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Trans-European Railway High-Speed
Master Plan Study

A general background to support further required studies

Phase 2

UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Trans-European Railway High-Speed

MASTER PLAN STUDY

PHASE 2

A general background to support further required studies

UNITED NATIONS
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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.

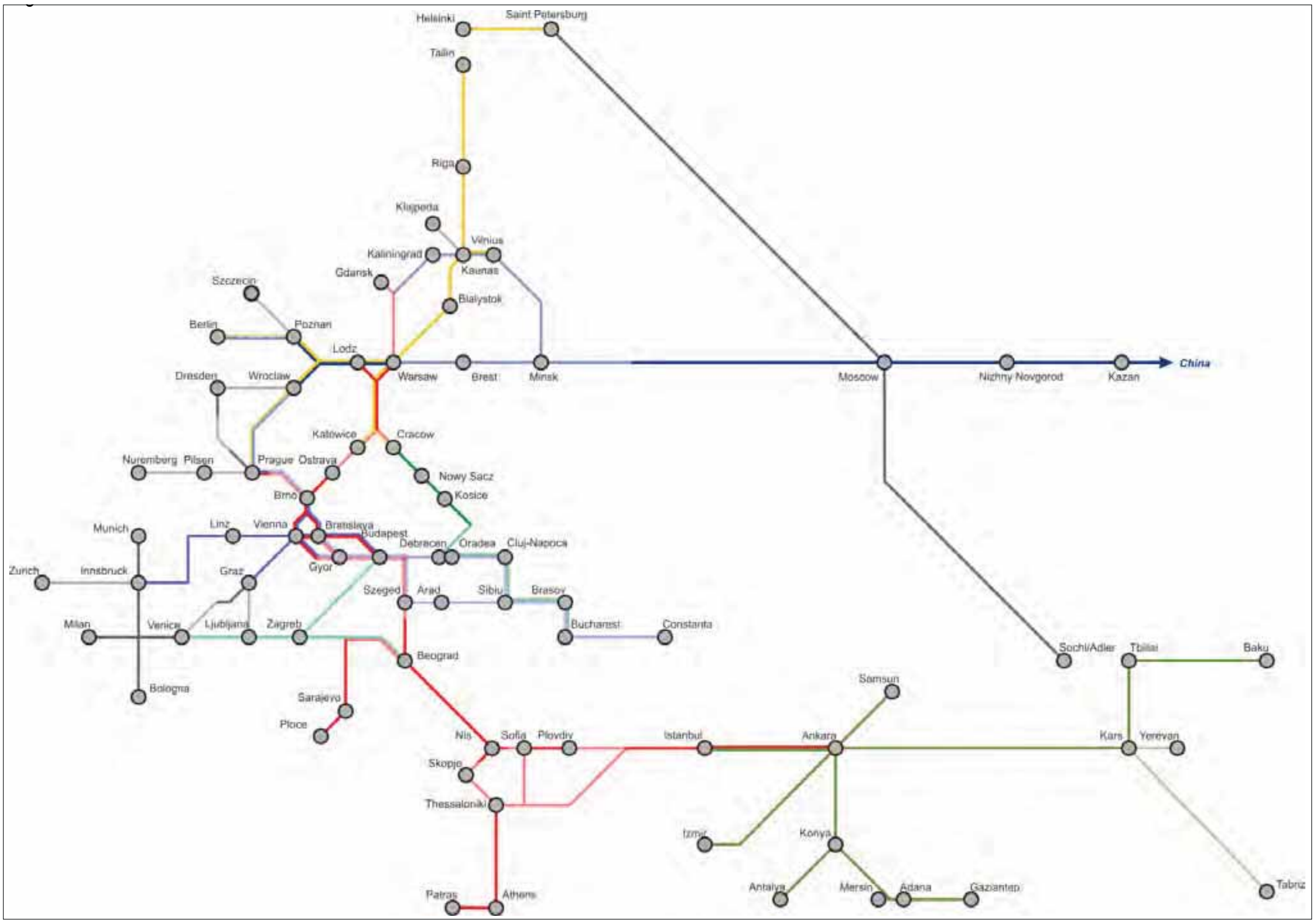
The investment plans have been considered with two milestones: 2030 and 2050 with the final network identified in figure I completed by 2050.

