and their conversion of market to accounting prices
		The forecasting of total operating costs and their conversion of market to accounting prices
		The forecasting of residual value
		The forecasting of other cash flows (outflows and inflows)
	Defining the social discount rate	
	The calculation of the economic project performance indicators	
	The calculation of the co-financing rate	
	Assessment of economic performance sensitivity and risk	

Source: Own study.

In carrying out this analysis it is important to choose a time horizon that correctly reflects the full economic life of the project.[98] The reference time horizon recommended for railways investment projects is 30 years.

[98] *Guide to Cost-Benefit Analysis of investment projects Structural Funds, Cohesion Fund and Instrument for Pre-Accession*. European Commission, Directorate General Regional Policy 2008.

The discount rate used in the financial analysis should reflect the opportunity cost of capital to the investor. This can be thought of as the foregone return on the best alternative project. The social discount rate is used in the economic analysis.

Estimating cash flows requires a reliable and credible analysis of the distribution over time of their individual elements generated by the investment project. Usually, the incremental method is used in cash flow forecasting. They represent the difference (increase) between the values of cash flows after the completion of the project and the values of these streams without the project. This value can be calculated from the formula:

$$CF_{k,t} = CF_{k,t}^{WI} - CF_{k,t}^{WBI}$$

where:

$CF_{k,t}$ – Incremental cash flow *k*–a type in *t* year

$CF_{k,t}^{WI}$ – Cash flow *k*–a type of examined variant of an investment in year *t*

$CF_{k,t}^{WBI}$ – Cash flow *k*–a type in the baseline option in year *t*.

In accordance with the incremental principle, only differential flows are included in the forecasting of cash flows. They refer to the change in the size of the stream, resulting from the implementation of the investment project, compared to the stream that does not include this project.

Forecasting investment costs consists in determining the total amount of anticipated costs of acquiring or producing the necessary fixed assets, as well as the necessary increase in current assets conditioning the operation of the intended project. In transport infrastructure investments particular attention should be paid to the reliability of investment outlay estimates. Experience shows that the financial and economic efficiency of investments is very sensitive to changes in investment costs.

The level of investment costs related to the construction of transport infrastructure, including HSR lines, is estimated on the basis of the construction and assembly works as well as the costs of purchasing the necessary equipment conditioning the desired operating parameters. The technical project is the basis for determining these amounts. The level of costs is primarily influenced by:

- The degree of complexity and technical diversity of infrastructure;
- Geographical conditions; and
- Operational load.

The experience of building high-speed lines shows that investment costs range from 10 to 40 million euros per km with an average of 18 per km with the range resulting from different topographical conditions. Costs are highest where it is necessary to build tunnels in difficult mountainous terrain.

The costs of maintaining and operating transport infrastructure are one of the important elements of investment effectiveness, both in financial and economic terms. These costs reflect the negative cash flow generated during the lifetime of the project for the infrastructure manager. The correct determination of the level of these costs has an impact not only on the results of the assessment of financial and economic effectiveness, but also on the financial sustainability of investments. In the case of income-generating projects, it also affects the level of project co-financing from the EU.

The forecast of infrastructure maintenance and operation costs should be prepared separately for the identified investment options and the non-investment option in order to identify the change as a result of the investment.

In the absence of commonly accepted standard methods for estimating the cost of maintaining and operating infrastructure, heuristic methods are used over a relatively long-life cycle of projects (30 years). It is also important to use historical data from infrastructure managers operating high-speed lines. The research shows that unit costs in euros per km per single track range from €12,919 in Italy to €33,457 in Spain. The structure of these costs is presented in table A2-4 below.

Table A2–4 Cost of HSR infrastructures maintenance by country. Costs are expressed in 2002 EUR per kilometre of track

	Belgium		France		Italy		Spain	
km of track	142		2 638		492		949	
Maintenance of track	13 841	43.7%	19 140	67.3%	5 941	46.0%	13 531	40.4%
Electrification	2 576	8.1%	4 210	14.8%	2 455	19.0%	2 986	8.9%
Signalling	3 248	10.3%	5 070	17.8%	4 522	35.0%	8 654	25.9%
Telecommunications	1 197	3.8%	0	0	0	0	5 637	16.8%
Other costs	10 821	34.2%	0	0	0	0	2 650	7.9%
Total maintenance cost	**31 683**	**100%**	**28 420**	**100%**	**12 919**	**100%**	**33 457**	**100%**

Source: G. de Rus et al., Economic Analysis of High-Speed Rail in Europe, Fundacion BBVA, 2009.

The data presented in the table above indicate significant cost differences. In many of the States surveyed they are at the level of €30,000 per kilometres of single track.

The restructuring of railways in the EU resulted in the separation of infrastructure management from the activities related to the provision of services. Infrastructure managers bear the costs associated with its maintenance and operation. They provide this infrastructure to railway operators collecting track access charges. Their amount depends on the state policy and the amount of budget funds allocated for financing the costs of maintaining railway infrastructure.

1.4 Efficiency of HSR operators

The assessment of the effectiveness of investment related to the construction and operation of the HSR system should include a CBA with reference to railway operators. Similarly, to the assessment focusing on infrastructure managers, it is necessary to forecast the cash flow of the investment costs, operational costs and revenues.

The investment costs for a rail operator are primarily associated with the purchase of rolling stock. Forecast expenses can be estimated on the basis of rolling stock market prices.

Operational costs and revenues can be forecast based on rail operators' data. Research in this area indicates that there is a correlation between average costs and train speed as the average costs decreases as train speeds increase. This is due to the improvement in the level of utilization of the resources of the HSR operator, in particular for rolling stock and personnel. The average annual rolling stock mileage as a function of commercial speed is shown in table A2-5.

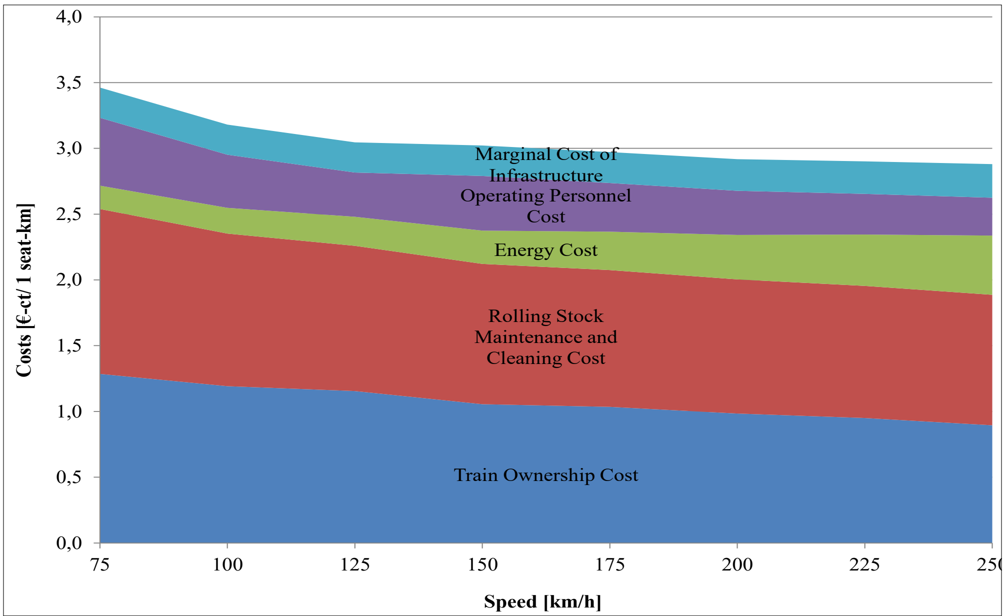
Table A2–5 Average annual rolling stock mileage as a function of commercial speed and average service time at turning stations

Commercial speed [km/h]	Long distance transport (D = 500 km);			Regional transport (D = 200 km)		
	R = 90 [min]	R = 60 [min]	R = 30 [min]	R = 45 [min]	R = 30 [min]	R = 15 [min]
75	156 429	166 630	178 256	149 561	161 368	175 200
100	196 538	212 917	232 273	185 818	204 400	227 111
125	232 273	255 500	283 889	217 447	243 333	276 216
150	264 310	294 808	333 261	245 280	278 727	322 737
175	293 197	331 204	380 532	269 962	311 043	366 872
200	319 375	365 000	425 833	292 000	340 667	408 800
225	349 209	396 466	469 286	311 797	367 920	448 683
250	365 000	425 833	511 000	329 677	393 077	486 667

R –time at turning stations
D – length of the serviced line [km]
Source: A. Garcia, *Relationship between rail service operating direct costs and speed*. Fundación Ferrocarriles Españoles, UIC, 2010.

A detailed analysis of individual groups of direct costs related to the performance of rail passenger transport indicates that as the speed increases, the costs of traction energy consumption and charges for access to infrastructure clearly increase. On the other hand, unit capital costs (related to the purchase of trainsets), rolling stock maintenance and cabin crew labour costs decrease. These dependencies – based on calculations carried out for a 200 m long train serving long-distance passenger services on a 500 km line, with turnaround times at stations of 60 minutes – are presented in figure A2-4. They show that in the analysed case the total average costs decrease – with an increase in commercial speed from 70 to 250 km/h (which corresponds to a maximum speed of approx. 120-350 km/h) – by approx. 17 per cent. The largest decrease in unit costs is noticeable up to approximately 160 km/h. With an increase in maximum speed from 160 to 350 km/h, unit costs decrease by, about 5.5 per cent.

Figure A2–4 Structure of direct unit costs of long-distance transport as a function of train speed and type of transport



Source: Own study based on A. Garcia, *Relationship between rail service operating direct costs and speed*. Fundación Ferrocarriles Españoles, UIC, 2010.

The considerations presented so far focused on comparing the costs of providing transport services with rolling stock traveling at different speeds. Cost aspects, although significant, cannot constitute a sufficient basis for making investment decisions and need to be accompanied by the benefits of providing transport services – the revenue gained from selling tickets. These benefits are a function of the number of passengers using rail transport and the price paid by the passenger for the journey (the fare).

The number of passengers, which is a measure of the demand for rail transport services, is determined by many factors both dependent on the operator (e.g. price of the service, quality of the offer) and independent of the operator (e.g. propensity to pay, communication behaviour patterns, consumer needs and preferences). The most important factors determining the demand for rail transport services include the price of services and travel time.

The increase in train speed – leading to a reduction in travel time – increases the demand for services. The time elasticity of demand is used to measure the strength of the relationship between demand and travel time. This term is used to describe a relative change in demand as a response to a relative change in travel time of 1 per cent:

$$e_t = \frac{\Delta Q}{Q_0} : \frac{\Delta T}{T_0}$$

where:

ΔQ – Change in demand (number of passengers transported)

ΔT – Travel time change

Q_0 – Demand at travel time T_o.

According to the law of demand, together with the price increase, the demand for good decreases (in further considerations the unusual cases of demand will be ignored). The strength of the relationship between these market elements is reflected in the price elasticity of demand. It is determined in the same way as in the case of travel time flexibility:

$$e_p = \frac{\Delta Q}{Q_0} : \frac{\Delta P}{P_0}$$

where:

ΔQ – Change in demand (number of passengers transported)

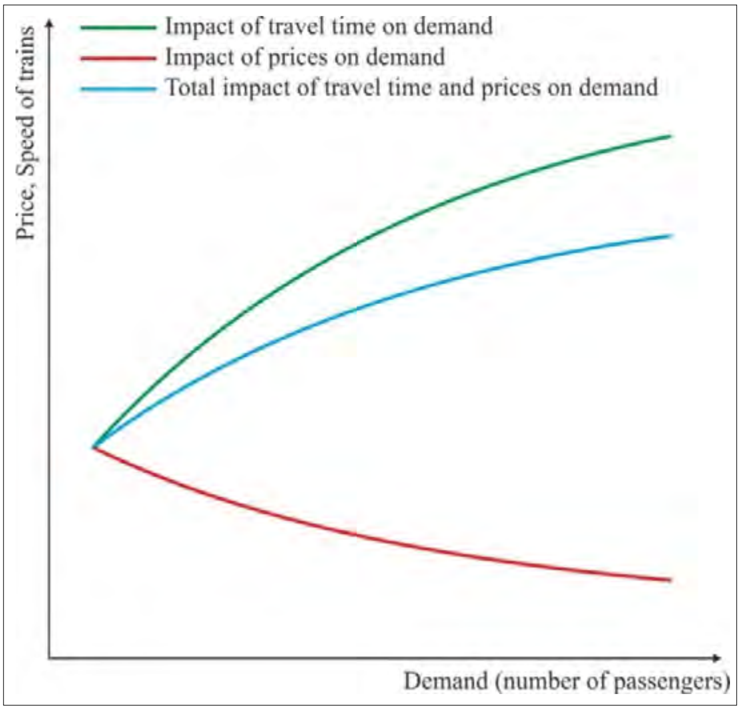
ΔP – Price change

Q_0 – Demand at price P_o.

It is common practice in the rail passenger market to increase the price as the commercial speed of trains increases. The price and travel time have an opposite effect on the demand for transport services. The final evolution of demand depends on the level of price elasticity and the flexibility of travel time.

An analysis of the rail passenger market indicates that travel time flexibility is higher than the absolute value of the price elasticity of demand (the first of these measures is typically positive and the second negative). Consequently, despite the increase in the price for transport services, after increasing the speed of trains, demand increases. This relationship is shown in figure A2-5.

Figure A2–5 Impact of price and travel time on demand



Source: Own study.

1.5 Summary – examples of investment efficiency in HSR

Desired investment efficiency and financial support

An example of economic efficiency in HSR can be seen in the results of the development of the HSR system in France, presented in table A2-6.

Table A2–6 Examples of economic indicators for the first high-speed lines in France

		Commissioning year	Economic rate of return for the railway system (TOC + IM)	Socio-economic rate of ROI	Subsidy rate
LN 1	Sud-Est	1983	12%	23%	0%
LN 2	Atlantique	1990	10.5%	14%	24%
LN 3 Nord	Nord Européen	1993	2.9%	5%	4%
LN 3 Jonction	Interconnexion	1996	6.9%	15%	9%
LN 4	Rhône-Alpes	1994	6.1%	10.6%	8%
LN 5	Méditerranée	2001	4.1%	8.1%	11%
LN 6	Est-Europeen (1)	2007	5.9%	4.2%	77%

Source: HS revelance. SNCF presentation. UIC Workshop. "Operating high-speed lines: in search of efficient solutions", Paris, 31 January 2019.

The first Sud-Est line obtained a relatively high value of financial rate of return. Such a high value was obtained despite the lack of public investment support (subsidy rate = 0 per cent). It was possible due to relatively low investment outlays and very high demand for high-speed trains.

Other lines (LN2 – LN6) needed support from public funds (subsidy rate 4-77 per cent). Thanks to financial support, the rate of return ranged from 2.9 per cent to 10.5 per cent.

Obtaining financial efficiency of projects is particularly important when they are implemented under PPP. Private partners expect a satisfactory rate of return on invested capital. Experience shows that such projects need to be co-financed from public funds. This is confirmed by examples of two PPP projects implemented, i.e. BPL and SEA. In the first case co-financing from public funds amounted to 58 per cent, in the second case 38 per cent.

