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ETR

INTERNATIONAL EDITION

Railway Technology Review

- The ICE 4 in regular operation
- High-speed travel
- Track maintenance
- Iran-Europe Transport Corridors

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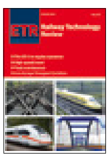
Advertiser's Index

TO THE COVER



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Rail is an efficient mode of transport with massive future potential

Dear readers,

Realisable and rapidly visible innovations are critical to the survival of the rail system as it competes with other modes of transport. To play an appropriate role in future mobility, it has to succeed with ambitious projects in collaboration with innovative operating companies, both in the main-line rail sector and in local urban transport, as well as being quick to go in totally new directions in freight transportation. Of course, this is all happening against the backdrop of the general trend towards digitalisation and networking of all modes of transport.

In many areas, rail transport is clearly the ideal solution. This is the case both for transport between key economic and urban centres and, in particular, for local passenger transportation in cities and their surrounding areas. Environmentally friendly electromobility has been a key part of all areas of rail transport for a long time.

> In the future, the rail industry will play an important role in climate protection and the mobility revolution, which will require everyone to implement innovative solutions."

The Austrian Association of the Railway Industry as a representative of an export-orientated industrial sector

The Association of the Railway Industry was established in 2005 to help positively shape the development of this performance-based and innovative sector. The Association's purpose is to represent the interests of Austria's railway industry. Our member companies come from all areas of production and development, and are involved in creating solutions for a huge range of rail transport systems. (www.bahnindustrie.at)

The Austrian rail industry as an innovation and export leader

In international comparisons, the Austrian rail industry is extremely strong and innovative. Its strength in innovation is particularly apparent in the areas of rails, points, rail construction machinery, electric drives, chassis and bogies, passenger carriages, underground trains, trams and safety, control and communication systems. This is attested to by the fact that Austria has the highest number of inventions per head of population in terms of rail-related patents than any other country in the world.

The Austrian rail industry is also an export world champion. Despite the country's relatively small size, we are in fifth place worldwide for exports in the "rail vehicles and associated equipment" sector. Per capita, Austria actually has the highest level of rail-industry exports.

If you are interested in the Austrian Association of the Railway Industry's activities, we would be delighted to hear from you at www.bahnindustrie.at.

Dipl.-Ing. Dr Angela Berger
Association of the Railway Industry
Director of the Austrian Association of the Railway Industry

The next mobility revolution

The railway industry in Germany is producing the digital rail transportation of the future, bringing greater climate protection and enhanced customer quality. Our mission: Achieving the best mobility there has ever been in conjunction with partners throughout the world. Rail 4.0 is more environmentally friendly and free of local emissions, making it more health friendly, economical and quiet particularly in mega-cities. The digital mobility revolution is shifting the boundaries of what is technically feasible. Intelligent infrastructure, automated driving, real-time information and entertainment, predictive maintenance, intermodal logistics, cyber security – all of this can only succeed with innovations from the creative workshops of the railway industry.

Our mission:
Achieving the best mobility there has ever been in conjunction with partners throughout the world.

Climate protection is one of the human race's most crucial future challenges. The Paris Agreement targets must be upheld. But mobility has to play a key role. Measured by absolute greenhouse gas emissions, transport is making an insufficient contribution to climate protection. Rail 4.0 can do more. For example, 90% of rail transport in Germany is already electric. But we can go further – in the future emission-free electromobility will be possible with no overhead line thanks to innovative battery, hydrogen and hybrid technologies, all "made in Germany".

Digitalisation will also bring more freight onto the tracks. Sustainable rail transportation – with monitoring of the cargo temperature and, of course, with precise geolocation – will be able to play a greater role in intermodal data-based logistics in the future.

Rail 4.0 is both sustainable and exciting. Automated driving? State-of-the-art on the rails. Automatically controlled vehicles consume up to 30% less energy thanks to optimised acceleration and braking. This means better climate protection and lower costs. And what's more, automated underground trains can run at much more regular intervals, during rush hour for example. For people, this means less waiting time, no more overcrowded trains and better quality of life in cities around the globe. A smart, virtually developed design can also make a key contribution. Travelling by rail makes sense and is enjoyable.

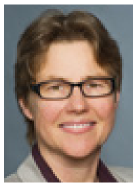
Innovations from digital timetables through to digital signal boxes make rail transport more reliable than ever. Infrastructure and computer systems equipped with ETCS monitor trains and regulate their speed. This makes rail a more flexible system, whose capacity is continuously optimised. As a result, ETCS is the backbone of the modern railway network. ETCS allows attractive high-speed connections to be operated between major cities. For example, between Berlin and Munich or Barcelona and Madrid, the train will be the first choice for an increasing number of customers.

The mobility of the future has begun: Rail 4.0 will be a success story – if we write it together.

Dr Ben Möbius
Chief Executive
The German Railway Industry Association (VDB)

The ICE 4: Latest ICE now in regular operation in the DB long-distance fleet

As Deutsche Bahn AG (DB) changed its timetables on 10 December 2017 the first five ICE 4 (BR 412) trains came into regular operation in Germany.



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Managing Editor
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1. DETAILS OF THE CONTRACT AND OPERATION OF THE ICE 4

In 2011, Deutsche Bahn and Siemens AG concluded a framework agreement for up to 300 ICE 4 trains. In an initial call, DB ordered 119 trains, an investment volume of 5.3 billion euros.

The ICE 4 has been running since the timetable change, with five trains from the 412 series on the Hamburg – Munich and Hamburg – Stuttgart routes. From February 2018 six trains will be used, and then nine trains from June 2018. The ICE 4 fleet is set to grow to a total of 119 trains by 2023. Of these, 100 will be the twelve-car version and the other 19 the seven-car version. The ICE 4 is then likely to account for more than 40 percent of all seating capacity available on the entire ICE network.

As the ICE 4 fleet can be equipped with ETCS, it can also be used on the newly constructed Berlin – Munich route. The ICE 4 has gone through a year of trial operation. Two trains ran almost daily between Hamburg and Munich from October 2016 to October 2017. DB employees have been receiving training for the new train since August 2016.

DB hopes the new ICE 4 fleet will help it achieve its growth targets. The intercity transport strategy adopted in 2015 includes expanding intercity services by 25 percent by 2030. DB wants to attract 50 million additional passengers per year.

2. TECHNOLOGY AND CONFIGURATION

The ICE 4 has been completely redesigned by Siemens. The multi-unit concept of the ICE 4 is based around maximum possible flexibility. Based on five car types, 24 train configurations are possible and can be adapted to the required space, the maximum speed and the route profile. The key to configurable trains lies in the power car concept. In these powered cars, the essential drive and power supply components are positioned and linked under the floor. This means that there are passenger areas in the end cars. As a result, 830 seats are now available on the ICE 4, around 10 percent more than on an ICE 1 with a comparable length.

Trains can be configured from the power cars, service car, central cars, the two end cars and the restaurant car. A 12-car ICE 4 is powered by six power cars and has a maximum speed of 250 km/h. The twelve-car ICE 4 has two end cars, one service car, a restaurant car and eight passenger cars. The service car contains an infant section, a family and wheelchair area and service areas for train personnel. There are 205 seats in 1st class and 625 in 2nd class (see table).

The ICE 4 uses the new SIBAS PN (Siemens Profinet rail automation system) vehicle control system developed by Siemens. Each car has a dedicated computer that controls exclusively the systems in the relevant car (e.g. doors or air conditioning). The full train control is also active in the leading end car. This innovative software architecture thus also supports a flexible train configuration. Cars can be interchanged and reconfigured with no problems. The software configures itself for each car.

Seats:	830, of which 205 seats 1st class
Maximum speed:	250 km/h
On-board restaurant	22 spaces
Bistro with standing area	
Train length:	346 metres
Occupied weight:	764 tons
Unladen weight	670 tons
Number of entrances on each side of train:	22
Number of toilets:	20 standard toilets, 1 disabled toilet, 1 staff toilet
Car body length (end car/central car)	28.6 m/27.9m
Car body width (external/internal)	2,852 mm/2,642 mm
TSI axis load	18 t
Compatible platform heights	550 mm – 760 mm
Ambient temperature	-25 C to +45 C
Bicycle spaces	8
Min. cornering radius	150 metres
Max. tilt	12-car: 40 per mil

TABLE: ICE 4 (BR 412) technical data and facts

3. INTERIOR FITTINGS

With a length of 346 metres, the 12-car ICE 4 has 830 seats. It has large luggage racks close to the seats. A family section provides more space than in previous series. Additional areas for pushchairs are provided in the infant and family areas. Four wheelchair spaces are available. A totally new feature in the ICE fleet is that on the ICE 4, eight bicycle spaces can be reserved in the end car.

An innovative lighting concept featuring LED lighting control based on the time of day creates a pleasant atmosphere in all cars. A brand new air conditioning system ensures that temperatures can be adjusted within a broad range from minus 25 to plus 45 degrees Celsius. It has two redundant cooling systems, ensuring that if one cooling circuit fails the other continues to run.

The new seats have improved headrests. The seat backs slide into the seat shell when adjusted rather than moving backwards, so they do not disturb the person sitting behind. Every 1st class seat also has its own mains socket and a reading light. Reservation information and seat numbers are integrated into the seat headrests in a clearly visible location.

The trains use multi-provider technology to provide the latest Wi-Fi technology. During travel, the system accesses the fastest data networks available (LTE, 3G) and combines the capacity of different network operators, allowing higher data volumes to be processed. This gives passengers a faster and more stable Wi-Fi connection.

A passenger information with ceiling monitors in the large cars and additional screens in the boarding and exit areas, the infant section and the on-board restaurant shows information about the journey and connections in real time.

The on-board restaurant on the ICE 4 has space for 22 guests in a redesigned ambience. The on-board bistro has an open counter area and a curved display case.

4. BARRIER-FREE FITTINGS

There is an area with space for four wheelchair users, including seats for the people accompanying them. The tables in this area are height-adjustable and next to them is an emergency call button with intercom function. Two on-board lifts assist with boarding and exit. Visually impaired passengers can find their way from the door (door location signal) to their reserved seat, to the toilet or to the on-board restaurant using tactile displays (tactile pictograms, braille and guide strips in the aisles).

FIGURE 1: Test operation of the new ICE 4 series 412 between Hamburg and Munich, began on 31.10.2016, shown here: Munich Hbf

(Photo: Deutsche Bahn AG/Uwe Miethe)

5. ENERGY CONSUMPTION

Despite its seating capacity of 830, the 12-car train is comparatively light. Compared to an ICE 1 with twelve central cars and two end cars, the ICE 4 is around 120 tons lighter, with an unladen weight of 670 tons. The ICE 4's energy consumption per seat is up to 22 percent lower than an ICE 1. In addition, attention has been paid to use of environmentally friendly and recyclable materials.

6. MAINTENANCE AT ICE PLANTS

In 2018, the ICE 4 trains will be maintained at the ICE plants in Hamburg and Munich. The infrastructure has been adapted to handle the new train design. Further plants in Berlin, Cologne and Basel will follow. In some cases, new capacity will be created in the maintenance depots and sidings. Because of its length (346 metres), the ICE 4 takes up two spaces in a standard 200 metre maintenance depot. Reconstruction will take place gradually as the number of trains increases. ◀

Literature

[1] Hubert Hochbruck, Hochgeschwindigkeitsfahrzeuge, ETR – Eisenbahntechnische Rundschau, (64), Heft 6/2015

[2] www.deutschebahn.com

[3] www.siemens.com/presse/ice4

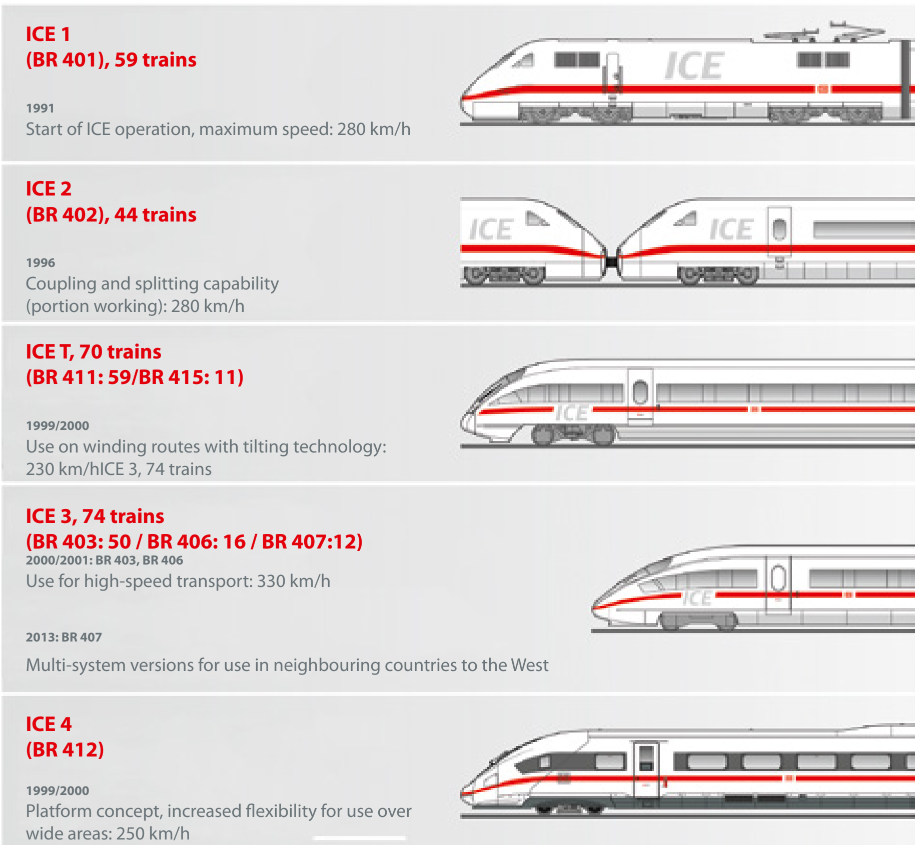

FIGURE 2: Comparison of ICE series (source: Deutsche Bahn AG)

NBS Nuremberg – Halle/Leipzig – Berlin: Germany Unity Transport Project Number 8

Significance and effects of the Nuremberg – Berlin project for Deutsche Bahn AG's national and European passenger and freight transport

In December 2017, commissioning of one of Europe's most innovative rail routes heralded a new era in rail travel. It was an event with historic significance for Germany. The eighth and also biggest German Unity transport project (VDE 8) means that Germany has finally been brought together by rail.

Berthold Huber
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THE BIGGEST IMPROVEMENT IN SERVICES IN THE HISTORY OF GERMAN RAILWAYS

A total of 17 million people will benefit from shorter journey times on the new route, which is made up of around 230 kilometres of new track and 270 kilometres of upgraded track. It's not just travellers between Berlin and Munich who can look forward to journey times of under four hours and up to 10,000 additional seats on the 35 daily ICE trains on the new route. The positive effects of the largest timetable change in Deutsche Bahn history will also be felt by rail passengers throughout the German and cross-border rail network. In future, every third long-distance DB train will be faster or more regular. The VDE 8 project is a crucial element of our "Future Rail" quality programme's aim of making DB's products and services more reliable, easier and more comfortable.

COMPETITIVE WITH ROAD AND AIR

Since December 2015, commissioning of the newly constructed Erfurt – Halle/Leipzig route (VDE 8.2) has already significantly increased the speed of East/West travel – passengers travelling between Dresden and Frankfurt now get to their destination an hour sooner than before (Figure 1). The new route means shorter journey times for our customers.

FIGURE 1: VDE 8.2 in operation (Photo: Deutsche Bahn AG/Oliver Lang)

Trains can run at up to 300 km/h on the entire new route. Rail travel between Berlin, central Germany and Bavaria will be up to two hours faster than today. Our Sprinter trains will break the 4-hour mark between the main cities Berlin and Munich – a genuine record time.

The Sprinters will depart from both cities three times a day, at times that are interesting to more than just business travellers. We are confident that they will also be popular with leisure travellers as they make day trips to the two cities a genuine possibility. This makes rail competitive with flights and driving.

