
Report

# Cross-border Rail Transport Potential

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# Executive summary

This report assesses how the further removal of technical and operational barriers at European cross-border sections would contribute to the attractiveness and competitiveness of rail transport.

Four case studies were selected, two for freight and two for passenger rail transport. The analyses present an in-depth view on the literature and collected data. The cases on cross-border passenger transport build primarily on qualitative inputs, including observations on international high speed rail connections.

The two case studies focusing on freight provide a quantitative evaluation of the impacts of technical and operational barriers on travel time, which in turn adversely affect rail volumes and the modal split.

Based on the findings, and after highlighting the limitations of the study and possible follow-up analyses, the report emphasizes the need for the further cleaning of national rules. Moreover, the Technical Specifications for Interoperability can contribute to lowering some barriers by closing open points and reducing, where appropriate, specific cases. Doing so would improve the prospects of international rail transport.

# Introduction

The modal shift to rail is a key pillar of the EU strategy to reach climate neutrality by 2050, and cross-border transport is critical to realise the EU's Green Deal objectives. Rail transport is however hampered by missing links [4] and where links are present a range of barriers impact the competitiveness of rail transport ([1], [2], [3] and [4]). Particularly, resolving technical and operational barriers remains key to enhance the interoperability of the Union rail system and to improve the performance of international rail transport.

This study assesses the possible reduction in travel time and the growth potential of cross-border rail traffic that would derive from a further removal of technical and operational barriers. The focus is on both passenger and freight rail transportation in Europe covering cross-border trips. It should be emphasized that, while acknowledging their importance, the following issues have been assessed in different studies and are out of the scope of this report:

- Capacity, connectivity and missing links;
- Market/commercial specific considerations (e.g. PSOs, unprofitable services and subsidies infrastructure charges, tariff integrations and ticketing systems, market foreclosure etc.);
- Differences in settlement structure, population density and demand;
- Complex institutional, administrative and political contexts;
- Passenger rights.

The study has been performed following the steps below:

1. Literature review on studies of cross-border rail transport aiming at complementing our analysis;
2. Case study analysis and possible modelling to provide qualitative and quantitative findings (re. modal shift potential);
3. Extrapolation of findings from literature review, case study analysis and modelling to generalise results and put forward targeted recommendations.

Regarding the structure of this document, after a general overview on cross-border transportation (focusing not only on technical and operational barriers) the case studies are described. For the two rail freight cross-border connections, considerations and a rough quantitative estimation of the potential demand are presented, while the case studies for the passenger cross-border services provide a more qualitative analysis. Finally, general considerations on cross-border High Speed (HS) international services are reported.

# 1. Overview on cross-border transportation

Cross border transport is a key contributor to improved accessibility and cohesion on the short and on the long distance, and is instrumental towards achieving ambitious European modal shift targets.

A well-connected cross-border railway system is the backbone of European transnational mobility and key to the European TEN-T Policy to develop a Europe-wide rail network. Despite improved connectivity in terms of infrastructure, many European cross-border points function like a patchwork reflecting different national systems. The technical and operational barriers between countries keep rail from realising its potential.

Although the interoperability of the EU railway system is improving, progress has been slow so far, and it appears to be uneven across different areas. Solid progress has been achieved in aligning rules and procedures, whereas improvements have been slow in the area of rolling stock and infrastructure, partly owning to their long-life nature. Progress in the widespread adoption of technical standards supporting information availability and data exchange has also been delayed across the EU [29].

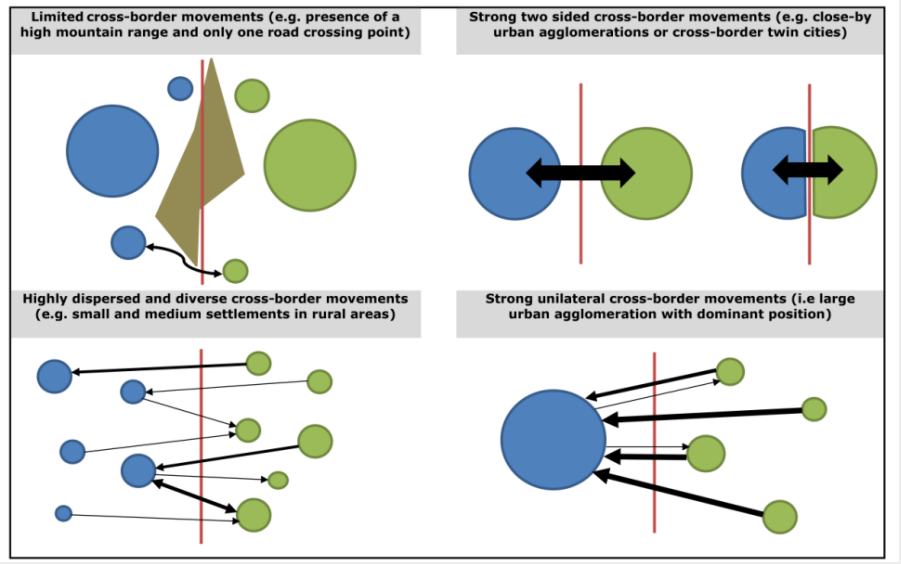
This uneven progress is believed to have hampered EU railways in increasing their modal share over the past decades, despite being the most sustainable mode of transport. The relative share of people and goods transported by rail, as compared with other modes of transport, appears to have stagnated at rather low levels. Rail passenger volumes in Europe have increased slightly but consistently, while freight volumes have remained stable. International rail traffic is significant only for freight services at about 50% of the total rail freight traffic, but only ~6% of passenger services. These proportions remained largely unchanged since 2006, suggesting that the EU is far from achieving its ambitions in this area [29].

To understand this evolution, the geographical typologies for cross border transportation should be understood:

1. Long-distance (truck, bus and passenger/freight train) services usually cross two or more national borders (with possibly several stops along the route);
2. The majority of passenger services have several stops on both sides of the border;
3. Some services widely found across Europe are services with several stops on one side of the border, but only one on the other side;
4. There are several cases of the terminus of a bus or train service at the border crossing point.

Potential demand for cross-border traffic depends on the characteristics of the agglomerations/locations connected, and regarding short-distance/regional cross-border traffic, potential demand tends to be wide-ranging in more densely populated and urbanised cross-border regions.

**Figure 1:** Examples of patterns of cross-border traffic movements, source [2]




The majority of cross-border freight transport is carried out by road, while passenger cross-border trips (by public transport) prior to the COVID-19 pandemic were mainly by air, with rail and coach only carrying around 10% of international passengers each [3].

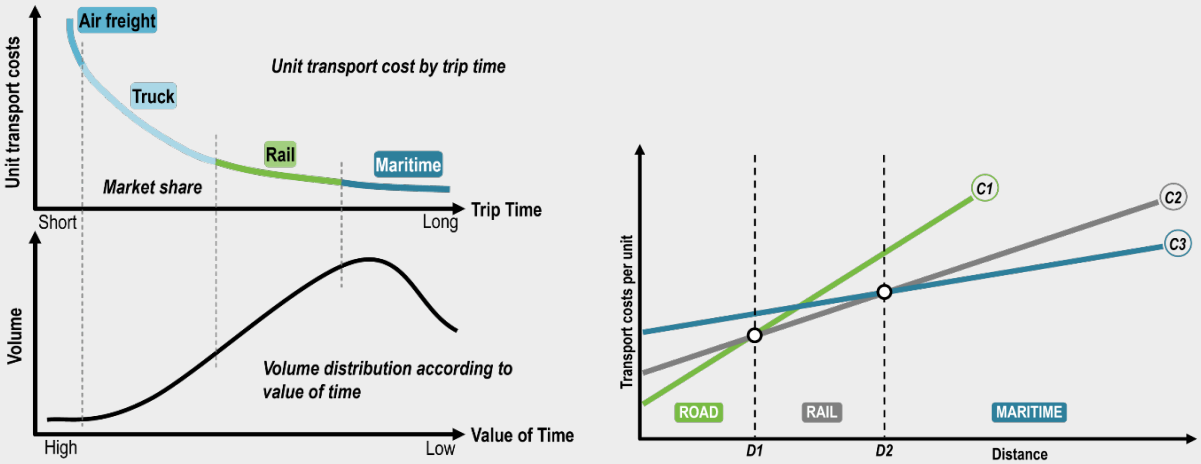
By far the most passenger rail services are in border areas between Germany, Austria and Switzerland, while the lowest number of rail services is in more peripheral European regions [2]. There are cross-border bus services at all European borders, although less in the East and North. Cross-border tram services exist only between France, Germany and Switzerland. Cross-border ferry services operate with quite different frameworks and different purposes across lakes, rivers and the sea in many parts of Europe. Within this context, short distance cross-border passenger transport rail competes mainly with car.

## 1.1. Freight transport

Shifting freight to rail can help in achieving high-level policy objectives such as environmental sustainability, better connectivity and increased safety. This applies also to international and cross border transportation.

Rail frequently competes with road transport which is often found to offer more flexible and reliable services, particularly for smaller shipment sizes. Demand for rail transport is mostly for long distance transport, while trucking demand is higher for shorter distances. Although rail freight is often cheaper per transported tonne-kilometre, it usually adds costs to shippers' logistics systems.  Non-road modes offer economies of scale while the external costs generated by road transport are generally higher than for other modes.

**Figure 2:** Distribution of freight demand and transport costs by mode, source [32]




Lack of interoperability in the rail sector is one of the main barriers when considering cross-border transport. It is a complex barrier as it is the combination of a series of technical, administrative and infrastructural issues that generate operational problems resulting, for example, in: (i) slower transport operations; and (ii) an increase of the operating costs borne by railway undertakings.

Focusing on freight transport, the Issues Logbook (ILB) study [1] identified 15 main technical and operational barriers to interoperability which hamper international rail freight traffic. They are grouped as follows:

- Braking sheets and braking performance;
- Technical checks at border stations and mandatory checks in MSs;
- Train composition (harmonisation of wagon list, real-time communication and harmonisation of train composition message, working handbrake last wagon, no push 6 axles wagons, buffer wagons);
- Taillights versus plates;
- New train number;
- Two people cabin crew;
- Equipment of border stations with commutable electric power supply;
- Operational implementation of the traffic in ERTMS,

## 1.2. Passenger transport

In Europe, only 6-7% of total rail passenger-kilometres involve crossing one or more borders and only a proportion of these cross-border rail passenger journeys are long-distance services.

The total number of long-distance passenger cross-border services in the EU, Norway, Switzerland and the United Kingdom, appears to have changed little since 2001, with around 4,500 train pairs per week [3].

Several obstacles can be identified for the expansion of long-distance cross-border rail services, including [3]:

- Infrastructure charges vary widely, also for different market segments.
- Infrastructure capacity, including at many city centre stations, may limit the scope to operate additional long-distance cross-border trains.

- Rolling stock will also be needed to operate additional cross-border services, and lack of suitable rolling stock may represent an obstacle to introducing them (e.g. couchette and sleeping cars for night trains [3]).
- Ticketing systems are necessary for passengers to research travel, to buy tickets and to make reservations, and to provide evidence to railway undertakings that passengers are entitled to travel on their services. A lack of end-to-end fares, and a range of different ticketing and sales systems, remain barriers to selling tickets for cross-border journeys.
- Passenger rights in relation to successive railway services operated by one or more railway undertakings are technically complex but important. Passengers making journeys requiring changes of train are often concerned at what will happen if, for whatever reason, they fail to make the connection onto one or more of the trains on which they intended, or are booked, to travel.
- Difficulties/challenges in setting up cross-border structures for PSO tendering.
- Technical and operational obstacles to cross-border operations remain. Differences in electrification systems can be dealt with by multi-system locomotives and trains, but there is a limit to the number of different systems that can be accommodated within a locomotive or fixed-formation train set. Differences in track and structure gauge can be managed with stock with gauge-changing equipment and smaller dimensions, and standard gauge high-speed lines are extending into Spain, with the Iberian gauge, and into the Baltic states, with the Russian gauge. Many other technical differences are being addressed through the TSIs. The limitation is however that existing assets, systems and procedures are rarely enforced to adopt TSI changes. Legacy non-interoperable systems therefore diminish at a rather slow pace.
- Different prioritisation for different market segments.

Regarding regional and short-distance cross border passenger transport services, despite the efforts of European integration and cohesion policies made over the past decades, many citizens in border regions of the EU still experience lacking or low-quality rail transport services.

Some of the examples of poor availability of cross-border services are caused by the absence of adequate cross-border network infrastructure, although the mere presence of operational railway border crossing points is not a sufficient precondition for efficient and useful connections.

The obstacles faced can be different than those for domestic and long distance rail transport. The particularities occur, firstly, because of structural features along the state borders and the functional relations between neighbouring regions in different countries. Secondly, crossing state borders implies that Cross Border Public Transport (CBPT) services have to be planned, established and operated in a heterogeneous legal framework often in a complex context.

These particularities lead to seven problem groups [2]:

- Diverse public transport governance systems and complex administrative procedures;
- Inadequate cross-border integration of domestic tariff systems and suboptimal passenger information;
- Unprofitable cross-border services, or other aspects leading to adverse financial effects;
- Inadequate railway infrastructure or inadequate interoperability;
- Unfavourable territorial context conditions and/or missing demand potential for the service;

- Suboptimal development of cross-border services;
- Suboptimal timetable coordination and / or non-user-friendly timetables.

Often, actors from border regions are discouraged by obstacles instead of seeing them as an opportunity. Structural differences, such as different population densities on both sides of the border could generate demand for specific transport services to name just an example.

Even if this section described a wide range of obstacles for cross border passenger transport, as already mentioned, this study and the next parts of the report will focus only on technical and operational barriers (falling under the remit of the Agency).

# 2. Case studies

## 2.1. Introduction

Case studies have been performed to provide an in-depth look into technical and operational barriers. The influence of these barriers on travel time are analysed, which in turn can have an adverse effect on rail volume/modal split (even acknowledging that barriers may well have other effects).

The study focuses only on the potential effects of removing specific technical and operational barriers (analysed singularly), without addressing the possible spill over effects emerging from more measures adopted simultaneously.

A more detailed quantitative modelling exercise could form part of a future follow-up analysis, since in this study the quantitative evaluation is limited in scope.

A qualitative analysis has been carried out for four case studies, respectively two case studies for rail freight transport and two for passenger rail services. For the passenger case studies, mainly qualitative considerations are presented. For the two case studies focusing on freight a rough quantitative evaluation on potential demand and modal share is presented, since from the literature review more data are available (compared to the passenger services). Modal shift potential is evaluated based on elasticities retrieved from the review of literature on how likely freight will shift due to travel time reductions.

These four case studies have been selected and assessed on the basis of data availability and relevance of the issues. Apart from these 4 case studies more general considerations on international high speed rail connections are also extracted from the literature.

It is important to highlight that the removal of technical and operational barriers represents a possible contributing factor to the increase of modal share, but it is not the only and sufficient factor for modal shift to rail.

Also possible approximation related to data availability may partially affect the results. For example, a preliminary literature review shows a good availability of elasticities values for rail and road freight transportation, which anyway represent in general national values, also quite variable across countries. The selection and application to the specific/local cross border sections present instead some difficulties. Similarly, demand data are generally available and reported at national level, while disaggregated values/considerations applicable to the specific cross border area are much more limited.