The need to co-finance infrastructure projects from public funds is widespread in Europe. An example would be high-speed lines built in Spain, presented in the table below. The average level of funding there was almost 50 per cent.

Table A2–7 Percentage of EU co-financing for high-speed line projects in Spain

Investment	EU funding rate
LAV Madrid – Saragossa – Barcelona	49.58%
LAV Madrid – Segovia – Medina del Campo	49.16%
LAV Cordoba – Malaga	41.63%
Average	**48.18%**

Source: UIC.

In the assessment of infrastructure projects, including those related to the construction of HSR, economic efficiency analysis is of particular importance in appraising the project's contribution to the economic welfare of the region or country. It is made on behalf of the whole of society instead of just the owners of the infrastructure, as in the financial analysis. The key concept is the use of accounting shadow prices, based on the social opportunity cost, instead of observed distorted prices.

The construction of high-speed lines usually generates relatively high social and economic benefits. They are primarily the result of the environmentally friendly nature of the railway and its high level of safety. This is reflected in the low external costs of HSR (this issue is the subject of consideration later in this study). Shortening the travel time is also an extremely important factor. The latter factor, visible in the figure above for HSR projects in France, leads to a significant increase in the number of rail passengers. A significant part of the capture is from road and air. These two types of transport are characterized by significantly higher external costs than rail transport. Consequently, the capture of these passengers leads to a reduction in the external costs of transport.

The relatively high economic efficiency of HSR construction projects is confirmed by the results for high-speed lines in France presented in table A2-6. In each case analysed, the economic rate of return (in the socioeconomic rate of ROI) is much higher than the social discount rate recommended by the EU for infrastructure projects in rail transport.

2. External costs

2.1 Definitions

External costs constitute that part of social costs (including all costs related to the construction and maintenance of transport infrastructure and carrying out of transport activities), which are not private (internal) costs incurred by the transport user and which are not passed on to the user by the market. This means that there is no market for prices related to those costs that would affect the decision of the entities. They are usually presented in the following groups:

- Uncovered infrastructure costs and other uncompensated consumption of material resources;
- Environmental costs, including depletion of non-renewable natural resources as well as devastation and defragmentation of the ecosystem;
- Costs incurred by those connected but not directly involved in the transport system.[99]

Table A2–8 Structure of social transport costs

Cost category.	Social cost	
	Private cost.	**External cost**
transport expenses	Fuel costs, costs of transport means, tickets	costs paid by other entities (e.g. expenses for the construction of parking lots, parking spaces)
infrastructure costs	Users' fees, taxes from the inside transport, fuel taxes	uncovered infrastructure costs
accident costs	Costs covered by insurance, own accident costs.	Uncovered accident costs (pain/suffering caused by others)
environmental costs	Losses borne by users	Uncovered environmental costs (nuisance to other members of society caused e.g. by noise)
Congestion costs	Costs of time loss incurred by users	Delays, time losses of other members of the society

Source: Pawłowska B, *Zrównoważony rozwój transportu na tle współczesnych procesów społeczno-gospodarczych*, Gdańsk 2013.

External costs are a valuable expression of externalities. In transport, they refer to situations when the transport user does not pay all costs associated with the transport process or does not receive the full benefits associated with it. External costs are borne by those who do not contribute to its creation but bear its negative effects.

2.2 The volume of external costs for HSR and other means of transport

HSR has the lowest external costs among all modes of transport. The amounts of these costs and unit costs per pkm have been analysed at length with the costs set out in table A2-9 below.[100]

[99] B. Pawłowska, *Zrównoważony rozwój transportu na tle współczesnych procesów społeczno-gospodarczych*, Wydawnictwo Uniwersytetu Gdańskiego 2013.

[100] *Sustainable Infrastructure Charging and Internalisation of Transport Externalities: Main Findings*, 2019, n.d.

Table A2–9 External costs in the EU28 in 2016 (all figures are PPS adjusted)

Vehicle	Total external costs	Average external costs
Passenger transport modes	**Billion EUR**	**EUR-cent per pkm**
Passenger car	565	12.0
Bus/coach	19	3.6
Motorcycle	41	24.5
High speed train	1	1.3
Electric passenger train	11	2.6
Diesel passenger train		3.9
Aircraft	48	3.4
Freight transport modes	Billion EUR	EUR-cent per tkm
Heavy Goods Vehicle	78	4.2
Electric freight train	5	1.1
Diesel freight train		1.8
IWT vessel	3	1.9
Maritime vessel	98	0.7

Source: Self study based on EC, Sustainable Infrastructure Charging and Internalisation of Transport Externalities: Main Findings, 2019.

Compared to conventional rail, the external costs generated by HSR are 11 times lower, despite the fact that high-speed trains account for 28 per cent of passenger traffic in passenger-kilometres. The main competitor of HSR – air transport has almost three times higher unit external cost and road – transport by passenger cars about 11 times higher.

At the present initial stage of the development of freight on high-speed lines, this mode of transport has not yet been specified in the statistics, but it is likely that the external unit costs for high-speed freight trains will not be significantly different from conventional freight trains operated with electric traction.

Table A2-10 presents the distribution of external costs into individual types according to their source, following a broader classification than in the table above.

Table A2–10 Average external costs 2016 for EU28 passenger transport by cost category and transport mode [Billion EUR]

	Road transport				Rail transport		
Cost category	**Passenger car**	**Bus**	**Coach**	**Motorcycle**	**HS Train**	**Conventional electric train**	**Diesel train**
Accidents	4.5	1.0	1.0	12.7	0.1	0.5	0.5
Air Pollution	0.7	0.8	0.7	1.1	0.0	0.01	0.80
Climate	1.2	0.5	0.4	0.9	0.0	0.0	0.3
Noise	0.6	0.4	0.2	9.0	0.3	0.8	1.4
Congestion*	4.2	0.8	0.8				
Well-to-Tank	0.4	0.2	0.1	0.5	0.3	0.8	0.1
Habitat damage	0.5	0.1	0.1	0.3	0.6	0.6	0.8
Total costs	12.1	3.8	3.3	24.5	1.3	2.71	3.9
Environmental costs**	3.4	2	1.5	11.8	1.2	2.21	3.4

*Congestion in terms of delay costs

**Air Pollution, climate, noise, well-to-tankandhabiat damage

Source: Sustainable Infrastructure Charging and Internalisation of Transport Externalities: Main Findings, 2019.

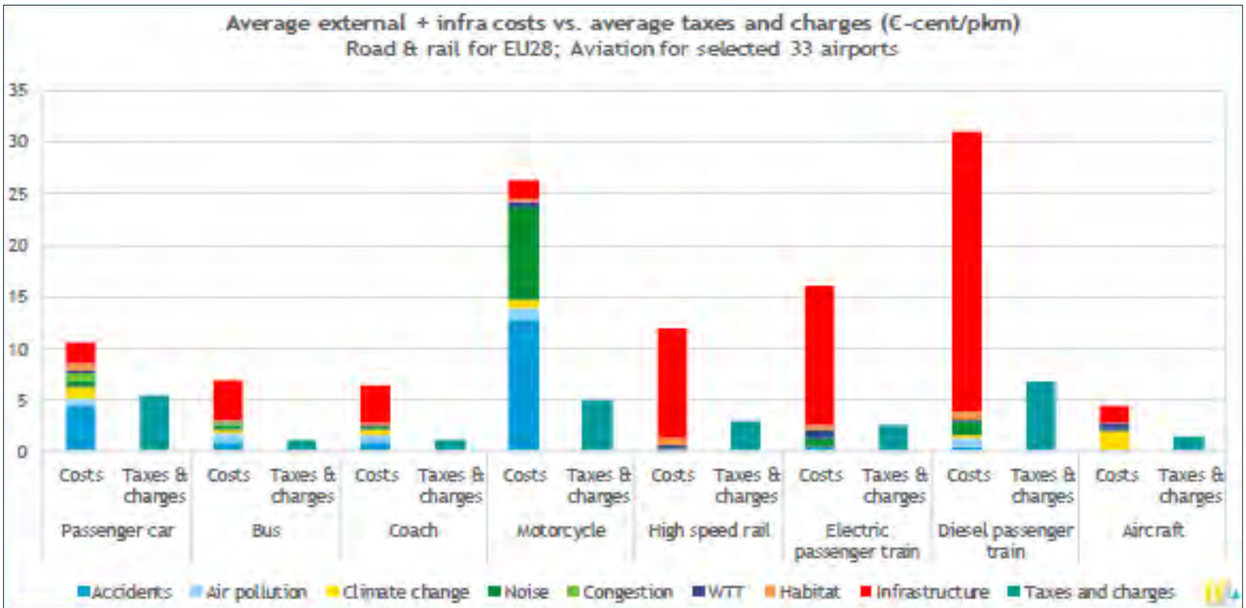
Some external costs are covered by tax revenue and direct charges with the degree of coverage being different for each means of transport. The overall cost coverage ratio provides an insight into total cost recovery, determining whether external and infrastructure costs are internalised by taxes and related charge. Figure A2-6 displays the average external and infrastructure costs and the average tax/charge revenues for all passenger vehicle types.

For rail transport, the cost coverage ratios for the different types of passenger trains are in the same range. For high-speed trains the ratio is equal to 31 per cent, while for overall electric (including high-speed) and diesel passenger trains these ratios are 20 and 23 per cent. Differences in infrastructure utilization, load factor and energy taxation (diesel vs. electricity taxes) are the main explanations for this variance in cost coverage ratios.

The highest average cost coverage ratio is found for passenger cars; the average tax/charge level of 5.5 EUR-cent per pkm covers 51 per cent of the average external and infrastructure costs of about 11 EUR-cent per pkm.

For aviation only 32 per cent of the average external and infrastructure costs (about 4.8 EUR-cent per pkm) are covered by taxes and charges. But the cost coverage ratio for an average airplane (covering both short- and long-haul flights) and hence cannot directly be compared to the cost coverage ratios of the other modes.

Figure A2–6 Average external and infrastructure costs vs. average taxes / charges for passenger transport



Source: EC, Sustainable Infrastructure Charging and Internalisation of Transport Externalities: Main Findings, 2019.

2.3 The environmental costs of HSR

High speed projects are usually appraised by means of two important balances: economic and environmental. The environmental balance spans the life cycle of the infrastructure from the very first design to final recycling of its components, through the construction and operation periods. For high-speed lines, UIC published data on CO_2 emissions detailing the stages from design to construction.

Carbon emissions were identified in detailed stages:

- Designing the line, because the engineers and draftsmen will need buildings and devices to shelter them and provide;

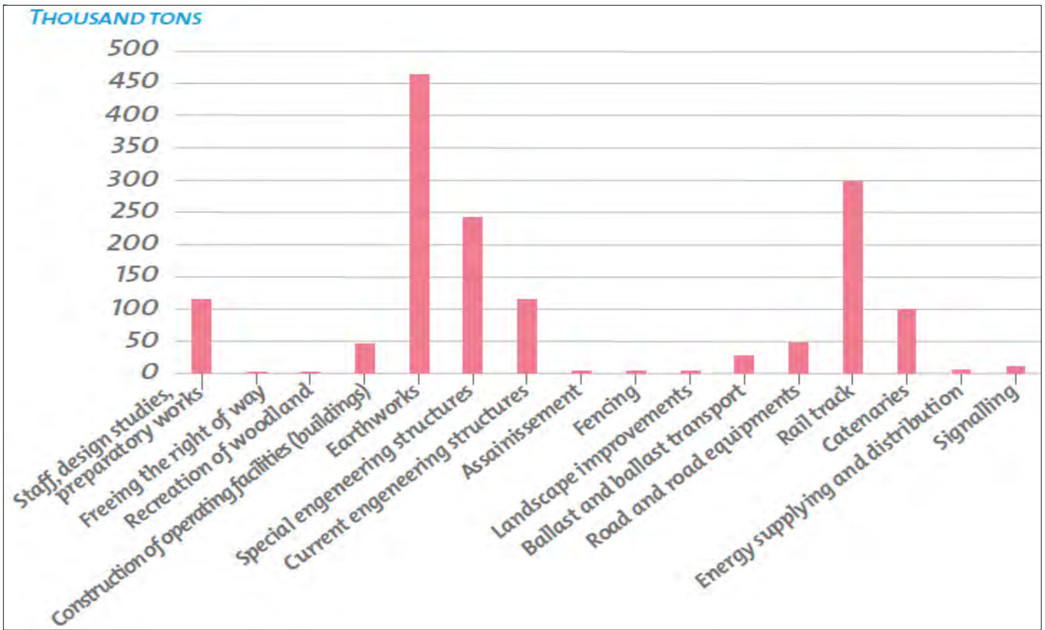
- Comfort and heating or air conditioning, fuel for going in the field or to meetings, etc.;
- Constructing the line, the stations and the rolling stock;
- Including the emissions for extracting and shaping materials (e.g. steel or cement), and for their transport (e.g. moving);
- The earth or transporting the rails);
- Operating trains and stations;
- Maintaining the infrastructure and the rolling stock;
- Distributing tickets;
- Recycling the components of the infrastructure and the rolling stock.

These emissions lead to a substantial footprint spread along the life of the project (from 50 to 100 years), but this is strongly concentrated at the start due to the impact of construction. In the case of a 300 km long HS line (such as the Oceane Line in France), the CO_2 emissions amount to 1.5 million tonnes.

However, these emissions are offset during the revenue period because of the CO_2 savings due to the traffic capture from road (50,000 tonnes per year) and air (80,000 tonnes per year) to rail. This means that the carbon balance, which is heavily negative at the end of the construction period, improves year on year of operation. In the previous example, the carbon emission break-even (carbon neutrality) will be achieved in 2029, i.e. 12 years after the line is commissioned.

Therefore, a high-speed line project is only environmentally feasible if there is a strong certainty that the traffic capture volumes will be significant. This is even more important where there are predictions of changes to the technology of all transport modes, such as cars, and even planes, powered by electricity.[101]

Figure A2–7 CO_2 emission for the construction of a 300 kilometres HSL

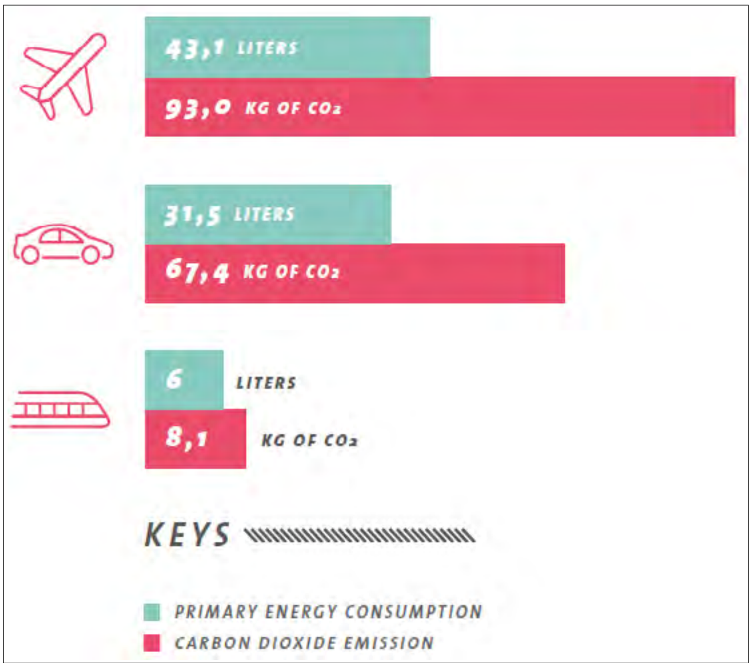


Source: UIC, High Speed Rail. Fast Track to Sustainable Mobility, Paris 2018.