FASTER, MORE DIRECT, MORE COMFORTABLE

The catchment area of the new North/South axis stretches from the Baltic coast to the Alps and from the Harz mountains to Görlitz. A direct ICE train travels on the new high-speed route from 45 locations throughout Germany at least once a week. Here too, customers benefit from significant reductions in journey times. To spread the benefits as widely as possible, good connections are crucial, both between the ICE lines and from

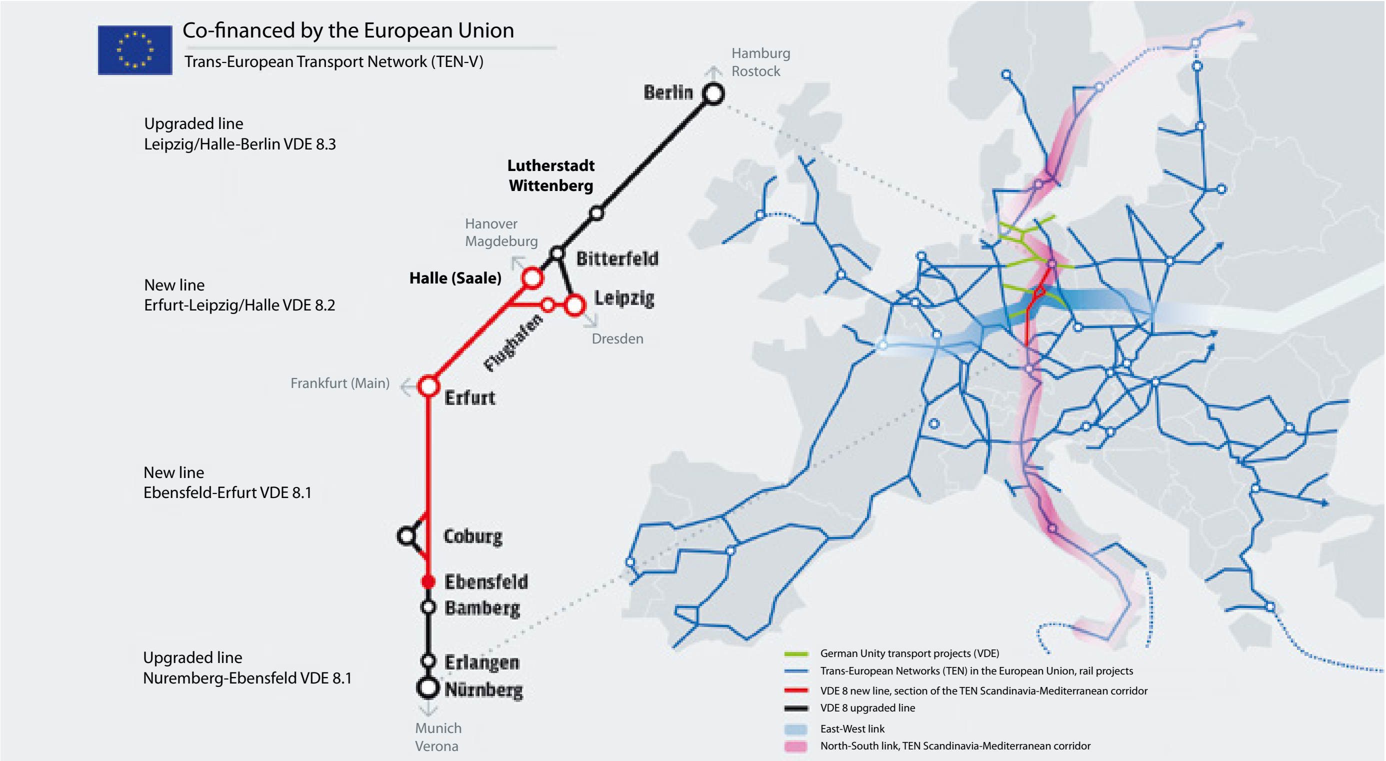


FIGURE 2: Trans-European Transport Networks (TEN-T) (Source: DB AG)

and to regional transport. Where agreed interchange connections already exist, we have adjusted the ICE timetables. The trains stop in Erfurt at half past the hour and in Nuremberg on the hour. But the other ICE stops also have excellent connections for continuing a journey on local transport. In addition to Erfurt, the hubs at Leipzig and Halle play a key role. They have been made the central interchange points in their regions. This means that improvements in journey times on the main line are passed on to regional trains. Meanwhile, generous time windows provide stress-free transfer between long-distance and regional trains. This makes travelling by rail more attractive than ever.

IMPORTANT FOR TOURISM

With the opening of the new high-speed route, rail now provides a bridge between Thuringia and Bavaria. The journey time between the World Heritage cities of Erfurt and Bamberg is now just 45 minutes. We expect demand on this core section of the line to almost double compared to today. The new connection will also play a significant role in national tourist travel. Well-known and popular destinations in the Alps and on the Baltic will benefit from being accessible more quickly by rail. For example, in the future it will be possible to get from Halle to the summit of the Zugspitze in just 6 ½ hours. However, tourist areas along the route such as the Thuringian Forest, the Eastern and Southern Harz mountains and the Franconian lake district can use the new route in their own marketing.

A ROUTE WITH A HISTORY

The new rail line was built on what was an important trade and transport route in the past. The Via Imperii ran from South to North from Italian and Southern German markets to the Hanseatic trade centres on the Baltic and North Sea. It linked cities like Nuremberg, Leipzig and Berlin (Cölln). The Via Regia provided a West to East trade route for goods and ran through Erfurt and Leipzig, where it crossed the Via Imperii. Over the last two hundred years, historic trade routes have often been the basis for construction of the German railway network. It was the expansion of infrastructure associated with the industrial revolution that helped the connected cities and regions in Franconia, Thuringia, Prussia and Saxony to achieve economic progress.

The Nuremberg – Fürth rail line was the cradle of the German railway back in 1835. Germany's first long-distance rail line was opened in 1839 between Dresden and Leipzig. The Erfurt – Halle route opened in 1847. In 1884, the steep section through the Thuringian Forest via Suhl created a direct link between Erfurt and Würzburg.

The fast connection between Nuremberg and Berlin on the new line is opening up huge opportunities for the future – for people and markets as part of European integration. »

FIGURE 3: The Saale-Elster viaduct

(Photo: DB AG/ Hannes Frank)

EUROPE IS MOVING TOGETHER

The new high-speed route is not just significant for Germany. The European dimension is also impressive. The route between Nuremberg and Berlin is an important section of the Trans-European Transport Networks (TEN-T) and closes a previous gap. The line is one of the nine core corridors for rail transport, the Scandinavia-Mediterranean corridor, which stretches from the eastern border of Finland to Sicily (Figure 2).

Closing the Nuremberg – Berlin gap means that in future it will be possible to travel across borders from Southern to Northern Europe without changing locomotives, stopping or changing the train control system. Comprehensive and safe – they are the most important factors for tomorrow's European rail transport.

The key word is interoperability. This starts with the height of platform edges and ends with the train control system. The Nuremberg – Berlin line meets all the required European standards – including barrier-free platforms to assist mobility impaired passengers. As a result, the concept of "Rail without borders" has taken a big step forwards.

THE PROJECT IS FULL OF SUPERLATIVES IN ENGINEERING AND RAIL TECHNOLOGY

The new Berlin – Munich high-speed line is not just a project. It is a once-in-a-century construction undertaking, a technical masterpiece employing state of the art technical standards, created by around 4500 people: engineers, architects, construction workers and commercial teams. The work involved in constructing the line right through Germany was huge. To cite just a few figures: 26 tunnels and 37 viaducts have been constructed, while 4 million tons of concrete and 156,000 concrete slabs were used for the slabbed track. Germany's longest railway bridge is on this line: The Saale-Elster viaduct, which is 8.6 kilometres long (Figure 3).

We have returned landscapes to their original state, inserted bridge sections from the air, diverted entire rivers, adapted platforms for people with disabilities, constructed noise protection facilities for people living along the line, established a modern safety concept in the tunnels and developed a train control system based on the European Train Control System (ETCS) on the line not using signals.

The German government and railway operator have invested a total of 10 billion euros. And we are proud to say that the most complex infrastructure project in the company's history came in on time and on budget. This project proves beyond all doubt that DB can handle major projects.

GOODBYE TO LINE SIGNALS: HIGH-TECH CONTROL FOR THE FUTURE

State of the art technical standards: on the newly constructed line, there will be no more signals. We will use the European Train Control System, ETCS for short, and the GSM-R wireless system to control trains safely without the need for line signals. The most important data is transmitted wirelessly between the train, the line control centre and transponders in the rails. The new train control technology is mandatory for all newly constructed lines in Europe. ETCS is intended to completely replace the around 20 existing safety systems that currently impair cross-border transport within Europe.

The upgraded and new line is completely controlled by electronic signal boxes. A total of 17 electronic signal box control centres (twelve along the line, five in the hubs at Erfurt, Leipzig and Halle) are directly connected with the main control centres in Leipzig and Munich, from where the traffic controllers adjust the lines by computer.

SAFETY TECHNOLOGY – BEACONS FOR ETCS LEVEL 2

With the European Train Control System ETCS and the GSM-R wireless system, trains can be safely routed without line signals. The most important data is transmitted wirelessly between the train, the line control centre and transponders in the rails. The two new sections, Ebensfeld – Erfurt and Erfurt – Halle/Leipzig, are equipped with the very latest control and safety technology systems. The latest version of the ETCS European Train Control System (known as baseline 3) has been introduced.

To allow speeds of up to 300 km/h on the route, the track is based on a slabbed system without the conventional ballast.

You will see: A line of superlatives. A line that will change rail travel in Germany. A line that was finished on time and on budget. We are delighted to be able to celebrate the opening of the new high-speed Berlin – Munich line in a few days.

BALANCING RAIL CONSTRUCTION AND THE ENVIRONMENT

Making construction as environmentally friendly as possible – choosing the best possible route for the track has enabled us to avoid interfering with nature at numerous points. But the construction work itself also contributed. The Saale-Elster viaduct was partially constructed using the end tipping construction method. The piers were placed in the ground from the air, from a suspended scaffold. Work on the wetlands was also stopped for several months to avoid disturbing the breeding season of rare birds. These are all measures that minimise interference with the ecosystem.

When building a railway line, interference with nature and the landscape is unavoidable but it can be minimised or compensated for. If habitat losses for animals and plants cannot be compensated for on site, they are replaced with equivalents in other locations. Many watercourses were renatured, thousands of trees and shrubs were planted, sheep maintain orchid meadows in the Unstrut valley, wild horses are pasturing on special meadows near Erlangen, all to maintain biodiversity.

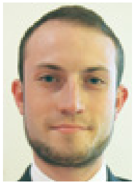
MORE RAIL, LESS NOISE

How high is the noise level produced by the new line? Specialists have investigated the effects of noise and vibrations over the entire line. The basis was the legal requirements that apply to rail systems – particularly the Federal Immission Control Act and the traffic noise regulations derived from it. Walls and embankments are active noise protection measures that ensure a reduction in the noise levels for people living along the line. If the legal limits are exceeded in spite of this, additional passive noise protection measures are used, for example noise insulating windows.

All these measures ensured that commissioning of the new line on 10 December 2017 was a success for everyone involved and affected. Above all, this project will make an important contribution to the move towards environmentally friendly transport. Climate-friendly and comfortable travel with competitive journey times: On the most important domestic air route, Berlin-Munich, we want to replace air travel as the market leader and double our market share to 40 percent. We are confident that the improved service on this route will underpin our huge potential to become the means of transport of the 21st Century. ◀

Potential for high-speed overnight train travel in Europe

European high-speed trains already provide an alternative to inter-European flights on short routes (500 – 1000 km). However, to date high-speed trains have been mainly limited to daytime routes. Targeted use of overnight trains could also enable rail to provide a genuine alternative to air travel for distances up to 2000 km. This article highlights the potential for using high-speed overnight trains in Europe.



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1. INTRODUCTION

Compared to the high-speed trains operating during the day, conventional overnight trains frequently use outdated rolling stock. In many cases, the speeds are also below those of daytime services, resulting in long journey times for relatively short distances and often not yet having arrived at the destination after sleeping. Because of the strong competition in air travel, particularly the relatively cheap ticket prices, there has been growing pressure on rail companies, which has led to significant reductions in services in recent times, particularly overnight services. At the same time, the high-speed rail network in Europe is being expanded. The construction of new lines for higher speeds and the use of modern high-speed trains result in considerably shorter journey times between major European cities, which, in many cases, represents competition for conventional overnight services and, in the past, has contributed to a decline in overnight rail travel.

This article addresses the question of whether the railway infrastructure would allow high-speed overnight rail services in Europe to be set up. It asks whether the existing infrastructure, as well as what is planned and currently under construction, will enable long distances to be completed in a reasonable time during the night in future. It also investigates which of the possible routes already have high passenger volumes for air travel and thus where high-speed overnight trains could represent direct competition.

2. POTENTIAL IN EUROPEAN INFRASTRUCTURE NETWORK 2025+

To determine the potential for high-speed overnight rail services, it is necessary to present an overview of the existing, under construction or planned infrastructure that would allow this kind of traffic. The key basis for assessment is the "Trans-European Transport Network" (TEN-T) corridors and the European Transport White Paper. Based on the future European internal infrastructure network, possible journey times and example routes for high-speed overnight trains are then determined.

The high-speed network in Europe already has numerous options for high-speed overnight train travel, and these will increase in the coming years.

The European Commission's Transport White Paper of 2011 contains the vision for European transport in 2050 and a strategy to implement it. One of the aims of this vision is to triple the length of the existing European high-speed rail network by 2030. According to the Transport White Paper, it is crucial to create a common European transport area for strategic implementation. The remaining barriers between transport providers and national systems are to be eliminated to simplify the process of integration and promote the emergence of multinational and multimodal operators. There are major challenges in the domestic market for rail transport services, where technical, administrative and legal barriers have to be overcome to facilitate entry into national railway markets.[1)]

To implement a common transport area, the European Union has designated corridors that combine to form the TEN-T networks (Trans-European Network-Transport). The common guidelines created for the TEN-T networks for establishing a trans-European transport network provide a general framework for the development and expansion of internationally significant transport infrastructure within the EU up to 2020. At present, there are 30 priority projects that are scheduled for completion by 2020. Of these, 18 are exclusively rail projects. The aims of the rail corridors include linking up 15,000 km of rail lines that are designed for high-speed traffic, removing bottlenecks by creating 35 cross-border projects and connecting 38 major airports to important conurbations by rail.[2)]

The journey times that will be possible in the European infrastructure network in 2025 will depend on the extent to which national and international rail projects based on the TENT-T have been realised. To obtain an overview of possible future links, as part of this work, the future journey times from the three European cities – Paris, Frankfurt am Main and Vienna – to other European cities have been calculated. In addition to the central locations of these three cities, Paris and »

1) See Transport White Paper 2011, p.1ff

2) See http://europa.eu/rapid/press-release_MEMO-13-897_de.htm [10.04.2014]

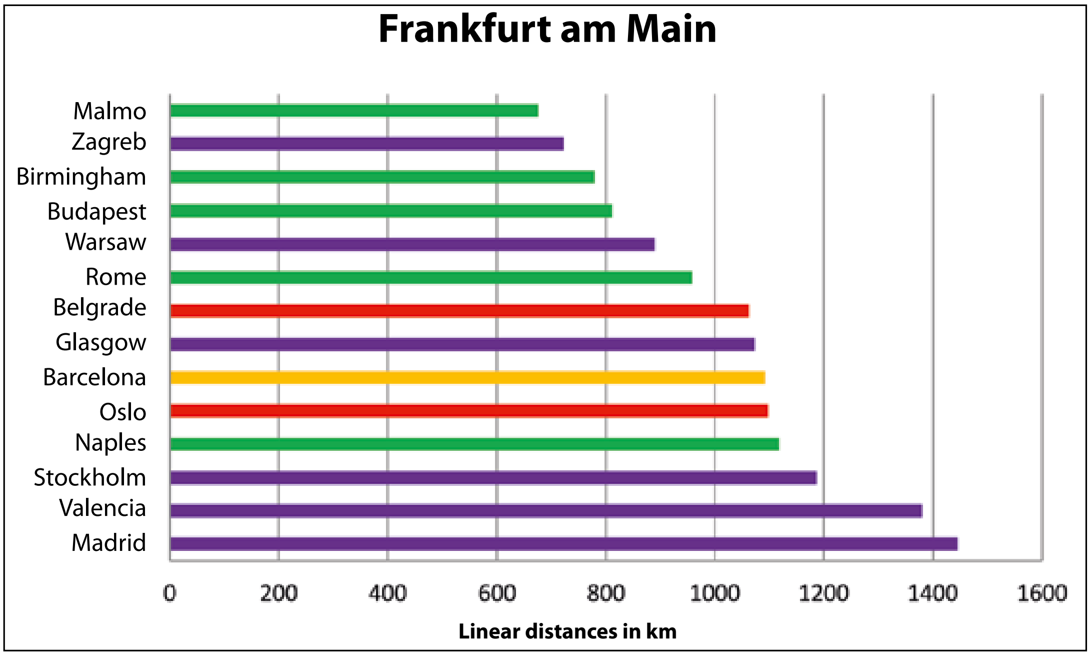

FIGURE 1: Distance to selected European destinations and future journey times, based on the example of Frankfurt am Main. Journey times: Green ≈ 8 hours orange ≈ 10 hours purple ≈ 12 hours red ≈ 14 hours

Frankfurt have the second and third largest airports in the European Union by passenger numbers.[3] The central locations of the cities provide a good representation of the accessibility of various regions of Europe, while the passenger data for the airports (e.g. passengers by destinations, air services by destinations) show the potential for possible future routes.