3. Transport potential in the region

The TER network covers a total area of more than 6.4 million km^2 with varying natural, economic, and social conditions, and has a population of approximately 338 million. The average population density is 50/km^2. 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

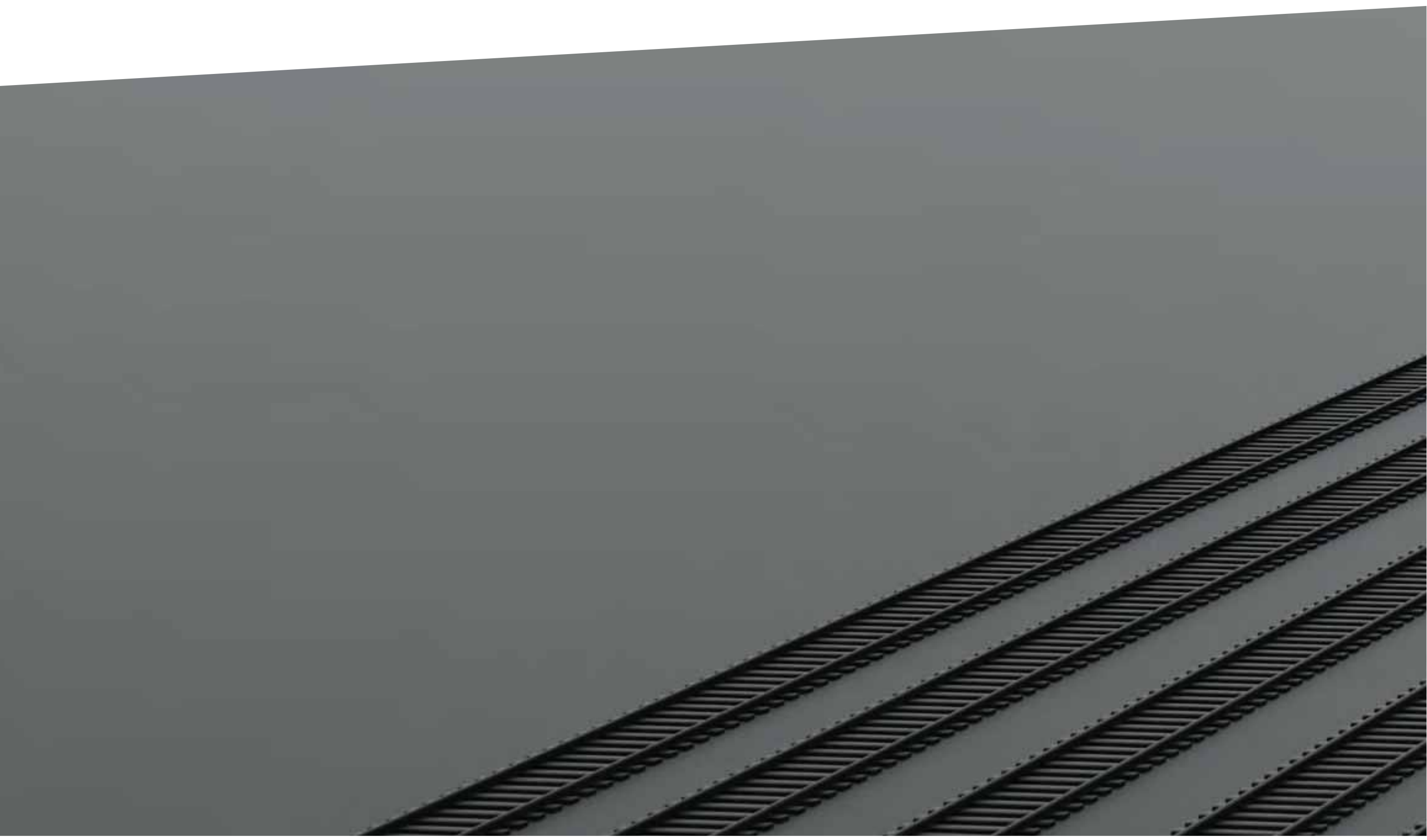
With such a large number of HSR projects under consideration within TER States, it will be possible for those states to close transport gaps across the region, and create effective HSR corridors with a positive impact on the development of the regions. The most significant network gaps exist in the Balkan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



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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