Based on these case study findings, at the end of this report targeted recommendations are provided to strengthen international rail transport and increase rail's modal share.

## 2.2. Cross-border freight transport

From a first analysis of the literature review it was possible to extract information on various possible case studies. For example, the Issues Logbook study [1] identifies 15 main (technical and operational) issues (representing barriers to interoperability hampering international rail freight traffic) by analysing over 70 Cross Border Points (mainly on Rail Freight Corridors) across Europe. The Impact Assessment for the TSI OPE (2018) reported as positive examples the freight railway operations between Germany, Denmark and Sweden (e.g. between Padborg in Denmark and Flensburg in Germany along RF3), despite the remaining different train braking rules; it reported, instead, significant time losses on RFC7 at the cross-border stations Curtici (RO) and Ruse (BG).

Two main cases studies are presented:

- Rail freight connection Innsbruck (Austria) - Brennero (Italy), along RFC3
- Rail freight connection Giurgiu Nord (Romania)- Ruse Razpredel (Bulgaria), along RFC7

While those connections are analysed in detail, small analyses (box insights) are also proposed on specific issues related to other possible examples/connections.

### 2.2.1. Rail freight connection Innsbruck (Austria) - Brennero (Italy)

The Alpine region offers several north-south and east-west transport axes, with all cross-border traffic (including trans-European transit traffic) by road and rail; sustainable management of traffic flows and a well-developed railway infrastructure is therefore crucial.

The München-Verona line over the Brenner Pass is a section of the Scandinavian-Mediterranean Core Network and Rail Freight Corridor 3 that connects Italy with Austria and Germany with a strategic role for the exchange of goods between Southern and Northern Europe, making it one of the busiest freight corridors in Europe.

Traffic on the Brenner Corridor includes passengers and freight rail services: long-distance passenger services (both international and domestic) are present in modest numbers, while there is a significant number of regional passenger and freight trains [21].

In 2007, the 'Brenner Corridor Platform'[1] (BCP) was set up to guarantee an integrated transport policy approach for the multimodal Brenner Corridor between Munich and Verona. In 2009 Italy, Austria, Germany and the EC signed a Memorandum of Understanding and the Brenner Action Plan 2009-2022 promoting a modal shift was put forward. The plan aims to implement measures for an efficient use of the cross-border rail connection between Munich and Verona, to enhance the modal shift and to protect the alpine environment which is heavily impacted by road traffic.

The particularities of the Alpine territory and challenges for the TEN-T north-south transport corridor have long motivated to develop and establish solutions for sustainable public mobility; today, the Federal State of Tyrol and the two Italian Autonomous Provinces of Bolzano–South Tyrol and Trentino have a well-developed regional public transport system which remains a top priority in the political agenda together with the intense cooperation on cross-border public transport. A major internal public transport development project of the State of Tyrol was the Tyrol suburban railway (S-Bahn Tirol) in 2007, which has quickly become a success story; 10 years after its introduction, passenger numbers on the S-Bahn Tirol have already doubled [2].

The railway line between Verona and Munich has a length of 435 kilometres. The section is double track with 3 kV DC electrification between Verona and Brennero and 15 kV AC between Brennero and Munich. The characteristics of the infrastructure allow operating trains with a D4 axle weight (22.5 tonnes per axle), with restrictions on the Bolzano-Brenner section. The structure gauge of the line is P/C 80 on its entire length [21]. The Italian section is equipped with command and control system SCMT, and traffic regulation functions are realised by a SCC system. In the Austrian and German section signalling system is PZB; for the Austrian section, ERTMS (ETCS L2) has already been deployed, and it is in operation [31].

Coping with the challenging topography of the Alps, the Brenner railway line experiences significant limitations in terms of gradients and curvature, which require a reduction in speed and the use of double traction for many freight trains.

The most critical section is between Bronzolo (near Bolzano) and Innsbruck, with gradients of 30 per thousand. On this section, the maximum speed allowed for freight trains is less than 100 km/h. The maximum mass that can be towed in single traction is less than 800 tons, resulting in the need for frequent use of multiple traction [21].

1 The BCP members are three EU Member States (Austria, Germany and Italy), five regions (Bavaria, Tirol, Alto Adige, Trento, Verona) as well as railway and highway companies and the European Commission. See also https://www.bcplatform.eu/corridorstudies.

Within this context, the 'Brenner Base Tunnel' (expected to be completed in 2032) would attract considerable rail traffic from the current Brenner Railway line.

The Brenner Base Tunnel is a straight, flat railway tunnel running for 55 km from Innsbruck in Austria to Fortezza in Italy. The tunnel consists of two tubes, each with a single track, with design speed for freight and passenger traffic respectively of 120 km/h and 250 km/h; energy supply for railway traction will be 15 kV 16.7 Hz and 25 kV 50 Hz, while the control and command system will use ETCS Level 2. Passenger and freight trains will travel through the Brenner Base Tunnel and for a few kilometres also through the Inn valley tunnel (another railway bypass of 12.7 km was opened south of Innsbruck in 1994).

**Figure 3:** Scandinavian-Mediterranean Core Network Corridor and the Brenner Base Tunnel


After the opening of the Brenner Base Tunnel, all rail freight traffic and some passenger transport between Innsbruck and Fortezza could go via the tunnel underneath the Brenner Pass. Rail traffic above ground would continue, with more capacity for local and regional cross-border passenger transport.

Indeed, the Brenner railway line currently appears not sufficient, both in terms of capacity (especially for freight) and in terms of average travelling speed. For the 125 km of the cross-border section between Innsbruck and Bolzano, the average speed is 62 km/h and the journey takes a little more than 2 hours, mainly due to the considerable gradient and tight curves. The TTR-Pilot Brenner 2021 Capacity Model by RNE [22] considers average journey times of 65 minutes for the section München/Trudering (Germany) - Kufstein

(Austria), 150 minutes between Kufstein and Brenner (in Austria) and 200 minutes for the section Brennero Verona (in Italy).

The system separation point at Brenner/Brennero station may also involve waiting time affecting the journey time. This border railway station has a non-switchable separation point, limiting the Italian and Austrian power systems to a specific side of the station. Over all the tracks, the overhead catenary is separated by a neutral section approximately in the middle. This means that trains with a single-system electric traction unit (i.e. locomotive, multiple units or others) would have to either change their traction unit or terminate at Brenner/Brennero station.

Below several technical and operational barriers are described for the cross-border section Brennero - Staatsgrenze nächst Steinach in Tirol, drawing mainly from the Issue Logbook study. Moreover, Table 1 provides an overview of the estimated time losses (and costs) that follow from these barriers.

**Table 1**: Time and cost estimates for the main (technical and operational) issues according the ILB for the cross-border section Brennero - Staatsgrenze nächst Steinach in Tirol (source [1])

| Issue | Annual number of trains concerned | Time loss per train | Annual hours saved | Cost per train | Annual costs [M€] |
|---|---|---|---|---|---|
| Train braking rules and documents (ILB issues 1 and 2) | 19 960 (100%) | 20 min | 6 653 | 66€ - 100€ | 1,32-1,98 |
| Technical checks at border stations and mandatory checks in MSs (ILB issues 8 and 9) | | 30 min | 9 980 | 86€ - 122€ | 1,72-2,42 |
| Real-time communication (ILB issues 15) | | 116 min | 38 752 | 258€ - 313€ | 5,14-6,24 |
| New train number (ILB issue 11) | - | 118 min | - | - | - |
| Two-people cabin crew (ILB issue 13) | N/A. Only total values per country are estimated | | | | |
| Equipment of border stations with commutable electric power supply (ILB issue 14) | 5 988 (30%) | 40 min | - | - | - |
| Restrictions for the train length (and/or weight)* | - | 75 min | - | - | - |

* Authors' estimations (not included in the ILB, see below for more details)

- **Train braking rules and documents, i.e. braking sheets and braking performance (ILB issues 1 and 2)**. According to the current ILB, the issue on braking sheets emerges as many Member States and RUs use braking sheets with different layouts and contents, while the braking performance issue stems from Member States setting different requirements for braking performance (notably the braking percentages) and braking calculations. Therefore, RUs are required to switch braking regimes at border crossings even if the train composition does not change. The ILB assumes that all trains (running in the defined sections) are affected and that each train loses a total of 20[2] minutes. For the section Brennero - Staatsgrenze nächst Steinach in Tirol, by solving these issues the ILB estimates 6653 hours saved annually for the 19 960 trains passing through the cross-border section, with a total economic saving variable from 1,32 M€ to 1,98 M€ (i.e. with an average cost impact per train variable between 66€ and 100€). Anyway, it is important to emphasise that ERA has recently (2022) published the Acceptable Means of Compliance (AMOC) on checks and tests before departure, including brakes and checks during operation[3]; these have been thoroughly analysed and considered within the activ-

2 Braking sheets: 5 min for handover braking sheet; Braking performance: 15 min for 600m train length= 10 minutes for walking (1 second per meter train length) + 5 min switching brake regime.

3 Available on the ERA website here. According to art. 2(33) of the Directive (EU) 2016/797, Acceptable Means of Compliance (AMOCs) are "non-binding opinions issued by the Agency to define ways of establishing compliance with the essential requirements".

ities of the Brenner Corridor Platform, in order to be applied (i.e. possible solutions of these issues are already in an implementation phase).

- **Technical checks at border stations and mandatory checks in Member States (ILB issues 8 and 9)**. According to the current ILB, RUs need to perform safety checks on CBPs; this can happen on one side of the border or on both sides of the same border. In addition, some Member States require different mandatory wagon checks that might have to be performed at border stations, at regular distances and/or time intervals, and sometimes before steep gradients (brake check). These issues lead to inefficiency and stem from Member States' national rules. The ILB assumes that 100% of the trains (using the section under analysis) are affected by the issues with an additional waiting time at border in Italy of 30 minutes[4]; this leads to 9980 hours, with a total economic impact per year varying between 1,72M€ and 2,42M€ (i.e. average cost impact per train variable between 86€ and 122€). Again, it is important to remind the Acceptable Means of Compliance (AMOC) on checks and tests before departure, including brakes and checks during operation[3], which have been thoroughly analysed and considered within the activities of the Brenner Corridor Platform (in order to be applied).

**(Temporary) speed restrictions in Italy for trains with silent brakes**

In November of 2021, the Italian Agency for Rail, Road and Motorway Safety (ANSFISA) introduced a new urgent prescription for freight trains having in composition wagons equipped with organic low friction coefficient (LL) brake blocks (IB 116* type), concerning speed restrictions as a major preventive safety measure (i.e. 80km/h for general freight and 60km/h for trains carrying dangerous goods). These brakes are commonly known as silent brakes and these restrictions were established since more than 29 events (of which 8 on trains transporting dangerous goods) affecting vehicles equipped with LL brake blocks took place over the past two years. In these cases, the brake blocks, due to the malfunction of the continuous automatic brake, had an increase in temperature which caused flames generating in some cases negative consequences to the wheel tread [21].

On 30.11.2021 a Joint Network Secretariat (JNS) Urgent Procedure Task Force was launched in order to analyse the incidents and to define short-term risk control measures as a replacement for the Italian measures, with outcomes and a final report released by the task force on 02.02.2022:

- Part 1: Principles and organisation
- Part 2: Action plan containing short-term risk control measures
- Part 3: Detailed information on the work of the JNS task force

The Agency carried out internally a rough estimation of the costs (in terms of time lost) which could have been incurred proceeding with the measures proposed by ANSFISA without intervention of the JNS. In particular the evaluation has focused on two main impacting restrictions lifted by the JNS:

1. Speed restrictions to 80 km/h for freight train with one or more breaking wagons operated with IB 116* (not taking in account in the calculation the heavier reduction to 60 km/h for wagons carrying dangerous goods).
2. Performing the complete braking system checks even in the cases where a partial braking system check was required.

For the entire Italian network (and the related traffic), a few estimations on different possible scenarios seemed to indicate as reasonable an increase of travel time of 30-35 minutes per train due the reduction of the max speed down to 80 km/h. Assuming that the requirements of complete braking system checks (even in the cases where a partial braking system check was required) would have caused on average an additional time of 10-15 minutes, it was estimated that the mentioned restrictions would have caused an increase of the travel time of around 45 minutes for each train with one of more wagons using LL brakes with IB 116*. The estimation assumed a conservative (and likely underestimated) percentage of around 20% of total trains (and thus transported goods) impacted by the restrictions.

4 Estimated between 30 and 60 minutes of additional waiting time.

- **Real time communication (ILB issues 15)**. The case study in the ILB focuses on the impacts generated from improved train running information, with the time saved proxy in each RFC estimated based on the assumption that the delays could be reduced by 22% if a smooth transmission of estimated time of arrival (ETA) and an active traffic management of the second IM exists. As a result, the ILB estimated that 116 minutes per train could be saved with all trains crossing the analysed borders affected. With these hypotheses, by solving these issues on the section Brennero - Staatsgrenze nächst Steinach in Tirol, the ILB estimates 38752 hours saved annually, with economic savings variable between 5,14M€ and 6,24M€ (and an average cost impact per train variable between 258€ and 313€).This issue is linked to the reliability of the freight trains (see also the example below in the box "Heavier, faster and more reliable trains on the Rail Freight Corridor Rhine-Alpine"); along the transport chain, insufficient and/or lack of immediate information on delayed trains may result in interruption of production processes or a lack of supply. This may have a strong impact on the suitability of rail transport for specific commodities which rely on just-in-time production [24].
- **New train number (ILB issue 11).** The issue occurs when no changes are performed in the train composition, nevertheless, the Infrastructure Manager assigns a new number to the train. When this occurs, the train is considered as a new one and all train preparation procedures (such as full technical wagon check and brake test) must be performed again. The ILB study estimates that an average of 118 minutes per train[5] is required to solve the issue.
- **Two-people cabin crew (ILB issue 13)**. There is no harmonised rule on the number of cabin crew members and the number of cabin crews/drivers required in each train varies for the different Member States; in some cases, two drivers are required, while in other cases one driver and one additional staff member are required on certain lines or line sections. On average, the staff costs represent about 25% of the total operational costs for a railway undertaking. Within staff costs, train drivers represent about 40% of the total. For Italian RUs the ILB estimates staff costs representing the 23% of the total operational costs with a percentage of 40% for train drivers' wages in staff costs. Unlike the other issues, the issue on two-people cabin crew can be considered indirectly an interoperability issue, this being related with the nature of the solution implying more linked to labour policies rather than operational aspects. In particular, the ILB study does not provide impacts per corridors, but the total costs for all cross borders in each country. For Italy, by solving this issue yearly savings are estimated to be variable between 123M€ and 127M€ (with around 150000 trains affected in 2019). These cost estimates are not included in Table 1.
- **Equipment of border stations with commutable electric power supply (ILB issue 14)**. Different electrification standards imply that in border stations between networks where different kind of electrical current is supplied and where trains travel with single system locomotives one of two elements can be foreseen to solve the problem: Shunting manoeuvres or the purchase of multisystem locomotives. Regarding the section Brennero - Staatsgrenze nächst Steinach in Tirol available evidence from one IM suggests that some 60-80 % of freight trains crossing it are equipped with multi-system traction units, with a possible stop of around 5-10 minutes at the neutral section (to switch between the two different voltages). For trains with single-system locomotives, instead, the IM indicated a planned stop time of 40 minutes to change locomotive (neglecting possible delays due, for example, to the non-availability of the shunting locomotive).