Figure 1 shows examples of the distance by air from Frankfurt am Main to selected European destinations. Likewise, the graph in Figure 1 illustrates the future journey times achievable after completion of the specified infrastructure projects.

The significant West/East difference in future journey times is striking. According to the forecast maps for the high-speed network in Europe in 2025, as is the case currently, the high-speed routes will be predominantly in Western Europe, meaning that longer journey times can still be anticipated in Eastern European countries in the future.[4]

When looking at the use of high-speed routes at night, any operational restrictions also have to be taken into account. For example, there are high-speed lines designed for mixed operation, which means that the line can be used for both passenger and freight trains. This mixed operation means that the line often has reduced capacity and devising the timetable is very complicated. Therefore, on lines with mixed operation freight transport is often restricted to the nights, which could inevitably result in lower maximum speeds for night time passenger trains. In addition to usage by freight trains, there may also be restrictions due to maintenance work and inspections at night.[5]

3. EFFICIENCY AND USAGE

Alongside the necessary infrastructure that will allow high-speed rail transport at night, another crucial factor is whether the possible future routes will have sufficient potential in terms of demand. To answer this question, passenger numbers for internal European air travel are analysed in greater detail. Looking at current forecasted passenger numbers on different air routes within Europe allows us to estimate whether there could be a high number of potential passengers on these routes and whether high-speed overnight trains can be profitably used as a direct alternative to air travel.

In 2012, according to the European statistical office Eurostat, the number of passengers carried by the aviation sector in the 27 EU member states at that time (EU-27) was 826.7 million passengers. Of this total air travel volume, 510.5 million passengers (approx. 62% of total volume) took flights within the EU-27 states. This figure is made up of 159.5 million passengers on domestic flights and 351 million passengers on cross-border flights within Europe. Within the EU-27 states at that time, the biggest passenger flow was between the United Kingdom and Spain, with 31.4 million passengers. This is followed by Germany – Spain with approx. 22 million passengers and Germany – United Kingdom with 11.8 million passengers.[6]

To indicate the possible potential in terms of utilisation of high-speed overnight trains, the flight data for each airport is used, shown in Figure 2 using the example of flights departing from Frankfurt am Main airport.

Using the possible journey times in the 2025 European infrastructure network and the passenger data from European air travel, different example routes can be represented. The 2013 UIC study of high-speed overnight trains includes one such example, a route from the United Kingdom to Spain (see Figure 3).

In terms of the journey, three sections are differentiated: The "boarding section" refers to the period in which the train stops at one or more stations for passengers to get on. The study specifies the journey time for this section at between zero and three hours, depending on the number of stops. The distance travelled is between 0 and 400 km. The next section is the "night time", in which the train travels through with no stops while passengers are sleeping. This should involve a distance of 1100 to 2200 km in six to twelve hours. The final section is referred to as the "de-boarding section", in which – as in the first section – the train stops at just one or several selected stations to allow passengers to alight. The journey time should once again be between zero and three hours, with a travel distance between 0 and 400 km.[9]

The model used in the UIC study, with the "boarding section", "night time" and "de-boarding section" can be applied to other

3) See http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/7-05112013-BP/DE/7-05112013-BP-DE.PDF
4) See Rambausek, 2009, p.60f.
5) See UIC Study, Night Trains 2.0, 2013, p.16.
6) See German Aerospace Centre, Air Transport Report 2012, p.85f.

routes, for example routes starting from Frankfurt am Main. Using the air travel data from Frankfurt am Main airport and the general European air passenger flows, we can estimate the routes that tend to attract a higher volume of passengers. The most passengers are on flights from Frankfurt to Italy and Malta (see Figure 2). Of course, air passengers to Malta are not relevant as potential customers for high-speed overnight trains, but the majority of the passengers to Italy and Malta specified in Figure 2 are made up of passengers travelling to Italy. [10] An example route from Germany to Italy would be from Frankfurt to Naples. The journey time in 2025 will only be around eight hours, which is why it appears logical to extend the route to Brussels or Amsterdam to achieve an appropriate journey time for the entire North-South route. A train could start in Amsterdam at eight in the evening and would be in Cologne after a journey of 2:44 hours, and in Frankfurt an hour later. After a further six and a half hours, the train would then be in Rome around seven in the morning, before reaching Naples after a further 1:18 h. Possible intermediate stops in the early morning would be Florence or Bologna.

Although the most passengers from Frankfurt fly to Italy and Malta, at national level the biggest passenger flows are between Germany and Spain. For example, around 957,000 passengers departed from Frankfurt for Spain in 2012, excluding the Balearic and Canary Islands (see Fig. 2). An example route could be from Frankfurt via Paris to Barcelona and Madrid. The future travel time would be around 12 hours between Frankfurt and Madrid.

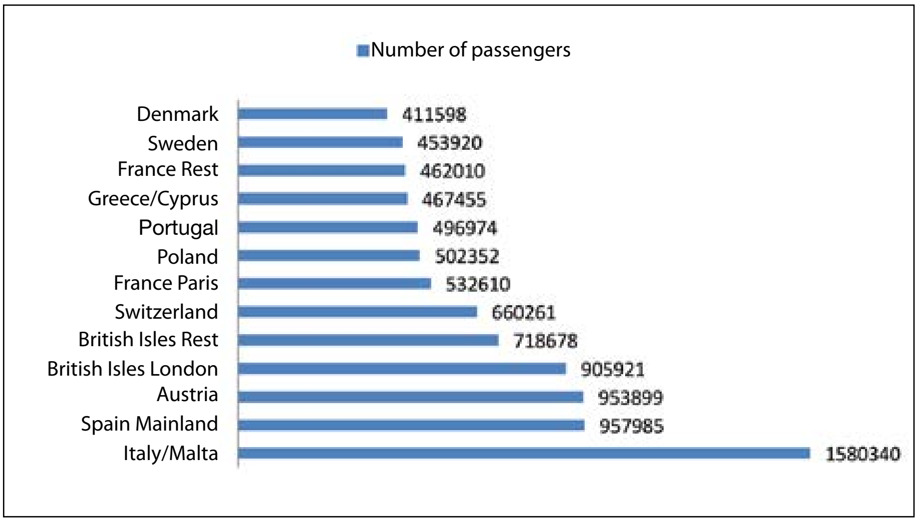

FIGURE 2: Passengers on board internal European flights departing Frankfurt airport 2012 (scheduled and charter flights)[7]

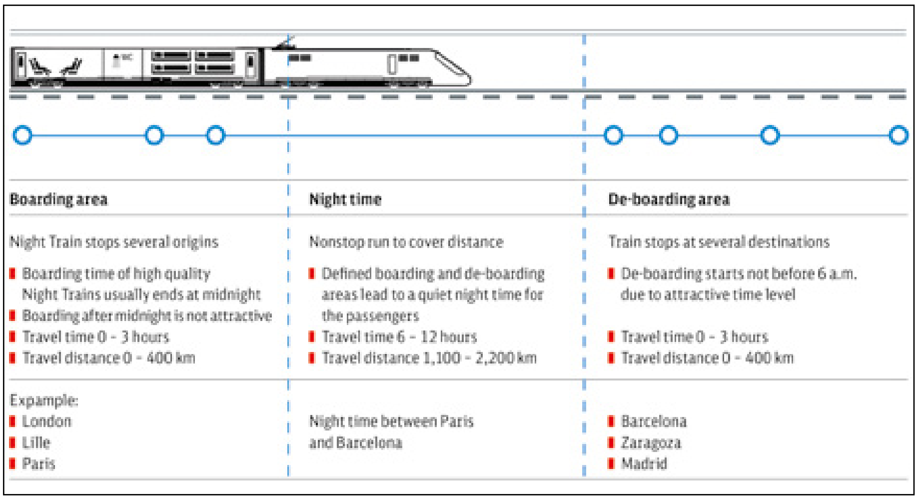

FIGURE 3: Example overnight train route from United Kingdom to Spain[8]

4. CONCLUSION

Because of the existing high-speed lines in many European Union countries, there is some potential for high-speed overnight trains even today. However, there are significant differences between Western and Eastern Europe. For example, Western European countries such as Spain, France, Italy, Germany, Netherlands and Belgium have had extensive high-speed networks for many years and national programmes for further expansion, which will reduce journey times accordingly. By contrast, the journey times – relative to the distance travelled – in EU member states such as Romania, Bulgaria, Croatia, Czech Republic, Hungary, Greece etc. and in the Balkan states, are considerably longer than those in Western Europe. Even though further expansion of the high-speed network is the stated objective of the European Union, it is currently mainly restricted to Western Europe. From today's perspective, at least until 2025 no significant reduction in journey times on Eastern European routes is to be expected, and therefore the potential for high-speed overnight trains in that region is much lower. One exception is Poland, where there are already plans to build a high-speed network. Although a large network of high-speed lines already exists in Western Europe, there is still a general lack of international high-speed links between these networks. The existing links are between France and Spain, and between France, the Netherlands, Belgium and England. However, other important high-speed links are under construction or in the planning phase. These include the Brenner Base Tunnel with connecting routes, the line from Lyon to Turin including the Mont Cenis Base Tunnel, the Fehmarnbelt fixed link and the route between Madrid and Lisbon. Once these and other crucial projects, most of which correspond to the TEN-T corridors, are completed the true potential of numerous European internal routes will be apparent. Routes up to 1400 km could be completed within 12 hours (category 1 reasonableness). Examples include the Frankfurt – Madrid, Amsterdam – Naples and Paris – Lisbon routes. The fact that some of these links would already be possible today is shown by the London – Madrid route. A comprehensive network of high-speed lines would currently allow a journey time of less than 12 hours. When it comes to cross-border routes, the necessary interoperability has to be ensured. In particular, it is essential that the interoperability directives stipulated by the EU are appropriately implemented and there are no national differences in the »

7) Own visualisation; see German Aerospace Centre, Air Transport Report 2012, p.141
8) UIC Study, Night Trains 2.0, 2013, p.6.
9) UIC Study, Night Trains 2.0, 2013, p.6.
10) http://www.frankfurt-airport.de/flugplan/airportcity?pax&sprache=de&ext=/de/ [01.07.2014]

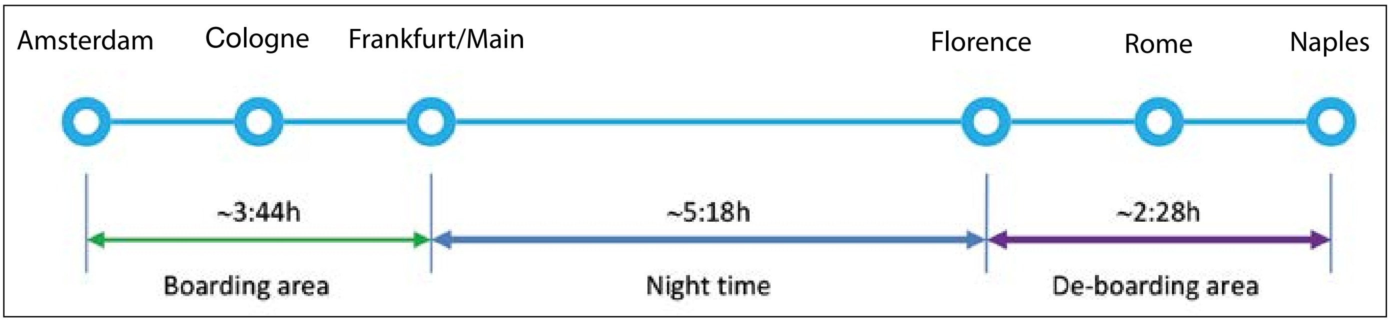

FIGURE 4: Example Amsterdam – Naples route[11)]

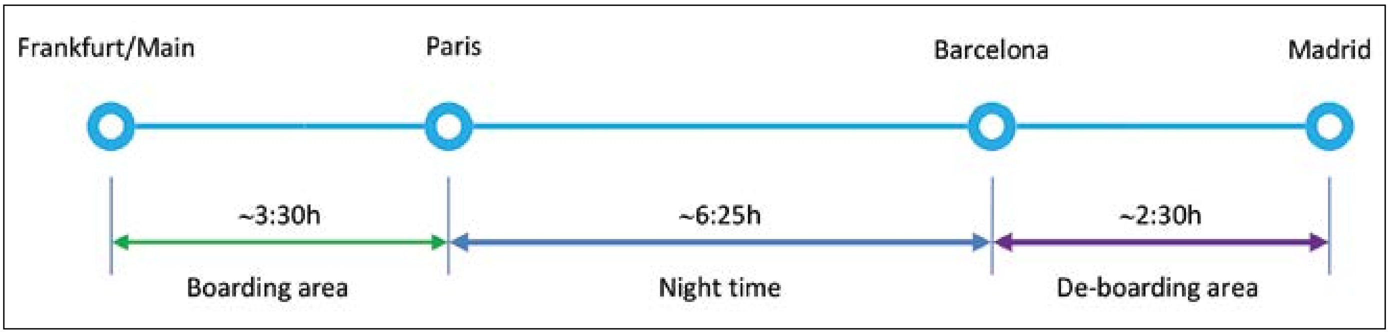

FIGURE 5: Example Frankfurt/Main – Madrid route[12)]

high-speed networks. Differences between national networks can lead to extended journey times due to border stops being necessary. Possible operational restrictions on high-speed lines due to maintenance or mixed operation at night must also be taken into account, but should not lead to any notable restrictions with appropriate planning.

For air travel, the biggest traffic flows within EU member states are between the United Kingdom, Spain, Germany, Italy, France, the Netherlands and Belgium. Based on flight data from Vienna and Frankfurt airports, it is apparent that there are seasonal differences in the services on different routes. For example, on the Frankfurt – Madrid route around 1400 seats are available per day in July and only around 650 per day in January. If annual passenger traffic is broken down to a daily level, an average of around 2600 passengers per day fly to the Spanish mainland from Frankfurt alone. Throughout Germany the figure is around 11,000 per day. Even on lower volume routes such as those between the United Kingdom and Portugal, an average of 7000 passengers per day fly in one direction. On the routes where there is significant potential due to the high passenger flows, the aim should be for a proportion of passengers to travel by high-speed overnight train rather than by air.

Potential customers include business travellers, who can save themselves a flight and a night in a hotel by using the train. Another important group are people with a fear of flying, particularly those who only board a plane if there is no alternative. Ultimately, it is also a question of environmental awareness. Many customers could be motivated to switch to high-speed overnight trains by the CO_2 savings achieved by avoiding flights. A key advantage of the train compared to flying can be seen on the example routes. On a high-speed overnight train, it is possible to schedule any number of stops during the "boarding section" period. This enables passengers to be "gathered" from across a wide area. This is almost impossible when flying. The same applies to the "de-boarding section" time, when passengers can be spread over a wide area. Here, a major advantage of an overnight train service compared to air travel is that destinations away from major airports can be reached directly without the need, as is often the case when flying, to change to another means of transport to reach the departure point or final destination. The travel distances to or from the airport can be reduced.

In summary, we can say that from an infrastructure perspective there is definite potential for European internal high-speed overnight train travel, and this potential will increase further with the continuing expansion of the network up to 2025 and beyond. However, this potential is largely limited to Western European countries.

Although specific potential in terms of possible passengers is yet to be separately examined, current passenger numbers for various destinations within Europe definitely suggest that a corresponding high-speed overnight train service would be taken up and that there would be sufficient demand. ◀

11) See http://www.bbt-se.com/projekt/fragen-antworten/ [17.06.2014] http://www.bahnprojekt-stuttgart-ulm.de/details/verkehrlicher-nutzen/fernverkehr/ [17.06.2014] ÖBB timetable information: https://www.oebb.at/# [17.06.2014]
12) See ÖBB timetable information: https://www.oebb.at/ [17.06.2014]

Literature

[1] European Commission: White Paper / Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, Brussels, 2011

[2] European Union website, Press Release Database, Memo – The new EU transport infrastructure policy, Brussels 2013 [retrieved 10.04.2014] http://europa.eu/rapid/press-release_MEMO-13-897_de.htm

[3] Eurostat website, Press release 05.11.2013, Air passenger transport in the EU27 [retrieved 06.06.2014] http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/7-05112013-BP/DE/7-05112013-BP-DE.PDF

[4] Rambausek: Netzgestaltung und räumliche Wirkung von Hochgeschwindigkeitsbahnnetzen im europäischen Vergleich [Network design and spatial impact of high-speed rail networks, a European comparison], Dissertation at TU Vienna, Faculty of Architecture and Land Use Planning, 2009

[5][8][9] International Union of Railways (UIC) Study: Night Trains 2.0/New opportunities by HSR?, 2013

[6][7] German Aerospace Centre, Air Travel Report 2012, Cologne, 2013

[10] Frankfurt airport website, Online timetable [retrieved 01.07.2014] http://www.frankfurt-airport.de/flugplan/airportcity?pax&sprache=de&ext=/de/

[11] Brenner Base Tunnel website, Project Q&A [retrieved 17.06.2014] http://www.bbt-se.com/projekt/fragen-antworten/

[12] ÖBB timetable information website [retrieved 17.06.2014] https://www.oebb.at/

Wheel bearings for high speed trains

High speed trains are getting faster with every generation. NSK has been involved in this development for over fifty years. It all began with the first Shinkansen trains in Japan, for which NSK supplied the axle box bearings. Since then, NSK has repeatedly brought innovations for new high speed railways to series production – with a condition monitoring system for axle box bearings being just the latest example.

