University of Zurich[UZH]

Distributive Effects in the European Intercity Rail Network: A Geovisual Analysis of the Impacts of Rail Infrastructure Projects

GEO 511 Master's Thesis

Author
Jens Grafström
19-734-607

Supervised by
Dr. Tumasch Reichenbacher

Faculty representative
Prof. Dr. Sara Irina Fabrikant

21.09.2024
Department of Geography, University of Zurich

Abstract

The transportation sector causes around 28.5% of the European greenhouse gas emissions. Passenger transportation by road and air is thereby particularly problematic. However, the European rail network is in desperate need of improvements and upgrades to realize a shift toward sustainable mobility by rail. As a series of projects are currently being planned or are under construction, analyzing how they affect passenger train travel is essential. Nonetheless, such studies do not yet exist on a European scale, and local studies fail to address distributive effects. This thesis models the current full-scale European intercity rail network based on infrastructure and timetable data to fill this research gap. The modeled network is updated with new travel times resulting from all currently known projects which will be completed by 2050. A series of analyses, including network metrics such as the average shortest path length, node and edge betweenness centrality, and node closeness centrality, is conducted in close coordination with geovisual approaches such as flow and dot maps, cartograms, and isochrones. The results showcase how distributive effects strategically reshape core corridors of European train travel and particularly benefit peripheral regions. Besides the prominent Fehmarn Fixed Link, Rail Baltica, Euroalpin Tunnel, and Brenner Base Tunnel, a group of southeastern European projects emerges as an unexpected yet particularly relevant component in reshaping the continent's future rail network. The results show that new corridors are likely to emerge while certain peripheral regions particularly benefit in terms of accessibility and connectivity within the full-scale European context. Case studies moreover illustrate the dense political and planning-strategical dynamics surrounding such projects.

Keywords: rail infrastructure projects, rail network, travel time analysis, rail projects, intercity rail, network analysis, betweenness centrality.

Note: all used images are available in full resolution on GitLab (link below).
https://gitlab.uzh.ch/giva/public/masters/euro_train_expansion_jens_grafstroem

Table of Contents

List of Figures

List of Tables

Terms and Abbreviations

General Abbreviations

CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
ERTMS	European Rail Traffic Management System
EU	European Union
HS2	High-Speed 2
GIS	Geographic Information System(s)
KD-tree	k-dimensional tree
OSM	OpenStreetMap
RQ	research question
TEN-T	Trans-European Transportation Network
Vmax	maximum velocity

Units

m	meter(s)
km	kilometer(s)
h	hour(s)
min	minute(s)

Network Metrics

ASPL	average shortest path length
EBC	edge betweenness centrality
NBC	node betweenness centrality
NCC	node closeness centrality
NDim	network diameter

Specifics Terms

potential travel time(s)

travel times that purely base on infrastructure properties (i.e., length and Vmax)

realistic travel time(s)

travel times that source from timetables and are achieved in reality

haversine distance

distance between two points on a sphere (given their longitudes and latitudes)

Euclidean distance

length of a straight (non-bent) line segment (here: given two points on a plane)

1 – Introduction

1.1 – Motivation

Transportation plays an essential role in the interconnected globalized world, facilitating the movement of both people and goods across all spatial scales. However, this vital sector is a major source of greenhouse gas emissions, thereby significantly contributing to climate change. This is especially true in Europe: among the EU-27, transportation is responsible for approximately 28.5% of all greenhouse gas emissions (European Commission, 2022). Meanwhile, the sector’s share is even bigger in Switzerland at around 32%, not including international aviation (BAFU, 2020). As Figure 1 illustrates, a more differentiated view reveals that passenger road traffic (ca. 45%) and passenger aviation (ca. 11%) together account for more than half of the EU-27’s transportation-related (European Commission, 2022; Ritchie, 2020). Consequently, passenger travel must be targeted by emission reductions within the transportation sector.