5 1. If the PaP is changed from "corridor" to "operational train" level, this means waiting time until the train receives a new train path for the national rail network. Moreover, the train will lose priorities assigned to corridor trains, which might lead to additional time loss in case of conflicts with other trains.
2. An additional technical examination of the train including brake test is required. 600 m train length/20 m = 30 wagons per train * 4 axles/wagon = 120 axles/train. Time need = 0.9 min/axle * 120 + 10 (approaching/walking back + paperwork) = 118 min.

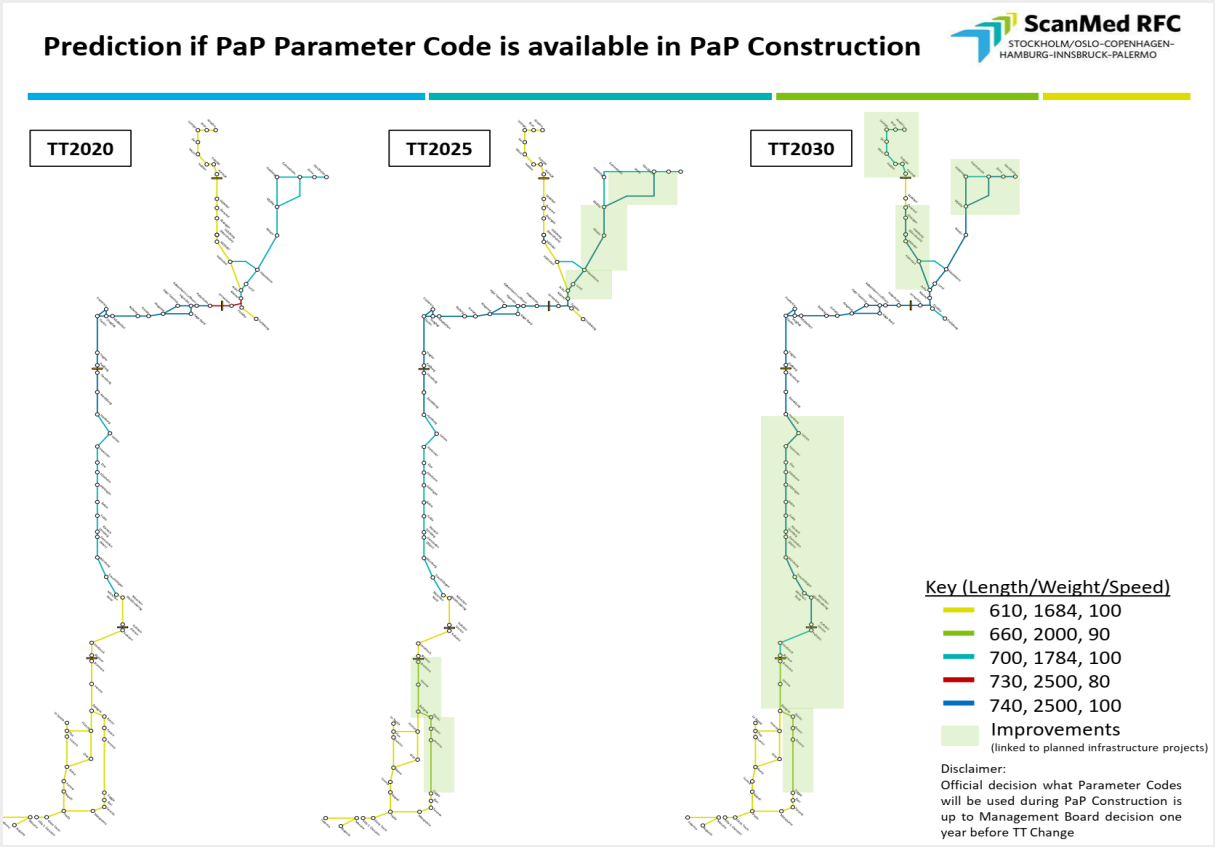
- **Restrictions for the train length (and/or weight) along the rail corridor/ route.** Even if this issue has not been analysed in the ILB study, it affects many RFCs on many sections, where different maximum train lengths and/or weights are permitted (e.g. [23]). One of the main strengths/benefits of rail compared to road (and/or air), is the capacity to transport high quantity of goods/passenger with a single train (see Figure 2), reducing thus the environmental and economic effort per tonne-km or passenger-km. Longer and heavier freight trains could help in achieving climate goals, to have a better profitability and to possibly reduce capacity constraints (by reducing the number of trains). The recent (2021) Freight Traffic Study commissioned by the Brenner Corridor platform [21], for example, estimated an average cost reduction on that corridor for an increase in train length from 18 up to 21 wagons/train (i.e. from 569 metres to 639 metres) equal to -14% for the fixed transport costs (shunting and train preparation) and -12% for the hourly operating costs (which is indicated as the main cost component). Anyway, long (and heavy) trains may need to be split and, in some cases, also reordered along the routes due to limitations in train lengths and weights (e.g. see the example of the line from Vidin to Sofia reported in the next box 'Rail connection Vidin – Craiova through the New Europe Bridge'). It is assumed that, similarly to other issues analysed in the ILB, 75 minutes[6] are needed on average to split/reshuffle the train and that this problem affects a proportion of trains within the section depending on the differences/limitations in lengths and weights along the interested corridor. The recent study on Longer & Heavier Trains for the ScanMed RFC [23] indicated that (in 2020) only the Danish part of ScanMed RFC's network and some of the Norwegian, Swedish and Austrian parts were compatible with the TEN-T requirement of 740 meters, even if freight trains up to 740 meters should be able to run on most parts of the corridor by 2030 (see figure below). As regards axle load, most parts of the corridor already corresponded to the TEN-T requirement ≥ 22.5 t/axle, that could be fully achieved by 2030. The study estimated that infrastructure improvements will impact the predicted Pre-arranged Paths (PaPs) on several origin/destination relations, with an increase, for example, from 16 to 40 PaPs between Hallsberg/Katrineholm-Malmö and from 24 to 32 PaPs between Malmö-Maschen in 2030 [23].

**Table 2**: Parameters for the Brenner Routing (source [22])

| IM | Validity Check in Dossier | Train Length | Weight of Set of Carriages |
|---|---|---|---|
| RFI Brennero (ITA) – Verona (ITA) | 03RFI01 | 600 | 1600 |
| | 03RFI02 | 500 | 1300 |
| | 03RFI03 | 490 | 1100 |
| | 03RFI04 | 600 | 1200 |
| | 03RFI06 | 490 | 1300 |
| ÖBB Infra Kufstein (AUT) – Brenner (AUT) | 03OBB01 | 600 | 1600 |
| | 03OBB02 | 600 | 1300 |
| | 03OBB03 | 600 | 1300 |
| | 03OBB04 | 490 | 1350 |
| | 03OBB05 | 490 | 1350 |
| DB Netz München/ Trudering (GER) – Kufstein (AUT) | 03DB01 | 600 | 1600 |
| | 03DB02 | 600 | 1200 |
| | 03DB04 | 600 | 700 |
| | 03DB11 | 690 | 1600 |
| | 03DB12 | 690 | 1530 |
| | 03DB13 | 690 | 1590 |

6 75 minutes as a result of 60 minutes for the train to be split and/or the wagons to be reordered and another 15 minutes of waiting for the shunting service to occur.

**Figure 4:** Infrastructure improvements by 2030 - ScanMed RFC, source [23]



**Heavier, faster and more reliable trains on the Rail Freight Corridor Rhine-Alpine (RFC RALP) [24]**

A recent study [24] analysed the potential for rail modal shift linked to possible enhancements in terms of heavier, faster and more reliable trains along the RFC RALP.

Heavier trains and permitting 740m-long trains on the whole corridor would make rail freight services more competitive, with the main challenge represented by the topographical limitation in Switzerland and the 1,600 tonnes weight limitation in Italy. Despite the improvement linked to the base tunnels built along the corridor (in Switzerland), the topography poses some limitations given that slopes on Alpine sections limit the maximum train weight (since limits on train weight are function of the speed, gradient and traction power of the locomotives). A workaround already in use is the deployment of additional locomotive(s) when needed; however, this requires additional shunting operations for adding/removing locomotives and extra operating costs which may compromise the competitiveness of rail services when compared with the road.

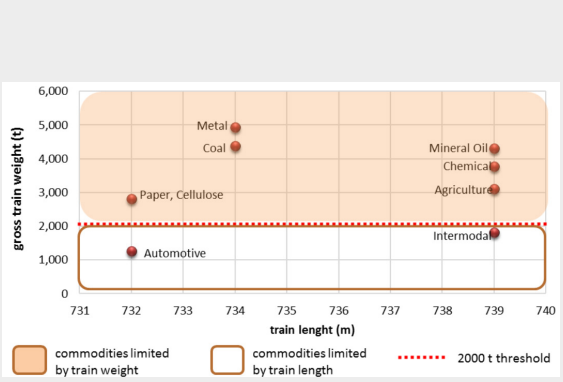
While introducing heavier and longer trains would require a check of the railway network infrastructure (e.g. bridges) and changes to national regulations (e.g. in Italy), running faster trains is also a result of the timetable planning process; allocation of capacity between passenger and freight transport can represent a challenge (especially in the proximity of urban nodes and in some congested sections).

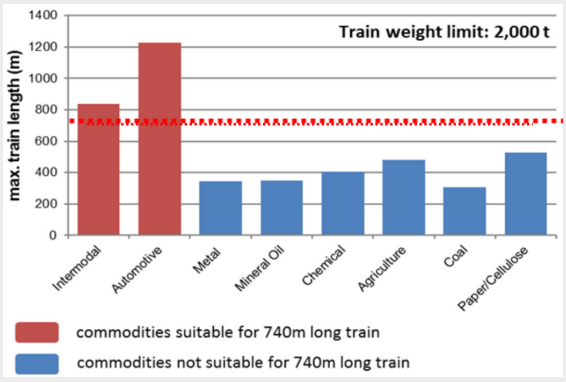
Additional constraints in reaching the faster train target can be found in operational issues. The RUs (interviewed during the study) pointed out that stops due to the change of locomotives and adding supplementary traction are a result of infrastructure constraints and interoperability conditions; stops at handover points due to lack of interoperability among the national rail networks are quite frequent along the RFC RALP, even if positive examples exist as well, such as between Zevenaar and Emmerich where no stop is needed to cross the border section between Germany and the Netherlands.

Regarding the relationship between reliability and attractiveness of the rail freight service, the interviewed stakeholders indicated that the current low level of reliability discourages part of the market to use the railways not only on the RFC RALP but also on all those routes where road transport offers faster and more reliable connections. The study indicates that reliability could be improved with better management of operational issues, which requires cooperation between different IMs and RUs, improved interoperability and a clear allocation of traffic priorities (between intercity, regional and freight trains).

The second issue linked to the reliability of rail freight services concerned the promptness in getting information about delays when they occur (availability during the journey of reliable information on estimated time of arrival).

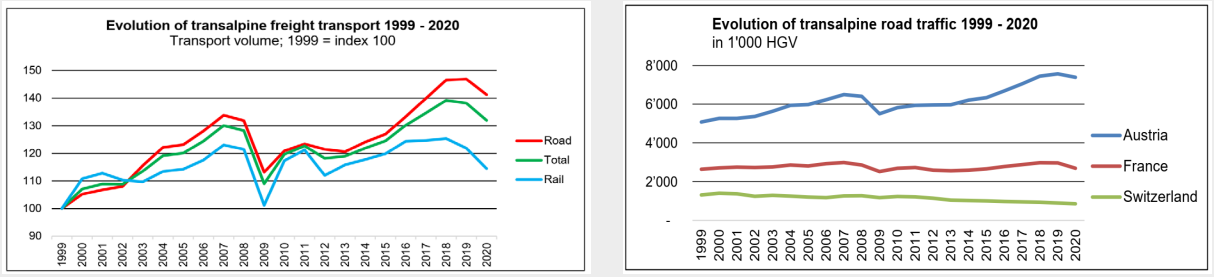
**Figure 5:** Gross weight for 740-metre-long trains (left) and maximum length of trains assuming a weight limit of 2,000 tonnes (right), per commodity group - section Basel-Genoa (with 1 locomotive); source [24]



Regarding traffic volumes[7] for the analysed section, a significant proportion of international goods transport between northern and southern Europe goes over Swiss alpine passes. In 2020 and 2019, over 200 million tonnes of goods (respectively 211.9 and 223.5) were carried each year across the Alps; around 70% of the total amount was carried by road and the remaining 30% by rail. The large majority of road freight crossed the Alps in Austria (over 60%).

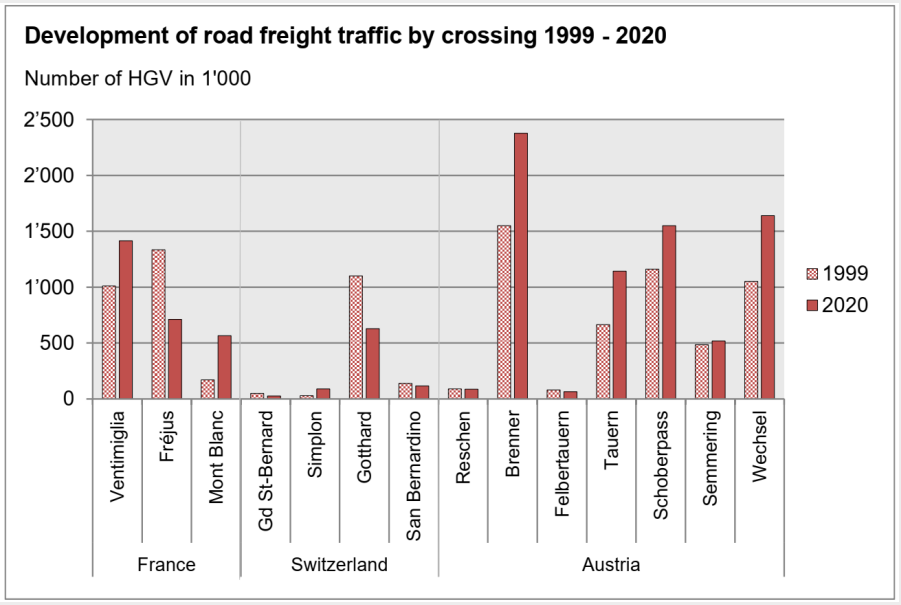
**Figure 6:** Evolution of transalpine freight transport, source [11]




The development of transalpine road traffic in Austria is characterised by consistent growth, which has only been interrupted twice: between 2007 and 2009 (economic crisis) and since 2019 (Covid-19 pandemic). In 2020, the number of goods vehicles crossing the Alps in Austria (i.e. 7.4 million) was slightly below the record level of 2019. The volume of goods transported had increased by +73% compared to 1999.

The important crossings in Austria all show increases compared to 1999. The Brenner remains the most important passage; it registered in 2020 a small reduction in the number of HGV crossing, after the record in 2019 with more than 2.5 million goods vehicles.