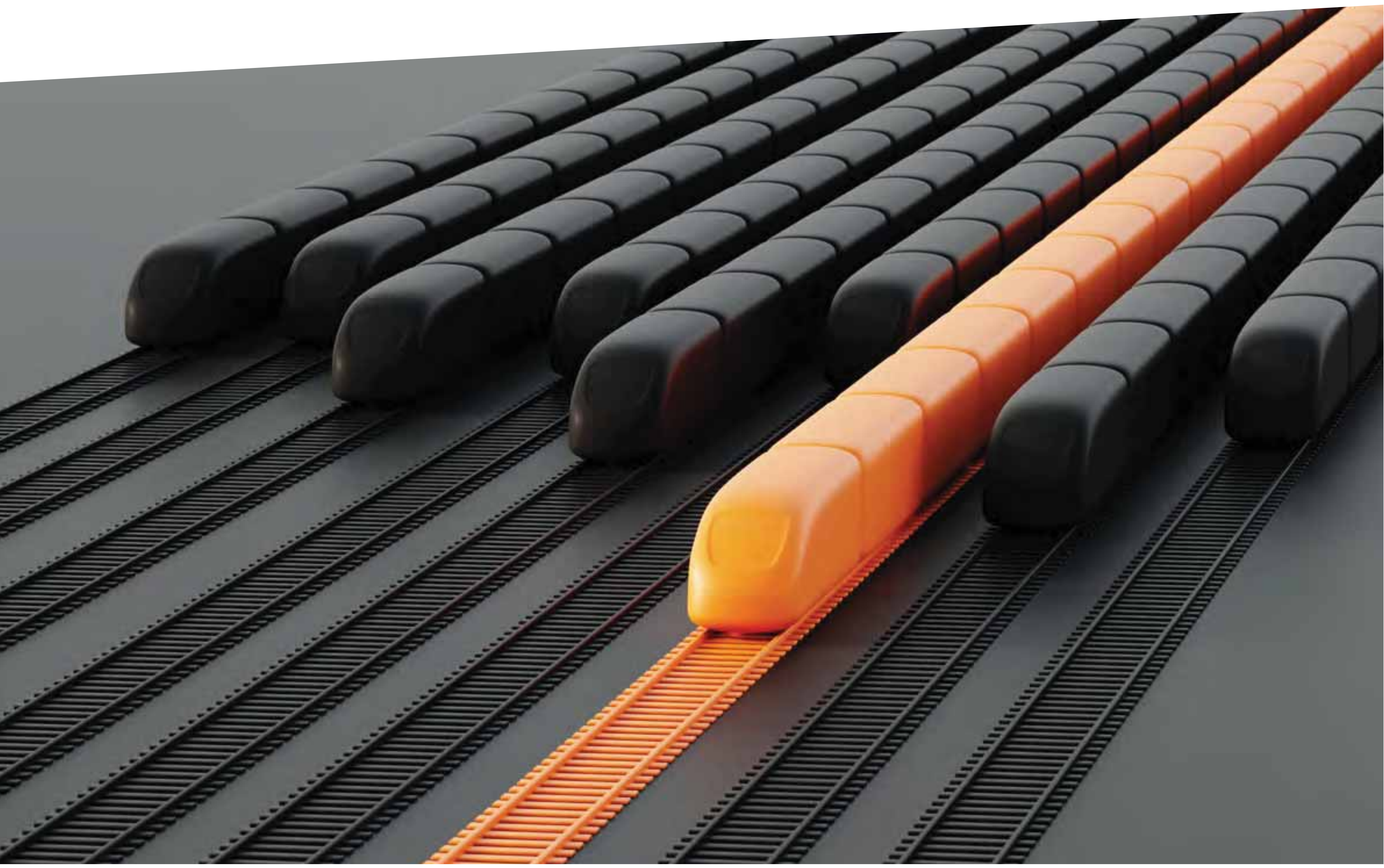
The coordinated development of HSR projects must occur at international level. This could be achieved through the TER HSR project by the development of an HSR network in the form of a framework investment schedule, which will also ensure that priorities are optimised. This option has to be carefully 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.

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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

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[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.