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▶ Since the 1960s, Shinkansen high speed trains have provided rapid rail travel between Japan's major cities. The network is being continuously expanded, most recently in 2015 and 2016 with connections to Hokuriku and Hokkaido prefectures. Japan was and remains a pioneer in high speed rail travel.

FIGURE 1: Axle of a current Shinkansen high speed train with main bearings (Photo: NSK)

NSK has supported these developments with the continuous evolution of (wheel) bearing technology for rail rolling stock. The Shinkansen trains are the best example. When series 0 was launched in 1964, the 81 kilo axle bearings consisted of a combination of cylindrical roller bearings and ball bearings. The main aim here was to ensure that the trains, which travelled at up to 210 km/h, had the required reliability. The radial load - including the weight of the trains themselves - was absorbed by two rows of cylindrical roller bearings, while the lateral loads, which mainly occur on bends, acted on a single ball bearing. This was state of the art technology at the time.

Let's jump ahead to the 300 series Shinkansen from 1992: On these trains, with speeds up to 270 km/h, NSK cylindrical roller bearings with reinforcing ribs were used. On the N700 series, which came into service »

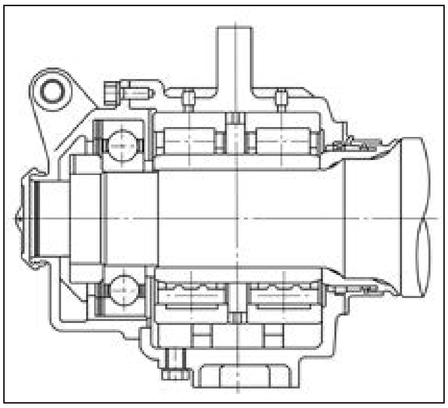

FIGURE 2: The axle bearing for series 0 of the Shinkansen – a combination of cylindrical roller bearings and ball bearings – weighed 81 kg and was state of the art in 1964 (Photo: NSK)

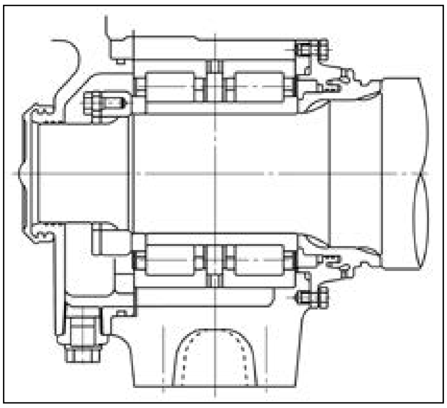

FIGURE 3: NSK cylindrical roller bearings with ribs were used on the 300 series of the Shinkansen in 1992 (Photo: NSK)

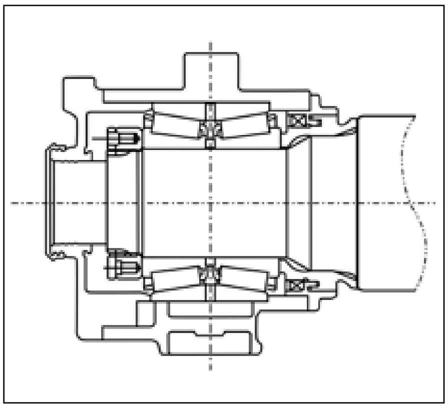

FIGURE 4: The tapered roller bearings in the axles of the N 700 series weigh just 23 kg (Photo: NSK)

FIGURE 5:
The first Shinkansen was put into operation on October 1, 1964 – nine days before the Olympic Games in Tokyo
(Photo: Giovanni Gagliardi/Dreamstime)

FIGURE 6: The 300 series was launched in 1992 and set a new speed record for commercially operated trains at 270 km/h (Photo: Sakuragirin/Dreamstime)

FIGURE 7: N700 series Shinkansen trains have been in use since 2007 – at speeds of up to 300 km/h (Photo: iStock.com/winhorse)

in 2007, the advancements in bearing technology are clear. The trains are even faster (up to 300 km/h) and also lighter and more comfortable. The NSK tapered roller bearings in the axles weigh just 23 kilos. This is a genuine lightweight design – a weight reduction of almost a factor of four compared to series 0. At high speeds, a high bearing weight has a significant influence on noise and vibration. As a result, there is a particularly strong desire, or even necessity, to cut the weight.

Even though the bearings are becoming increasingly compact and light, safety is always the number one priority. Designers employ their expertise in material technology to guarantee this safety and to develop bearings that work reliably even under very unfavourable ambient conditions. This includes efficient maintenance programmes. NSK recently made a breakthrough in this area. In Japan, the company developed the very first system that detects irregularities in roller bearings – and thus bearing damage – before any deterioration in performance or failures occur.

This condition monitoring system is already being used on conventional passenger trains. Sensors are attached to the bearing and continuously record parameters such as speed, vibration and temperature. The values are compared with reference data that NSK has gathered. The system allows operators to move away from conventional time-based maintenance procedures, where bearings are replaced after a defined operating time or distance regardless of their condition. Instead, they can now be replaced when required. NSK expects more and more manufacturers and operators of rail vehicles to employ this system as the advantages in terms of increased safety and the cost savings resulting from longer maintenance intervals are obvious.

Developments like this have made NSK the market leader in Japan for roller bearings for rail vehicles. Operators of high speed trains worldwide also rely on the company's expertise and product range. More than 50 % of roller bearings that NSK produces for rail vehicles are used outside Japan. ◀

50 years' experience with ballasted track on Tokaido Shinkansen

In 2014, the Tokaido Shinkansen celebrated its 50th anniversary. Up to 1986, the former Japan National Railways (JNR) was responsible for the rail network. Since the privatization in 1987, the Central Japan Railway Company (JRC) has been operating the high-speed train. Track maintenance and the progress in tamping workload are of particular importance for the company.

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1. OVERVIEW OF THE TOKAIDO SHINKANSEN [1, 2]

The Tokaido Shinkansen, which was the world's first high-speed rail, was commenced operations by Japan National Railways (JNR) in 1964. Then, in 1987, those operations were inherited by Central Japan Railway Company (JRC). JRC owns the whole railway system, including civil engineering structures, tracks, electric and signaling system, and rolling stock. Characteristics and performance of the Tokaido Shinkansen are overviewed as follows;

Safety and Reliability
- → No passenger fatalities or injuries due to train accidents
- → Annual average delay: 0.6 minutes per train (FY2014)

Mass Transportation
- → High frequency: 350 trips per day in average
- → Large capacity: 1,323 passengers per sixteen-car trainset
- → Ridership: 431,000 passengers per day, 157 million passengers per year (FY2014)

Environmental Adaptability
- → Low energy consumption, low CO_2 emissions
- → Low wayside noise
- → Small ground vibrations along high-speed lines (Axle load: 11.2 tonnes)

2. PRIOR TRACK R&D ON TRACK

More than 50 years ago, before the construction of the Tokaido Shinkansen, operating speed of Japan's conventional lines were about 100 km/h. The highest speed in other countries' was 160 km/h. Japanese engineers at that time researched and developed about track based on these proven technologies and experiences. And they concluded that ballasted track could be used and also economically maintained even under higher speed conditions.

Also the need of slab track was discussed. However, slab track did not have to be required.

3. TRACK MAINTENANCE IN THE ERA OF JNR

Changes in tamping workload, daily train number and train speed in about 50 years are shown in Figure 1. Track maintenance from 1964 to 1986 is described here. This period means era of JNR.

When the operation was started, roadbed especially on earth structures were not stabilized enough. For this reason, huge workload on tamping was needed. As the roadbed was stabilized in about five years, the tamping workload decreased obviously. The roadbed stabilization was conducted by adding water drainage facilities and consolidation action of repeated load of train passing.

After that, replacements of 50 kg rails with 60 kg rails were conducted (FY1972-1981). However, a large volume of tamping work was still needed.

4. MAINTENANCE CHARACTERISTICALLY CONDUCTED BY JRC

JRC commenced operations in April 1987 upon the privatization and break-up of JNR. As shown in Figure 1, daily train number has »

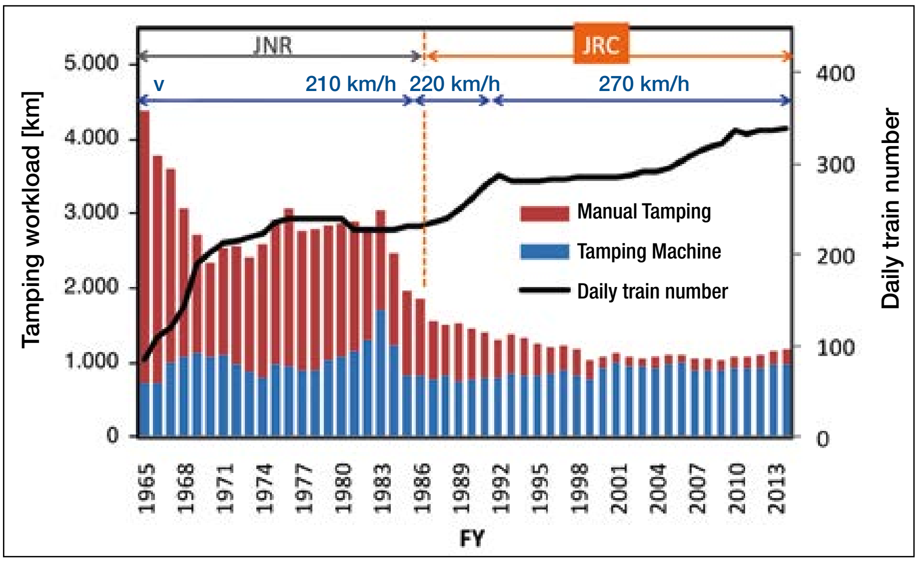

FIGURE 1: Changes in tamping workload, train speed and daily train numbers

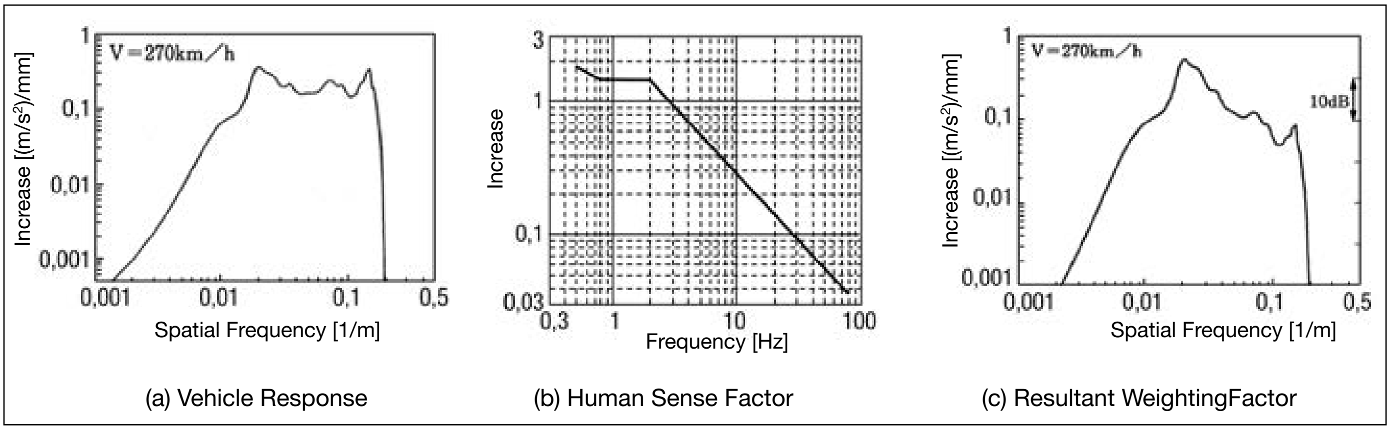

FIGURE 2: Weighting factor for riding comfort management

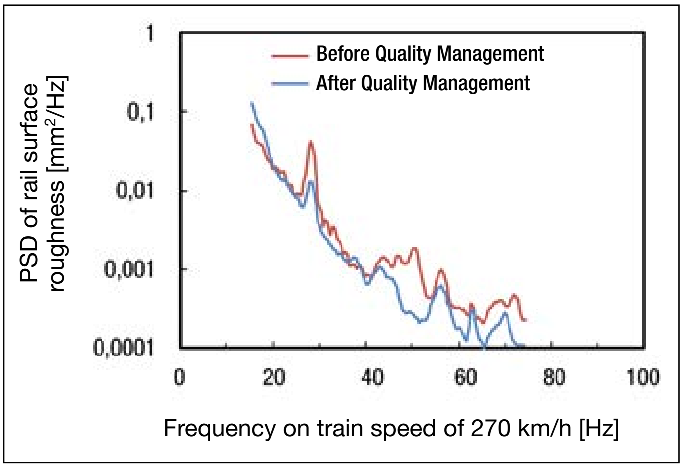

FIGURE 3: PSD of rail surface roughness

been increasing from past to present, and train speed has been also increased (max. speed: 285 km/h since 2015). However, tamping workload has been decreasing or roughly flat. The reasons why this situation can be achieved are described below.

4.1. TAMPING/LINING CONCERNING VEHICLE REACTION

Railway vehicle generally has some natural vibration modes, and generates dynamic forces which act on track. JRC conducts tamping/lining works for improvements in vehicle riding comfort. An example of the alignment management is described below[3].

A typical vehicle response to track alignment is shown in Figure 2(a). Human sense factor of lateral vibration is shown in Figure 2(b). Resultant weighting factor which is derived from multiplication of Figure 2(a) and 2(b) is shown in Figure 2(c). RMS values calculated from track irregularities filtered with Figure 2(c) are used for track maintenance planning. It is called as Estimated Riding Comfort Level.

When track maintenance is conducted, Restored Track Irregularity value is used for lining work. Restored Track Irregularity value has flat amplitude for wide wave length from 6m to 100 m. Therefore, track irregularities from shot to long wave length are corrected with this maintenance work. Then riding comfort level is improved significantly. At the same time, dynamic lateral force associated with lateral and yaw vehicle motions are decreased. In the result, workload of lining is also decreased. Tamping work is planed and conducted in a similar way, and is reduced.

4.2. RAIL QUALITY MANAGEMENT

JRC conducts two kinds of rail quality management. One is longitudinal surface roughness related to dynamic wheel load. The other is cross-section re-profiling related to dynamic lateral force.