**Figure 7:** Road freight traffic by crossing section, source [11]

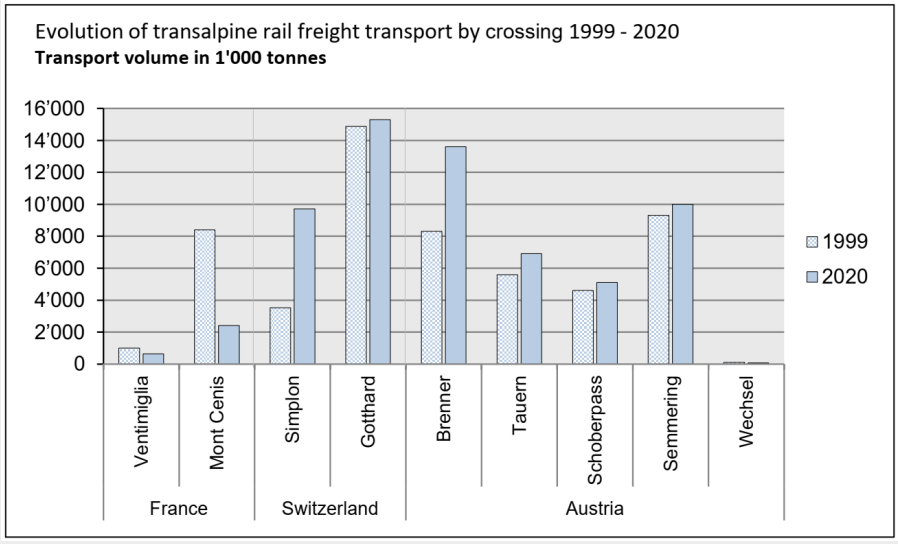



7 See for example [11] ('Observation et analyse des flux de transports de marchandises transalpins: Rapport annuel 2020') and the Swiss Federal statistical Office

The modal split of transalpine traffic (and its evolution since 1999) varies significantly from one country to another. In the Swiss Alpine crossings the share of rail traffic increased slightly (71.8%) in 2020 compared to 1999 (68.7%) and it went even more up in the first half of 2021 (74,4%)[8]. Despite between 2003 and 2019 Austria managed a change in modal split from road to rail [5], the trend for the transalpine traffic is the opposite: in 2020 the share of rail was 26.3% (27% in 2019) while in 1999 it was 32.2% [11]. In France, the share of transalpine rail transport has fallen even more sharply from 19.9% (in 1999) to 7.4% (in 2020) [11].

Overall, the volume of goods transported by rail across the Alps has increased by +14% between 1999 and 2020, while in Austria it increased by +28% within the same period. With the exception of the Semmering and the Schoberpass, which show only little change compared to 1999 (+8% and +11% respectively), the major rail crossings in Austria exhibit considerable growth rates: +23% at the Tauern and +64% at the Brenner.

**Figure 8:** Evolution of transalpine rail freight transport by crossing, source [11]




Focusing more on the Brenner Corridor, as indicated in [21], the number of freight trains varies during the year and during the week, with no particular asymmetries in the two directions (even though the gradient conditions of the line are different). The tables and the graphs below show the rail volumes on the relevant sections of the Brenner Corridor in 2016, by train type and by traffic components (WL=Wagonload traffic, UCT= Unaccompanied Combined Transport, ACT=Accompanied Combined Transport).

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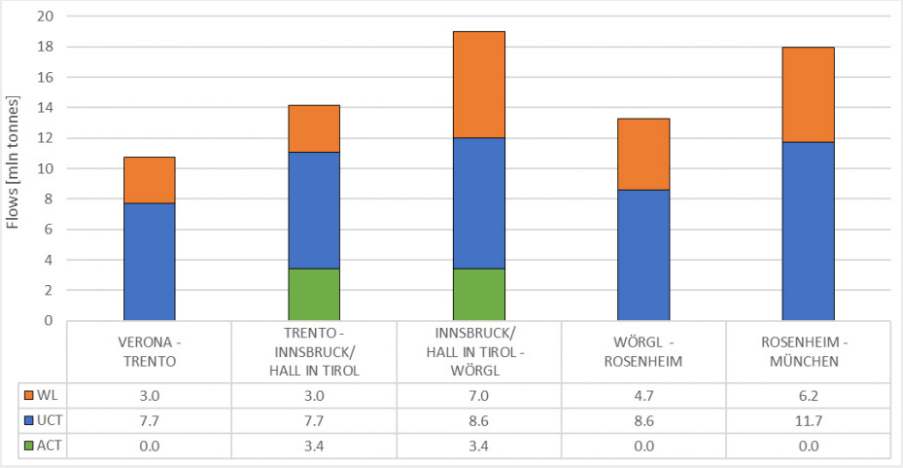
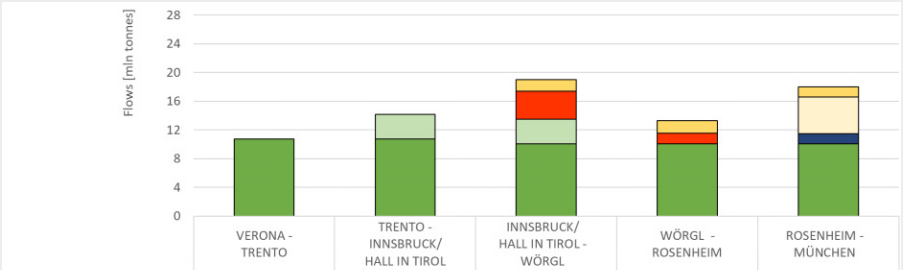
**Figure 9:** Annual freight transport flows on the Brenner Corridor in 2016 by train type, source [21]



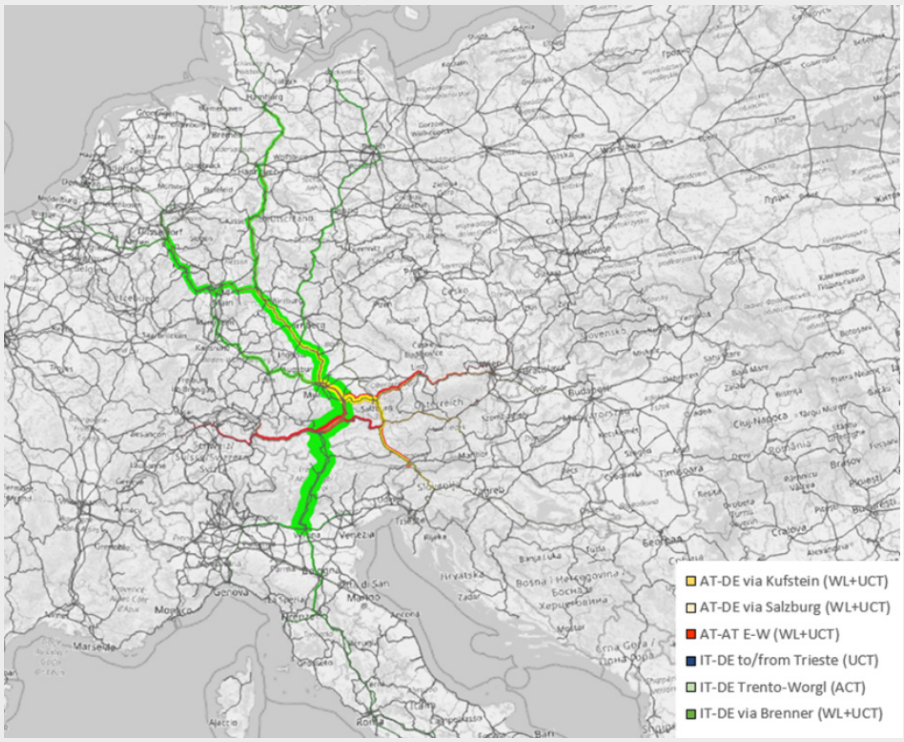

| | VERONA - TRENTO | TRENTO - INNSBRUCK/ HALL IN TIROL | INNSBRUCK/ HALL IN TIROL - WÖRGL | WÖRGL - ROSENHEIM | ROSENHEIM - MÜNCHEN |
|---|---|---|---|---|---|
| WL | 3.0 | 3.0 | 7.0 | 4.7 | 6.2 |
| UCT | 7.7 | 7.7 | 8.6 | 8.6 | 11.7 |
| ACT | 0.0 | 3.4 | 3.4 | 0.0 | 0.0 |

**Figure 10:** Rail volumes by traffic components in 2016, source [21]




| | VERONA - TRENTO | TRENTO - INNSBRUCK/ HALL IN TIROL | INNSBRUCK/ HALL IN TIROL - WÖRGL | WÖRGL - ROSENHEIM | ROSENHEIM - MÜNCHEN |
|---|---|---|---|---|---|
| AT-DE via Kufstein (WL+UCT) | 0.0 | 0.0 | 1.6 | 1.7 | 1.4 |
| AT-DE via Salzburg (WL+UCT) | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 |
| AT-AT E-W (WL+UCT) | 0.0 | 0.0 | 3.9 | 1.5 | 0.0 |
| IT-DE to/from Trieste (UCT) | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 |
| IT-DE Trento-Worgl (ACT) | 0.0 | 3.4 | 3.4 | 0.0 | 0.0 |
| IT-DE via Brenner (WL+UCT) | 10.7 | 10.7 | 10.1 | 10.1 | 10.0 |

**Figure 11:** Rail volumes in 2016, source [21]




### 2.2.2. Rail freight connection Giurgiu Nord (Romania)- Ruse Razpredel (Bulgaria)

The Ruse district is located in the northern part of Bulgaria, at the border with Romania along the Danube river; its specific geographic location has created favourable conditions for its development. The region has an important role in several different spheres, e.g. transport, economics, logistics, culture, etc.

The distance between the city of Ruse and the city of Giurgiu (located in the southern part of the Romania) is about 13 km and this proximity creates very good conditions for cross-border activities and partnership establishment in different development spheres aimed to increase economic, social and territorial cohesion between both countries. The transport connection between both cities is carried out through road and railway transport.

In particular, the Danube Bridge connects the Bulgarian city of Ruse with the Romanian city of Giurgiu since its opening in 1954; it is characterized by two lanes of road and single rail track. The last rehabilitation for the Bulgarian part of the bridge occurred in 2011. This bridge represents the first of the two bridges in Bulgaria crossing the Danube River; the second one, called "the New Europe Bridge", connects the cities of Vidin (Bulgaria) and Calafat (Romania) and it was officially opened in June 2013 (for more details, see next Box).

**Rail connection Vidin (Bulgaria) – Craiova (Romania) through the New Europe Bridge (source [2])**

The second bridge connecting Romania and Bulgaria is the New Europe Bridge, which is part of Pan-European Corridor IV, a transport route that connects Dresden with Istanbul and Thessaloniki. The new bridge (informally called the Vidin-Calafat Bridge) has a four-lane highway, railway track, bike paths and pedestrian lanes. Vidin is a port on the southern bank of the Danube in north-western Bulgaria, in one of the poorest regions in the EU. Calafat is a small, quiet Danube port near Craiova. Officially opened on 14 June 2013, it is the second bridge on the Danube between the two countries and was partially financed by the European Union as part of the TEN-T network.

Until construction of the bridge, the Danube River was regularly crossed by only a ferry service for road and rail transport, with two ferries running all day between Vidin and Calafat. However, this service could not deal with transport needs between Romania and Bulgaria and more remote countries. Crossing the Danube by ferry was a time-consuming process, mainly because of the long waiting times. Without considering waiting time, crossing the Danube took between 30 and 45 minutes. Generally, the waiting time to board the ferry could be up to 5 or 6 hours. About one month after the bridge opened the ferry between Vidin and Calafat was suspended.

The main target group for the Craiova-Vidin rail connection is cross-border freight traffic between Romania and Bulgaria. There are up to 14 freight operators in the cross-border region with high demand from local businesses to improve the national railway service. Demand is mainly from car manufacturers in Romania, such as Renault and Ford, but also for farm products (mainly cereals). Passengers on the service are a mix of commuters and tourists, though very few commuters use the line since border control makes it difficult to commute for work abroad (neither Bulgaria nor Romania are part of the Schengen Area). For the time being, the rail service is considered sufficient by the operator. However, to make a difference in the region, also in terms of modal shift, more trains are needed. This can only happen with better connections between the Danube bridge and national railway networks.

While the bridge itself has been built, Romanian authorities have kept postponing modernisation of the rail link that connects the bridge to the main railway network. This is a 95 km section that connects Golenți station which is the terminus of the newly built railway link to the bridge 5 km away, and Craiova which is in an advanced state of degradation and has no ERTMS and electrification. On a 58 km section of this line, trains are limited to 30 km/hour, due to the extremely poor condition of the infrastructure. On the other 38 km, the maximum speed is 70 km/hour. Signing the technical project and execution of rehabilitation works was scheduled for the beginning of 2023, if financing is guaranteed.

Given the current state of the railway line, the average number of trains transiting the New Europe Bridge on a daily basis is extremely low. Bad access links hamper the efficiency of the Danube bridge, including for freight companies. While they gain time crossing the bridge, they are then confronted with major bottlenecks due to poor national infrastructure.

For example, even if the railway line is electrified from Vidin to Sofia, due to weight restrictions, freight trains must be 'split' in two to continue their trip. Furthermore, ERTMS is not implemented; this creates major obstacles to the cross-border service, especially regarding the frequency of trains.

The situation is unlikely to change in the short term due to financial constraints, worsened by the pandemic. The Danube bridge cannot be a solution working on its own, but it needs the links leading to this bridge to complete the line.

The Danube is the second longest river in Europe running through the territory of Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Bulgaria, Moldova and Ukraine. The Port of Ruse is the biggest Bulgarian port on the Danube River with a crucial role in the national transport system. The port represents an important multimodal transport centre, connecting inland waterways, with the national rail and road network.

Two Pan-European transport corridors (7 and 9) interest the Ruse district; in particular the connection Giurgiu Nord (Romania) - Ruse Razpredel (Bulgaria) is part of the RFC 7.

In May 2002 the Regional Administration Ruse and Giurgiu County Council established the Danubius Euroregion, which joined the Association of European Border Regions (AEBR) in 2005. In the European policy framework "Euroregion" is considered to be a structure of transnational cooperation between two or more territories located in different European countries. The need for cooperation of local authorities (cities, municipalities or group of municipalities) lead to the creation of associated regional groupings, which often exceed the limits of several administrative regions. The Euroregion framework has been created with the aim to promote cooperation in cross-border areas, to encourage common cross-border interests, to stimulate welfare of the border population and to balance the development on both sides of the border.

Euroregion Ruse-Giurgiu has an area of 517,8 $km^2$ and it includes the city of Ruse in Bulgaria and the city of Giurgiu in Romania, as well as other 13 settlements in the territorial scope of Ruse municipality. The greatest part of the Euroregion area is located in Bulgaria, specifically, 469,2 km2 (i.e. 90,6% of the total area) and the Romanian part represents 48,6 $km^2$ (i.e. 9,4% of the total area); 219,622 inhabitants lived within the Euroregion Ruse-Giurgiu in 2011, and 92% of them lived in urban areas. The most important cities are the cities of Ruse and Giurgiu.