101 *UIC, High Speed Rail. Fast Track to Sustainable Mobility, Paris 2018*, n.d.

Equivalent consumption and CO_2 emission for 600 km journey for car, plane and High-speed train is shown in figure A2-8.

Figure A2–8 Equivalent consumption and CO2 emission for 600 km journey



Source: UIC, High Speed Rail. Fast Track to Sustainable Mobility, Paris 2018.

2.4 Land-take by transport infrastructure

Both in the spatial development plans of the regions and also from the environmental point of view, the loss of land for infrastructure buildings is a particularly important problem. Therefore, it is important to keep these losses as low as possible.

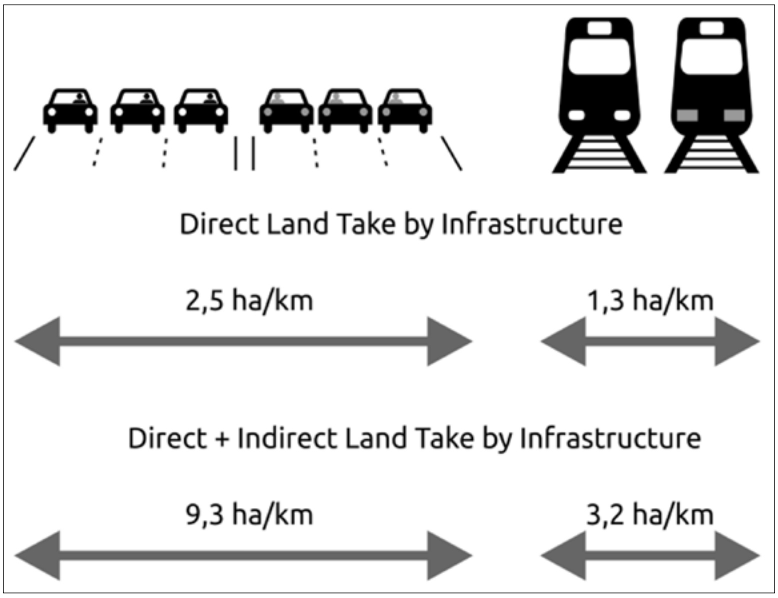
High-speed lines take up relatively little space, about three ha per kilometre of line, including: embankments, excavations and auxiliary installations as well as station areas. They require significantly less space compared to a motorway with three lanes (9-10 ha per kilometre of road, including: embankments, excavations, switches, toll booths).[102]

Indicators for railways are also favourable compared to air transport:

- Paris CDG airport – 3,200 ha
- LGV Bretagne high-speed line – Pays de la Loire (214 km) – 2,300 ha
- High-speed line LGV Rhine – Rhône (140 km) – 1,400 ha.

[102] *High Speed Rail & Sustainability. Report. UIC, 2011.*, n.d.

Figure A2–9 Land-take by roads and rail

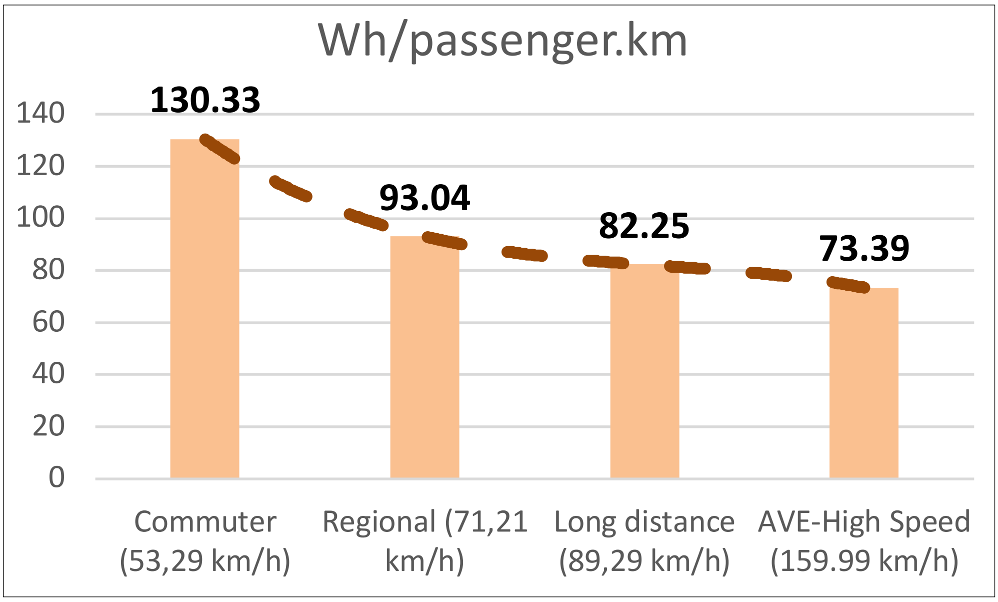


Source: *High Speed Rail & Sustainability*. Report. UIC, 2011.

2.5 Energy efficiency of high-speed trains

Despite the widespread opinion about the high energy consumption of high-speed trains, the real facts are different. High-speed trains have the lowest specific energy consumption per passenger-kilometre when compared to other types of trains, which in turn are lower than other means of transport. Studies by UIC[103] indicate that the lower is the train category, the higher is the specific energy consumption. The analyses were carried out for four categories of trains in Spain as shown in figure A2-10.

Figure A2–10 Relationship between speed and Energy consumption for different types of trains



Source: High speed, energy consumption and emissions. Study and Research Group for Railway Energy and emissions. UIC, 2010.

[103] *High speed, energy consumption and emissions. Study and Research Group for Railway Energy and emissions*. UIC, 2010, n.d.

Relatively low electricity consumption by trains above all results from:

- Lower mechanical resistance in new train constructions and better parameters of high-speed lines (depending on the radius of the arcs);
- Reduced aerodynamic drag when driving at high-speeds thanks to new technical solutions;
- Smoother high-speed train travel on a line separated from regional and freight traffic – optimal train traffic analysis can be used;
- Better energy recovery conditions during train braking in high-speed systems;
- Shorter operation of train auxiliary systems (including air conditioning, heating) when traveling on routes of the same length as a conventional train.

Comparison of energy and environment efficiency of different modes of transport is also in favour of high-speed services. This is presented in the analysis for the Paris – Marseille routes (table A2-11).

Table A2–11 **Table A2–11 Comparison of transport modes for the Paris – Marseille connection**

Indicator		Plane	Car	HS train
Commercial distance	[km]	634	769	750
Energy/fuel consumption		4 038 l/rejs	49 koe	17.3 MWh
Average passenger flows		122	2	400
Seats number		150	4	516
Seats occupation	[%]	80	50	77.5
CO_2 consumption (toe)		3.9	0,1	3.8
CO_2 emission	[kg]	11 823	179	692
Energy efficiency	[goe/pas.km]	51	37	13
Wear	[koe/pas.]	32.2	28.8	9.6
Environmental efficiency	[kg CO_2/pas.]	97	89	2

Source: ADEME (French Environment and Energy Efficiency Agency) http://www2.ademe.fr/servlet/KBaseShow?sort=-1&cid=96&m=3&catid=17585.

3. Operators' costs and revenues

3.1 Market conditions for high-speed rail transport

HSR transport in the EU is carried out according to market conditions as a result of the separation of the high-speed operations from infrastructure maangement. Therefore, HSR undertakings operate on the same basis as air carriers.

There is no practice of subsidizing HSR transport (prior to 2020), although it is legally possible for selected segments for social reasons on the basis of PSC contracts specified according to EU legislation. A characteristic of passenger rail transport in Europe is that it is subsidized by public funds. In States that do not have a HSR network, the subsidy rate for all passenger transport is very high and ranges from 90 to 100 per cent. In States where there are HSR systems, the share of subsidized transport is much lower and amounts to 58 per cent in Germany, 56 per cent in Italy, 43 per cent in Spain 38 per cent in France.

The only intervention tool possessed by the state is financial support for the construction of railway infrastructure. The examples cited above show that this is a common practice but is also used in other modes of transport. This support essentially pays for the socioeconomic benefits that HSR brings to States. Thanks to such investment support, the amount of the access charge paid by the operator to the infrastructure manager after the investment has been completed allows for market fares to be charged to users.

Within the EU, but also in other States (most recently in South Korea), access to the market for the provision of HSR services is not restricted if the carrier meets the conditions set out in legal requirements above all in the field of rail safety. In practice, competition on this market is present on a larger scale only in Italy (Trenitalia and private operator Italo) and on a smaller scale where parts of the operations of Eurostar and Thalys services overlap (prior to their merger). The Italian example is given as a positive benchmark for market opening, because the volume of passenger growth and reduction in fares as a result of competition.

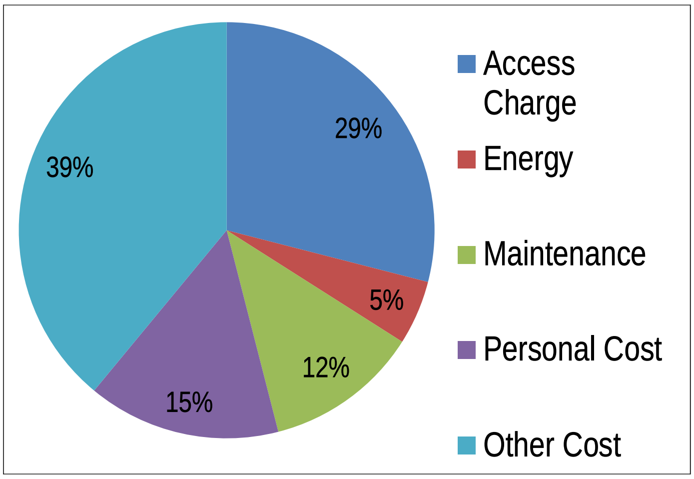
3.2 Operating expenditure of railway undertakings

Examples of the structure of operational costs for Italo and SNCF are shown in figures A2-11 and A2-12. SNCF is one of the largest national HSR operators in Europe with nearly 150 million passengers a year and a fleet of several hundred high-speed trains. Italo is a small private operator with 47 trains. In both cases, despite differences in the classification of costs for their basic items, the share of the cost items are very similar.

The analysis shows that access charges are the largest single component of operating expenditure, followed by rolling stock maintenance costs and staff costs. The share of electricity costs is relatively low in both cases.[104]

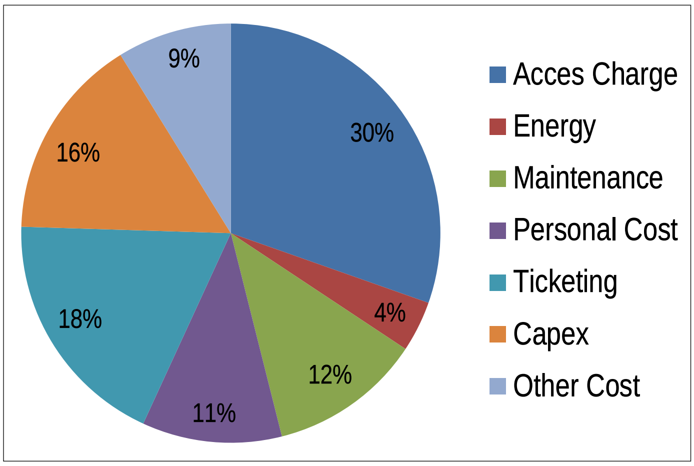
[104] J.-P. Arduin, *High Speed Rail Economy. UIC Workshop. "Operating high-speed lines: in search of efficient solutions"*, Paris, 2019; A. Giuricin, Competition in the HSR: key driver of efficiency in operation? UIC Workshop. "Operating high-speed lines: in search of efficient solutions", Paris, 2019.

Figure A2–11 Operational costs structure of Italo



Source: Competition in the HSR: key driver of efficiency in operation? Andrea Giuricin. UIC Workshop. "Operating high-speed lines: in search of efficient solutions", Paris, 31 January 2019.

Figure A2–12 Operational costs structure of TGV (SNCF)



Source: *High Speed Rail Economy*. Jean-Pierre ARDUIN. UIC Workshop. "Operating high-speed lines: in search of efficient solutions", Paris 31 January 2019.

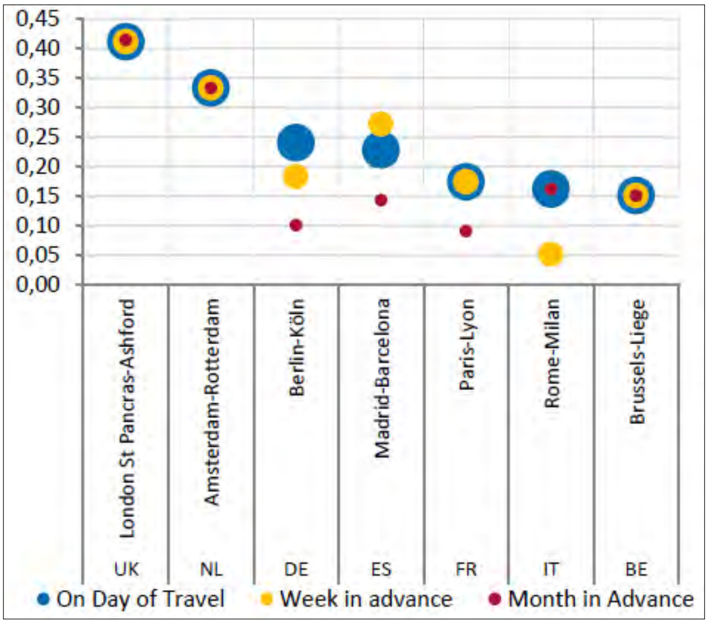
3.3 The costs of purchasing and maintaining rolling stock

New generation rolling stock prices have fallen in recent contracts. The latest contract for SNCF for the purchase of 100 double-decker trains is €25 million for each 200 m unit compared to previous prices of €30 million. The lowest prices are recorded in China. Single-deck trains CRH-400 (350 km/h) have prices in implemented contracts of the order of €20 million. The average cost of rolling stock maintenance is about €2 per km of train. With an average train run of 2,000 km per day, it costs about €1.5 million per year.