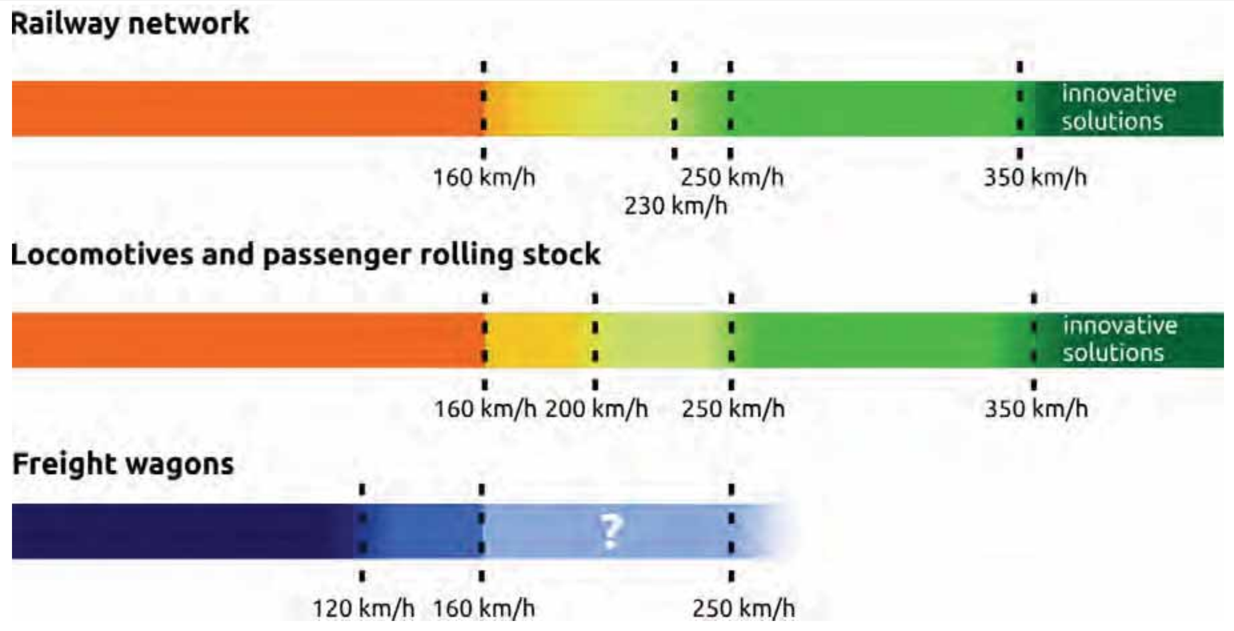
There are no legal restrictions on freight traffic on high-speed lines. The decision to operate freight trains on these lines depends on local conditions (demand, network capacity) while complying with legal requirements in terms of technical performance.

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;

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- **(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.

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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