To improve the transport accessibility both within Bulgaria and at cross-border level, one of the Bulgarian national priorities (reported also in the Euroregion Ruse-Giurgiu Operations –ERGO- Masterplan[9]) in the transport sector is to build a high-speed railway line between the cities of Ruse and Giurgiu which will pass through the Danube bridge; this will require the rehabilitation of the railway line of Ruse-Varna. The ultimate goal would be to have high-speed rail services along the route Bucharest-Giurgiu-Ruse-Varna, in order to improve transport accessibility.

Regarding the (technical and operational) barriers to interoperability hampering international rail freight traffic, the Issue Logbook study (ILB) indicated the following main issues for the cross-border section Giurgiu Nord-Ruse Razpredel:

9 https://obshtinaruse.bg/uploads/files/ERGO_Masterplan_EN.pdf

**Table 3**: Time and cost estimates for the main (technical and operational) issues according the ILB for the cross-border section Giurgiu Nord-Ruse Razpredel

| Issue | Annual number of trains concerned | Time loss per train | Annual hours saved | Cost per train | Annual costs [M€] |
|---|---|---|---|---|---|
| Train braking rules and documents (ILB issues 1 and 2) | 5232-5908 (100%) | 20 min | 1744-1969 | 64€ - 117€ | 0,34-0,69 |
| Technical checks at border stations and mandatory checks in MSs (ILB issues 8 and 9) | | 384 min | 33485-37811 | 405€ - 478€ | 2,12-2,81 |
| Real-time communication (ILB issues 15) | | 222 min | 19376-21880 | 254€ - 316€ | 1,33-1,87 |
| Working handbrake in the last wagon (ILB issue 5) | 2616-2954 (50%) | 45 min | 1962-2216 | 67€ - 120€ | 0,35-0,71 |
| No push 6 axles wagons (ILB issue 6) | 5232-5908 (100%) | 75 min | 6540-7385 | 116€ - 171€ | 0,61-1,01 |
| New train number (ILB issue 11) | 4186-4726 (80%) | 118 min | 8232-9294 | 134€ - 190€ | 0,70-1,13 |
| Two-people cabin crew (ILB issue 13) | N/A. Only total values per country are estimated | | | | |
| Cross border section not electrified (linked to ILB issue 14) | - | 120 min | - | - | - |
| Restrictions for the train length (and/or weight)* | - | 75 min | - | - | - |

* Authors' estimations (not included in the ILB, see below for more details)

- **Train braking rules and documents, i.e. braking sheets and braking performance (ILB issues 1 and 2)**. Considering the annual number of trains passing through the cross-border section Giurgiu Nord - Ruse Razpredel (variable between 5232 and 5908), by solving these issues the ILB estimates between 1744 and 1969 hours saved every year, with a total annual saving variable from 0,34 M€ up to 0,69 M€ (i.e. average cost impact per train between 64€ and 117€). The application of the recent AMOC on checks and tests before departure, including brakes and checks during operation[3], may help in solving these issues.
- **Technical checks at border stations and mandatory checks in Member States (ILB issues 8 and 9)**. According to the ILB, Romania is one of the most affected countries. Regulation n. 250[10] imposes technical checks both after arrival and prior to departure at border stations whenever trains experience a waiting time of 6 to 8 hours at the station. In addition, there is another regulation in Romania requiring wagon technical checks every 350km. The ILB estimates an additional waiting time at the border in Romania of 384 minutes[11], with all crossing trains affected; this leads, for the section under analysis, to a range of 33485-37811 hours saved by solving these problems, with a total economic impact per year varying between 2,12M€ and 2,81M€ (i.e. average cost impact per train variable between 405€ and 475€). Again, AMOC[3] application may help in solving these issues.
- **Real time communication (ILB issues 15)**. The ILB estimates that 222 minutes per train could be saved in RFC7, with all the trains crossing the identified borders affected. With these hypotheses, by solving these issues on the section Giurgiu Nord - Ruse Razpredel, the ILB study estimates between 19376 and 21880 hours saved annually, with economic savings variable between 1,33M€ and 1,87M€ (and average cost impact per train variable between 254€ and 316€).

10 Ordinul nr. 1817/2005 pentru aprobarea Instrucţiunilor privind revizia tehnică şi întreţinerea vagoanelor în exploatare nr. 250 (available here)

11 Technical check of 7 hours and additional 1,4 hours waiting for the border police. Given that the Orient East-Med RFC is implementing a minimum required time for technical checks of 2 hours, those two are then excluded from the analysis. This means that by solving the issues a time loss of 6,4 hours is assumed for all Romanian borders (instead of the total 8,4 hours).

- **Train composition - Working handbrake in the last wagon (ILB issue 5)**. This specific issue concerns the requirement that the last wagon of a train is equipped with a handbrake. Nevertheless, a working handbrake for the last wagon is not required in any TSI Regulation (nor in the UIC leaflet or as part of other standards). Moreover, requirements are not harmonised across Member States, with some countries even requiring a minimum of 2 wagons with a working handbrake. In case that the last wagon of an international train – entering a country or network with such regulation – is not equipped with a handbrake, this requirement might lead to unnecessary shunting at border stations. The ILB reports that national regulations in Romania establish that all trains in the country must have an active handbrake in the last wagon. The cross-border points between Lőkösháza (RO)/Curtici (HU) and Ruse (BG)/Giurgiu Nord (RO) are indicated as being the most problematic. The ILB estimates that 50% of the trains are affected by the issue and that every train loses a total of 45 minutes[12]. The total economic impacts expected from solving the issue on the section Ruse - Giurgiu Nord vary between 0,349 M€ and 0,707 M€ (with total hours saved annually variable between 1962 and 2216, and average cost impact per train between 67€ and 120€).
- **Train composition - No push 6 axles wagons (ILB issue 6)**. This issue is a result of legislative or internal company rules which forbid 6-axle wagons, even if the manufacturer's specifications state otherwise. In this case, unnecessary shunting at border stations is required. The issue affects a small group of railway undertakings which run very long-distance trains. Different rules for 6-axle wagons occur particularly in the high mountain areas. The ILB indicates that this issue is most severely observed in the mountainous areas of Romania and that it is especially relevant for transit traffic from/to Turkey, as this traffic predominantly consists of intermodal trains. The ILB assumes for the affected cross-border sections an additional time of 75 minutes[13] per train (for all the crossing trains). With these assumptions, by solving the issue on the section Giurgiu Nord - Ruse Razpredel the ILB study estimates between 6540 and 7385 hours saved annually, with economic savings variable between 0,606 M€ and 1,01 M€ (i.e. average cost impact per train variable between 116€ and 171€).
- **New train number (ILB issue 11)**. For the section (Giurgiu-Ruse), the ILB study estimates that between 8232 and 9294 hours could be saved annually by solving this issue, with economic savings variable between 0,701M€ and 1,13M€ (i.e. with an average cost impact per train variable between 134€ and 190€).
- **Two-people cabin crew (ILB issue 13)**. For Romania, on average staff costs are reported to represent about 20% of the total operational costs; within staff costs, train drivers represent about 41% of the total. By solving this issue the ILB study estimates yearly savings variable between 2,07M€ and 2,27M€ for Bulgaria (with more than 5000 trains affected in 2019), and between 9,71M€ and 10,10M€ for Romania (with around 24000 trains affected in 2019).
- **Cross border section not electrified (linked to ILB issue 14).** For the section Giurgiu Nord – Ruse, since the cross-border section is not electrified, a possible time saving of 120 minutes (as indicated by the ILB) is not on commutable power supply but rather for shunting manoeuvres to changes of electric traction to/from diesel (on both Romanian and Bulgarian sides, despite the similar electrification standards).
- **Restrictions for the train length (and/or weight) along the rail corridor/route.** As reported for the previous freight case study, even if this issue has not been analysed in detail in the ILB study, it is assumed that 75 minutes (see footnote 13) are needed on average to split/reorder a train and that this problem affects a percentage of trains within the section depending on the differences/limitations in lengths and weights along the interested corridor.

12 45 minutes as a result of 30 minutes for the wagon to be reordered (assuming a 600m train, wagon from middle to end, the shunting loco approach and coupling) and another 15 minutes of waiting for the shunting service to occur.

13 60 minutes for the train to be split and 15 minutes for the shunting service

## Potential modal shift for the analysed freight corridors

As indicated in many studies (e.g. [5], [13], [15], [18]) cost/price represents the main/core decision criteria towards modal choice of transportation; other important factors are largely related to overall time of travel, frequency and reliability/delays. There is abundant (scientific) literature analysing through elasticities how demand for each mode of transport is impacted by various factors (e.g. [5], [13], [14], [15], [24], [25], [27], [28]). Own (price) elasticities express the changes in demand for a transport mode (e.g. road transport) if the price of that mode changes, while cross-elasticities indicate the changes in demand for a transport mode (e.g. road transport) if the price of another transport mode (e.g. rail transport) changes.

It is important to note that elasticities differ per country, commodity, market structure and transport volumes, so they cannot always easily be compared or generalised. In our analysis, such generalisation is even more difficult, since the freight traffic concerns several European Member States along the RFCs.

As reported in [5], for example, there is a tendency for rail elasticities to be higher than elasticities for road freight transport (for which many cases of inelastic demand are reported). Road transport demand appears to be more price sensitive on longer distances and for heavy bulk goods, whereas rail and waterborne transport appear to be more price sensitive on shorter distances and for time-sensitive goods, such as agricultural products and food.

Cross-price elasticities have lower absolute values than own-price elasticities. This means that the demand for a transport mode tends to respond more to a percentage change in its own price than to the same percentage change in the price of a competing mode. However, there are differences between transport modes. The demand for rail, inland waterway transport and coastal shipping are relatively responsive to changes in the price associated with road transport. This is not the case the other way around: the demand for road transport is less sensitive to the cost of the alternative freight transport modes (a possible explanation being that trucks are considered to have a comparative advantage in service quality that is sufficiently high to off-set some price cuts of competing modes) [14].

Rapid transit times are of importance for shippers of time-sensitive goods. These goods are often transported by the more rapid transport modes, such as aviation and road transport. Rail transport and sea transport are generally slower transport modes, used for goods that are less time-sensitive. However, much depends on local circumstances. For the shorter distances, intermodal transport is often not competitive due to considerably longer transit times in comparison to road transport. Investments in infrastructure and intermodal capacity can help in reducing that gap in attractiveness.

Also poor reliability of rail transport is often cited as one of the factors hampering a more tangible modal shift towards rail. Time losses mean increased costs for RUs as well as for the market as a whole, and a reduction in delays may result in a reduction in overall transport costs. Within a survey carried out for the Transport Market Study of the Rhine-Alpine RFC [24], for example, a pool of industries, logistics operators and freight forwarders indicated the lack of punctuality (41%) as the primary issue discouraging the companies from using railway services, followed by the incompatibility with just-in-time production (32%). Intermodal transport is the segment most sensitive to changes in transport reliability as it directly competes with road transport where the logistics chain is simpler due to reduced handling operations and provision of door-to-door services. The main advantages of road transport are related to the reduced number of actors overseeing transport operations and to its flexibility that facilitates better reliability [24].

The own-elasticities are interpreted as the effect on mode substitution holding total transport demand constant. As mentioned, they reflect the changes in demand for that transport mode if one of its own attributes (e.g. transport time, costs, reliability) changes. Since from the analyses above we have evaluated the possible time savings per train by eliminating the technical and operational barriers in the cross-border sections, we will

focus mainly on demand elasticities for rail freight and for transport time. As there is only a limited number of studies expressing these service attributes into elasticities, the results should be interpreted with caution. In addition, as already mentioned, it should be kept in mind that the removal of technical and operational barriers represents a possible contributing factor to the increase of demand and modal share, but it is not the only one nor a sufficient factor.

Based on the estimates found in the literature, [5] and [14] provide a range varying from -0.1 to -1.3 for the time elasticity of rail freight transport; the values are negative, which means that the demand for rail freight decreases when its transport time increases. Also Jourquin and Beuthe (2019) [28] performed a pan-European study on elasticities using ETISplus data, suggesting an overall transit time elasticity of -1.05. For the analysis and the figure below we considered an average time elasticity variable between -0.7 and -1 (relative inelastic and probably conservative values).

Various studies also focused on rail demand elasticities linked to reliability. [27] for example used a rich data set on long-distance freight trains in Norway to estimate the effect of variation in train unreliability over time on transport demand; a drop in demand of about 3% was observed following a 10% increase in the risk of a long delay (one hour or more). [5], instead, indicated a range between -0.1 and -0.4 from the literature for elasticities for reliability (delay time) (focusing on rail freight transport).

Regarding the two presented case studies for the cross-border rail freight transport, the analyses above indicate possible time savings (neglecting the disruptions deriving from the two-cabin crew requirements and any other issue not fully analysed) varying from:

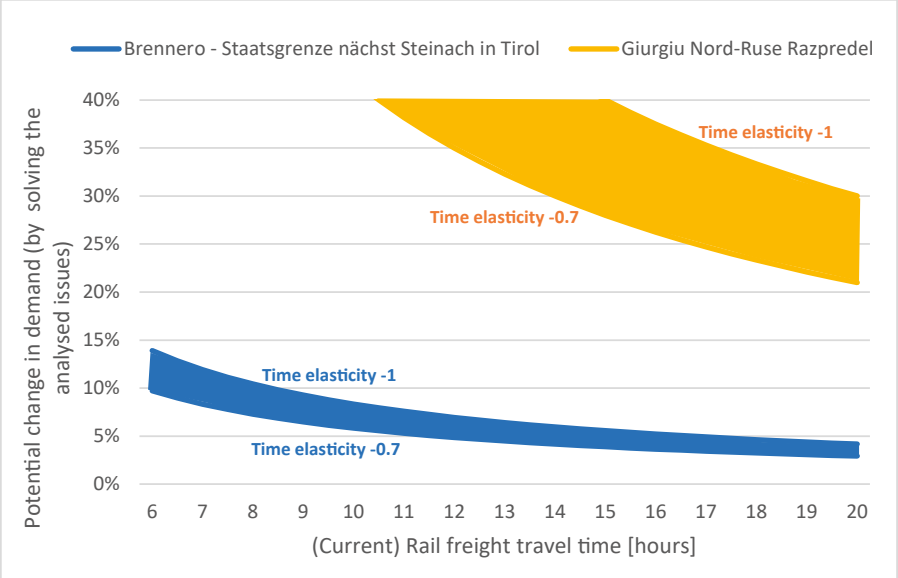
- a minimum of 50 minutes (20+30[14]) for all trains up to around 2 hours[15] in the worst and extreme cases for the cross-border section Brennero - Staatsgrenze nächst Steinach in Tirol. For the calculations below we assumed the conservative value of 50 minutes[16] for all trains by eliminating the technical and operational barriers. In addition, by improving train running information, the ILB evaluates a possible reduction of 116 minutes of delays per train on average.
- a minimum of 384[17] minutes for all trains up to 8- 9 hours[15] in the worst and extreme cases for the cross-border section Giurgiu Nord-Ruse Razpredel. For our calculation we assumed the conservative value of 6 hours for all trains by eliminating the technical and operational barriers. In addition, by improving train running information, the ILB evaluates a possible reduction of 222 minutes of delays per train on average.