3.4 Revenues estimates for operators

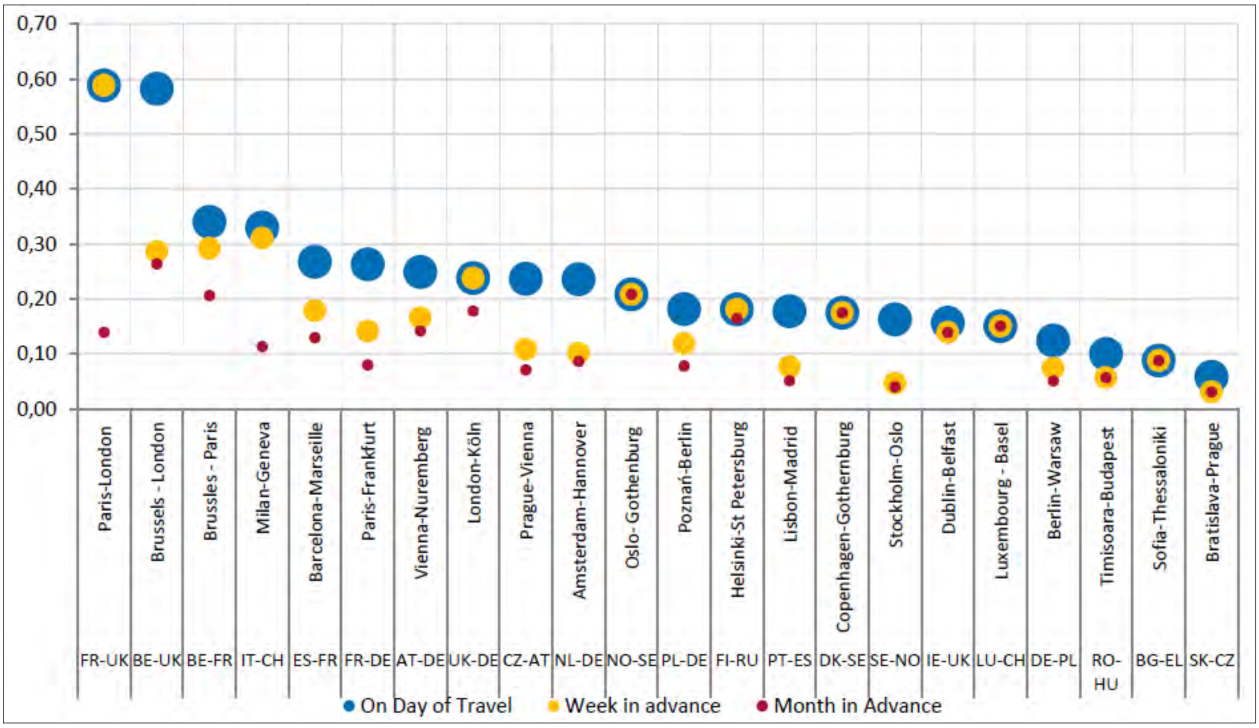
The main source of revenue for HSR operators are ticket sales. Some operators do not have regulatory and legal restrictions in shaping their tariff policy. The lack of PSC contracts makes it possible to set tariffs on a market basis of supply and demand. However, the price level is limited by strong external competition as well as more and more often competition within the sector.

Figure A2–13 Fare per pkm, high-speed domestic routes



Source: *Rail Market Monitoring Survey*, European Commission, 2016.

Figure A2–14 Fare per pkm, key European routes



Source: *Rail Market Monitoring Survey*, European Commission, 2016.

Fare systems increasing follow demand pricing principles similar to air transport. Ticket prices are not fixed and are determined by the volume of demand.

The effects of differentiated fares policy are visible when comparing fares for major high-speed routes in Europe. Examples of routes were selected in figures A2-13 and A2-14,[105] including those operated by high-speed trains. As you can see, railways use a different approach depending on the nature of the line. Ticket prices for two representative international connections are characteristic: Paris – London, and Brussels – London where prices are the highest and the way the fare is determined is most similar to the aviation sector.

A broader analysis of how high-speed ticket prices are set is presented in a report by the EU Court of Auditors. In the first of them (table A2-14), four routes in four States were selected for the purposes of analysis, with travel times estimated on a door-to-door basis, selecting key points in these cities as the start and end points.

The analysis showed that:

1. HSR is often much faster (on average 30 per cent to 50 per cent of travel time) than conventional rail. Air travel (from take-off to landing) is faster than HSR. However, when assessing real total travel time from city centre to city centre, including the travel to the airport and boarding procedures, HSR is often more competitive.
2. HSR is often much cheaper than air travel. Last-minute bookings for both transport modes are more expensive than tickets booked in advance. In Germany, ticket prices on the Stuttgart – Munich high-speed line are lower than conventional rail ticket prices
3. Some of the routes are not practicable by conventional rail; for example, travelling from Rome to Turin by conventional rail can take 20 hours (although is rarely over 10 hours). HSR takes less than third of the time, and air travel one-tenth of that. The situation is similar on the Madrid – Santiago connection.
4. The most successful connections in terms of business users (e.g. Madrid – Barcelona; Turin – Rome; Paris – Strasbourg) are also the most expensive. Overall, HSR costs in France are the highest per kilometre travelled (for business and leisure).

Table A2–12 Door-to-door travel time analysis on selected high-speed lines

	MADRID, Puerta del Sol – BARCELONA, Plaça de Catalunya		ROME, Piazza del Campidoglio – MILAN, Piazza del Duomo		BERLIN, Potsdamer Platz – MUNICH, Marienplatz		PARIS, Place de la Concorde – STRASBOURG, Place du Château	
Distance	607-698 km		572-661 km		587-654 km		466-548 km	
Mode of transport	Time	Price (EUR)	Time	Price (EUR)	Time	Price (EUR)	Time	Price (EUR)
Car	10:40 -18:20	138-190	10:40-18:40	180	10:00-16:40	95-142	8:40-12:20	44-79
Air	6:30-8:00	227-253	6:30-7:00	140	6:30-8:00	146	na	na
Coach	16:20-18:00	36-49	15:00-21:00	40	17:00-23:00	45-79	13:00-22:40	33-55
Conventional rail	11:30-12:00	124-128	9:00-23:00	61-103	na	na	na	na
High-speed rail	6:00-8:20	159-181	6:50-9:00	23-205	8:30-10:30	66	5:10-5:30	158-165

Source: Special report 19/2018 "A European high-speed rail network: not a reality but an ineffective patchwork". European Court of Auditors. Luxemburg 2018.

Table A2-13, compares travel costs per minute of travel and per kilometre. Average speeds on the above high-speed connections were 157 km/h in Spain, 103 km/h in Germany, 126 km/h in Italy, and 183 km/h in France. Table A2-14 provides analyses for 4 high-speed routes in Germany.

105 European Commission, Rail Market Monitoring Survey, 2019.

Table A2–13 Average cost in selected States

Country	EUR per minute of travel						EUR per kilometre	
	Business travel			Leisure travel			Business travel	Leisure travel
	High-Speed Rail	Conventional Rail	Air	High-Speed Rail	Conventional Rail	Air	High-Speed Rail	High-Speed Rail
Spain	€0.30	€0.15	€1.47	€0.35	€0.19	€1.37	€0.10	€0.12
Germany	€0.24	€0.18	€2.82	€0.19	€0.16	na	€0.15	€0.12
Italy	€0.24	€0.14	€1.97	€0.27	€0.13	€1.39	€0.12	€0.13
France	€0.58	na	Na	€0.64	na	na	€0.17	€0.19

Source: Advito and ECA.

Table A2–14 Business travel: Average prices and travel times: general overview. Case Germany

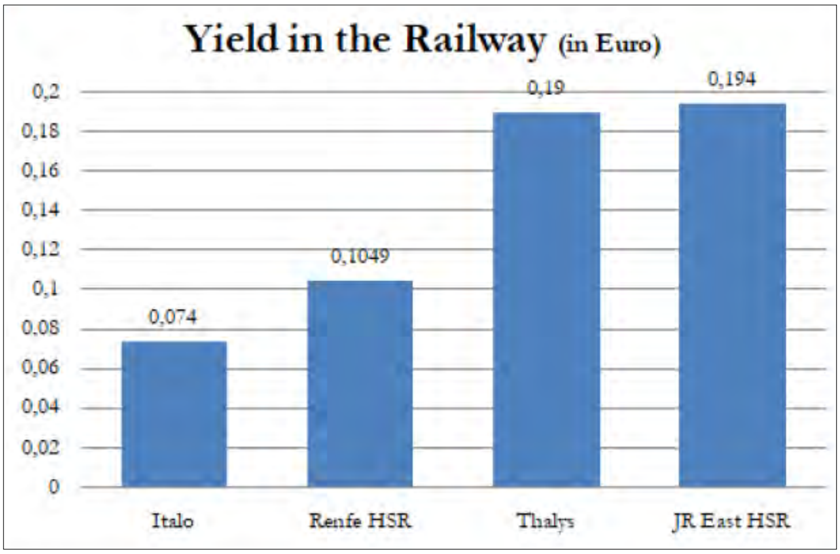
Route	Average Price and Travel Duration						Number of connections
	High-Speed Rail		Conventional Rail		Air		
Stuttgart – Munich – Stuttgart	**€76**	**04 h 36**	**€88**	**06 h 49**	**N/A**		**50-60**
Munich – Stuttgart – Munich	€74	04 h 31	€88	06 h 46	€229	01 h 30	50-60
Leipzig – Munich – Leipzig	€135	10 h 15	€117	13 h 33	N/A		40-45
Munich – Leipzig – Munich	€113	10 h 28	€118	13 h 32	€340	01 h 50	40-45

Source: Advito and ECA.

Conclusions

It can be seen therefore that HSR operators can get higher fares than conventional transport that is acceptable to travellers due to large time savings and that these fares compete favourably on price and travel time with air transport. The average fare for high-speed trains is about12 eurocents per km. Examples of revenues from one km for a subset of operators is set out in figure A2-15.

Figure A2–15 Examples of revenues from one km for various railway carriers



Source: Competition in the HSR: key driver of efficiency in operation? Andrea Giuricin.
UIC Workshop. "Operating high-speed lines: in search of efficient solutions", Paris, 31 January 2019.

3.5 Operators' profit motive

Data from financial reports (table A2-15) indicate that HSR operators in Europe achieve stable profits (EBITDA) of greater than 10 per cent, which is sufficient to finance development investment, including for example the purchase of rolling stock. The volume of transport is also stable and shows significant annual increases. They also do not require public support.

Table A2–15 Table A2–15 Financial results of enterprises dedicated to operating high-speed rail in Europe

Country	Revenues mln EUR			Profits mln EUR (EBITDA)			Number of passengers		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
France		**7 373**	**7 367**		**1 178**	**1 044**			
Italo (Italy)	364	454		95.0	155.7		11.1	12.8	
Germany		4 193	4 528		381	417	139	142	148

Source: Data according to annual reports of carriers.

APPENDIX 3

Methodology for determining the minimum number of passengers to obtain economic efficiency

1. Introduction

The minimum number of passengers to ensure economic efficiency of the analysed investments has been estimated using the CBA method. In this method, streams of economic benefits of a project, investment expenditure necessary for the implementation of the investment and the operating costs are assessed in order to determine economic efficiency, in accordance with the guidelines contained in the EU Guide to the benefit/cost analysis[106] and in the Blue Book.[107] The economic benefits of the project most often include:

- Value of travel time savings (VTTS) in transport of passengers;
- Savings in vehicle operating costs for individual users who have shifted from car use;
- Savings in costs of air pollution;
- Savings in climate change costs;
- Reducing the costs of accidents as a result of passengers switching from road to rail.

The analysis was based on the following general methodological assumptions:

1. A 30-year period of analysis. The first year of the analysed period was the so-called "year zero". This means that all cash flows occurring in the "year zero" are discounted by a discount rate of one. In practice, this means that they are taken at nominal values for the calculations.
2. The social discount rate (SDR) is 4.5 per cent.
3. Investment expenditure has been included in the "year zero".
4. Operating costs were calculated based on the length of the line, number of trains, and a unit cost. The unit cost of €70,000 per km has been assumed in the calculations.
5. Investment expenditure and operating costs were adjusted with fiscal effects.
6. The residual value was calculated using the income method.
7. Economic efficiency indicators, i.e. ENPV and ERR, were identified.
8. **A computational model was developed to determine the minimum demand for HSR services ensuring that the income earned would cover the costs.**

[106] E. Commission, *Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020*, Brussels

[107] JASPERS, *Blue Book. Rail Sector – Rail Infrastructure*, Warsaw, September 2015 .

2. Investment expenditure

The value of estimated investment expenditure is shown in table A3-1 for the three lines selected for assessment.

Table A3–1 Investment expenditure [EUR bn]

No.	Line	Expenditure
1	Budapest – Bucharest – Constanta	34 200
2	Warsaw – Brest – Minsk – Smolensk	15 105
3	Warsaw – Gdansk	5 755

Source: TER HSR Study – Table IV-1.

In accordance with the principle of economic efficiency of infrastructure projects, the estimated investment expenditures are adjusted with fiscal effects. As recommended, for the investment expenditure on infrastructure, the discount rate is – 0.82.

3. Operating costs

Operating costs are the sum of fixed and variable costs. The following unit cost structure has been adopted in the calculation of unit costs: fixed cost – 90 per cent, variable cost – 10 per cent.

Based on the assumptions adopted, the unit fixed cost is €63 per km, whereas the unit variable cost, assuming 10 pairs of trains, is €0.35 thousand per pkm.

Fixed costs have been calculated as the product of the length of the line and the unit fixed cost. The length of the line is shown in table A3-2.

Table A3–2 The length of the line [km]

No.	Line	Length
1	Budapest – Bucharest – Constanta	1 140
2	Warsaw – Brest – Minsk – Smolensk	847
3	Warsaw – Gdansk	385

Source: TER HSR Study – Part III.

Variable costs have been calculated as the product of variable unit cost, the length of the line and the number of trains. When calculating the number of trains, it has been assumed that the train is fully occupied, i. e. with 400 passengers on board.

In accordance with the principles of economic efficiency of infrastructure projects, the estimated operating costs are adjusted with fiscal effects. In accordance with the recommendations for operating costs, the discount rate is 0.76.

4. Benefits of travel time savings

The main benefit of the construction of High-Speed Rail (KDP) is a reduced passenger travel time, both for passengers currently using rail transport (conventional rail) and those taken over from other modes of transport. As a result, there are travel time savings. These savings are estimated as **the product of unit reduction in travel time and the number of passengers as well as unit travel time costs,** adopted on the basis of recommended values.

The travel times shown in table A3-3 have been used to estimate the benefits of travel time savings.

Table A3–3 Travel time savings [min]

No.	Line	HSR	Conv. rail	HSR – Conv.	Car	HSR – Car
1	Budapest – Bucharest – Constanta	310	1 090	780	760	450
2	Warsaw – Brest – Minsk – Smolensk	225	465	240	650	425
3	Warsaw – Gdansk	90	180	90	240	150

Source: own study.

The unit cost of time has been determined based on the values recommended in the Blue Book 2015. Based on the data concerning staff transport, commuter transport and other, the average unit cost of time has been set on the level of PLN 53.6 per hour. Based on the average EUR/PLN exchange rate of 2019 (PLN 4.31), the average unit cost of time has been calculated on the level of **€12.44 per hour**.

The structure of passengers in passenger transport was adopted on the basis of data from M. Lebeuf, High-Speed Rail. Paris 2014 and the expert method. The structure is shown in table A3-4.