Figure 3 shows Power Spectral Density (PSD) of rail surface roughness before and after the quality management[4]. Its lateral

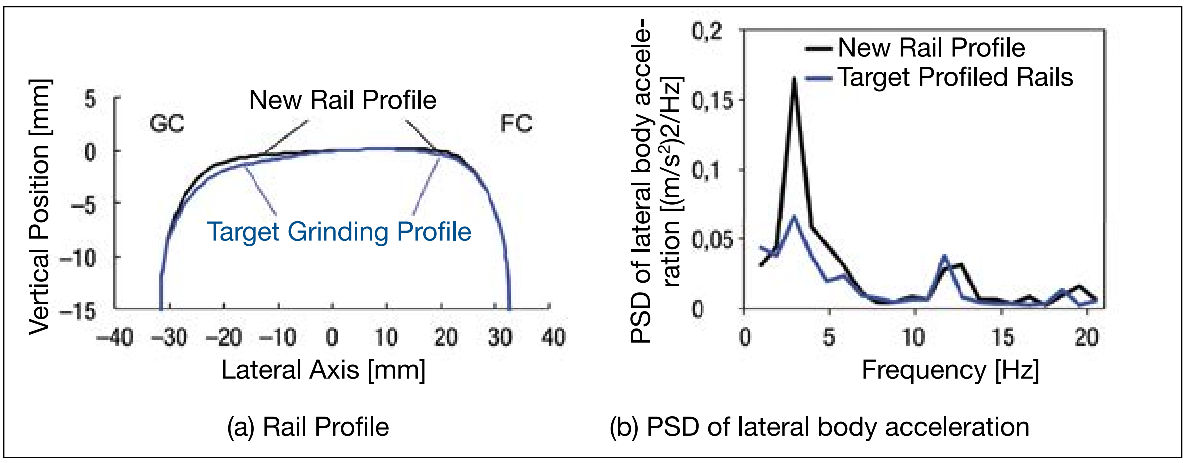

FIGURE 4: Rail profile management

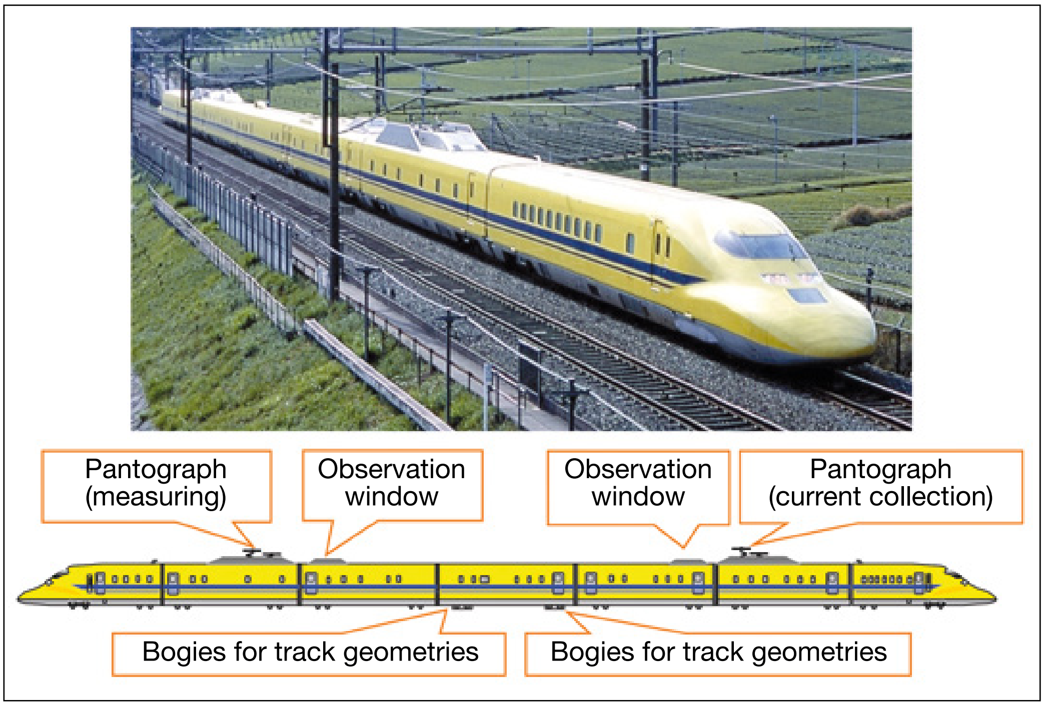

FIGURE 5:
High-Speed Track Inspection Train "Doctor Yellow"

axis shows frequency which is calculated from relation between rail roughness wave length and wheel load variation of vehicle traveling at a speed of 270 km/h. The most dominant peak about 30 Hz is caused by rail roughness originated with manufacturing process. This peak has been decreased with quality management performed by rail suppliers. PSD higher than 40 Hz has been decreased with rail grinding work. Trough these rail quality managements, dynamic wheel load acting on track has been reduced.

Figure 4(a) shows rail profiles of their upper part [5, 6]. Black and blue lines show new and target grinding profiles, respectively. Figure 4(b) shows PSD of lateral body acceleration of the vehicle running on these two rail profiles. Black and blue lines show PSD running on new and target profiled rails, respectively. When cross-section re-profiling is conducted, the dominant peak around 3 Hz is decreased obviously. In the result, dynamic lateral force acting on track is also decreased.

4.3. HIGH-PERFORMANCE MACHINERY

For the high quality track maintenance as described previously, high-performance machinery is absolutely necessary. Heavy machines for ballast tamping, distributing stabilizing and rail grinding are customized JRC's some specific needs and imported from Europe. High-accuracy track inspection train is also absolutely necessary. Figure 5 shows the high-speed inspection train used for the Tokaido Shinkansen called as Doctor Yellow.

4.4. VEHICLE WEIGHT REDUCTION

Figure 6 shows the history of Tokaido Shin- »

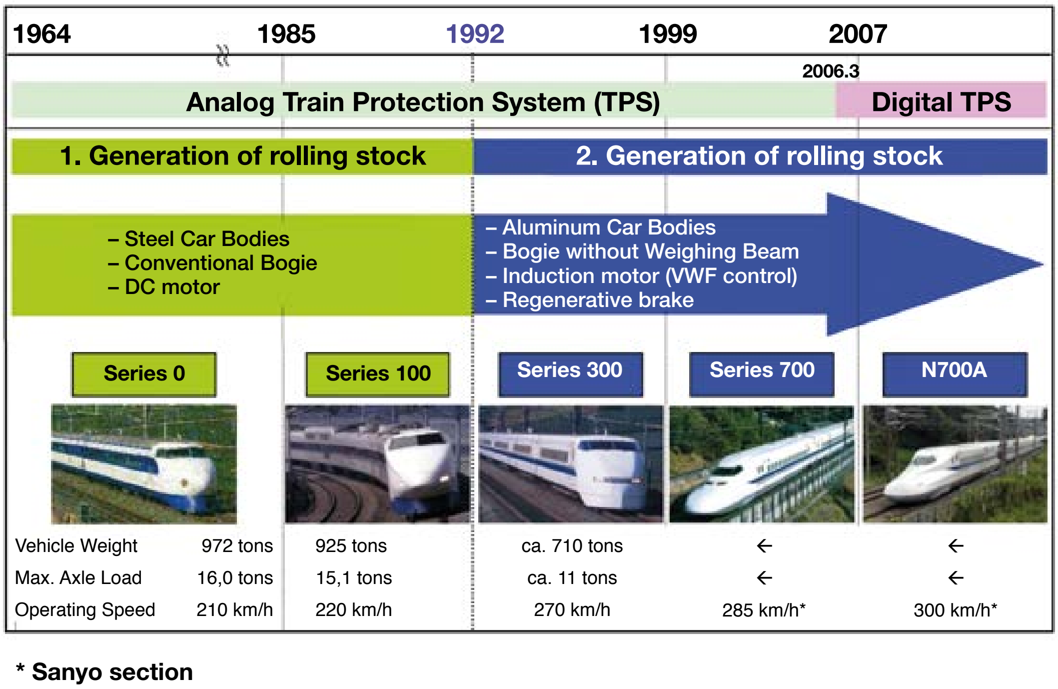

FIGURE 6:
Changing of the rolling stock

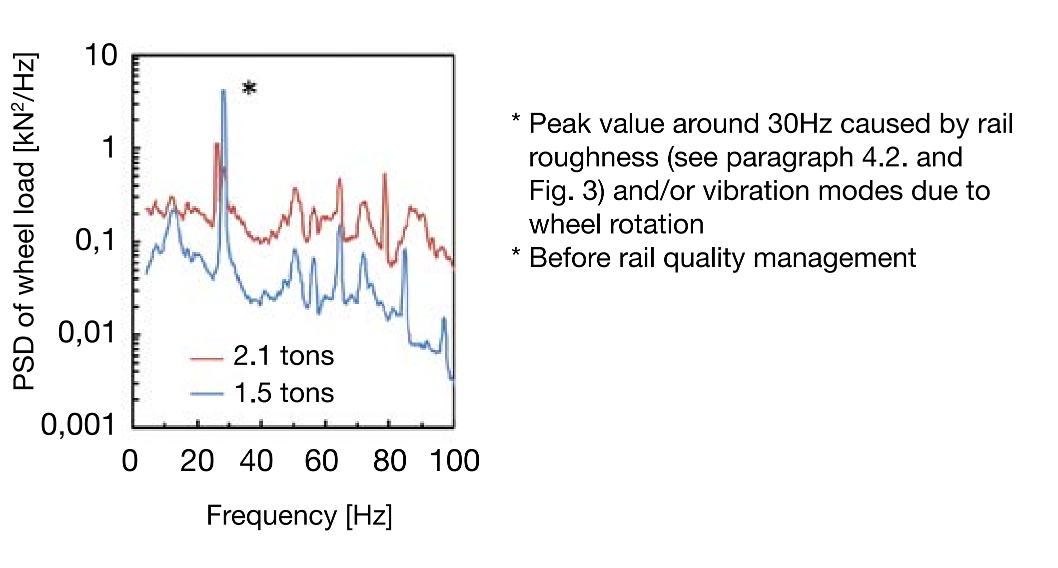

FIGURE 7:
PSD of wheel load

kansen's rolling stocks. Rolling stocks are separated into two generations. First generation rolling stocks have heavier axle load, running with slower speed. Second generation rolling stocks have lighter axle load, running with faster speed. The second generations have been developed for speed-up of Tokaido Shinkansen. At that time, significant weight reduction has been conducted in order not to increase ground vibration and track maintenance. The heavier first generation rolling stocks have retired before 2003. Now, all rolling stocks are lighter weight second generations running with faster speed.

It can be easily understood that axle load lightning effects track maintenance reduction. As describing below, lightning of unsprung-mass of vehicle is also very important. Figure 7 shows PSD of wheel load [7]. Red and blue lines show PSD of heavier unsprung-mass (2.1 tonnes) and lighter unsprung-mass (1.5 tonnes), respectively. Lightning of unsprung-mass effects on reduction of dynamic wheel load acting on track for wide frequency. Unsprung-mass of the second generation rolling stocks are lighter than the first generations.

5. KOMAKI RESEARCH CENTER

Since the company commenced operations in 1987, JRC has actively promoted R&D activities for ensuring safe and reliable transportation, enabling faster speeds, enhancing transport service, and reducing costs.

In 2002, the General Technology Division was established in order to approach various technology issues in a more integrated and comprehensive manner. Since then, Technology R&D Department (KOMAKI Research Center) has been pursuing two principles; one is to solve the issues of ensuring safe and reliable transportation in the railway industry, and the other is to pursue the technological development that will support our future in middle and long-term point of view.

In the KOMAKI Research Center, R&D for reasonable track maintenance and vehicle weight reduction as described previously have been conducted without interruption.

6. SLAB TRACK IN JAPAN

As well as ballasted track on high-speed lines, Japan also has about 40 years of practical experience with slab track. Initial construction cost of slab track nearly equals to that of ballasted track. Maintenance cost of slab track is much cheaper than that of ballasted track. Therefore, newly constructed Shinkansen lines in Japan have adopted slab track for almost the entire length.

So, how about replacing the Tokaido Shinkansen's ballasted track with slab track? It is unrealistic, because of account of the overall economical efficiency, and difficulty in performing such work while daily train operation is ongoing. Therefore, we will continue in our endeavor to make further advances with ballasted track on the Tokaido Shinkansen.

7. CONCLUDING REMARKS

JRC has developed ballasted track maintenance on the Tokaido Shinkansen successfully accomplished with;

→ Track engineers' strenuous efforts
→ Technological research and development, especially considering vehicle track interaction
→ Highly systemized management with computer and work with higher performing track maintenance machinery. ◀

References

[1] http://english.jr-central.co.jp/company/ir/factsheets/_pdf/factsheets2015.pdf
[2] http://english.jr-central.co.jp/company/ir/annualreport/_pdf/annualreport2015.pdf
[3] Y. Naganuma and H. Takai: Track maintenance method considering dynamics of Shinkansen rolling stock, RTRI Report Vol.9 No.9, pp.37-42, 1995. (in Japanese)
[4] T. Otake, et al.: Management on shortwave longitudinal track irregularities for suppressing wheel load variation in high-speed railway, Journal of JSCE, in press. (in Japanese)
[5] M. Miwa, et al.: Maintenance and Management of High-Speed Railway Track Considering Vehicle/Track Interaction, WCRR 2013 (USB Memory), 2013.
[6] M. Miwa, et al.: Rail Grinding for Shinkansen in Consideration of Wheel Contact and Vehicle Dynamics, J-Rail 2012, 2012. (in Japanese)
[7] M. Miwa and T. Funada: High speed running test and the new testing equipment for wheel/rail dynamic interaction, WCRR 2003 (CD ROM), 2003.

Point diagnostics with Diana – when infrastructure goes online

Digitalisation of infrastructure as an industrial necessity and a support tool for predictive maintenance strategies.

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▶ With its "Future Rail" programme, DB AG is consistently focusing all its activities on customers. The key aims of Future Rail are to eliminate annoyances, increase quality and punctuality and make the rail system the first choice for customers. Fault-free systems are an essential requirement to ensure punctual train operation. As part of a package of measures, DB Netz AG has decided to fit its essential points with point machine diagnostics. Continuous electronic monitoring of the point machines enables machine faults to be detected early and appropriate counter measures initiated. By 2020, point machine diagnostics will have been rolled out to a total of 30,000 points, making it one of DB's biggest digitalisation programmes.

POINT MACHINE DIAGNOSTICS WITH DIANA – PRINCIPLE

Points are subject to high stresses and can be switched up to 170 times a day. Fault-free point changing and reliable reaching of the end position are fundamental requirements for high availability railway operations.

The points are switched by electric point machines and connected transmission rods. The setting and condition of all moving parts, the condition of the lubrication and weathering can all have a significant influence on the required adjusting force. If the machine is no longer able to apply the required adjusting force, the points do not reach the end position. The line cannot be adjusted and the signal cannot be set to clear. Interruptions in operational procedures and train delays are the inevitable consequence.

The stiffness of the points leads to an increasingly high adjusting current in the point machine. The principle of point machine diagnostics is based on the contactless measurement of the current in the signal boxes. This is done by clamping specially developed sensors in the cable end rack onto the existing machine power cables or running the machine power cables through a special rack with pre-installed sensors. The current measurement is contactless and reactionless. The sensors for the points are »

DB AG/ Uwe Miethe

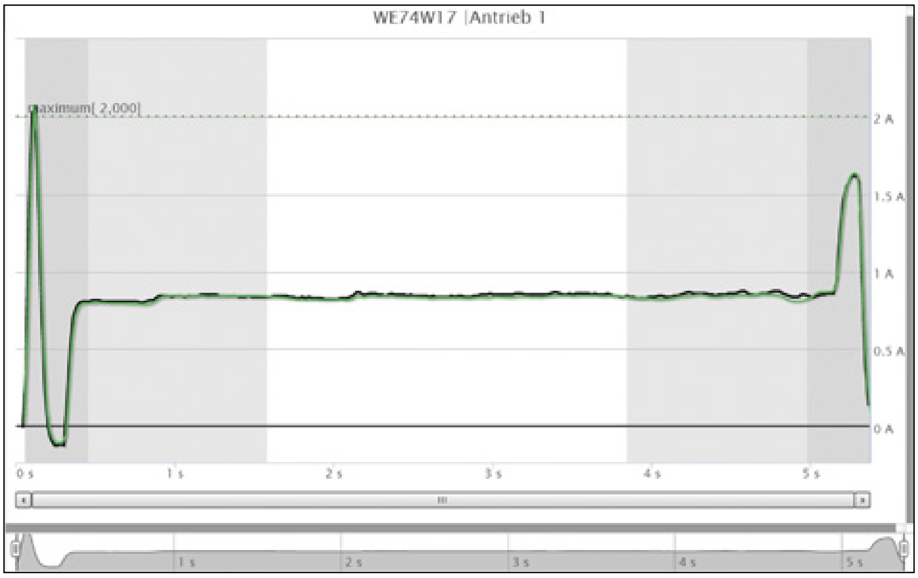


FIGURE 1: The figure shows the adjusting current and reference curve (green) for a point switching operation over the adjustment time.

connected directly to the DB Netz IP network using a universal junction box. For each switching operation, the measured current progression curves are displayed in real time in the Diana digital diagnostics and analysis platform developed by DB Netz and Mainz Technical University and evaluated completely automatically.

A complete point switching operation is recorded as a current curve over the total adjustment time and passes through six phases during this time. These six phases (Fig. 1) are named after the sections of a switch tongue's movement in Diana. In addition to the unlocking and locking phases, the actual adjusting operation for the two switch tongues by the slide chairs or the switch rollers is recorded in two further phases of the change. The final two phases to mention are the point machine switch-on and switch-off phases, although these are considered to be insignificant in terms of the mechanical switching movement.

Together, the four mechanical phases make up the core adjusting time for a complete points change. Additionally, the switch-on phase is preset to 0.4 s based on experience from field testing. If a point machine requires an extended switch-on time, which is possible with an electro-hydraulic point machine for example, there is an option in Diana to adapt the switch-on phase accordingly.

The switch-on time is thus one of three required settings for each machine as part of point machine diagnostics which enable points to be diagnosed. In addition to the switch-on time, plausible representation of the maximum adjusting current Imax is important. This current must be recorded separately for the two point changing directions and describes the maximum machine current (failure limit).