Based on the information reported above, the following graph provides a rough estimation of possible changes in demand per duration (length in hours) of the (hypothetical) rail freight transport services/connections; it is worth to remind that the resolution of the technical and operational issues indicated for each cross border section analysed can partially contribute to the increase of rail demand and modal share in conjunctions with other factors/measures. The results provided below should be considered as very indicative, and definitively not as a precise evaluation of automatic consequences of eliminating technical and operational barriers.

The durations of the rail trip reported on the x-axis refer to the current freight travel time (without solving the issues). For a current trip of 10 hours, taking in account the estimated lost time, the future travel time is assumed equal to 600-50=510 minutes for freight trains running through the Brennero - Staatsgrenze nächst Steinach in Tirol section, and 10-6=4 hours along the Giurgiu Nord-Ruse Razpredel route. This means that it is assumed a travel time decrease of 8.33%, (i.e. 50/600) in the first case and 60% (i.e. 360/600) for the latter.

14 It is assumed that some operations can be performed in parallel.
15 Some operations can be performed in parallel.
16 Which seems consistent with the data in the ScanMed RFC Border Crossing Dwelling Time Report (available here), reporting (for week 38 of 2019) at Brenner an average schedule time of 65 minutes and an average real time of 40 minutes.
17 It is assumed that the technical and mandatory checks at border (384 min) directly include the waiting time for train braking rules and documents (i.e. 20 min) (i.e. operations may take place in parallel)

**Figure 12:** Potential change in travel demand by solving the issues on the analysed sections, per (current) duration of rail freight transport (range of time elasticity between -0.7 and -1)




The figure refers to the travel time and not to the kilometres travelled. For a possible conversion, it should be taken in account that, as indicated in the paragraphs above, the average speed of rail freight (especially in the proximity of the analysed sections) is relatively low (for the geographical situation, i.e. gradients and hill in the Alps, and for the rail infrastructure conditions in Bulgaria and Romania). For example, the RNE KPIs indicate an average commercial speed for the Pre-Arranged Paths between Munich and Verona (446.6 km) of around 52 km/h[18] and of 28 km/h between Craiova - Svilengrad via Ruse (787.8 km)[19]

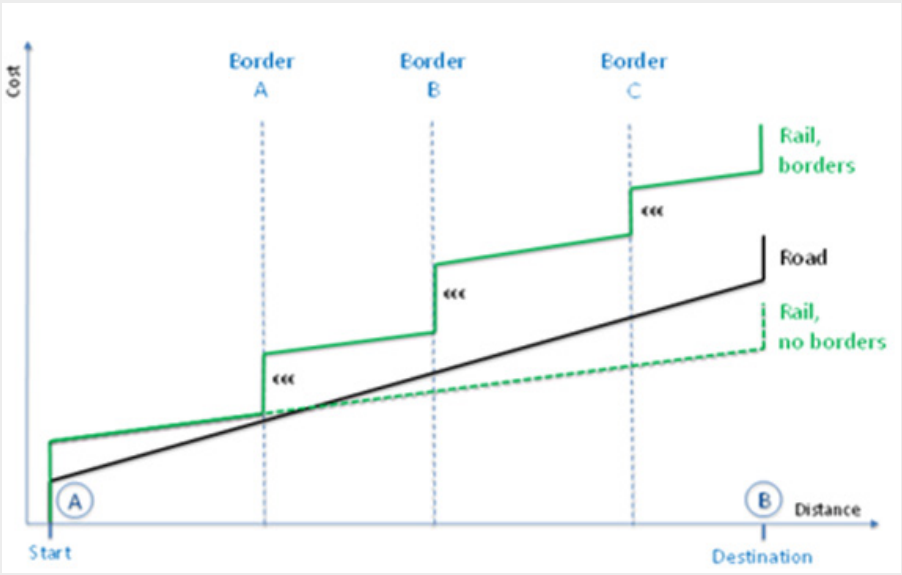
It is important to underline that the results presented in the figure above should be handled with substantial caution and should be considered only as a rough indication, given that:

- The time savings are based on the ILB study, which presents (for several sections) estimations based not always on information related to the specific cross-border, but averaged on the data/information available; moreover our calculation has made further assumptions/averages on those values.
- An analysis based only on time elasticities is surely not exhaustive and has various drawbacks. Several contributing factors together (more than single solutions/measures) influence rail demand and modal share. The removal of technical and operational barriers at cross-border points may have positive effects on the attractiveness and competitiveness of rail, but if considered/implemented alone, those effects could be limited by other factors/constraints.
- The value assumed for rail time elasticity is a rough/average value based on the available literature review, and not a value estimated for the specific sections/corridors (based on their geographical and socio-economical situations). The possible impacts of time reductions on rail demand are in general context-dependent. The estimation of increase in demand does not consider/explore in detail if indeed the additional potential demand is available, based on the geographical and socio-economical characteristics of the area (even if this seems to be the case for the two considered cross-border sections, see for example [21] for the Brenner Corridor).

18 See https://rne.eu/wp-content/uploads/RFC3-June-2022.pdf
19 See https://rne.eu/wp-content/uploads/RFC7-June-2022.pdf

- RUs may have operational stops for crew change and other commercial aspects that are done at borders for organisational issues, possibly unrelated to interoperability barriers (i.e. dwell time at BCPs may also be linked to commercial decisions and not only to technical/operational barriers).
- For long-distance transport, the freight train may cross additional borders, with additional time savings (see example in the next figure); the estimations above focus instead only on the reduction of time derived by solving the issues on the two analysed sections.

**Figure 13:** Example of multiple time savings at different borders.




## 2.3. Cross-border passenger transport

While there is some evidence in the literature that high speed railway (HSR) has contributed to modal shift to a certain degree on various routes (see also the next HS section/paragraph), in general, the lack of data for passenger transport (especially short and medium range) does not allow a well-informed understanding of the state of play in relation to modal shift, at least from road to rail. Thus, the selection of the case studies for cross border passenger services has been driven mainly by data availability (and secondly by the relevance of the specific issues). In addition, a more qualitative analysis has been carried out and is presented below.

Based mainly on [2] (from where the information on the cases studies has been extracted), the next paragraphs focus on the rail (passenger) connections:

- Vienna (Austria) – Győr (Hungary)
- Berlin (Germany) and Kostrzyn (Poland)

### 2.3.1. Rail passenger connection Vienna (Austria) – Győr (Hungary)

The rail transport service Wien Hauptbahnhof – Győr connects the Austrian capital Vienna with a regional centre in Hungary, and in a broader context it is part of the Vienna–Budapest route.

Győr is a city of 134,000 inhabitants, the 6th largest city in Hungary and the biggest in Western Transdanubia; it belongs to the fastest growing parts of Hungary.

The two cities are 111 km away from each other by train, with journey time usually of about an hour and a half (i.e. competitive with private transport). The railway service is a key element of the strong cross-border mobility in this area, with a significant and growing market demand.

Győr is located in a very advantageous position, with railway connections also to Bratislava (and so close and connected to two foreign capitals). The Vienna-Györ passenger train is one of several trains in the Vienna-Bratislava-Győr area ('the golden triangle' region), densely populated and with fast-growing industrial and service sector.

The train is the most frequent cross-border service in Hungary with 20 trains a day between Vienna and Győr. Five regional trains terminate in Győr, while the rest are long-distance trains (operated either by the Hungarian or Austrian state railways) between Budapest and Vienna or beyond, but all with a stop in Győr. To the west there are direct rail connections to Salzburg, Innsbruck, Munich, Frankfurt and Zurich, while to the east to Bucharest, Cluj Napoca, Baia Mare (Romania) and Záhony via Ukraine (Kiev). The famous Orient Express route between Paris and Istanbul followed this line.

This railway line is part of the Orient/East-Med Corridor (part of the Trans-European Transport Network), which connects the North Sea (Hamburg) with the Black Sea (Burgas) or Aegean Sea (Athens, Piraeus). In Hungary, this railway line has undergone significant developments, reaching a travel speed of 140-160 km/h.

Since EU accession commuters from Hungary work in Austria; most commuting takes place on a weekly or monthly basis, but daily commuting has also become more common in the past ten years (centred on Vienna). The target group of the rail service is very large and constantly growing, as the Budapest-Vienna axis is a beneficiary of demographic tendencies in Hungary. According to [2], ticket sales have seen a 93% increase in the last ten years until 2019, while annual number of passengers reached 1,275,000 in that year (2019).

Considering both long-distance and regional trains, there is a service every hour between Vienna and Győr, and in peak periods of the day even every half an hour, which is nearly the maximum capacity of the current infrastructure.

The service has changed the border area significantly; cross-border mobility has become widely used, also for people without a car. This has resulted in a growing property demand in Western Hungary, which provides good access to the Austrian labour market, with Győr and surrounding area becoming the second most developed part of Hungary (after Budapest) and the fastest-growing area.

Despite the area has a long history of cross-border railway services (due to the history of cooperation between Austria and Hungary), the train control system and the traction voltage differs slightly between the two countries entailing a stop at the border to change parameters. Practically, due to interoperability issues, trains stop at the border crossing point at Hegyeshalom in order to change technical parameters of the locomotives and staff. This causes an additional 10-15 minutes in the journey time, affecting negatively the competitiveness compared to road services (e.g. Flixbus, minivans).

Although the border between Vienna and Győr is very permeable with good technical conditions, the additional 10-15 minutes on a journey time of 70–115 minutes may be

crucial to daily commuters, significantly decreasing the attractiveness of rail compared to road transport.

There is a pilot project to test border crossing without stopping by using appropriate rolling stock. The railway service providers are cooperating to test new locomotives that are technically interoperable, e.g. automatically switch from one traction voltage to the other (in Hungary 25 kV, 50 Hz, in Austria 15 kV, 16 2/3 Hz). These systems are already installed on the newest elements of the rolling stock; as Hungary is mostly compatible with the German standards which are also applied in Austria, this is generally easy to implement.

Staff also need training to be qualified on both sides of the border (train driver, ticket controller) communicating in both German and Hungarian.

In summary:

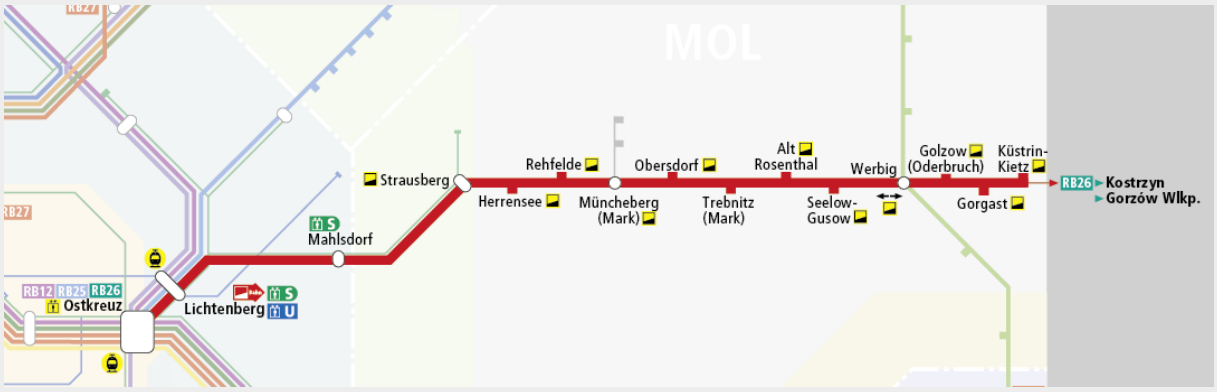
Thanks to this cross-border service, good accessibility is provided along both ends of the Vienna-Budapest axis. Development of railway infrastructure and services has made a significant contribution for the development of the cross-border economy in the Bratislava–Győr–Vienna triangle (e.g. making weekly and daily commuting feasible).

Rail service on this border section does not present a major pitfall; demand continues to grow (although it was hit significantly by the COVID-19 pandemic). Anyway, there is still room for improvement (in order to address the demand of the regional population even better) by eliminating the current cross-border barriers (e.g. decreasing the journey time with technical solutions to eliminate the train stop at the border and encouraging further language trainings).

### 2.3.2. Rail passenger connection Berlin (Germany) and Kostrzyn (Poland)

The rail connection between Berlin (Germany) - Kostrzyn nad Odrą (Poland) is an important German-Polish cross-border service which connects (by regional trains) the metropolitan region around Berlin with a border town in western Poland close to the German-Polish border. Kostrzyn is the final destination and the only stop in Poland; from here there are connections to Gorzów Wielkopolski, Szczecin and Poznan. On the German side the train has 15 stops (three in Berlin); the main purpose of this connection is to link the city of Berlin to its functional area in eastern Brandenburg. Trains operate hourly, alternating between stopping at all stations and an express service. Every day, some 223,000 people commute from Brandenburg to Berlin and 88,000 from Berlin to Brandenburg (source VBB as indicated in [2]). By extending the connection (serving the highly integrated metropolitan area around Berlin) across the German-Polish border, the service enables direct commuting from Poland to Berlin without changes.

**Figure 14:** RB 26 Berlin – Kostrzyn nad Odrą, source [2]



The Berlin-Kostrzyn connection mainly serves commuters between Berlin and surrounding sub-urban and rural regions in Berlin/Brandenburg, while Polish cross-border commuters are the most important target group for the cross-border section. Tourists who come from Poland to Berlin or travel from Germany to Poland also play a role. There are also train connections to the new Berlin Brandenburg Willy Brandt Airport (BER) from Berlin Ostkreuz. The new Tesla factory in Brandenburg, which could be reached by bus within 30 minutes from the station in Strausberg, might further increase (cross-border) commuter flows.

The connection between Berlin and Kostrzyn is the most used German-Polish regional train connection, with about 1,000 passengers crossing the border each weekday. This is due mainly to two reasons:

- the train is the only public transport service in the immediate border region (with no alternative bus line);
- the travel time by rail (i.e. about 80-90 minutes) is similar to the travel time by car (making it an attractive alternative for tourists, commuters and business trips).

Anyway, the still low-quality rail infrastructure represents a limiting factor, preventing not only regional public transport but also long-distance passenger and freight transport from fully exploiting the potential demand for cross-border services. The main problems are single tracks (reducing the capacity), track sections with a maximum speed of 120 km/h and lack of electrification.

Travel time between Berlin and Kostrzyn is 80-90 minutes (depending on the number of stops); the train runs once per hour in each direction (timetable 2021), with no difference during working days, weekends or public holidays. Due to the joint Polish-German construction on the railway bridge over the Oder/Odra border river, from December 2020 until probably December 2022, the train from Berlin ends in Küstrin-Kietz, which is the last stop in Germany, and passengers have to take a replacement bus (that takes them to the rail station in Kostrzyn in 9 minutes).

Among of the obstacles hampering the smooth development and implementation of the cross-border train connection, the following can be identified:

- The availability and compatibility of vehicles with technical standards for both sides of the-border. It can be challenging (also economically) to develop and produce vehicles that fulfil the standards in both countries (especially under the national focus/provisions). Currently, players in the German-Polish border region address this obstacle by using diesel vehicles (with the related air and noise pollution). Anyway, this challenge might require more attention in the future if/when the railway line will be fully electrified.
- Language barriers between German as a Germanic language and Polish as a Slavic language pose another important obstacle for authorities and operators as well as for potential users. While transport operators mainly communicate in English, no common working language could be established between the regional authorities and transport associations. Language is also important for train users; since the train mainly operates in Germany, information in Polish is limited. Announcements on the train are in German and Polish only for stops along the route (including welcome and farewell), but not about connecting services. Announcements in train stations are not in Polish so non-German speaking passengers might face additional challenges after leaving the train. Flyers and posters are usually available in German, English and Polish.