Table A3–4 Average unit external costs in passenger transport within EU [EUR-cent per pkm]

In total	100.00%
Including those taken over from:	
Private car transport	10.00%
Conventional rail	10.00%
Bus transport	10.00%
Air transport	20.00%
Induced traffic (travel)	50.00%

Source: Own study.

The benefits of travel time savings have been calculated for four traffic capture types: from passenger cars, from buses, from conventional rail and induced traffic. Conventional rail travel times have been used as the reference point for calculating the benefits of the induced traffic.

5. Benefits of savings in other external costs

The capture of some passengers who have shifted from cars and buses reduces traffic on the roads. This results in a reduced number of road accidents, less harmful emissions to the atmosphere, including greenhouse gases, and reduced operating costs for cars. **These benefits are also calculated on the basis of the number of passengers captured and the value of unit costs**.

The unit costs shown in table A3-5 have been used in the calculations.

Table A3–5 Average unit external costs in passenger transport in the EU [EUR-cent per pkm]

Cost category	Car	Bus	HSR	Conventional rail (electrified)	Airplane
Accidents	4.4548	0.9791	0.0579	0.4665	0.0174
Air pollution	0.7069	0.7451	0.0022	0.0086	0.1600
Climatic changes	1.1772	0.4570	0.0000	0.0000	2.1569
Noise	0.5545	0.3321	0.3252	0.7968	0.1949

Source: Handbook on the external costs of transport. Version 2019.

The benefits of improved safety are those resulting from passengers diverting from road traffic, i.e. cars and buses. For the passenger traffic captured from cars, these benefits have been calculated as the product of the number of passengers who shifted from passenger cars, the difference between the unit costs of accidents in HSR and crash accidents involving cars and the length of the line. For the passenger traffic captured from buses those benefits have been calculated as the product of the number of passengers who have shifted from buses, the difference in unit costs between accidents in HSR and crash accidents involving buses, and the length of the line.

The benefits of savings in costs of air pollution are the sum of the savings resulting from passengers captured from passenger cars, buses, conventional railways and airplanes less the costs of air pollution generated by the induced traffic. Benefits for individual traffic (passengers taken over and the induced traffic) have been calculated in the same way as the benefits of improved safety.

The benefits of savings in climate change costs have been calculated in the same way as the benefits of savings in air pollution costs.

The benefits of savings in vehicle operating costs are the difference between reduced vehicle operating costs and the cost of buying tickets. The savings in vehicle operating costs have been calculated as the product of the unit cost of vehicle operating and the reduced car traffic.

Unit vehicle operating costs have been based on the recommended values of €0.190 per vehicle-kilometre[108] and the average EUR exchange rate in 2019. The magnitude of the reduction in car traffic has been calculated as the product of the fall in the number of passenger cars and the length of the line. The number of cars has been determined as the product of the number of passengers captured from road transport and the average number of persons occupying the car (1.4). The road length has been assumed the same as the length of the rail line.

The cost of purchasing a train ticket has been set as the product of the number of passengers captured from cars, the average ticket price (10 EUR-cent per train-kilometre) and the length of the line.

[108] Blue Book. Rail Sector – Rail Infrastructure, JASPERS, Warsaw, September 2015.

6. Salvage (residua) value

The economic residual value has been calculated using the income method. It is the discounted net value of future cash flows that are expected to be generated by the further use of assets (after the analysis period). It has been assumed that infrastructure will be in use for 12 years after the end of the analysis period. The value of external benefits and operating costs adopted in subsequent years after the end of the analysis period has been assumed the same as in the last year of the analysis.

Given the relationship between variable costs and economic benefits and the number of passengers, a calculation model has been developed to determine the number of passengers at which the current net economic value will be €0. This number of passengers determines the minimum demand for HSR services ensuring that cash inflows (positive cashflows) are higher that outflows (negative cash flows). This means that transport services over the designated minimum will ensure the economic efficiency of the investment.

In the first step, the efficiency of the investment was calculated for the assumed number of trains, i.e. 16 pairs of trains for lines 1-3 and 48 pairs of trains for line 4. The results of this simulation-based calculation are presented in table A3-6.

Table A3–6 Economic efficiency – results of a simulation-based calculation

No.	Line	Pairs of trains	ENPV [EUR thousand]	ERR [%]
1	Budapest – Bucharest – Constanta	16	-23 154 834.55	None
2	Warsaw – Brest – Minsk – Smolensk	16	-10 123 895.96	None
3	Warsaw – Gdansk	48	-1 568 342.57	None

Source: own study.

With the initial assumptions adopted, none of the analysed investments demonstrates economic efficiency. The ENPV index for all of them is lower than ZERO (ENPV <0).

In the second step, the annual volumes of passenger traffic were calculated, which, given the assumptions adopted, would result in the coverage of negative cash flows by socioeconomic benefits.

The volume of passenger traffic with ENPV = 0 is shown in table A3-7.

Table A3–7 Minimum annual passenger transport – results of simulation-based calculation

No.	Line	Number of passengers per year
1	Budapest – Bucharest – Constanta	17 098 277.59
2	Warsaw – Brest – Minsk – Smolensk	15 076 084.36
3	Warsaw – Gdansk	15 030 071.05

Source: own study.

Based on the calculations, in order to achieve economic efficiency passenger traffic would have to be several times larger than the traffic initially assumed.

The results of simulation can only be treated as approximation results. More detailed analyses would require a series of research to be carried out for a specific rail line and a preliminary Feasibility Study.

APPENDIX 4

Examples HSR lines financed using PPP schemes

1. LGV Sud Europe Atlantique (SEA)

Table A4–1 LGV Sud Europe Atlantique (SEA)

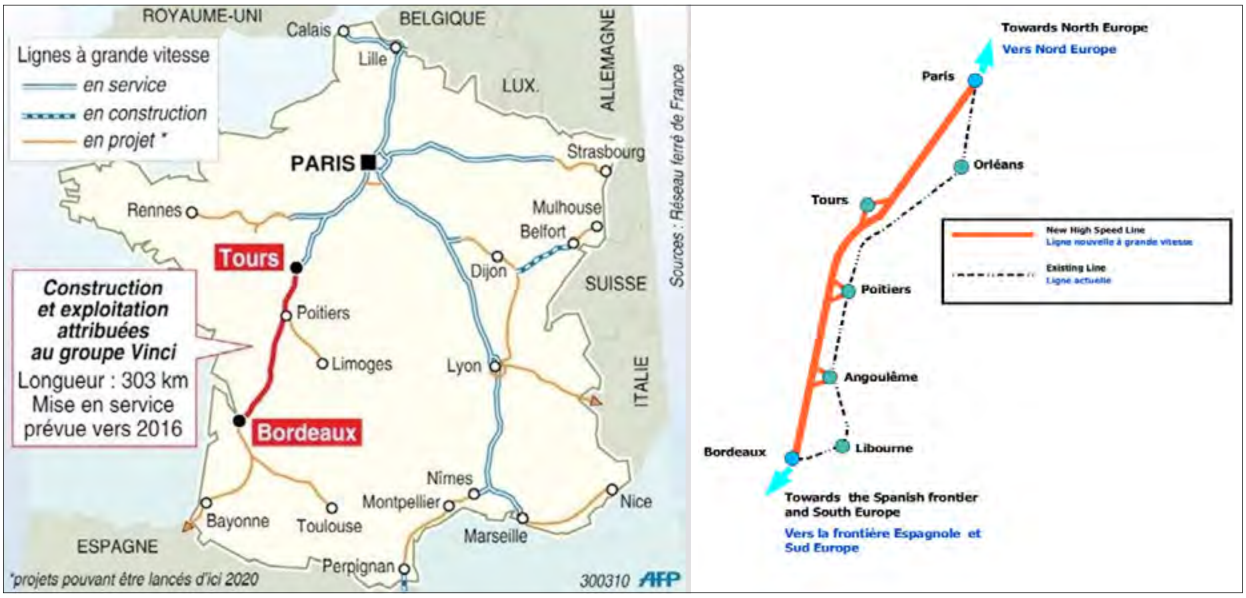
History/Background	• The project was a response to the heavy traffic on the existing rail line • 25 September 1990: Service began on the south-west branch of the LGV Atlantique to Saint-Pierre-des-Corps, west of Tours • 1 April 1992: Initial proposals for a high-speed link between Saint-Pierre-des-Corps and Bordeaux. Early in its conception, the line was going to be called LGV Aquitaine • 1994-1995: Public debate on the LGV Aquitaine project • 1997-1998: Preliminary studies on the Tours to Bordeaux line • 2011: A 50-year concession to build and operate the line is awarded to the LISEA consortium • 1st quarter 2012: Construction begins, expected to last 73 months (until 1st quarter 2017) • 28 February 2017: Inauguration of the line • 2 July 2017: Line opens commercially
Line characteristics	• 303 km double track connecting Tour and Bordeaux with several connections to the network; passenger traffic • Vmax = 320 km/h • It will reduce the journey time between Paris and Bordeaux to 2 hours 5 minutes which is a shorter journey time than by road or air • It is expected to increase annual passenger numbers by between 3.5 and 5 million
Financing	• Funding Structure of SEA (prior to commercial operation): Public Sector – 51%, Private Sector – 49% • Sources of SEA Funding over Concession Period: French State, Regional Authorities & EU – 39% (€3,000 million); Debt backed by: French Government – 19% (€1,460 million), RFF – 13% (€1,000 million), Debt backed by RFF – 10% (€757 million); Concessionaire Equity Contribution – 10% (€772 million); Non-Guaranteed Debt – 10% (€812 millions) ; Total 100% (€7,801 million) • Total financing requirements for constructing of the line was €7.8 billion of which capital cost was 6.2 billion euros. LISEA's contribution was €3.8 billion, with the remainder coming from RFF, national and local governments. The EIB offered to provide €1.2 billion, made up of a mix of government-guaranteed and non-guaranteed loans to the consortium and the French state, plus contributions to the EU's TEN-T programme; RFF's share of construction cost amounted to 14%
Model	• All design, construction and operation risk (incl. traffic risk) are borne by private concessionaires: LISEA (Vinci Concessions) – 33.4%, Caisse des dépôts et consignations – 25.4%, Meridiam – 22.0% and Ardian – 19.2%) • 50-year concession contracted the LISEA consortium in 2011 (for the period until 2061) • The concession provides operation and maintenance of the new line with a projected construction period of 6 years • Traffic risk: Patronage risk is borne by the concessionaire to achieve a better risk and reward package

Table A4–1 LGV Sud Europe Atlantique (SEA) (continued)

Additional comments	• LISEA will be remunerated in the form of traffic-related fees paid by users operating trains capable of travelling on the new line. Traffic risk rests with LISEA • Financing comes from both public and private sources with €1 billion of bank debt guaranteed by the French government and around €700 million provided by Fonds d'Epargne, managed by the Caisse des Dépôts and guaranteed by RFF. Both guarantees carry a premium rate • The LISEA shareholders are contributing nearly €800 million of equity and the remaining finance is being provided by a mix of non-guaranteed bank debt and EIB finance as part of TEN-T programme put in place jointly with the European Commission • The financing package is the first to benefit from the French government guarantee mechanism put in place under the 2009 French stimulus package designed to encourage PPP financing for large priority projects. It also includes public subsidies of €4 billion made by the French government, and subsidies from local communities and the European Union • RFF, as the operator of the French national rail network, will benefit from the additional revenues which the new line will provide on adjacent lines through traffic growth along the entire Paris-Bordeaux rail link. Furthermore, RFF is investing close to €1 billion by way of enhancements to the existing railway infrastructure (linking the new line to the existing network, capacity development leading to the Bordeaux train station, traffic control centre, and electric power modification).

Source: SNCF.

Figure A4–1 LGV Sud Europe Atlantique (SEA)



Source: SNCF.

2. Cross-border HSL Perpignan – Figueras (Franco-Spanish cross border link)

Table A4–2 Cross-border HSL Perpignan – Figueras (Franco-Spanish cross border link)

History/Background	• France and Spain have different rail gauges (1,435 mm in France, 1,676 mm in Spain); • Since 1988 Spain has progressively developed a UIC gauge network • The Perpignan – Figueras line is a direct link between the Spanish rail network to the rest of Europe (TEN-T) • Operation started 2009
Line characteristics	• 44.4 km double track (24.6 km in France and 19.8 km in Spain) for passenger (with Vmax = 350 km/h) and freight traffic • 2.9 km and 4.6 km single tracks for linking in Perpignan • A bi-tube tunnel (8.2 km) • 4 viaducts in France (983 m) and 6 viaducts in Spain (2.163 m) • Slab track inside tunnel, ballasted track outside • Signalling System: ERTMS level 1 & 2 • Detection of falling objects, detection of clearance, wheel flat spots and high pantographs • Fencing for the whole line
Financing	• Financing involved public investment of 57% of the project costs. • *The EU* contributed 25% (€69.75 million) from the Trans-European Transport Network budget and cited the benefits from cross-border mobility • Total cost €1.096,7 million including: construction cost – €952 million, Concessionary Cost – €60,9 million, Financial Cost – €71,8 million, Debt Service Reserve Account – €12,0 million; • Sources: Common Stock (€51,4 million), Subordinate Loan (€51,4 million), Interest of Subordinate Loan (€5,5 million), Own Resources (€108,3 million), Direct Subsidye (€523,5 million), Financed Subsidy (€64,9 million), Senior Debt (€400,0 million)
Financing Model	• The line was commissioned by the national railways of France and Spain, to be operated as a joint venture, and was built by a consortium of private firms representing both nations • The concessionaire took on financial risk in the venture in exchange for permission to operate the line's infrastructure and charge tolls on every passenger and freight train that crosses the tracks, at rates established in the concession agreement • 50 years concession contract: 5 years of construction + 45 years of operation + 10 additional years of useful life without renewals at the end of the concession • Mixed financing included own resources (€108 M), public subsidy (€540 M), outside loans with limited recourse (€400 M).

Figure A4–2 LGV Perpignan – Figueras

Source: SNCF.

3. LGV Bretagne Pays de la Loire (BPL)

Table A4–3 LGV Bretagne Pays de la Loire (BPL)

History/Background	• Between 1996 and 2001, French infrastructure manager Réseau Ferré de France (RFF) conducted preliminary studies into the potential construction of a 182 km extension of the LGV Atlantique's western branch, later known as LGV Bretagne-Pays de la Loire. During 2005, the process of acquiring land along the intended route was started. On 30 October 2007, it was announced that the proposed line had been granted a Declaration of Public Utility, a sign of formal recognition by the French government and a necessary step for any major publicly funded construction programme in France; The proposal also become a recognized element of France's rail expansion strategy under the Grenelle Environnement initiative • The proposed LGV Bretagne – Pays de la Loire was highlighted as one of four grand projects which were to be a recipient of funding under a national economic stimulus package • The completed line was opened on 2 July 2017 • The high-speed line featured a total of seven covered trenches and ten viaducts.
Line characteristics	• 182-kilometre double track connecting Le Mans with Rennes with 32 km of connections to existing network; passenger traffic; Vmax = 320 • Signalling System – ERTMS Level 2 for HSL and ERTMS Level 1 for conventional connections • All of the line's signalling is centrally controlled via a switching centre located at Rennes
Financing	• Contract, valued at €3.4 billion, which covered the construction and maintenance was signed 28 July 2011 • *Funding* Structure of BPL: Public Sector – 70%, Private Sector (borrowed) – 30% • Proportion of BPL Funding over Concession Period • RFF – 43%, French Government – 28%, Regional Authorities – 28%, EU-0%
Model	• Eiffage Rail Express (ERE) has 25-years PPP contract including finance and maintenance. Eiffage is also responsible for maintaining the new line for 25 years, while operational responsibility will remain with RFF. Once up and running, public payments is paid to ERE to cover its capital investment and maintenance costs. These payments are based on an availability scheme. As a result, the Public Authority effectively bears the traffic risk.