The maximum machine current is determined using what is known as the 4 mm probe. The 4 mm probe is used to simulate an end position fault caused by a foreign body between the switch tongue and stock rail. The machine presses the switch tongue against the obstruction and finally runs into the slip clutch until the signal box shuts down the machine. The resulting current is stored as the upper current limit in the Diana system.

In addition to the switch-on time and maximum adjusting current parameters, a third important variable is also involved in the diagnostic process. In order to be able to evaluate adjusting current curves in terms of stiffness, a reference curve is required, which is to be set according to the switching direction in the same way as Imax,. These reference curves are the averages from several switching curves that represent both a reproducible quality and steady, operationally stable points changes.

Each time the points are changed, the difference between the currently required adjusting current and the failure limit Imax is determined and evaluated against the difference between reference current and Imax. Using calculation algorithms stored in Diana, which are known as the system rules, Diana evaluates the individual phases independently of one another and issues a diagnostic message if the threshold value is exceeded. The diagnostic messages can be viewed in the system and can also be provided to assigned users at the same time by e-mail or text message.

Diana DIAGNOSTIC PLATFORM – USE

In close cooperation with InfraView GmbH from Mainz (a subsidiary of Mainz University), a web-based diagnostic platform was developed, with an Office version that users can call up on a PC. On site at the points, employees can access Diana as an app on their mobile device. In principle, systems from different manufacturers can be integrated into Diana.

After logging into Diana the user will see the points assigned to them, based on their function and their duties. They are displayed in a list view, which can be individually grouped.

The points list also shows the status colours assigned to the points locations. Green – meaning everything is OK or the points only show a slight variation – has a low current delta compared to the reference curve. If this variation increases later in the changing operation and exceeds a higher threshold value defined in the system rules, the points are assigned fault status, represented by amber. Following the traffic light logic, the fault can develop and move from amber fault status to red status, which means the points have a fault and are no longer available. This fault is to be avoided by looking at the condition between "points available" and "points fault" and dividing the amber fault status by an additional system status.

The most important area for diagnostic evaluations is in green and amber statuses, as this is where there is the most time to act before a fault event, and the user still has an opportunity to exert an influence using fault messages specially developed for Diana. Adjusting current curves are thus studied for changes in current and adjusting time and diagnosed using the freely adjustable system rules available in Diana.

From the perspective of a fault event, the adjusting current curves must be examined for variations before the event and the system rules adjusted. The "Green Plot" visualisation tool provided by Diana (Fig. 2) can support this process as it allows a long-term view over multiple successive point switching operations. The diagnostic system therefore allows the current condition of the system to be estimated by prompt comparison of current data with stored reference data and historic information.

POINT MACHINE DIAGNOSTICS ROLL OUT

Fitting the system to 30,000 points in just five years calls for stringent management. Alongside a central project team, regional

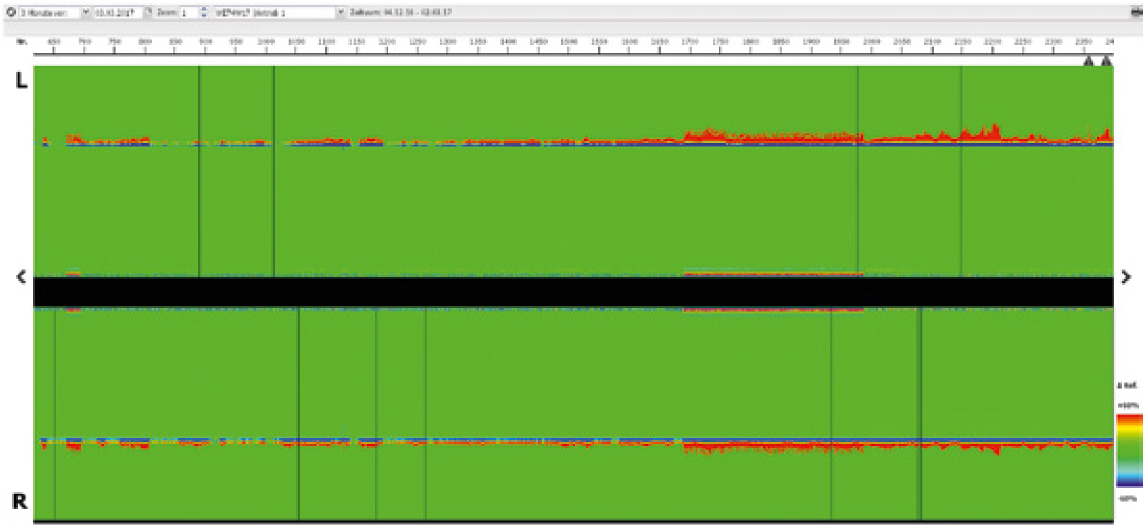


FIGURE 2: Green Plot visualisation tool for long-term diagnostics analysis

coordinators have been appointed to implement the roll out locally in conjunction with the installation teams. As the diagnostic hardware is installed at each signal box and not on each set of points, around 1800 signal boxes are to be fitted with the diagnostic system between 2016 and 2020. A system of milestones has been developed (Fig. 3) to monitor the measures at these signal boxes. Each measure passes through seven milestones before it is finally completed.

To supplement this, a checklist has been created for each of these seven milestones, which has to be completed alongside the work relating to point diagnostics. This checklist enables the key specifications to be documented and records the progress of the work. Not every measure follows the same procedure. They depend on the specific local conditions in the signal box. For this reason, milestone 2 "Site inspection carried out" is a key prerequisite for subsequent activities. To ensure a high quality, 145 employees from the inspection teams have been trained for this task in advance.

Milestone 4 "Signal box ready" verifies that all site preparations are complete so that the installation of the diagnostics hardware (milestone 5) can begin. After successful installation, commissioning can be carried out and the measure reaches milestone 6 "Diagnostics ready". This means that the points relevant for the roll out at the affected signal box are con- »

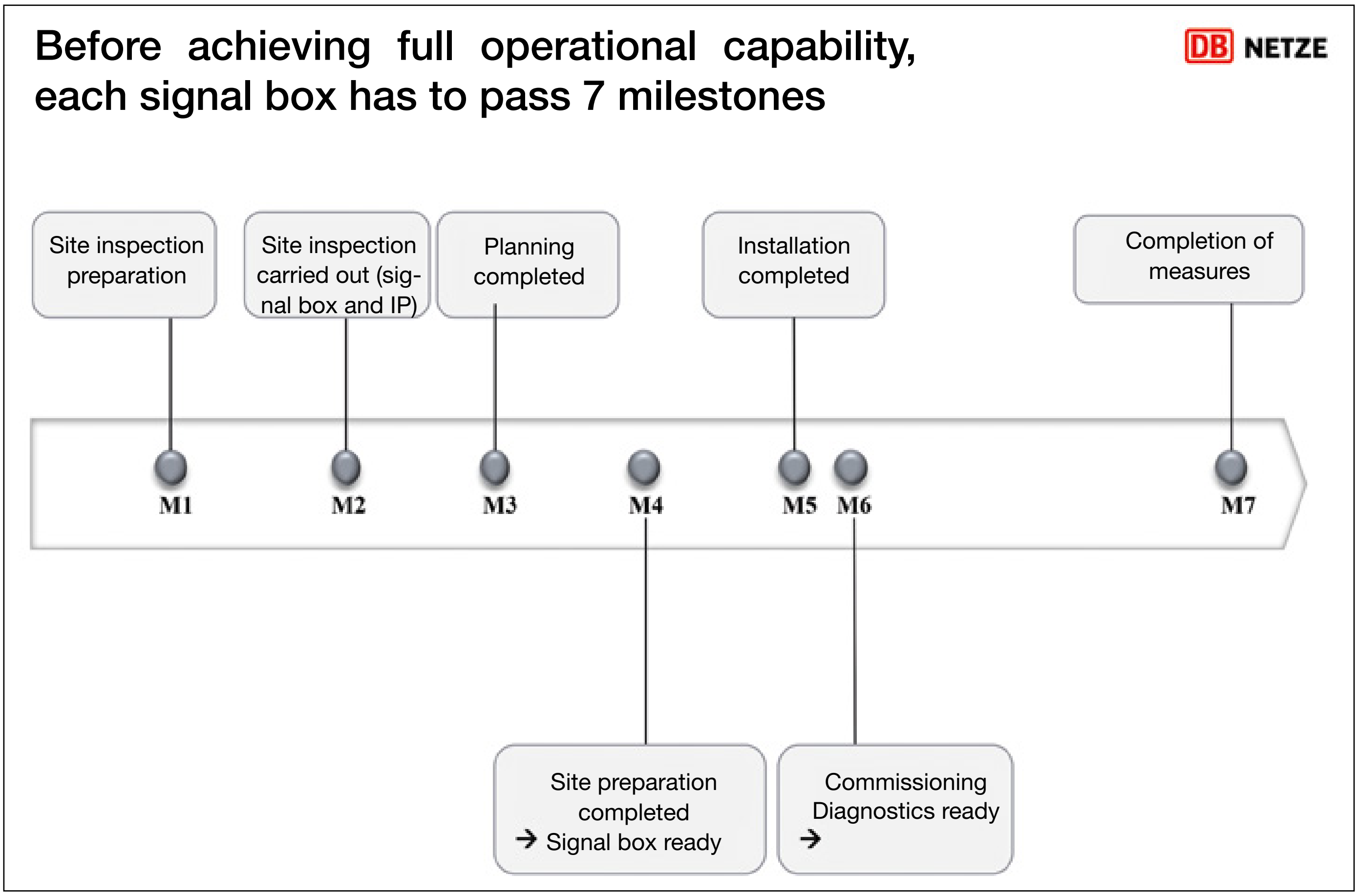


FIGURE 3: Milestones for point diagnostics roll out

FIGURE 4: Schematic process for handling of diagnostic messages

nected to the diagnostic platform and a reference curve, a theoretical maximum current and the switch-on time have been stored. To ensure a smooth process, 115 employees from the installation and commissioning teams have been trained.

Before the measure is completed at milestone 7, which can be up to six months after milestone 6, activities such as the handover to the system manager, performance of the 4 mm probe and, following this, any adjustment of the three basic settings, storing in technical system management and commercial completion are to be completed.

Central procurement of the diagnostic hardware is necessary to ensure the supply of materials throughout Germany. Like other LST materials, call-off from the manufacturer and storage at the signal plant in Wuppertal must be ensured. From there, materials are shipped to the seven regional areas.

Despite the numerous issues, thanks to constructive cooperation between the regions and the central departments, solutions have repeatedly been found and the intermediate target of 5000 points on the platform by 2016 has been exceeded. At the end of 2016, 6698 points had reached milestone 6. In 2017, the rollout has been proceeding consistently since the beginning of the year. As well as the increase in points at milestone 6, the focus this year has increasingly been on completing the measures (milestone 7) in the first signal boxes.

INTEGRATION OF DIAGNOSTICS INTO THE DB PROCESS ENVIRONMENT

In addition to development and large-scale roll out of the diagnostic system, the appropriate conditions for using the system have to be put in place.

Diagnostics is a new component of maintenance as part of the digital revolution and has to be integrated into the overall structure. Point machine diagnostics is contributing to the trend towards predictive maintenance and, at the same time, is influencing inspection, servicing and repair activities. The information obtained from the diagnostic system can be used to determine the optimum time for replacement of the points. The optimised reinvestment times subsequently lead to more efficient use of government funds based on actual technical requirements.

Therefore, DB Netz has developed a new, generally applicable diagnostic process. This is designed to ensure that diagnostic inspections are performed, regardless of the system types. The intension is that the system manager or a designated representative will scan the systems assigned to them in the diagnostic system and assess any resulting anomalies. The process thus represents the entire sequence of activities from the creation of a message to repair and commercial processing (Fig. 4).

In the case of point machine diagnostics, this means assessment of the current progression curves. Because of their expertise and knowledge of local conditions at the points, the responsible expert on site decides whether preventive measures are to be initiated and, if so, which. Two new diagnostic messages have been generated in the SAP R/3 network for this purpose. They primarily differ in terms of their processing priority (stackable or non-stackable anomalies). To differentiate them from the existing inspection and fault resolution jobs in the SAP R/3 network, a new job type has also been developed for diagnostics. This is used to initiate an inspection and minor defect resolution from a diagnostic message.

CHANGE MANAGEMENT AND TRAINING CONCEPT

The proper use of point machine diagnostics using the Diana platform and the importance of diagnostics from a corporate perspective have been outlined in training sessions. Around 4500 maintenance employees from DB Netz have received this training. Because of the high number of employees needing to be trained within a short time, a staged model was chosen. It is made up of three modules and is based on the train the trainer principle.

The first two modules are initially provided together at a two-day kick-off event at site level for DB Netz's 34 production sites. Employees from control and safety engineering (LST) department and superstructure department are invited to the first module. The content includes the rationale, objectives and benefits of point machine diagnostics, presentation of the role concept and the diagnostic process, and an initial overview of the Diana platform user interface. The second module is based on this and is attended by a pre-selected group from the LST department. These participants are designated as multipliers. On the one hand, they are the first users of point machine diagnostics and, on the other hand, they will instruct colleagues in their own areas as part of the third module. The second module, therefore, consists of practical training, in which participants learn how to use the system and the adjustment options. A summary of the first two modules provides the content for the third module.

The kick off events for point machine diagnostics have been taking place since October 2016 and over 800 employees have already attended. The forthcoming expansion of expertise in using diagnostics and ongoing support for the changes are key points of the project. To meet these requirements there are numerous facilities available to the users, such as national forums for sharing experiences, tutorials, and including point machine diagnostics as a topic in the functional training of employees in the coming years.

OUTLOOK

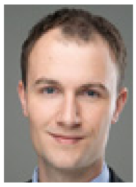
The introduction of point machine diagnostics at 30,000 points in the DB network marks the beginning of digitalisation in track system management. Point machine diagnostics lays the foundation for the continuous monitoring of systems using sensor data and is a prerequisite for predictive maintenance.

To make consistent use of the potential of sensor data for track system management, other applications are already being tested. They include the monitoring of point heating and acceleration sensors for measuring component stresses.

Digitalisation is a huge opportunity for track system management, particularly bearing in mind the widely differing systems and the personnel-intensive inspection and repair processes used on systems that have not been digitally connected to date. At the same time, however, it is a huge challenge that operators and suppliers will have to face up on an interdisciplinary basis. ◀

Iran-Europe Transport Corridors

Within the last few years Iran has demonstrated its strong political will to re-emerge as regional transportation hub. The country's effort to improve its physical connectivity and to become a center-piece for regional supply-chains has been spearheaded by an ambitious development plan for the Iranian railway sector that has been dubbed "Iran's railway revolution".[1]



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1. INTRODUCTION

With currently 7,500 km of railroad under construction, the declared goal is to extend the national railroad network from less than 15,000 kilometers today up to approximately 25,000 kilometers by 2025.[2] According to officials of Republic of Iran Railways (RAI), the expansion will not only produce almost 12,000 km of new railroad, but also considerable progress in the fields of electrification and double-track lines.[3]

In 2017 Iran has achieved considerable progress on its national connectivity agenda. This article first reviews major milestones reached in 2017. It then discusses the wider strategic context of Iran's corridor development programs and concludes with an analysis of potential routings between Iran and Europe.

2. IRAN'S CONNECTIVITY AGENDA IN 2017 REVISITED

Like other oil-exporting states, Iran is seeking to reduce its heavy-reliance on oil and gas exports by diversifying its economy. Since President Rouhani took office in 2013 the Iranian railway sector has profited immensely from government investments.

As a result, the share of rail cargo has increased from 8.5 % to 12 % in overall cargo volume during the period from 2013 to 2017. RAI sources expect it to climb up even further, reaching a share of 30 % by 2022.[4] The Iranian government has confirmed its determination to realize this rapid development by integrating railway investments into its sixth five-year development plan for the period of 2016 to 2021.