In summary:

The train connection between Berlin and Kostrzyn nad Odrą is an important link that connects Berlin to its wider hinterland in east Brandenburg and to the Polish railway network, improving cross-border accessibility in the border region. Despite the clear focus of train

stops in Germany, the connection serves target groups from both countries and contributes to cross-border integration.

Obstacles for its further development range from legal and administrative ('no common administrative procedures and legal basis'), to technical ('availability and compatibility of vehicles with technical standards for both side of the border') and to practical obstacles ('different language'). Handling these obstacles in a pragmatic way and working towards acceptable solutions are key success factors for the train service.

### 2.3.3. Cross-border/international High Speed rail services (passenger)

High-speed services are already in operation in many countries in Europe and worldwide. There is a variety of high-speed networks, tailored to the needs of the individual countries and their spatial structures. At the European level, for example, it is possible to distinguish between monocentric countries (e.g. France or Hungary) with radial high-speed lines and polycentric countries (Czech Republic, Germany, Italy or Poland) [19] where network effects have to be considered (e.g. integrated timetables).

Examples in France and other large countries show that time savings due to high-speed were high enough to cause a relevant shift from both road and air traffic to railways, sometimes even replacing air traffic completely. This is, in particular, the case where high passenger volumes allow combining high-speed with high frequency. In some cases, high-speed lines also serving the airports of large cities feed into long-distance flights or even have fully replaced former flight connections, for example on the Frankfurt — Cologne — Düsseldorf route and the Paris — Brussels route ([19], [30]).

**France high speed network (source [19])**

France is an example of a country with a clearly monocentric structure. Paris with about 12.5 million inhabitants in the metropolitan area is the centre of this structure. Apart from the capital, there are a small number of cities with between 0.5 and 2 million inhabitants at distances of several hundred kilometres from Paris and from each other. The rest of the country is sparsely populated, with most of the smaller cities not larger than 100,000 inhabitants. Accordingly, the railway network is oriented towards Paris, which is the main hub of the whole country.

In order to achieve the shortest possible travelling times even between very distant cities, e.g. Paris and Marseille, commercial speeds are close to the maximum technical possible and special TGV railway stations have been built in the outskirts of intermediate cities to avoid having to slow down when entering agglomerations as well as interference from other traffic.

In 1981 the first line, between Paris and Lyon, opened. Since then, high-speed operation between these two cities has led to a significant fall in car and even air traffic, including the cancellation of flight connections between the two cities. More recently, the line was extended to Marseille; LGV Sud-Est or Méditerranée now connects the three largest cities of France — Paris, Lyon and Marseille. It has turned out to be an important commercial success, being the most effective and efficient high-speed line of France. Already in 1987, after only six years of operation, the market share between Paris and Lyon had reached a level of 60%.

Similar to LGV Sud-Est, the "PBKAL" line (Paris — Brussels — Cologne — Amsterdam — London) served by TGV and Thalys trains (to Brussels and beyond) and Eurostar trains (to London) is very effective and efficient. For example, for the connection Paris — London the share of railway passengers has reached 70%, already. LGV Atlantique, LGV Est and LGV RhinRhone have less traffic demand, however are important for the internal cohesion of France.

Existing HSR-links will generally not experience capacity constraints; however, capacity bottlenecks may occur when rail travels between several city pairs use the same (traditional) track section and/or at urban nodes.

Although high-speed railways have a significant role in strengthening domestic but also cross-border cohesion of countries (i.e. with shorter travel times, distances between key centres essentially shrink), European border-crossing services by high-speed rail are relatively limited, examples being represented by the routes Paris-London-Brussels-Cologne-Amsterdam, Paris-Turin/Milan and by Barcelona-Perpignan (although the latter doesn't yet offer a fast connection to the French high-speed network and conveys only few cross-border trains per day) [16]. Rail interoperability is often obtained/guaranteed by using/supplying specific rolling stocks, as it is very costly to change fixed installations, such as the track gauge, the electrification mode (voltage or type of current) or the signalling system [18]. Examples of adopted solutions include:

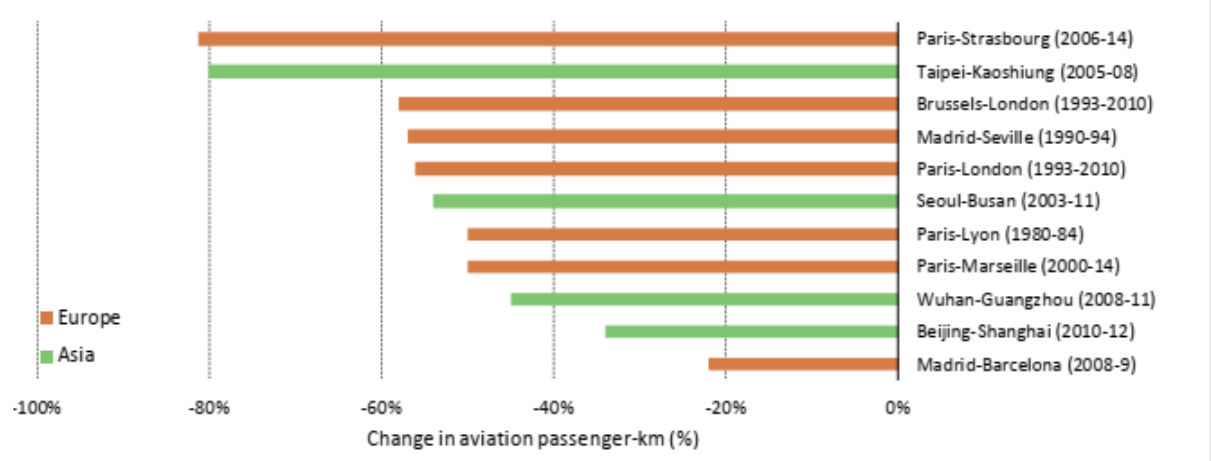
- Talgo trains are able to change gauge and therefore run on both standard gauge high speed lines and conventional lines with Spanish gauge.
- Cross-border Thalys trains can be powered by four different currents: 25 kV AC -50 Hz; 15 kV AC- 16 2/3 Hz; 3 000 V DC; or 1 500 V DC, and are fitted with European Train Control System Level 2 signalling equipment, French TVM430 and KVB, German LZB, and Belgium TBL2.

Shifting long-distance trips from aviation (primarily short-distance flights) and cars to conventional and high-speed rail is generally energy efficient and can deliver significant environmental gains [17].

Competition with the car is complex because of specific aspects of the private car, such as privacy, the ability to offer a full door-to-door trip, the choice of the departure date and hour (full availability), the choice of the route, the ease of handling luggage, the absence of any constraints linked to ticket distribution and reservation, etc.. Within this context, high speed rail remains efficient over long distances.

On the other hand, high-speed rail offers a low-carbon alternative to aviation for the transport of large volumes of passengers over distances of up to about 1 000 kilometres. There is some evidence ([17], [30]) of substantial (even nearly total) high-speed rail substitution for air traffic (see next figure). Countries with existing high-speed rail lines tend to have fewer short-haul flights than countries without high-speed rail, which is consistent with the observation that high-speed rail is most competitive for trips with travel times up to 4 hours [17].

**Figure 15:** Average change in passenger activity on selected air routes after high-speed rail implementation [17]

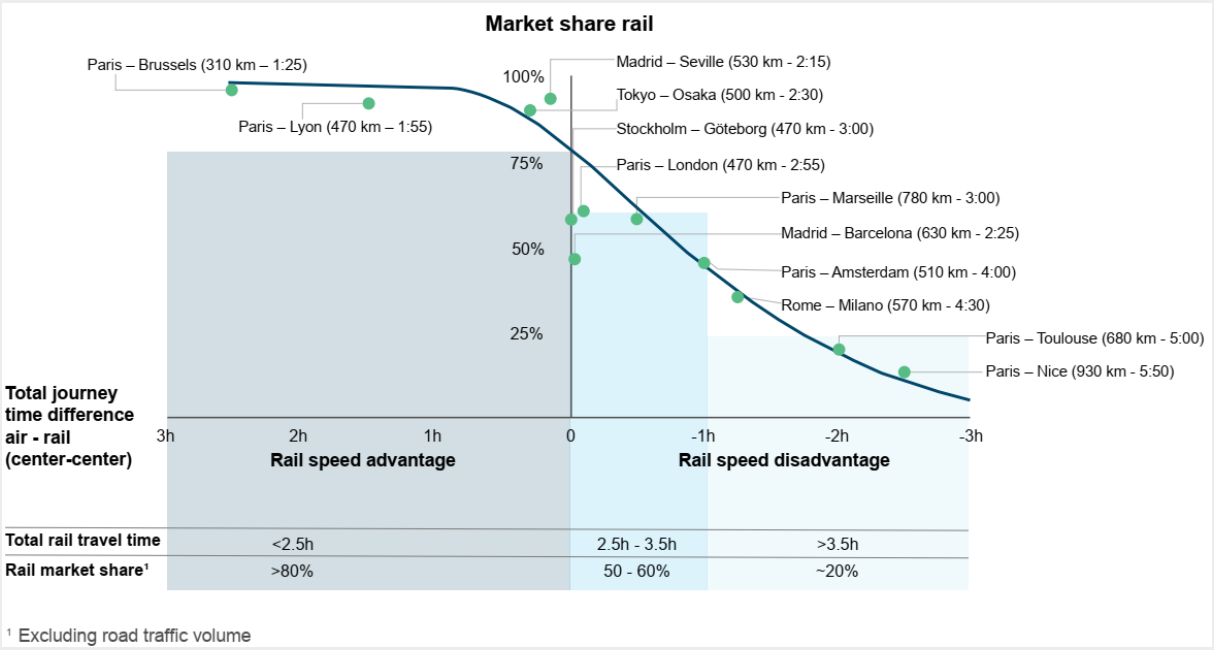



Density, speed, and frequency are three factors that position train travel as an efficient and convenient passenger service. A few examples from around the world indicate that high-density networks and high-frequency services are key for growing rail modal share. Switzerland, for example, combines dense and frequent network connections, its rail sys-

tem being one of the densest and most utilized networks in Europe. As a result, Switzerland's modal share is the highest in Europe.

In France, Germany, Italy, Spain, and Japan, the introduction of HSR massively increased rail modal share, replacing cars for shorter distances and planes for longer distances. With the introduction of high-speed services, rail modal share doubled for the route between Berlin and Munich (590 km) and between Tokyo and Ishikawa (450 km), while growing by 2.8 times between Madrid and Seville (530 km) [15]. High-speed connections are a key success factor as journey time critically impacts rail modal share when compared to air travel (see next figure).

**Figure 16:** Impacts of journey time on rail vs. air market share. Source [15], based on VIC, Press articles

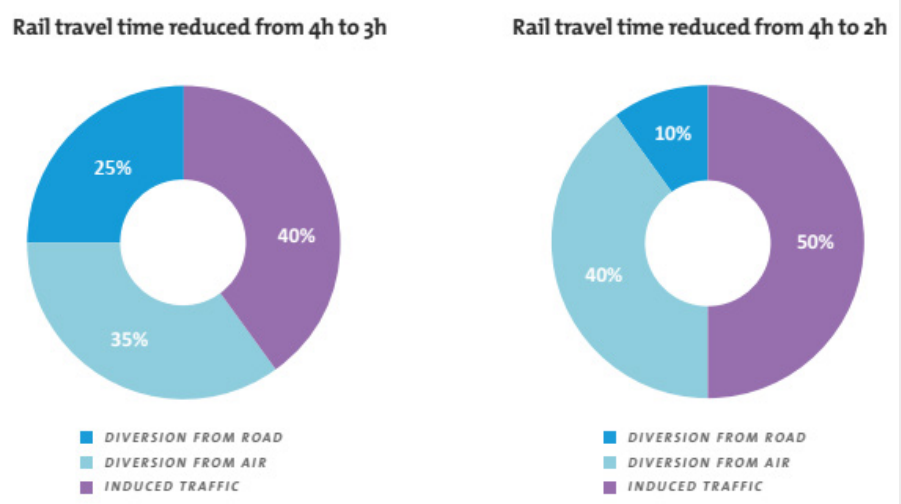



About 60-80% of present high-speed rail activity can be shown to derive from shifts away from conventional rail and planes, with the remainder from avoided road traffic (10-20%) and induced demand (10-20%) [17]. Induced traffic corresponds to people who would not have travelled or would have travelled less frequently if the HS line had not been created. In general, high-speed trains have a competitive advantage [20]:

- up to a distance of 300 km compared to travelling by car; and
- in the range of 300-800 km compared to travelling by air. In particular, high speed services up to a distance of 500-600 km may divert a significant share of passengers travelling by air.

The two pie charts below [18], instead, show that the volume of new traffic depends on the travel time saved and illustrate the respective shares for road and air diversions and induced traffic.

**Figure 17:** Diversion of rail share (and induced traffic) by reducing rail travel time, source [18].




Indeed, the literature indicates that the main determinant for the market share of (passenger) HS rail is represented by travel time, with costs, reliability and comfort also relevant to some extent.

The potential for flight traffic to be shifted to high-speed rail is driven by the relationship between the respective door to-door travel times[20]. Journey duration between pairs of cities by rail must offer time savings compared to aviation.

On many Origin-Destination (OD) pairs, the rail and air market shares can be predicted/derived by the high-speed train travel time [18]:

- Where rail travel time is less than 2h, HSR dominates the market and air companies may give up competing. A good example of this is the Paris-Brussels route;
- Where rail travel time is between 2h and 3h30 minutes, rail is the dominant mode;
- Where rail travel time is between 3h30 and 5h, air is the dominant mode;
- Where rail travel time is more than 5h, rail becomes a marginal actor compared to air.

Of course, this traffic split can be affected by other parameters, such as the location of stations and airports, ticket prices and service frequency, density of the network and the concentration of cities within the range of distance fitting high speed service characteristics. Regarding the last point, for reasonable/viable business cases for new high-speed rail connections several million passengers are needed per annum, which can be achieved by connecting two large cities (such as London and Paris) or by connecting several cities along the new track [16].

As indicated also in [20], focusing on Schiphol airport, a recent study by Savelberg and De Lange (2018) concluded that international high speed services linking Amsterdam with cities in Belgium, Denmark, France, Germany and the UK could shift approximately 1.9 million passengers from flights in 2030. This is equivalent to a reduction of 12 000-25 000 flights per year (i.e. between 2.5 and 5.0%).