Source: SNCF

Figure A4–3 LGV Bretagne Pays de la Loire (BPL)

Source: SNCF.

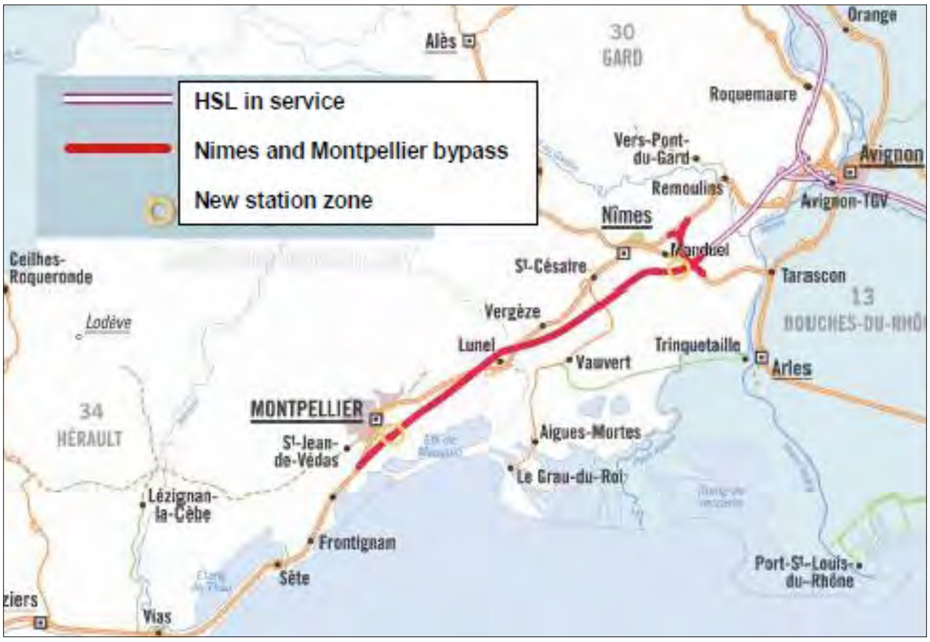
4. Contournement Nîmes – Montpellier bypass line (CNM)

Table A4–4 LGV Contournement Nîmes – Montpellier bypass line (CNM)

History/Background	• The main purpose of this line is to increase capacity for freight traffic in a semi-urban area. • 28 June 2012 – signature of the PPP contract
Line characteristic	• 60-kilometre mixed-traffic line; Vpas.max = 300 km/h, Vfreight =100-120km/h and 10 km of link on the right bank of the Rhone and 10 km of crossovers between Lattes (west of Montpellier) and Manduel (east of Nimes)
Financing	• Financing is structured as a partnership model, based on availability payments. The overall amount required to fund the Nimes and Montpellier bypass is €2.280 billion, including: • €1.500 billion for the part to be developed under the public-private partnership, spearheaded by the Bouygues TP Group • €0.500 billion for the part developed under public sector authority (studies and land acquisitions already completed, work on junctions with the national rail network, modernization of the line between Montpellier and Perpignan); • €0.280 billion for the new stations of Montpellier Odysseum and Nimes TGV. Financial contributions from the partners: • French State and European Union: 50% • Local authorities: 30% • RFF: 20%.
Model	• 25-year PPP contract (2037-end of the contract) covering financing and construction of the line. OC'VIA, a consortium consisting of a range of construction and infrastructure companies (including Alstom) and financing partners (Meridiam Infrastructure and banking group, FIDEPPP) was selected to design, build, maintain and finance the line. RFF also took direct responsibility for construction of stations at Nimes and Montpellier.

Source: SNCF

Figure A4–4 LGV Contournement Nîmes – Montpellier bypass line (CNM)



Source: SNCF.

5. HSL – Zuid High Speed Line

Table A4–5 HSL – Zuid High Speed Line

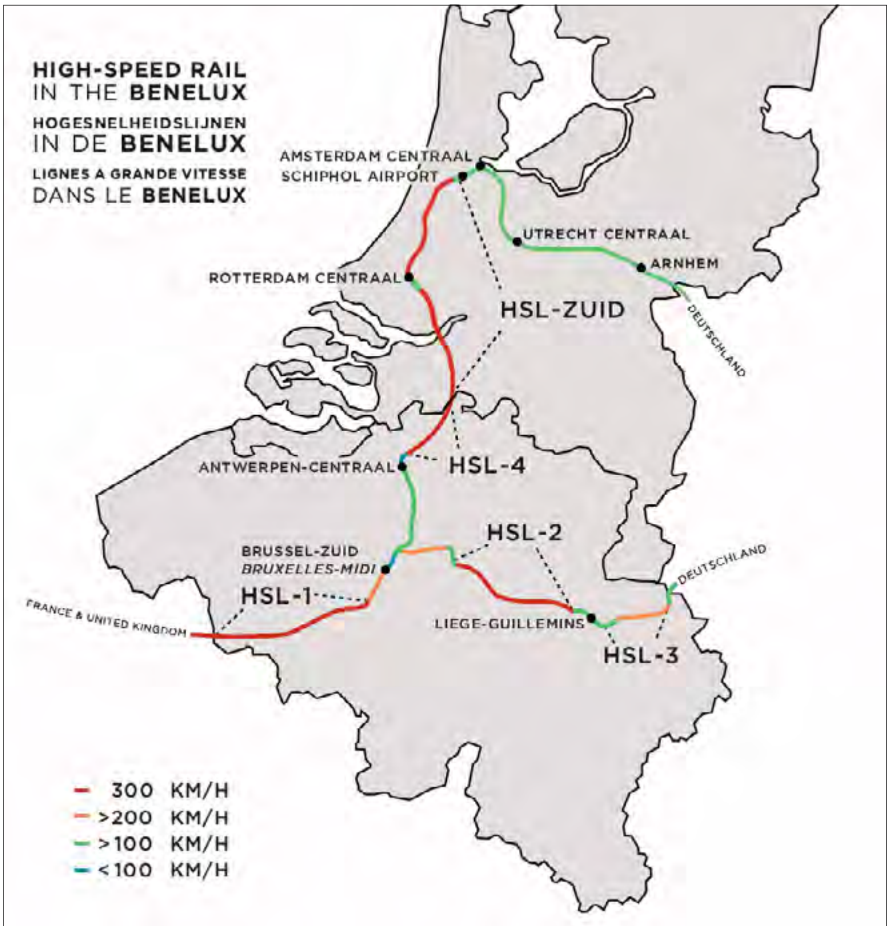
History/Background	• HSL Zuid is a 125 km high-speed railway line stopping at three stations: Amsterdam Zuid, Amsterdam Schiphol Airport and Rotterdam, before continuing to the Belgian border to connect with services to Antwerp, Brussels and Paris • The principal objectives of the project were to connect Rotterdam, Schiphol and Amsterdam to the European High-Speed Rail Network, to encourage economic development, and to provide an alternative to air travel to European destinations • To achieve a better risk allocation in the project, the construction works package was separated from track and signalling packages • The Dutch Transport Ministry was the client and financier of all civil works (including tunnels, bridges and elevated sections) throughout the project, and retains ownership of the line • Construction of the railway civil works was divided into several D&B contracts, each worth about €400 million, awarded to different contracting consortia. The track, power supply and signalling systems were developed by Infraspeed (a consortium comprising Fluor Infrastructure, Siemens Nederland, Koninklijke BAM Groep, Innisfree and HSBC Infrastructure) under a DBFM contract with a requirement that the track must achieve an availability target of 99% • The contract runs for 25 years from 2006 till 2031, with an availability charge paid to Infraspeed, depending on whether the 99% target is achieved • Following privatisation of Dutch railways, HSL Zuid was the first rail project developed with minimal influence from the national rail operator, NS, however the concession for operating the new line was awarded to a joint venture between NS and KLM (High Speed Alliance or HSA). HSA was loss making from the outset due to ongoing project delays and quality issues with the rolling stock ordered from Ansaldo Breda. HSA was taken over by NS in 2015.
Line characteristics/ Construction	• 100 km double track from Amsterdam to the Belgium border for passenger traffic; Vmax = 300 km/h • Project delays were caused by a variety of factors. There was public opposition to the route and disagreements in government prolonged the decision-making process. The choice of security system also caused delays: the specifications of the standard were confirmed late, which also delayed ordering and supply of trains. Opening of the line (in 2008) was subject to a 4-year delay overall • Project HSL-Zuid started in 2000. Opened on the Rotterdam – Antwerp route in mid-2006. The Amsterdam-Schiphol-Rotterdam route was completed in December 2006
Financing	• Total cost was approximately €5 billion with €2.6 billion coming from the Transport Ministry and around €1.7 billion provided by the FES fund (based on revenues from gas exports dedicated to economic development). Private funding amounted to €940 million • The financing for this project was based on a typical Public Finance Initiative • It is a PFI/PPP project. It was initiated with a small amount of base equity. The majority of the sponsors' contributions was injected via subordinated debt, together with the use of an equity bridge facility. The commercial loan facility has a maturity of 27 years with a grace period of 6 months. The loan carried a fixed interest rate during construction only, and thereafter, the interest rate risk exposure on this facility will lie with the state (Euribor plus margin). Margins were 90 basis points during construction, reducing to 80 basis points for the remainder of the term. The repayment profile is cover-ratio–driven.

Table A4–5 HSL – Zuid High Speed Line (SEA) (continued)

Model	• DBFM contract: Infraspeed, a special purpose vehicle (SPV) has a contract for five-year design, construction (build), and financing phase of the superstructure, followed by a 25-year maintenance phase of the HSL. Infraspeed have to ensure an infrastructure availability of at least 99% during operational hours of the 25-year maintenance period. EPC funding of $1.5 billion will be repaid from performance-based availability payments of $3.75 billion to cover the initial investment cost, maintenance cost, amortization, taxes, insurances, cost of capital, profit, and overhead.

Source: Dutch railways.

Figure A4–5 HSL – Zuid High Speed Line connected with Belgium HSL



Source: Dutch railways.

6. HS1 – St. Pancras International (London) to the Channel Tunnel

Table A4–6 HS1 – St. Pancras International (London) to the Channel Tunnel

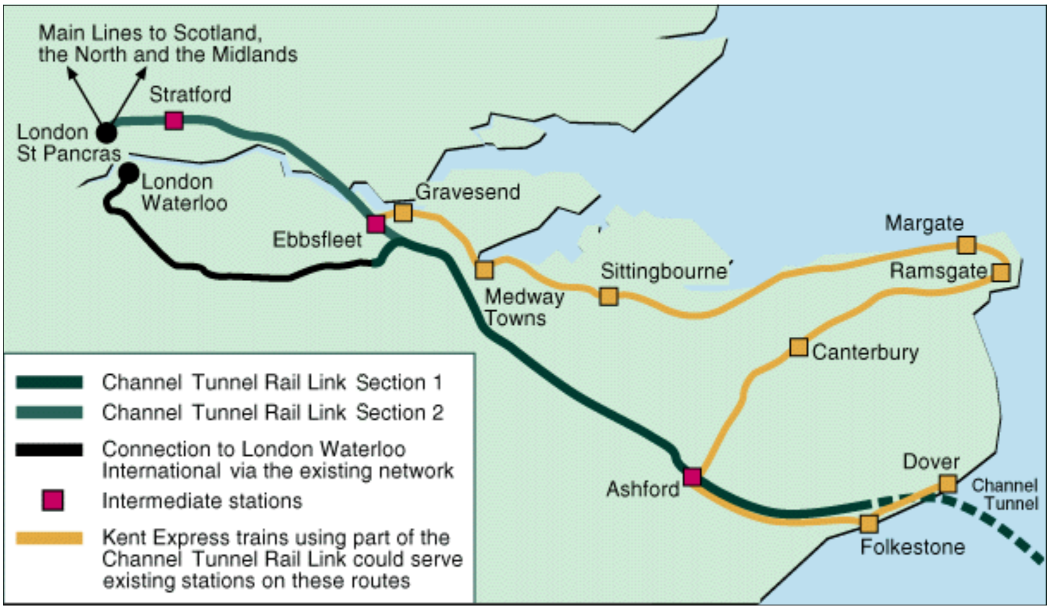
History/Background	• High Speed 1 (HS1) is the high-speed rail link between London and the Channel Tunnel. It connects Britain to Europe, securing around an 80% share of the London – Paris and London – Brussels travel market. In March 1994, the UK Government launched a public works concession for the construction and operation of a new high-speed railway between St Pancras station in London and the Channel Tunnel. The development of the new line – then known as the Channel Tunnel Rail Link (CTRL) – was the UK element of the Paris-Brussels-Köln-Amsterdam-London trans-European transport network priority project. It was Britain's first new railway line in over 100 years. More importantly, it is the physical connection between the UK rail network and the fast-expanding European inter-operable high-speed rail network. • London & Continental Railways Limited (LCR) was awarded a concession to design, build, finance, and maintain HS1 in 1996; It was a consortium company formed to bid for the project. The principal shareholders of the company were Bechtel, SNCF, National Express, EdF and UBS. LCR signed the concession agreement in February 1996. Government support for the project was provided by the way of capital grant as part of the concession arrangements. • Two phases – Section 1 completed in September 2003 and Section 2 completed in July 2007.
Line characteristic	• 100 km linking St. Pancras International (London) to the Channel Tunnel; passenger and freight traffic; • The first section of the CTRL from the Channel Tunnel to north Kent was opened to international services in September 2003; and the second section from north Kent to St. Pancras International – via new stations at Ebbsfleet and Stratford – was opened in November 2007. The new railway was renamed "High Speed 1" (HS1). • A further restructuring was undertaken during 2008 and a sale process resulted in the sale of the HS1 business in November 2010 to Borealis Infrastructure and Ontario Teachers' Pension Plan for £2.1billion. • HS1 is currently operated under contract by Network Rail (CTRL) Limited, a wholly-owned subsidiary of Network Rail.
Financing	• Capital cost of construction US$10 billion • *LCR's* original financing plan involved an IPO, however the traffic forecasts for the Eurostar business proved insufficient and a restructuring involving Railtrack, the privately owned operator of the domestic rail network, was implemented in 1998. This resulted in the CTRL being built in two phases with interim finance for construction being provided by way of government guaranteed bonds amounting to £6 billion in total. A further restructuring involving Network Rail in 2002 was necessitated by Railtrack's insolvency. • The principal sources of income for HS1 are track access charge payments in respect of both international (Eurostar) and high-speed domestic train services. Track access charges for the domestic train services are effectively guaranteed by the UK government and it is this revenue that underpins the financing for HS1.
Model	• HS1 procured as a privately financed project – process started in 1993 • 30-year concession (sale to Borealis Infrastructure/Ontario Teachers' Pension Plan consortium for US$3.3 billion in November 2010).