In 2017, further progress has been achieved on this path; In January, the Iranian parliament adopted a bill that allocates a fixed share of 1 % of national oil-driven revenues to connectivity projects in the Iranian railway sector. In this context Kheirollah Khademi, deputy minister of roads and urban development, expressed his conviction about the role of connectivity projects for Iran's economy: "I believe we should do away with the oil-dependent economy and turn to transit-driven economy […] Transit can be a replacement for oil revenues."[5] Together with an additional multi-billion USD funding stream for RAI, the recent developments are judged by some as foreshadowing a "new era of railway investment" in Iran.[6]

A potential roadblock to Iran's connectivity vision is its lack of foreign investment flows, which have failed to reach anticipated levels after the relief of international sanctions in 2016. In its 10/2017 economic outlook for Iran the World Bank highlights the absence of a complete integration of the Iranian banking sector into the international banking system and continued uncertainties regarding full implementation of the Joint Comprehensive Plan of Action as the two main reasons for the shortfall in international investment.[7]

In light of these challenges, completion of the cross-border link from Astara in Azerbaijan to Astara in Iran in March 2017 is especially worth mentioning.[8] The newly-constructed 82.5 meter long dual-gauge (1520 mm and 1435 mm gauge) bridge over the Astarachay River is the second rail border-crossing between the two countries. The completion of this single project was of strategic importance for regional corridor developments; It is the first segment of the Qazvin-Rasht-Astara railway route, a critical link in the so-called International North South Transport Corridor (INSTC). The INSTC is an intermodal freight corridor that is mainly sponsored by India, Iran, Azerbaijan and Russia. The missing part between the two Iranian cities of Qazvin and Rasht is expected to become operational by March 2018 and construction for the final linkage between Rasht and Astara will start in 2018.[9] Moreover, together with the Baku-Tbilisi-Kars railway (BTK), completed in October 2017, the Qazvin-Rasht-Astara railway route will integrate Iran even further into the network of rail corridors that are being developed under the umbrella of China's Belt and Road Initiative (BRI).

3. THE STRATEGIC CONTEXT OF IRAN'S CORRIDOR DEVELOPMENT

In fact, the purpose of Iran's rail sector development becomes much clearer with a view to its integration into a network of regional transport corridors. Iran's geographic position offers potential corridor routings that could link the Persian Gulf and the Gulf of Oman in its south with the landlocked Central Asian states, Russia, China and with Europe.

1) https://asia.nikkei.com/Viewpoints/Jon-B.-Alterman-and-Jonathan-Hillman/Iran-s-railway-revolution-aims-at-expanded-trade-investment
2) http://www.presstv.com/Detail/2016/02/10/449526/Iran-transportation-rail-Italy-deal-FS
3) http://www.globalconstructionreview.com/markets/how-islamic-republic-set-become-land-br8i8d8ge/
4) https://financialtribune.com/articles/domestic-economy/59784/share-of-rail-in-irans-cargo-transport-rises
5) https://financialtribune.com/articles/economy-business-and-markets/56738/railroad-expansion-assured
6) http://www.railwaygazette.com/news/policy/single-view/view/oil-funds-to-support-a-new-era-of-rail-investment.html
7) http://www.worldbank.org/en/country/iran/overview#1
8) http://www.railjournal.com/index.php/freight/azerbaijan-inaugurates-new-link-to-iran.html?device=auto
9) https://financialtribune.com/articles/economy-business-and-markets/75966/north-south-corridor-to-become-operational-by-march-2018

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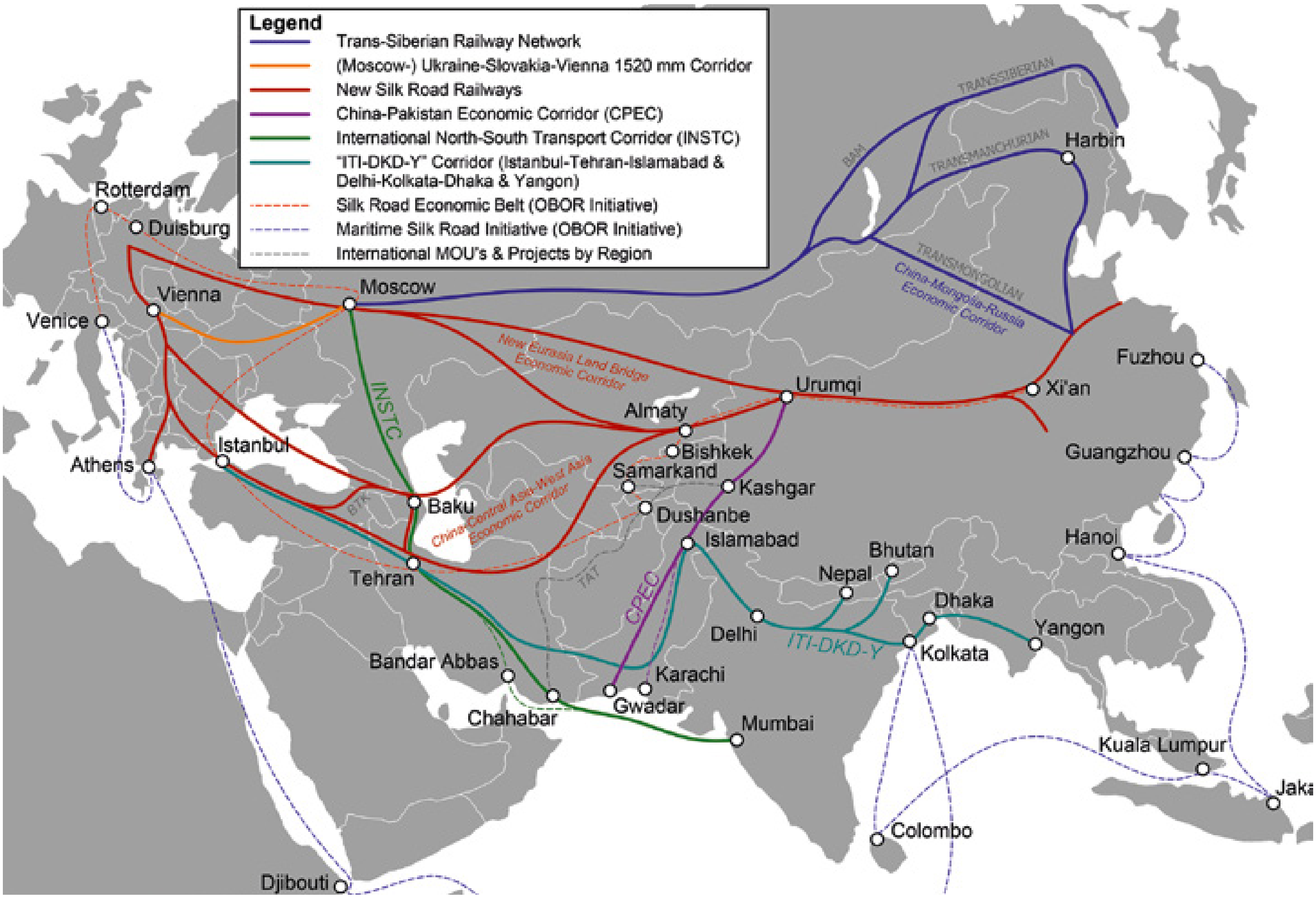

FIGURE 1: Eurasian corridor development, overview

This is why China is channeling one of its six proposed BRI-corridors, the so-called "China – Central Asia – West Asia Corridor", through Iran. Chinese interests in Iran's corridor development come along with visible investments into Iran's rail infrastructure. In July 2017, for example, China EximBank entered into a 1.5 bn USD loan agreement for financing the electrification of the 926 km Tehran – Mashhad main line, a project that will help to increase the routes maximum speed to up to 120 km/h for freight trains (250 km/h for passenger trains) and its yearly freight capacity to 10 million tonnes.[10] Chinese companies, lead by the China Railway Group Limited (CREC), are also constructing the 375 km long Tehran-Qom-Isfahan high-speed railroad.[11] The landmark project of China's engagement in Iran might be a high-speed connection from Urumqi to Iran for which plans have first been proposed in 2015.[12] During his Iran visit in 2016 Chinese President Xi Jinping announced that – partly due to Chinese infrastructure investments – Sino – Iranian bilateral trade volume could increase tenfold during the next decade.[13]

What adds to Iran's importance for China's BRI-corridors, is the fact that capacity limits have been reached at several cross-border bottlenecks on the northern routes of the BRI. Already in spring 2017 shortages at the border Malaszewicze/Brest (Belarus/Poland) have been reported. According to different sources, between 50 and 100 [14] [15] trains from and to China cross this border every week. Together with the opening of the Baku-Tbilisi-Kars railway, such capacity limits increase the strategic role of trans-Iranian rail corridors. Already today, freight trains run from several cities in China to Tehran.[16] They make use of two routings; there is a direct routing via Kazakhstan, Uzbekistan and Turkmenistan and secondly a recently opened routing along the Caspian Sea (Uzen – Serhetyaka – Bereket – Etrek – Gorgan). The map below displays the present state of rail transport along the corridors and its cross-border bottlenecks. The thickness of lines illustrates the volume of traffic.

The INSTC, the second emerging transport artery crossing Iran, is the second focal point of Iranian rail investments. The planned multimodal corridor is envisaged to connect Mumbai via shipping to Iran's Ports in Chahabar and Bandar Abbas. The northern part of the corridor will link Iran via Azerbaijan to Moscow. With the opening of the cross border bridge from Astara (Azerbaijan) to Astara (Iran) in 2017 the INSTC gained new momentum.

Various other projects are underway in Iran that have the potential to boost new patterns of regional trade. For example, lines are being developed to connect Iran with Basra in Iraq and with Herat in Afghanistan.[17] Clearly, the country seeks to leverage its geo-

10) http://www.railwaygazette.com/news/infrastructure/single-view/view/tehran-mashhad-electrification-loan-signed.html, http://www.globalconstructionreview.com/markets/how-islamic-republic-set-become-land-br8i8d8ge/
11) https://financialtribune.com/articles/economy-domestic-economy/68698/china-finances-tehran-isfahan-high-speed-railroad
12) http://www.chinadaily.com.cn/china/2015-11/21/content_22506412.htm
13) https://www.foreignaffairs.com/articles/2016-02-15/new-arms-race
14) U. L. Company, Interviewee, New Silk Road Trains. [Interview]. 20 6 2017.
15) http://www.xinhuanet.com/english/2018-01/02/c_136867206.htm
16) https://financialtribune.com/articles/domestic-economy/79577/three-freight-trains-due-in-tehran-from-china-this-week
17) https://reconasia.csis.org/analysis/entries/irans-railway-revolution/

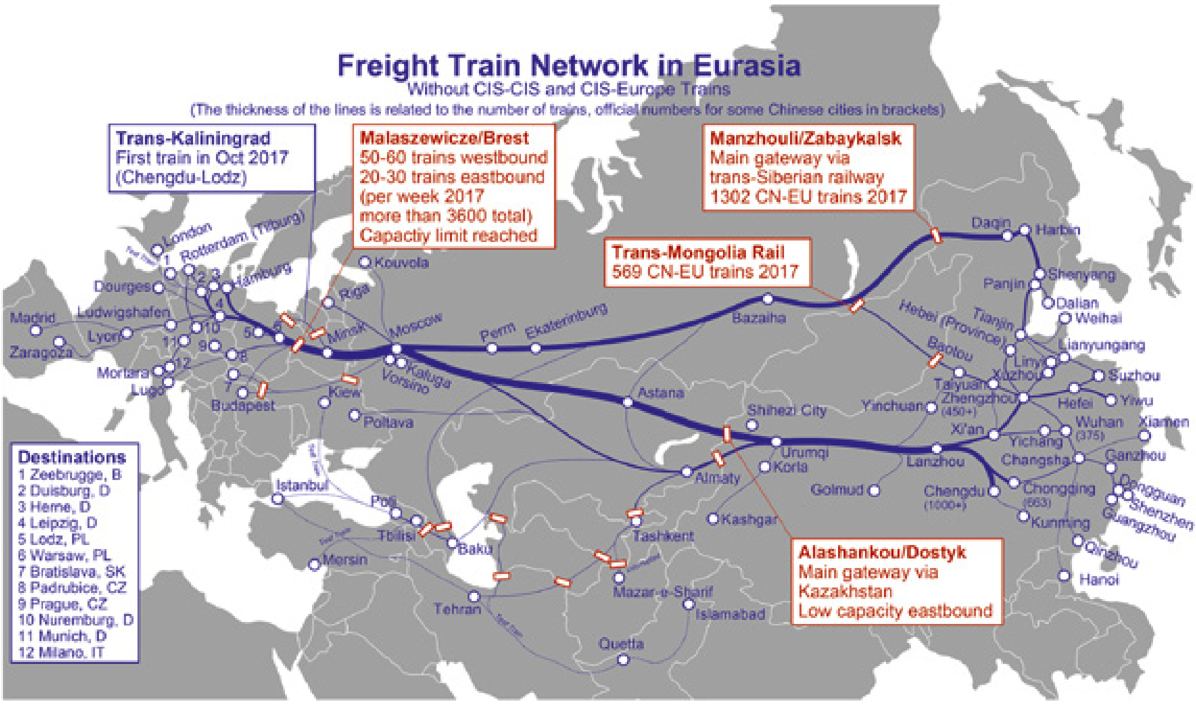

FIGURE 2:
Present state of rail transport along corridors

strategic position "at the cross roads of the East and the West". Abbas Akhoundi, Iran's Minister of Roads and Urban Development, has described his country's ambition as an attempt to become the "the point of equilibrium in the region".[18]

4. POSSIBLE ROUTES BETWEEN IRAN AND EUROPE

Despite Iran's strategic ambitions, routing for freight trains along its emerging transport corridors still faces a host of infrastructural and political challenges. Railway systems are not homogenous along the route and border crossings often come with a break of gauge or other systemic requirements. Politically, the terrain is no less challenging. Contested territories, such as Abkhazia, Nakhchivan and Kurdish territories in Turkey are in the close vicinity of the Iran's transport corridors. The railway routings need to navigate through a region that is marked by inter-state conflicts. Tensions between Turkey and Armenia, Armenia and Azerbaijan and between Ukraine and Russia are some examples, which could have detrimental or even disrupting effects on Iran's connectivity.

At present conditions, the travel time for a train from Western Europe to Iran will be at least 10 days. While container rates on most of Chinese-European trains still receive considerable Chinese subsidies, costs for railway transport via Iran would be more difficult to fund. The following sections portray and compare potential routings focusing on aspects of efficiency.

A. ROUTES VIA TURKEY

Several railway routes and freight train connections are operational connecting Western Europe to Turkey. Infrastructure has been upgraded recently, e. g. between Dimitrovgrad, Bulgaria and the Turkish border.[19] Nonetheless, on each of the three possible entry routes to Bulgaria, lines are single-tracked and without electrification.[20]

The alignment of many railways in Turkey is not beneficial for heavy freight transports. The two main East-West transit routes are mountainous and equipped with ramps, not electrified, and mostly single tracked. Various projects will improve this situation on some stretches. There are existing plans to connect Bulgaria via Istanbul with the recently opened BTK railway in Kars by high-speed lines until 2023 (partially under construction, partially finished).[21] While the high-speed line from Ankara to Sivas should be ready in 2018, construction of the Sivas-Erzurum-Kars section has not started yet. [22]

A big issue is the greater Istanbul area: The Marmaray tunnel is now in operation for four years. The rail connection to both networks (Asian and European) will be finished by 2018.[23] This connection of both sides via rail is basically built as commuter/subway line. It is still unclear, if freight trains will receive an allowance for the use of the Marmaray tunnel. In any case, dangerous goods will not be allowed to pass the tunnel and freight traffic will be limited to night times, when there is no commuter traffic.[24] A second railway will be built in Istanbul connecting the railway networks of its Asian and European part. It will include the new airport and uses the combined (rail and road) Yavuz Sultan Selim Bridge, that has been recently opened for road traffic. Construction of the railway has not started yet.[25] There is no decision so far, whether this line can be used for freight trains or not. The two routes described would be the only connections for freight trains to cross from Europe to Asia on rails without taking a ferry. At present rail transport always includes a ferry passage through the Sea of Marmara.