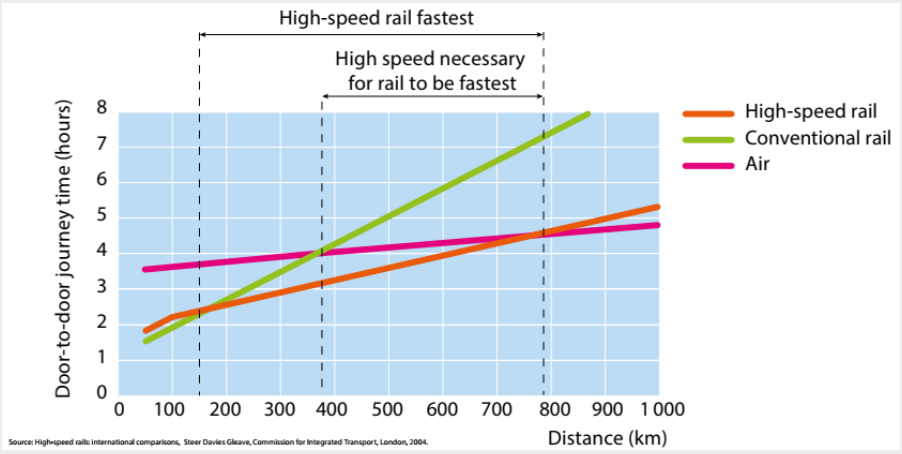
Depending on selected speed levels, high-speed trains are competitive against road for distances above 100km and against air up to 800 km. Night trains can be attractive on

20 Beside the actual travel time (on-board), the door-to-door travel time may account for 1) the travels between original departure point and airport/station and from the airport/station to the final destination (e.g. 1+1 hours for air and 30+30 minutes for train), 2) the waiting time at train station (e.g. 20 minutes) or the time for airport check-in, controls, boarding and luggage pick-up (e.g. 1.5 hours).

larger distances, up to 1200 km (see further details in the next text box). The reduction of travel times may induce new commuting behaviour, with distances of 200 km and more in everyday commuting.

The competitive advantage of high-speed rail falls in the range between cars (80-140 km/h) and airplanes (800- 900 km/h, compensated by long dwell times before take-off and after landing) [19]. High-speed trains are twice as fast as cars, half as fast as airplanes, and in many cases accessible not far from city centres. The next figure shows a comparison between conventional rail, high-speed rail and air.

**Figure 18:** Comparison between conventional rail, high-speed rail and air transport, source [19]



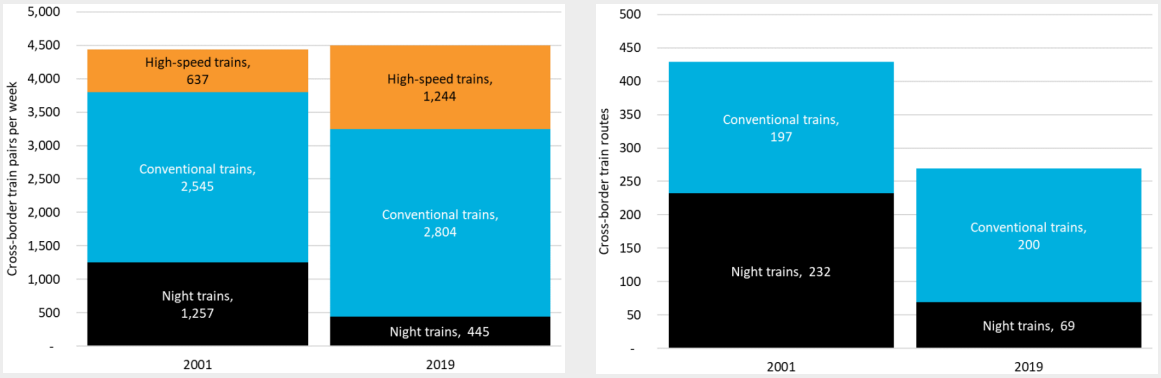
**Night trains ([3],[16], [25] and [26])**

Night trains can offer an alternative for daytime aviation trips. Most attractive are train departure times between 19:00 and 23:00, with arrival times between 7:00 and 9:00 the next day (within these timeframes, traveling by night train has less time loss than aviation). With an average speed of around 80 km/h, this results in a potential market for night trains at distances between 800 to 1200 km [16]. Indeed, a recent study [25], by investigating the willingness to use night trains as an alternative to airplane travel for long-distance travel in Europe, indicates that travel time is an important determinant of the mode choice alongside travel cost and comfort level. Given that one arrives early in the morning (i.e. 08:00) there is a slight preference for traveling by night train compared to flying in the early morning. If the arrival time is later in the morning (10:00) then there is a reverse preference which is slightly stronger, i.e. the morning plane is preferred over the night train.

The Austrian railway company ÖBB offers most international night trains in Europe, with many cities connected (including Wien, München, Hamburg, Berlin, Düsseldorf, Brussels, Venice, Milan and Rome) through Nightjet services. In 2018, 1.4 million passengers travelled by Nightjet while domestic night trains were run for example in Italy, Romania, Poland, France, the UK and Sweden. The ÖBB expanded its night services during the last years and intends further enlargements, while on the other hand, Deutsche Bahn ended its night trains in 2016 and SNCF limited its night services. The market for rail travel during nights is declining; main factors are the growth in daytime high-speed rail services and the rise of low-cost carriers. HSR and night trains compete partly for the same passengers. Other obstacles for the operation of night trains are lack of track capacity during the night (due to maintenance works and slow freight trains), lack of capacity at main stations during the morning peak hours and availability of suitable rolling stock (new or second hand). National differences in gauge width and power voltage also need to be overcome at many international connections.

As indicated in [3], the cumulative changes in the number of (long-distance cross-border pairs of) night trains (one in each direction) per week, decreased by 65% from 2001 and 2019, with 70% fewer night train routes (i.e. down from 232 to 69, see next figure).

**Figure 19:** Long-distance cross-border trains pairs per week (left) and origin-destination pairs served (right), 2001 and 2019 (source [3])

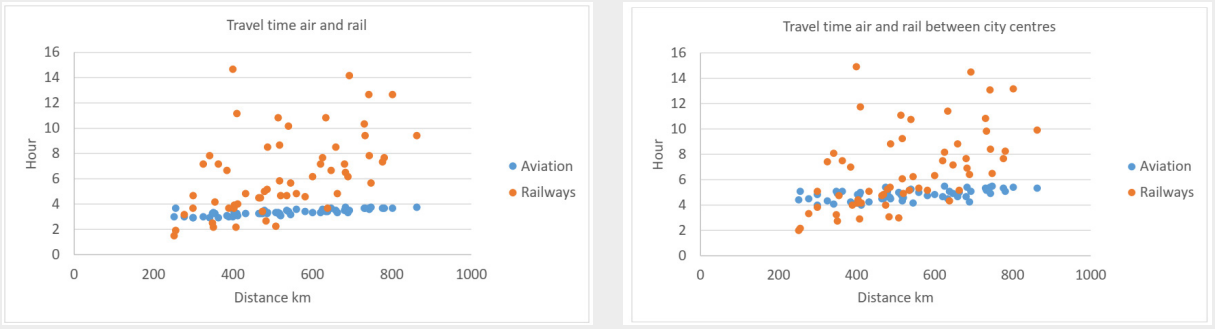



Anyway, as indicated in [25], night train services are being relaunched in the past few years in a revised form throughout Europe. As reported by UITP [26], for example, Transdev Sweden launched in June 2021 cross-border night train services (Snälltåget) which allow passengers to travel without any train change from Stockholm, Malmö, Copenhagen to Hamburg and Berlin in both directions, by tackling technical (e.g. different signalling systems in all three countries, requiring the change of locomotive), regulatory (e.g. different authorisations required to operate in each country) and linguistic challenges. The service has made it possible to reduce the number of flights and car trips between Sweden, Denmark and Germany.

Provided that the railway operates a certain route and that there are no other obstacles against the use of rail, in passenger transport, conventional rail has advantages in everyday commuting and over distances of between 100 and 600 km. For distances below 200 km the time to and from stations may be dominant. As illustrated in the previous figure, the threshold between rail and air strongly depends on the speed of the railway service. It is in the order of 500 km for conventional rail, but may reach 1,000 km or even more if high-speed is available.

The next figure reports travel times by rail and aviation as collected for 58 European city pairs in [16]. Only seven routes have a shorter travel time (to station/airport) by rail than by air; these are all connected by HSR. When comparing travel times between city centres for the same city pairs, instead, train is more competitive. Up to a distance of 700 km, the train can offer an equal travel time between city centres as aviation (e.g. for trips between the centres of large metropolitan areas, traveling to and from the airports can be time consuming). However, only part of the passengers travels between city centres.

**Figure 20:** Travel time between airports and railway stations (left) or between city centres (right) of 58 city pairs, source [16]




The next table gives an overview of the 11 city pairs with a shorter travel time by rail than by air [16] from the previous figure. All connections are between the centres of two large cities (including traveling to and from the airports/stations).

**Table 4**: Travel time between the city centres at least 10 minutes shorter by railway than aviation (out of the 58 analysed city pairs), source [16]

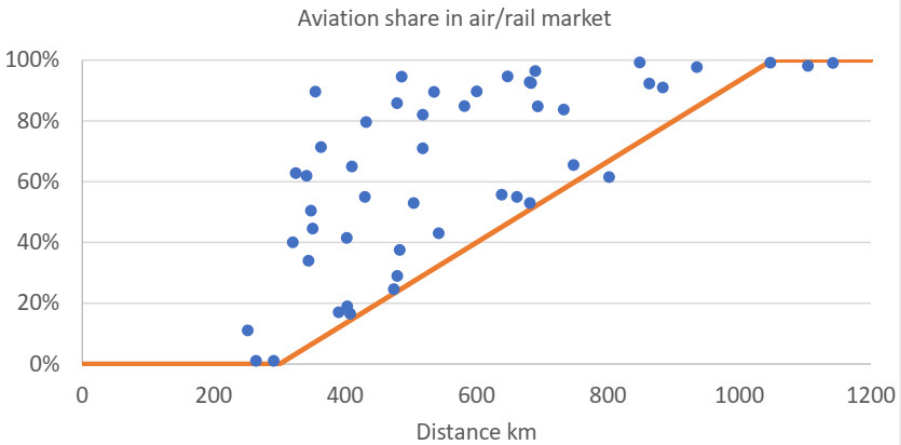
| City pair | Distance | Time rail | Time air | Rail Mpax | Air Mpax | Share rail |
|---|---|---|---|---|---|---|
| Milano - Rome | 474 km | 4:00 | 5:25 | 4.0 | 1.3 | 75% |
| Barcelona - Madrid | 483 km | 3:05 | 4:40 | 3.9 | 2.3 | 62% |
| Lyon - Paris | 407 km | 2:55 | 4:50 | 3.4 | 0.7 | 83% |
| London - Paris | 348 km | 3:15 | 5:05 | 2.4 | 2.4 | 50% |
| Amsterdam - Paris | 402 km | 4:10 | 4:50 | 2.0 | 1.4 | 58% |
| Brussels - Paris | 251 km | 2:00 | 4:25 | 1.5 | 0.2 | 89% |
| Marseille - Paris | 638 km | 4:20 | 5:05 | 1.3 | 1.6 | 56% |
| Brussels - London | 350 km | 2:45 | 4:55 | 0.8 | 0.7 | 55% |
| Bordeaux - Paris | 508 km | 3:00 | 5:00 | | 1.5 | |
| Lisbon - Porto | 277 km | 3:20 | 4:30 | | 1.1 | |
| Berlin - Hamburg | 255 km | 2:10 | 5:05 | 1.1 | | |

Travel time by air is a well correlated function of distance while the travel time by HSR also increases with distance, but with a much greater variance. The net-speed is lower, because of the use of conventional track on part of the trip, detours from the geographical distance and intermediate stops; it can vary approximately between 100 and 200 km/h, which reflects an important variation in quality of the rail service [16].

Empirical data on the modal split in the air/rail market, depending on distance, are presented in the next figure extracted from [16]. Data are based on several HSR connections between city pairs. The best rail connections have a modal share of 100% below 250-300

km and hardly any share above 1000 km; the line between these two points reflects the best rail services as indicated in the figure (with many connections not performing as well as the best). All connections with the highest rail share related to distance (i.e. close to the orange line in the figure) are between large cities, benefitting from the fast access from HSR to the city centres.

**Figure 21:** Best practice high-speed rail, dependent on distance; source [16]



# 3. Study limitations and possible ways forward

As outlined in the report, the analyses are based mainly on available information. Due to time and resources constraints, the study focused on presenting, in an aggregated and meaningful way, data and insights collected from the literature review. Therefore, it is characterized by a number of limitations which should be taken in account in order to handle and interpret with care the results presented, such as:

- As a general remark, the study focuses only on the possible removal of technical and interoperability barriers (falling under the remit of the Agency), which constitutes a contributing factor for increasing the attractiveness and competitiveness of rail compared to other transport modes, but the final results/outcomes are definitely influenced by (and should take in account) the wider context and other elements impacting demand and modal share.
- In line with the comment above, an analysis of the potential growth in demand based only on time elasticities is not fully exhaustive and has various drawbacks. The results presented (e.g. in figure 12) should be considered as very indicative; a more detailed modelling (e.g. in a follow-up study) would definitely provide more robust insights.
- The case studies focus on four specific cross-border sections (two for freight and two for passenger). Despite that the analysis of the technical and operational barriers is based on considerations at EU level (from the ILB [1]), the results of this study are quite context specific. A further analysis for more cross-border sections may offer a more varied and clearer picture of the limitations and consequences of interoperability issues in more EU borders.
- The quantitative analysis of the possible time savings is based mainly on the ILB [1], which presents estimations averaged at EU level and based on the data/information available (and not fully representing the specificities of the particular cross-border section under consideration). The analyses in the freight case studies aimed to further contextualise, whenever possible, the inputs from the ILB, but surely a more targeted collection/verification of the data (through surveys/interviews or on-site visits) could help in further fine-tuning the estimations/assumptions made.
- Each case study analyses a single cross-border section, but freight trains may cross several borders along their long-distance trips with additional time savings. It may be interesting to perform more targeted analyses at corridor level or along routes between more distant origins/destinations. More detailed analyses could be performed for international passenger and high-speed connections (e.g. through targeted data collection), since this report mainly summarises the (qualitative) considerations/insights from other studies.
- Besides an analysis of the possible benefits (e.g. time savings) obtained by removing technical and operational barriers at cross-borders, it would be interesting to explore (e.g. in a follow-up study) the possible costs associated with that removal and/or to identify which issues are more significant/impacting from a cost/benefit perspective.

# 4. Conclusions

The analyses presented in this report confirm that, although the interoperability of the EU railway system is improving, technical and operational barriers at cross-borders still hamper the seamlessness of international rail connections and the modal shift to rail. There is a substantial potential for time savings at cross-borders by solving technical and operational issues.

While the case studies indicate that there is room for improvement in several areas (e.g. infrastructure, communications, ticketing, etc.), possible recommendations/ways forward to tackle in particular the technical and operational barriers (falling under the remit of the Agency) at cross-border points could be for example:

- A further cleaning/reduction of the national rules. Various issues analysed in the case studies are linked/due to specific national rules in some Member States, leading to non-harmonized procedures in neighbouring countries with consequent time losses at borders.
- A further harmonisation and revision of the Technical Specifications for Interoperability. Progressing with the further closure of remaining open points and with the reduction (where possible/appropriate) of specific cases would have a positive effect on interoperability (also at cross-borders).

Regarding instead the study and its limitations, follow-up studies/analyses would be highly beneficial for fine-tuning the findings and/or for focusing more deeply on specific aspects.

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