Table A4–6 HS1 – St. Pancras International (London) to the Channel Tunnel (continued)

Project specific features	• Procurement strategy: At the time of the Railtrack restructuring in 1998, the overriding imperative was to keep to the project timetable. A re-tender was not therefore considered to be an attractive option and so the transaction was structured as a hive down of the project to two subsidiaries of LCR which in turn contracted with Railtrack. Railtrack's interest was transferred to Network Rail in 2002 and the sale of the concession in 2010 was structured as a business sale. • State Aid: The various restructurings have required *a numb*er of notifications to the EU Commission and clearance was obtained on each occasion subject to conditions. • Concession: The concession agreement is not a typical PPP arrangement and contains unique and innovative features. No concession fee is payable and there is no compensation payable for termination caused by contractor default. There are long cure periods to allow time to find a solution and higher thresholds are set for contractor default. • Operator arrangements: The operation and maintenance of the railway is sub-contracted to Network Rail (CTRL) Limited under a long-term contract that is co-terminus with the concession agreement • Electricity supply arrangements: Traction power for HS1 is provided by a dedicated supply and distribution network built and maintained by EdF under a long-term contract • Regulatory Regime: A separated regime was established to regulate the track access charges for HS1. It is based on the regime that applies to the UK domestic rail network. The Office of Road and Rail is the regulator for both • Stations: The charging arrangements for HS1 stations provide for the accrual of a fund to finance lifecycle expenditure on a long-term basis.

Source: High Speed 1, Ltd.

Figure A4–6 HS1 – St. Pancras International (London) to the Channel Tunnel



Source: High Speed 1, Ltd.

7. The Chunnel (Tunnel under English Chanel)

Table A4–7 The Chunnel (Tunnel under English Chanel)

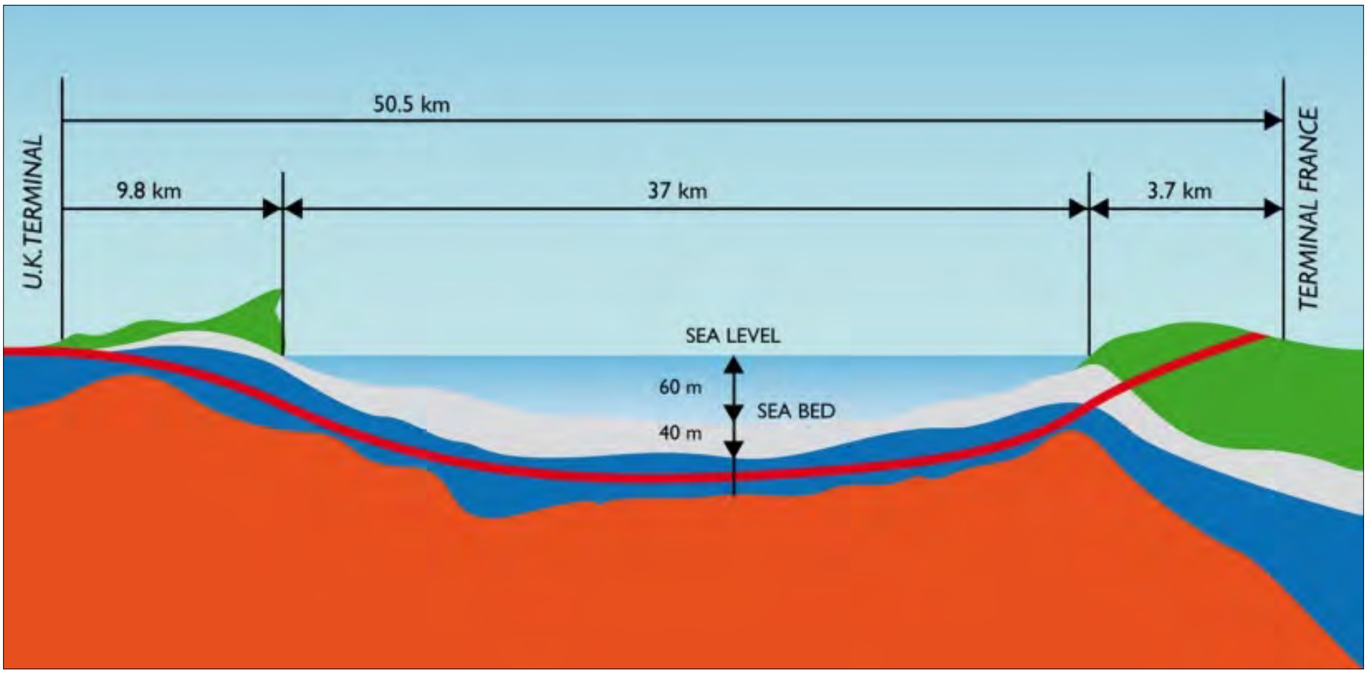
History/Background	• In 1984 French and British banks study – the concession is viable • Eurotunnel – TransMancheLink (builder: 5 French, 5 British companies) • Works 1987-1993 • Assessed cost €4.6 billion (bridge solution – about €10 billion) • Eurotunnel group consisted of private French-British company concession holder for 99 years; European leader in rail-road transportation, quoted at the Paris, London and Brussels stock exchanges; Business model financed by tolls from operators (SNCF, EWS) • Eurotunnel Group: 700,000 small shareholders, which is 65% of the equity
Line characteristic	• It involves a 31-mile tunnel under the English Chanel (since 6 May 1994) for HSR, freight, crossing services (cars and trucks)
Financing	• Final cost – €16 billion • *7 year*s of work without revenue • fast financial worsening – risk of bankruptcy in 1997 • underestimation of costs, overestimation of the traffic (6,8 m travellers in 2003 instead of 30 m estimated in 1986), and overestimated assets • Outcomes: 10 years of financial chaos: Stockholders equity = €1.7 billion • Yearly turnover = €838 million (2003) • Debt = €9 billion • Annual interest = €500 million • The share reached €13.5 in 1989, later less than €1. Listing stopped in 2003 • A salvation procedure and debt reconstructuring saved the company in 2007
Model	• PPP – concession
Additional comments	The project is technical success but financial failure.

Source: https://www.britannica.com/place/English-Channel.

Figure A4–7 The Chunnel (Tunnel under English Chanel)

Source: https://www.britannica.com/place/English-Channel.

Figure A4–8 Tunnel cross section



Source: https://www.britannica.com/place/English-Channel.

APPENDIX 5

China experience in HSR funding and financing

1. Background

China built an HSR network of almost 20,000 km, as for the World standards, rapidly and at a relatively low unit cost.[109] Lower costs means lower demand for funding and financing. But China has also become a leader in providing resources for this project. There are a number of distinct characteristics of Chines HSR which may serve as examples to other States involved in HSR endeavours. A word "may" is of key importance in the preceding sentence. This issue must be carefully addressed to before making any final conclusions on applicability of the Chinese solutions in HSR projects of other States

Paying the due respect to China, we have to remember that their economic system is built on very different principles than European and North American systems. Also, a political system of managing a country and making political decisions is different. Such an analysis definitely extends beyond the scope of this chapter, but it would be a good idea to initiate some analytical steps in this area. It is important that we avoid simplistic conclusions and unjustified recommendations. As always, the truth is in a small print. Saying that, we conduct a brief review of the Chinese successful experiment and point several selected issues which may have important meaning in further analyses of HSR funding.

China in 20 years has surpassed the entire world in the development of high-speed train. It not only that they have the largest HSR network, but also that they devised many innovative engineering and economic solutions to make the HSR program work. EU and the rest of the World should, and let's say even stronger, can learn from the China experiences.

2. HSR in China

Definitions of HSR differ between China and EU, but generally, railways with a maximum speed of 250 km/h or more are considered as HSR (UIC, 2008). According to Order No. 34, 2013 from China's Ministry of Railways, HSR refers to newly built passenger dedicated lines with (actual or reserved) speed of 250 km/h and above.

By 2013, China had completed construction of a high-speed rail network of more than 10,000 route-km. China's HSR network now far exceeds the HSR network in any other country and is larger than the HSR network in the entire European Union. It will continue to grow as more than 12,000 route-km HSR are currently under construction in China. In addition, China has built a number of new 200 km/h express passenger railways and 200 km/h mixed use railways. This note covers both the HSR and new 200 km/h speed railways in China.

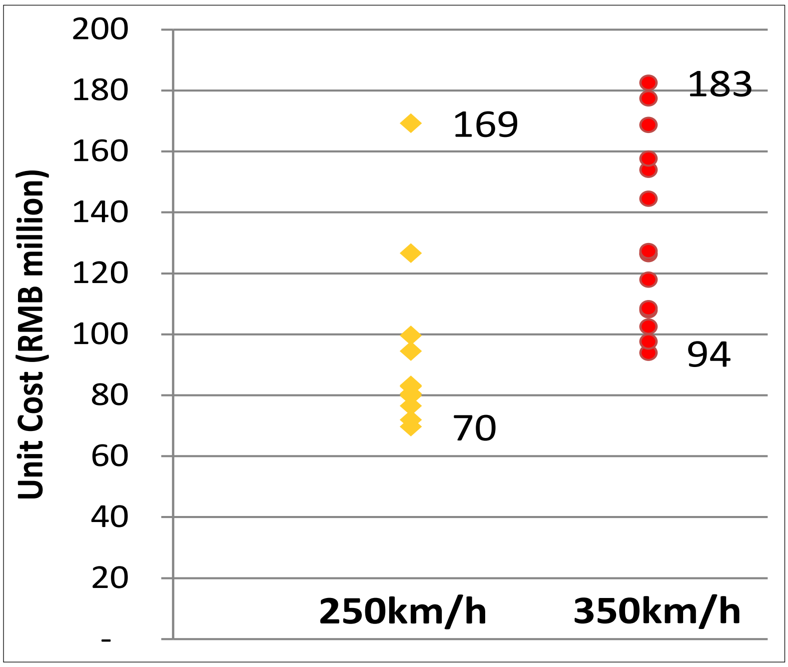
109 The World Bank in China completed a number of papers on this issue. For example: G. Ollivier, J. Sondhi, N. Zhou, High-Speed Railways in China: A Look at Construction Costs, World Bank Office, Beijing, 2013. This text has been used as a main source of information.

In China, HSR lines on high density corridors such as Beijing – Shanghai and Beijing – Guangzhou tend to have a maximum design speed of 350 km/h. HSR corridors with more modest volumes of passengers have a maximum design speed of 250 km/h. Generally, both of these types of HSR are passenger-dedicated lines (PDL) and are newly built as green-field projects. Most of the metropolitan regions in China are either connected, or in the process of being connected, to lines with a maximum speed of 200 km/h or above.[110]

3. Cost of HSR Lines

An analysis of the cost for 27 HSRs in operation[111] at the end of 2013 showed the unit cost varied substantially. The unit cost of 350 km/h projects was between RMB 94-183 m per km (figure A5-1).

Figure A5–1 Unit Cost of PDL[112] (Based on Estimated cost at the time of Project Approval)



Source: Yearbooks of China Transportation & Communications 2007-2013, China Railway Yearbooks, Currently, 1RMB is equal to €0.13.

These costs provide a general indication of construction cost levels, but this data is only available in aggregate form at this point. Expenditures were incurred over different years, so costs may not be directly comparable,[113] given the impact of inflation as well as fluctuations in the supply and demand for rail construction services. But they nonetheless provide a useful range of benchmarking values for new projects.

110 All HSRs and 200 km/h speed trains are operated with Electric Multiple Unit trains (EMU) consisting of 8 or 16 carriages.

111 Cost data sourced from official publications of China Railway Corporation and former China's Ministry of Railways.

112 The unit cost for a new 250km/h would be higher as most of such lines were completed by 2010.

113 250 km/h lines were built about 2 years earlier.

4. Financing and funding of China's HSR

(a) Central Budget

In principle, the HSR system in China has been funded form the central budget. It was done based on planning which provided funds designated to this project. In the last two years the government of China turned its attention to possibilities for attracting private funds to the HSR program. This requires some comments. The economic and property structure in China is different than in the western world. Often "private" entities are joint stock companies owned or influenced by the government. Bank are similarly impacted by governments. So, unless we talk about foreign private entities, it is highly probable that HSR program is funded by state funds or funds controlled by the state.

(b) HSR Projects Supported by the World Bank in China

Significant financing was insured by IFIs namely The World Bank Group. The main features of railway projects which have been supported by World Bank are summarized in table A5-1. Since 2006, the World Bank has provided financial and technical support for six railway projects with speeds of 200 km/h or above. One of these, the Shijiazhuang-Zhengzhou HSR project, which is part of the Beijing-Guangzhou HSR, was completed and commissioned in December 2012, while the others are at different stages of implementation.

Table A5-2 shows the average estimated unit cost of some elements of railway projects supported by the Bank. Information gathered during project supervision indicates that actual costs are close to the estimated costs. An analysis of the actual cost of building the Shijiazhuang – Wuhan PDL (841 km), which included the Shijiazhuang – Zhengzhou Railway, indicates that the actual unit cost was about 5 per cent below estimates.

Table A5–1 Railway Projects Supported by the World Bank in China

Project	Max. Speed kph/Type	Length km	Total Estimated Cost RMB b	Unit Cost RMB m/km	Bridges+ Viaduct+ Tunnels (% of route km)	Period of Construction
Shijiazhuang – Zhengzhou	350 PDL	355	43.9	123	69	2008-2012
Guiyang – Guangzhou	250 PDL	857	94.6	110	80	2008-2014
Jilin- Hunchun	250 PDL	360	39.6	110	66	2010-2014
Zhangjiakou – Hohhot	250 PDL	286	34.6	121	67	2013-2017
Nanning – Guangzhou	200 Mixed	463	41.0	89	53	2008-2014
Harbin – Jiamusi	200 Mixed	343	33.9	99	48	2014-2017

Notes: 1. Total project cost includes the cost of project preparation, land acquisition, construction of the railway and regular stations, contingencies, rolling stock and interest during construction. The cost of railway excluding cost of project preparation, rolling stock and interest during construction is estimated at about 82 per cent of the total cost. 2. Currently, 1RMB is equal to €0.13.
Source: Cost References: GG-Revised FSR Dec. 2010, NG- PAD May 2009, Shi-Zheng PAD May 2008, Jituhun-PAD 2011, Zhang-Hu-FSR, HaJia-Revised Feasibility Study Oct.2012/PAD.