18) http://www.presstv.com/Detail/2016/02/10/449526/Iran-transportation-rail-Italy-deal-FS
19) http://www.railjournal.com/index.php/europe/bulgaria-completes-modernisation-of-rail-link-to-turkey.html
20) Bachelor's Thesis Lukas Mani
21) https://www.thefreelibrary.com/Edirne+to+Kars+High+Speed+Rail+Line.-a0462384207
22) https://www.trenhaber.com/hizli-tren/ankara-sivas-erzincan-erzurum-kars-yuksek-hizli-tren-projesi-nezaman-h1644.html
23) https://www.sondakika.com/haber/haber-ulastirma-denizcilik-ve-haberlesme-bakani-ahmet-10436832/
24) https://railturkey.org/2016/03/03/frequently-asked-questions-about-marmaray-project/
25) https://www.dailysabah.com/business/2017/06/07/plan-for-new-high-speed-rail-in-istanbul-waiting-for-approval

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i. The only Route without Gauge Change: Istanbul – Lake Van – Tabriz (Train ferry)

	2018	2025
Km	5701	5452
+	Only 1435 mm	Only 1435 mm
–	Istanbul Reload to ferry Political tensions	Istanbul Reload to ferry

This route was used by a weekly passenger train from Ankara to Tehran until it was interrupted in 2015 due to political tensions.[26] More than 1,800 km separate Istanbul and Tatvan at the western end of the Lake Van. From there a rail ferry carries the train to Van at the eastern end of lake. Newly built ferries allow to transport a 500 m train (four tracks, 130 m in length each) in a single ride and one hour faster than the current ones. In January 2018 test runs of the first ferry have been completed.[27] Still in Turkey, the track heads for the border with Iran at Kapiköy, before reaching Tabriz. With the opening of the Bostenabad – Mianeh railway in 2018, the line to Tehran will be shortened by 114 km.[28] The announced electrification from Tehran to Tabriz will also benefit this route.[29]

26) https://www.seat61.com/Iran.htm
27) http://www.milliyet.com.tr/turkiye-nin-en-buyuk-feribotu-van-golu-van-yerelhaber-2520468/
28) https://financialtribune.com/articles/economy-domestic-economy/79657/irans-6-prioritized-rail-projects-to-come-on-stream

ii. Via Baku – Tbilisi – Kars and Astara

	2018	2025
Km	6180	5941
+		Modern railroads
–	Trucking from Astara Reload to 1520 mm Istanbul	Reload to 1520 mm Istanbul

After several delays the BTK railway was put into service by October 2017.[30] First freight trains have been sent along the new track.[31] The BTK is often mentioned as one of the important pieces of the "New Silk Road"[32] Along the whole route modern and new railroads have been built. But still, the BTK is a detour compared to the direct route. Breaks of gauge in Akhalkalaki and Astara require reloading.

29) https://www.tasnimnews.com/en/news/2017/06/08/1430992/russia-says-ready-to-electrify-tehran-tabriz-railway-in-iran
30) https://www.dailysabah.com/deutsch/wirtschaft/2017/10/30/baku-tiflis-kars-eisenbahnstrecke-in-baku-eingeweiht
31) https://azertag.az/de/xeber/Gutertransport_von_China_nach_Europa_mit_BTK_Bahnstrecke_begonnen-1130459
32) https://en.trend.az/business/economy/2849247.html

iii. Via a new Line between Kars and Tabriz

	2018	2025
Km	-	5478
+	-	Only 1435 mm
–	-	Istanbul

Discussions are underway to build a new standard gauge line between Kars and Tabriz. Together with the Ankara-Kars high speed line, this project would finally complete a high capacity standard gauge railroad between Europe and Iran. First ideas would route this line through Nakhchivan, where already a 1520 mm stretch exists.[33]

B. ROUTES VIA RUSSIA

In fact, routes via Russia are the shortest possible ways via rail to Iran. In comparison with Turkey as transit country Russian railroads are mostly flat, straight, often electrified and double-tracked. However, at least two transshipments to different wagons are required due to the wider CIS 1520 mm gauge.

33) https://www.dailysabah.com/business/2017/06/01/turkey-seeks-to-build-an-alternative-road-to-baku-tbilisi-kars-railway

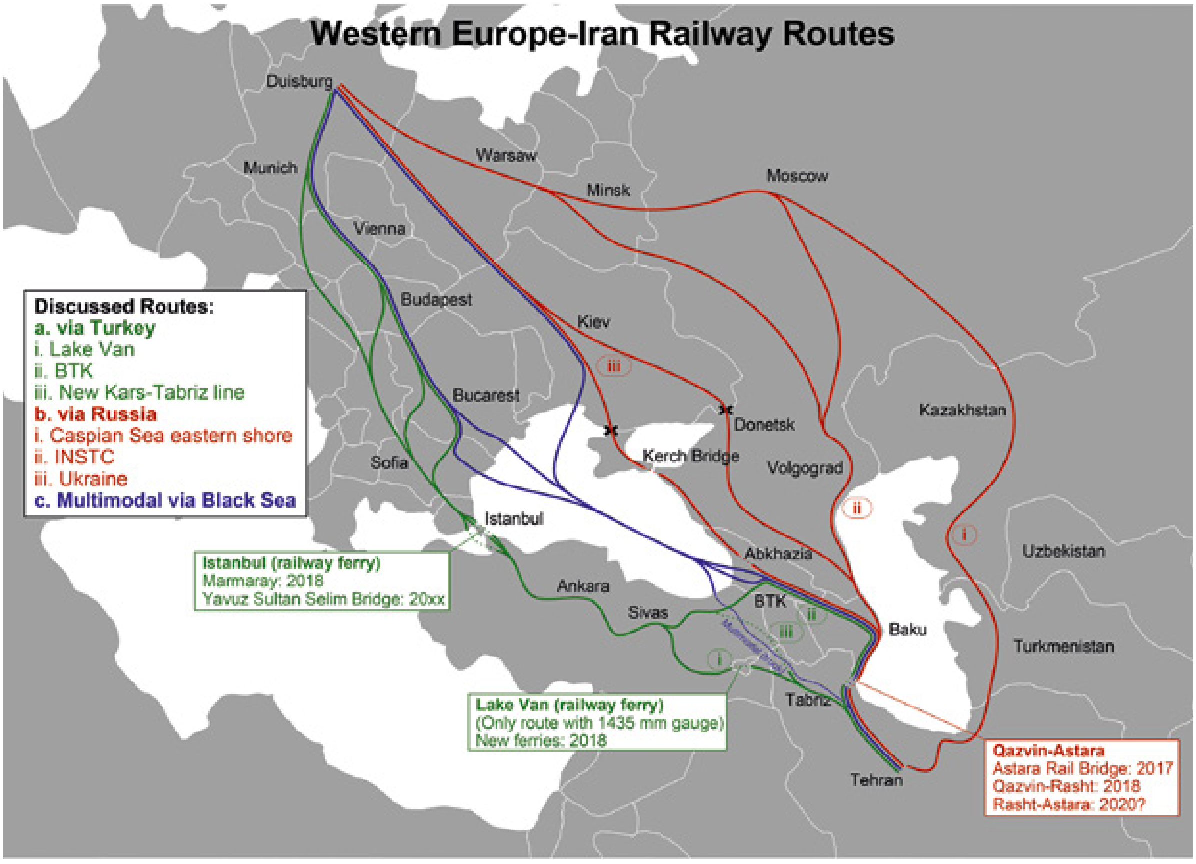

FIGURE 3: Possible rail- and multimodal routes between Western Europe and Iran

i. The only Route without Leaving Rails today: Via Kazakhstan and Turkmenistan

	2018	2025
Km	6344	6344
+	All on railroad	–
–	Long route, 1520 mm Via Kazakhstan and Turk-menistan	–

With the inauguration of the Uzen – Serhetyaka – Bereket – Etrek – Gorgan in 2014[34] on the eastern shore of the Caspian Sea it is possible (within an affordable way) to send trains to Iran. The route is longer than the routes via Turkey or Azerbaijan and two additional countries (Kazakhstan and Turkmenistan) need to be crossed.

34) http://www.railwaygazette.com/news/news/asia/single-view/view/iran-turkmenistan-kazakhstan-rail-link-inaugurated.html

ii. Via Russia and INSTC

	2018	2025
Km	5155	5155
+	Short	Short
–	Trucking from Astara Reload to 1520 mm	Reload to 1520 mm

The fastest way in near term will be the usage of a combination of well-developed freight corridors in Europe and Asia. The TEN-2 corridor (Berlin-Moscow) together with the China-Europe train development is connected to the INSTC from Moscow to India. The whole length of this line will be further developed and modernized. With the predicted completion of the last stretch between Astara (Iran) and Qazvin[35] the line can be seen as modern freight corridor along the entire path. Shortcuts to the south of Moscow (starting already in Belarus) cut the distance by some hundred kilometers. The line via Briansk and Volgograd is the shortest possible route, without crossing regions with considerable political risks.

35) 26 https://www.azernews.az/business/125875.html

iii. The shortest: Via Ukraine

	2018	2025
Km	5080	5080
+	Shortest route	Shortest route
–	Trucking from Astara Reload to 1520 mm Political interrupted	Reload to 1520 mm Political tensions?

Even shorter would be a possible routing via Ukraine. Heading from Poland all the way through Ukraine to Rostov and further to the Caspian Sea coast. This route is the shortest possible route with just over 5000 km. Currently this railway is threatened[36] by tensions in the Donezk region.

In future, another short route could possibly cross the Crimean peninsula via the new Crimea-Bridge, which is currently under construction,[37] and then run along the Black Sea Coast (Sochi/Adler) connecting to Georgia via Abkhazia. The railway bridge between Abkhazia and Georgia is still destroyed, but

36) https://rian.com.ua/story/20170526/1024404112.html
37) http://www.maritimejournal.com/news101/marine-civils/marine-civils/crimea-bridge-progress

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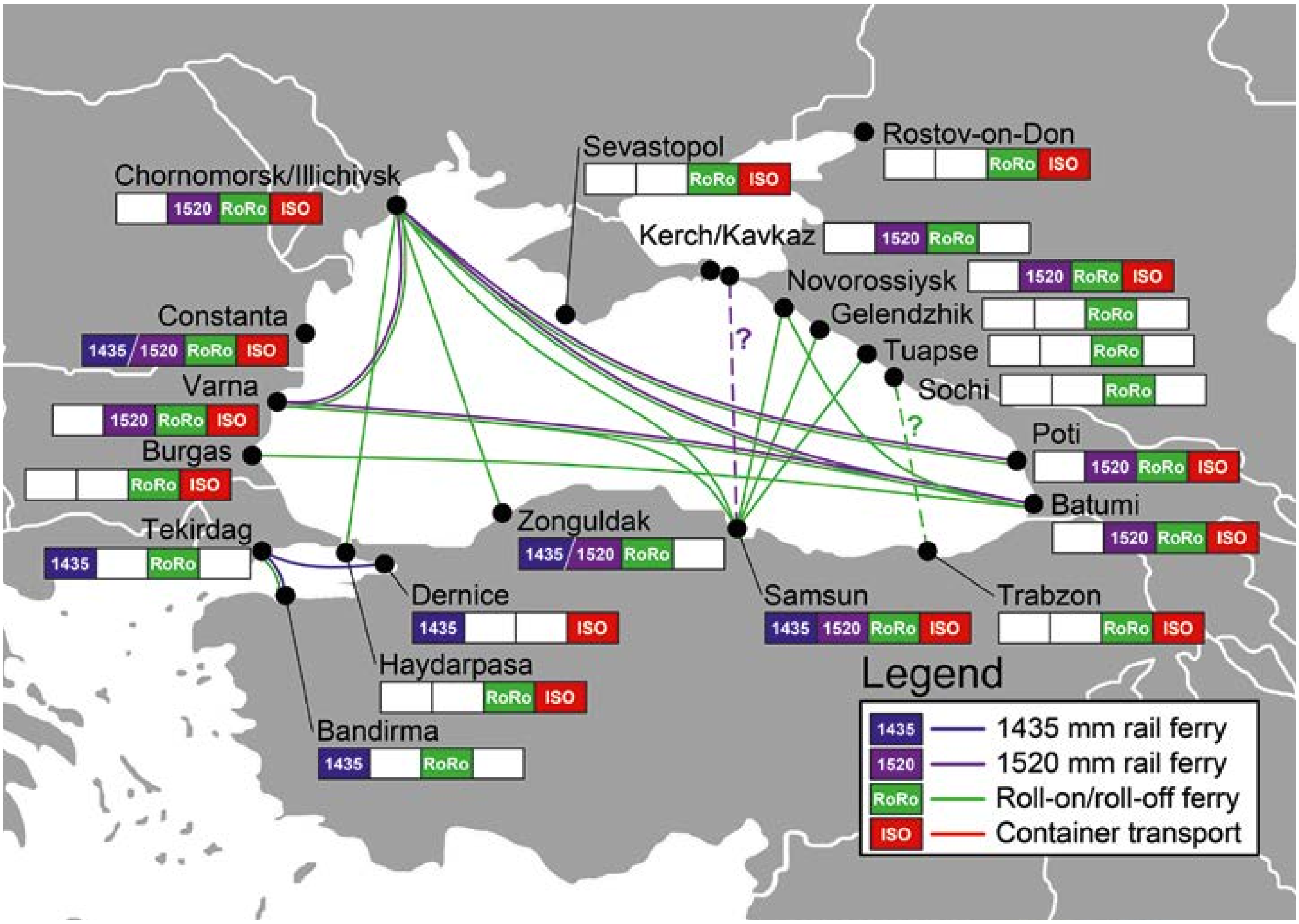

FIGURE 4: Black Sea ferries and ports

D. IMPORTANT RAILWAY INFRASTRUCTURE PROJECTS FOR IRAN RELATED FREIGHT TRAIN TRAFFIC (NOT COMPLETE)

Project	Country	Kind of Project	Benefits	Inauguration
Dimitrovgrad – Kapikule Railway	Bulgaria	Railway upgrade	Faster connection and more capacity between Bulgaria and Turkey	2016
Astara – Astara Railway	Azerbaijan+Iran	New line	Border crossing line to Iran	2017
BTK	Turkey+ Georgia	New line	Connection of Turkey and Georgia	2017
Qazvin – Rasht railway	Iran	New line	INSTC completion	2018
Bosetenabad – Mianeh railway	Iran	New line	Reduction of 114 km between Tabriz and Tehran	2018
Tatvan – Van ferry	Turkey	Railway ferry	500m trains on a single ferry, shorter travel time	2018?
Marmaray tunnel	Turkey	New line	Connection of European and Asian networks	2018?
Ankara – Sivas railway	Turkey	New high-speed line	Fast and shorter Railway for both trans-Turkey routes	2018?
Tbilisi – Makhindzhauri	Georgia	Upgrade + Tunnel	Batumi/Poti – Tbilisi route 1 hour faster	2019

Project	Country	Kind of Project	Benefits	Inauguration
Rasht – Astara railway	Iran	New line	INSTC final gap	20xx
Sivas – Erzincan railway	Turkey	New high-speed line	Fast and shorter Railway for the Istanbul-Kars line (construction start 2017/2018)	20xx
Erzincan – Erzurum – Kars railway	Turkey	New high-speed line	Fast and shorter Railway for the Istanbul-Kars line (construction start 20xx)	20xx
Edirne – Istanbul railway	Turkey	Upgrade	Faster Service, more Capacity	20xx
Yavuz Sultan Selim bridge	Turkey	New line	2nd Connection of European and Asian networks	20xx
Kars – Tabriz railway	Tureky+ Iran	New line	Iran rail network connection with Turkey without using a ferry	20xx
Tehran – Tabriz railway	Iran	Upgrade	Electrification	20xx
Sumgayit – Yalama railway	Azerbaijan	Upgrade	INSTC benefits	20xx
Budapest – Belgrade railway	Hungary+ Serbia	Upgrade	Shortest way to Istanbul will be even faster	20xx
Nis – Dimitrovgrad railway	Serbia	Upgrade + Electrification	Europe-Turkey all electrified	20xx

reconstruction has been discussed.[38] Due to several political tensions (Ukraine-Crimea and Abkhazia-Georgia) this route will not be operational in the near future.[39]

C. MULTIMODAL ROUTES VIA BLACK SEA

The Black Sea is crisscrossed with railway ferry connections in both (1435 mm and 1520 mm) gauges. The map on page 29 gives an overview about the ports and their modalities.

However, under efficiency considerations it does not make much sense to opt for rail ferries, if the Black Sea needs to be crossed. This option would always entail a break of gauge at the European coast, thus raising transport times and costs. A more suitable solution would be the transshipment of containers only. Currently, transshipment from Bulgaria to Georgia is faster or equal to the route via Turkey. Some shippers have already tested this solution. In Georgian ports of Batumi and Poti containers can be loaded onto the train. Still, this option needs an additional transshipment at the Azerbaijan-Iranian border to trucks or, in the future, to 1435 mm gauge. Today, it might be more reasonable to use only trucking services between the Black Sea and Iran.

E. CONCLUSION

Today, no optimal route solution exists for freight trains from Europe to Iran. Various routings exist, but each has its own characteristic downsides. If railway is the preferred mode of transport, transport should be directed via Russia today and in near future. It is the shortest way with the best infrastructure conditions and the remaining gap between Iran and Azerbaijan will be closed soon.

In 2018 new ferries on Lake Van should become operational and cargo trains should be able to use the Marmaray tunnel. Under these circumstances, and if the political situation in Kurdistan allows for it, a test train could be sent with European and Turkish wagons from Western Europe to Iran without leaving 1435 mm standard gauge.

Under efficiency considerations, the route via the BTK railway and Azerbaijan is currently not the preferred choice, as it requires too many changes of the modes of transport. However, due to the growing number of railway projects in and around Iran, several routes are likely to become faster and better suitable for railway transports in the near future. ◀

38) http://www.iai.it/sites/default/files/2013_core-policy-brief-5.pdf
39) http://georgiatoday.ge/news/1084/Georgian-Silence-as-Russia-Abkhazia-Railway-is-Restored

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