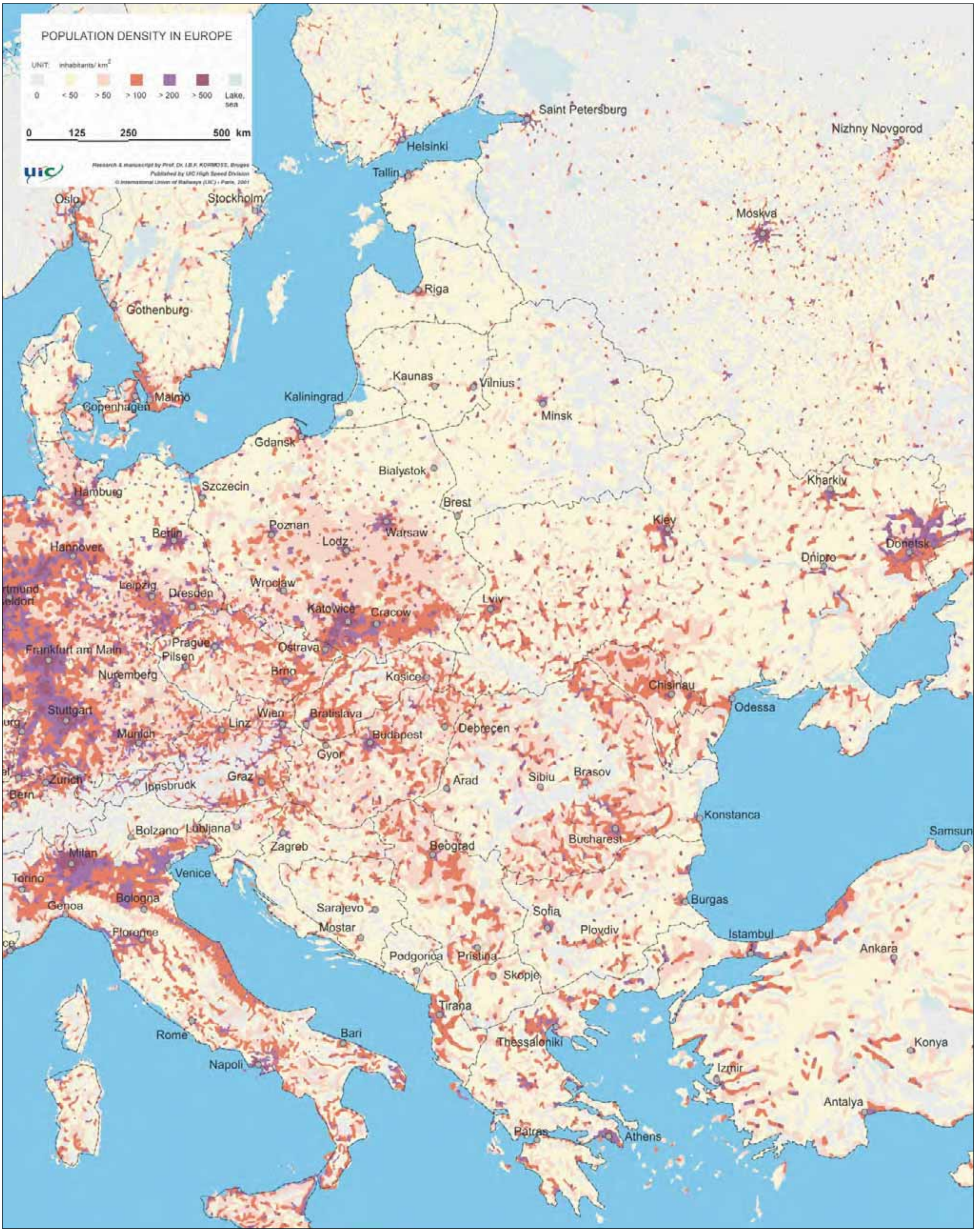
The TER area is occupied by approximatively 500 million inhabitants, which gives an average population density of 50 people per km². The distribution of population in the area remains very uneven, with large uninhabited areas and population areas of less than one person per km². In the Carpathians and 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 km^2. Values between 20 and 60 km per 1,000 km^2 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.

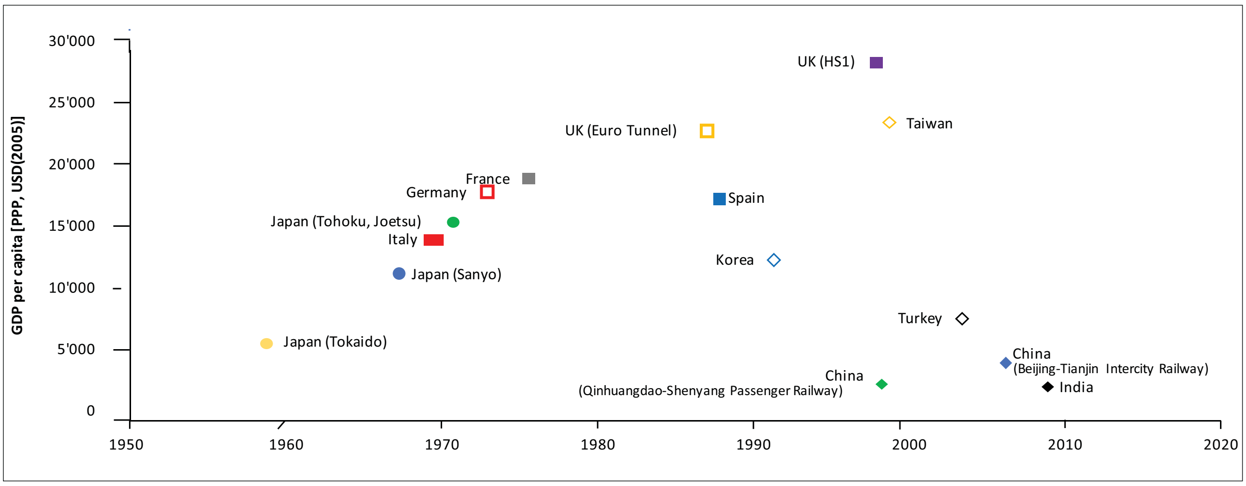
1.5 Affordability for TER States to build high-speed lines

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.