Table A5–2 Range of Average Unit Costs (RMB million/per km of double track)

Element	350 km/h	250 km/h	200 km/h
Bridges/Viaducts[114]	*41**	*13-25*	*25-27*
Buildings including stations	2	2-4	3-5
Civil works	48	50-54	44-51
Electrification	5	4-5	4-5
Embankment	*6*	*7-12*	*13-15*
Land acquisition and resettlement	4	4-8	6-9
Rolling stock	15	3-4	5-7
Signalling and communications	4	3	4
Track	9	9-11	6-7
Tunnels	*0**	*16-29*	*2-13*
Other costs	Balance	Balance	Balance

*Ballast-less slab track is used for 350 and 250 km/h PDLs while ballasted track is employed for 200 km/h railways.
Source: FSR/PAD for projects.

(c) Cost Factors

Several factors influence the cost of an HSR and 200 km/h railway project construction. The major factors include the line design speed, type of tracks, topography along the alignment,[115] weather conditions (such as very low temperature requiring special design features for the road bed), land acquisition costs (these are high in dense urban areas), use of viaducts instead of embankments, the construction of major bridges across wide rivers, and the construction of mega stations.

For example, the Beijing-Tianjin HSR unit cost was higher than usual at RMB 183 m per km since it included the cost of two mega stations built at Beijing South and Tianjin, which serve other lines as well. The unit cost of Shanghai-Hangzhou HSR (RMB 177m per km) was high since it included several major bridges and a high cost of land acquisition and resettlement as it traverses densely populated areas of Eastern China with high land values. Laying track on viaducts, even if more expensive than embankment, is often preferred[116] in China to minimize resettlement and the use of fertile land as well as to reduce environmental impacts.

The following paragraphs provide some details on the cost of viaducts and bridges as experienced under World Bank supported projects and at the cost of stations.

114 The unit cost of bridges/viaducts includes that for short/medium length bridges over water and specially designed bridges over large rivers as well as viaducts built over dry land.

115 In particular, mountainous areas require extensive tunneling and bridge construction, which can reach as high as 80% of the alignment length.

116 Three very long over-land bridges (viaducts) are part of the Beijing-Shanghai HSR which commenced operation in 2011. These are: the 164 km long Danyang–Kunshan Grand Bridge, the 114 km long Tianjin Grand Bridge and the 48 km long Beijing Grand Bridge – the first, second, and fifth longest in the world respectively at the time. Shi-Zheng Railway has 69% of track on viaducts to minimize land take resettlement in the fertile plains it traverses.

5. Low Cost Viaduct Construction

In the projects supported by the World Bank, the estimated cost of viaducts in China ranges from RMB 57 to 73 m per km for a double track line.[117] Such costs are kept low through standardization of the design and manufacturing process for casting and laying bridge beams on viaducts. The span of viaduct beams has been standardized at 24 and 32 m (weighing about 750-800 t). Bridge beams are cast in temporary facilities established along the railway alignment. Each beam is transported over a distance up to 8 km by a special beam carrier vehicle (having as many as 18 axles) and is launched over the viaduct columns by specially designed equipment. The cost of a 32 m-bridge beam is about RMB 0.8-1.0 m. The slab track is also cast in temporary facilities established along the railway alignment. After project completion, the bridge beam and slab track casting facilities are dismantled and reinstalled at another site. The vacated land is systematically restored by relaying the site with the original topsoil and is handed over to its owners for agricultural use.

6. High Cost of Unique Bridges

Special bridges that cross large navigable rivers (class three and up) or that need to accommodate special topographic features like mountains have a cost per kilometre that can be much higher than that of a regular viaduct. Those bridges are designed to address unique challenges and require much more intensive design work and sophisticated construction techniques. Usually such bridges represent a small percentage of the total number of bridges. Projects having larger proportion of special bridges will tend to have a high unit cost, like the Xijiang and Sixianjiao bridges under World Bank supported projects. Cost information: Xijiang River Bridge near Zhaoqing, *Arch suspension bridge with a main span of 450 m over the Xi river and a total length of 618 m. Cost: RMB 580 million. Unit cost: RMB 938 million per km*; Sixianjiao Bridge: *Cable-stayed steel truss bridge with 105 m high pylons. Total length of 567m. Estimated cost of RMB 490 million. Unit cost of RMB 864 million per km. (credit to Guiguang Co).*

7. Railway Stations

Railway stations play a dual role as transport hubs and urban centres. Many of them are urban landmarks that seek to reflect the local culture and heritage, while supporting urban expansion. Traffic volumes vary widely across stations. Accordingly, the size and cost of stations varies markedly with small stations (3,000 sq m station building) costing about RMB 40 million, while mega stations, more akin to airport terminals, may cost up to RMB 13 billion. The cost of regular stations, other than mega stations, is generally included in the project cost and is of the order of 1.0 to 1.5 per cent of the total project cost.[118] The mega stations are frequently built as independent projects and their costs are not always included in the HSR project cost.

Mega stations are traditionally built in the largest cities, and tend to be large airport-type buildings, with close attention to architecture and local culture. Hence, Beijing South Station is reminiscent of the Temple of Heaven,[119] and Wuhan Station resembles a bird spreading its wings, inspired by the Yellow Crane, the symbol of Wuhan City.[120]

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117 The actual cost of a typical viaduct on the ShiZheng Railway was RMB 60-70m per km.

118 The cost of 16 new stations on Guiguang Railway (250 km/h) is estimated at RMB 1.16 billion, i. e. 1.2% of the total project cost.

119 http://zh.wikipedia.org/wiki/%E5%8C%97%E4%BA%AC%E5%8D%97%E7%AB%99

120 http://en.wikipedia.org/wiki/Wuhan_Railway_Station

Mega stations are large and expensive to build, but they fill up rapidly during peak travel period. Such stations have three to five levels and provide interchange facilities between railway, road and metro systems. The mega station at Shanghai Hongqiao has interchange facilities for the airport and for a future maglev train. These stations seek to provide facilities that promote quick and comfortable transit for large volumes of traffic. Notable among these are stations at Beijing South (RMB 6.3b-US$1.0b; 310,000 sq m), Wuhan (RMB 4.1b US$0.70b; 114,000 sq m), Guangzhou South (RMB 13b US$2.1b; 486,000 sq m) and Zhengzhou East (RMB 9.5b US$1.5b; 412,000 sq m).[121]

8. Factors Explaining Relatively of Low HSR Costs in China

HSR construction costs in China tend to be lower than in other States. Based on experience with World Bank supported projects, the cost of railway construction[122] is about 82 per cent of the total project costs mentioned earlier. China HSR with a maximum speed of 350 km/h has a typical infrastructure unit cost of about US$17-21 m (RMB 100-125 m) per km, with a high ratio of viaducts and tunnels. The cost of HSR construction in Europe, having design speed of 300 km/h or above is estimated to be of the order of US$25-39 m per km (see table 4 and 5). HSR construction cost (excluding land, rolling stock and interest during construction) is estimated to be as high as US$ 52m per km in California.[123] Based on D.P. Crozet,[124] the unit cost for four HSR lines under construction in France in 2013 ranges between US$24.8 m and 35.2 m (table A5-3).

Table A5–3 Estimated cost of the four lines under construction in France

	EAST Strasbourg	BPL Brittany	CNM Nimes-Montpellier	Sud Europe Atlantique	Total
Total cost (Euro m)	2 000	3 300	1 800	7 800	14 900
Length (km)	106	182	80	303	671
Cost/km					
(Euro m)	18.9	18.1	22.5	25.7	22.2
(US$ m)	25.9	24.8	30.8	35.2	30.4

Source: International Transport Forum, December 2013.

Table A5–4 Estimated Cost of Recent HSR Projects in Europe

High-Speed Rail Project	Length (km)	Approximate Construction Cost per km (US$ 2012 m)	Construction Completion Date
Cordoba – Malaga (Spain)	155	US$27	2007
Madrid – Barcelona – Figueras (Spain)	749	US$29	2008
LGV East (France)	300	US$31	2007
Madrid – Valladolid (Spain)	177	US$39	2007

Source: Texas A&M Transportation Institute (2013) based on US Government Accountability Office (2009).

121 From www.Baike.baidu.com.

122 Including civil works, track works, regular stations, yards, signaling, control and communication, power supply and other superstructure components; excluding the cost of planning, land, some of the mega stations, rolling stock and interest during construction.

123 California HSR Authority, Draft Business Plan 2014.

124 International Transport Forum, December 2013.

It is apparent that the cost of construction of HSR in China is significantly lower. Although comparison is at best approximate considering difference in accounting and cost procedures. Aside from the lower cost of manpower, several other factors are likely to have led to lower HSR unit cost in China. Major factors were:

- At a program level, the declaration of a credible medium term plan for construction of 10,000 km of HSR in China over a period of 6-7 years energized the construction and equipment supply community to build capacity rapidly and adopt innovative techniques to take advantage of very high volumes of work related to HSR construction. This has led to lower unit costs as a result of the development of competitive multiple local sources for construction (earthworks, bridges, tunnels, EMU trains etc.) that adopted mechanization in construction and manufacturing.
- Large volumes and the ability to amortize capital investment in high-cost construction equipment over a number of projects contributed to the lowering of unit costs.
- Relatively low cost of land acquisition and resettlement.[125]
- Localization of the design and manufacture of goods and components as well as the standardization of designs for embankments, track, viaducts, electrification, signaling and communication systems. For example, the slab track manufacture process was imported from Germany, but the cost of the Chinese made product is about a third lower than the German product as a result of large volumes and a lower labour cost.
- The technology developed for construction of tunnels not only resulted in a low unit cost but also a speed of 5-10 m of tunnel construction per day. The HSR tunnel construction cost in China (about US$10-15 million per km) is a fraction of that in other States.[126] Tunnel costs are heavily influenced by geology and labour costs and, in the case of China, the latter has also helped in cost reduction.

Closing remarks

China Railway has accomplished a remarkable feat in building about 20,000 km of HSR network in a period of six to seven years at a unit cost that is lower than the cost of similar projects in other States. The HSR network operates with high traffic volumes on its core corridors, and with good reliability. This has been accomplished at a cost which is at most two-thirds of that in the rest of the world.

Besides the lower cost of labour in China, one possible reason for this is the large scale of the HSR network planned in China. This has allowed the standardization of the design of various construction elements, the development of innovative and competitive capacity for manufacture of equipment and construction and the amortization of the capital cost of construction equipment over a number of projects.

Initially one may think that the Chinese experiences should be transplanted to the European market. In theory yes, in practice it may not be easy. The opportunities and conditions for the development of HSR in China and Europe are very much different. This concerns not only direct issues of HSR projects development but also many other general factors in economics and politics. A detailed addressing of these issues is definitely beyond a scope of this assessment. One statement of caution should however be made. All attempts of applying the Chinese experiences in HSR development should be carefully assessed to ensure that differences in economic and political environments are not precluding such

[125] The cost for site work and right of way in California HSR is estimated at US$10 million per km contributing 17.6% of cost. In China Land acquisition and resettlement costs are still below 8% of project cost.

[126] Average tunnel costs per km are reported to be about US$43 m in New Zealand, US$50 m in the US and US$60 m in Australia (Analyzing Tunnel Cost, Efron and Read, 2012).

steps. On the other side, there are some issues that should be given particular attention by EU decision makers. Europe may profit from some lessons learned by the Chinese. This may include such issues as: a systemic approach to HSR development, implementation of stability and predictability of funding for HSR, wider usage of similar standards and components for HSR construction, etc. If further analysis of the HSR in Europe is awarded, these issues should be an important, element of such an evaluation. Any attempts of implementation of China's experiences in HSR without their assessment and adjustments may turn out to be very risky.

Table A5–5 Summary of findings: HSR in China versus Europe (and TER States' specifics)

	China	Europe (continental system)	TER States (specific)
HSR program size	• Very big, has continental characteristics due to size and number of lines and infrastructure	• Very Big, continental due to size and number of lines and infrastructure	• A portion of a continental network
Conceptual approach to HSR development	• Centralized, coordinated. Long-term planning and completion of concrete elements of the network (lines). • Major designated funding ensured in a long-term perspective • Attracting private capital as an additional, supplementary source. • Uniform project assessment approach focused on the total network development and incorporating more and less profitable sections of the network.	• Objectives centralized, execution and management decentralized, • *HSR de*velopment dependent mainly on national priorities and decisions, • No designated funding, projects funded from generally available funds, • HSR system is being developed by a criterion of funds assignment/availability and not as stage-based network development. • Private funds are sought to complement and fill in gaps where public funds are not sufficient. • A framework for project evaluation exists, detailed assessment varies by country.	• For non-member States, funding is available from limited, specialized public funds. • The availability of private funds is limited because of insufficient legal environment.
HSR development pattern	• Long-term vision, periodically verified • Detailed program development instruments established • Strict national (system) management system	• Long-term vision • Decentralized program implementation and management	• General vision • System approach under development
Development decisions	• Centralized	• Decentralized	• Depending on political system
Funding and financing decisions	• Centralized with regions' input consideration	• National and negotiated with regions	• Under development

Table A5–5 Summary of findings: HSR in China versus Europe (and TER States' specifics) (continued)

	China	Europe (continental system)	TER States (specific)
Labour costs	• Low due to national economy and economy of scale in HSR construction	• Average with options to lower due to economies of scale	• Low because of national economy and lower general cost of labour
Terrain	• Various with significant country area	• Mainly developed and industrialized area with significant metropolitan areas crossing	• Various with significant country area
Speed	• Various, depending online with some sections allowing very high-speed	• Sufficient in the terrain limitations with some limited sections with very high-speed	• Planned faster than average lines
Construction	• By designated companies controlled by the government • Quick selection process	• Independent companies selected based on competitive procurement • Selection process usually takes a long time	• State procurement procedures often lengthy and politically motivated
Total Costs	• Very low in comparison with other HSR projects (labour, land acquisition, economies of scale, low cost engineering solutions) • Low cost rolling stock	• High mainly due to high labour, land acquisition cost, and limited application of economies of scale, as well as more difficult terrain. • More expensive rolling stock.	• Average
Ridership	• Close to initially forecasted or more • Capacity needs often higher than supply	• Depends online, but gradually improving • Significant short ride traffic • Sometimes forecasts are bloated	• Slow growth
Financial results	• Feasible although detailed results unknown. • Judging by levels of ridership should be *feasib*le and profitable	• Vary • Some lines highly profitable other much less. • Competitive environment much more complicated than in China. • Significant number of competitive mobility alternatives	• Remains to be seen after more lines are in place

Source: own study.

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Trans-European Railway High-Speed

Master Plan Study – Phase 2

The rapid development of high-speed rail (HSR) networks has been observed worldwide in recent years. The experience of states operating these systems demonstrates that they are setting new standards of quality and contributing to the renaissance of railway as a mode of transport. The development of an HSR network in the TER region would significantly improve the competitiveness of rail, increasing the sustainability of the transport sectors in TER countries.

The TER HSR Master Plan Phase 2 is a continuation of the work undertaken in Phase 1, and extends its analysis to the following areas:

- Technical and legislative aspects
- Socioeconomic analysis
- Conditions for the establishment of national and international networks
- Financial and planning elements of HSR.

Currently, there are few railway lines in some TER member States that allow high speed operation. This creates a unique opportunity for developing HSR systems in individual TER member States, while ensuring that this development is integrated across the wider TER region through adequate international connectivity. This study aims to provide decision-makers with the necessary tools to define what, if any, HSR network should be developed in their respective states.

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