2.8 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.

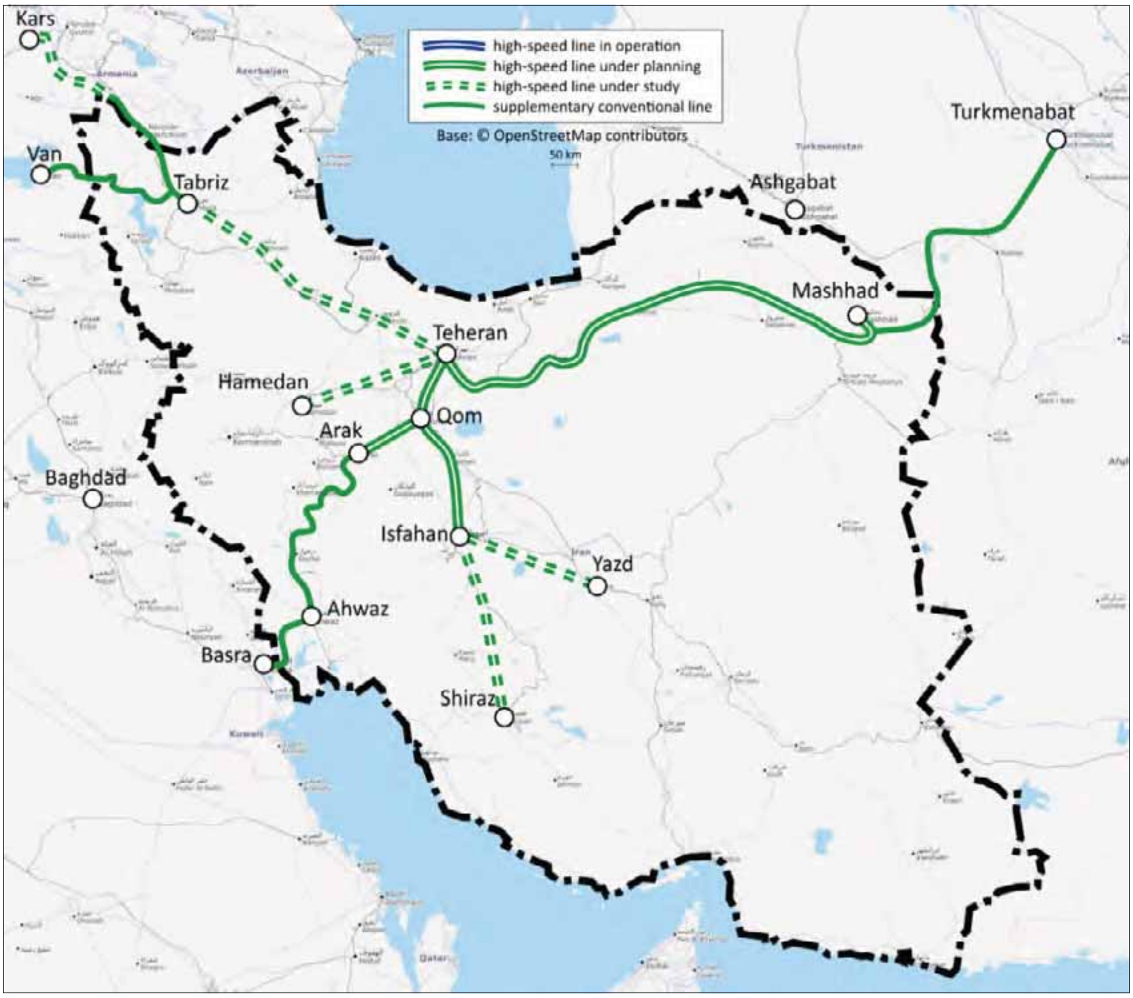
Further plans include the construction of the Qom – Arak, Tehran – Hamedan high-speed line and the modernisation or construction of the Tehran – Tabriz line. One of the concepts also provides for Iran to be located on one of the branches of the New Silk Road connecting Asia and Europe. The route would 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.