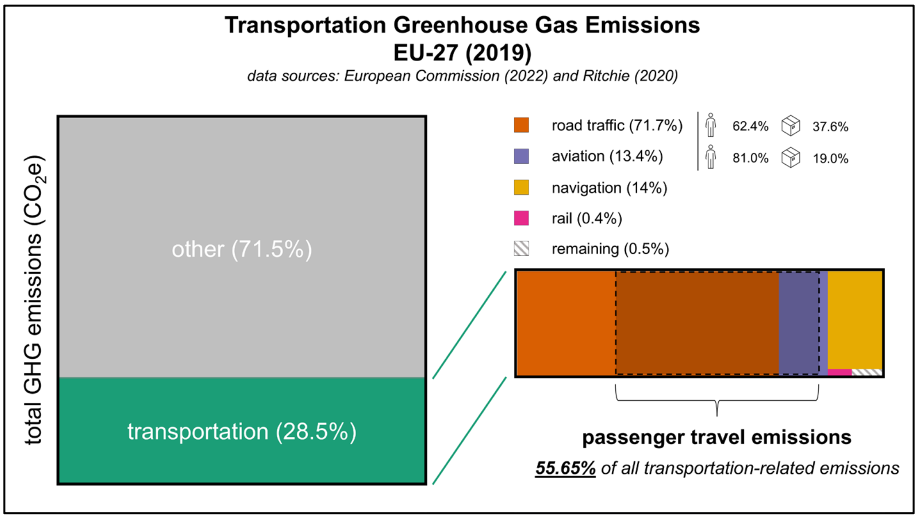


***Figure 1**: Distribution of transportation-related greenhouse gas emissions within EU-27, based on data from Ritchie (2020) and European Commission (2022). Source: own illustration.*

It is thereby evident that trains (besides bus coaches) represent the mode of travel causing the fewest CO_2 emissions (Ritchie, 2023). As is revealed by statistics for the United Kingdom (visualized in Figure 2), rail operations come with up to 35 g of CO2 equivalents (CO_2e) per traveled km, which is surpassed by both flights (up to 246 g CO_2e/km) and all types of cars (up to 171 g CO_2e/km). This is even more remarkable if taking into consideration that only about 38% of all tracks in the United Kingdom are electrified, and nearly 60% of all train-related emissions source from non-electrified diesel operations (ORR, 2023a; ORR, 2023b). In return, it can be expected that the overall train-related emissions on a European scale are even smaller since around 60% of all European tracks are electrified, thereby covering over 80% of all passenger kilometers traveled by train (IEA, 2019; ORR, 2023a).

Therefore, attempts to transform the overall European mobility behavior by enhancing rail travel are not surprising. However, this desired modal shift requires rail travel to be widely perceived as an attractive alternative to cars and planes. Specifically, trains’ attractiveness depends on four significant aspects: travel times, reliability, availability, and convenience (Meyer de Freitas & Blum, 2023). This means that a journey by train should not take much longer from start to end than by car or plane, should operate relatively frequently and with as few changes or transfers as possible, and should not be canceled or significantly delayed. Regardless of these central aspects being determined by different influences of various kinds, a specific one can be seen as the most critical overall limiting factor: infrastructure (Antonowicz & Kwarcinski, 2023). Infrastructure sets up the potential framework of how frequently and efficiently trains could be run and which regions could be connected – even though the actual use of infrastructure is decided by other factors such as political/economic variables.

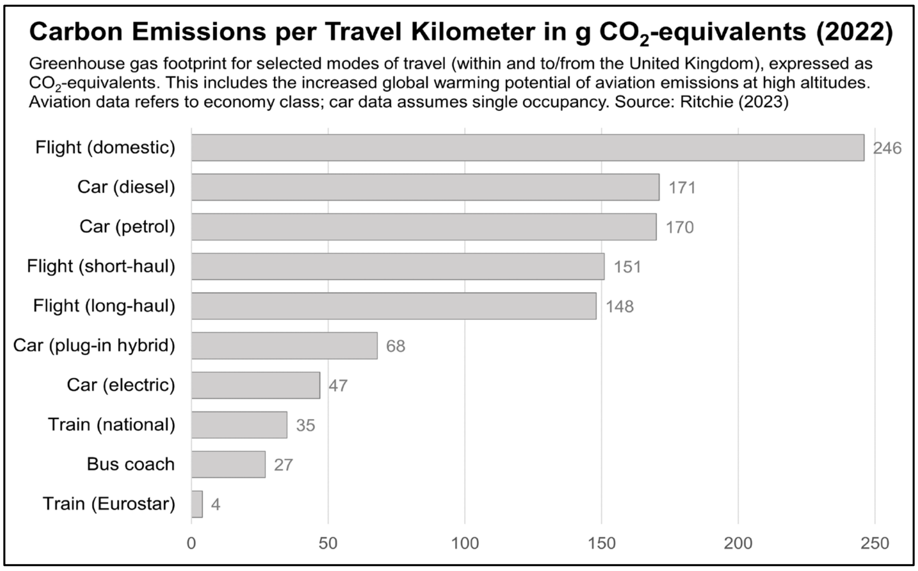


***Figure 2**: CO_2 emissions of different modes of travel, based on Ritchie (2023). Source: own illustration.*

However, identifying infrastructure as a limiting factor is concerning regarding a future perspective with a desired modal shift toward passenger transportation. Since numerous sections of the European rail network are already operating near or at their limits, increased demands may not be feasible (Islam et al., 2016). This might either disable the operation of additional trains or reduce reliability, frequency, and/or travel times, negatively impacting the perceived attractivity of traveling by train. Consequently, the aim for more sustainable transportation imposes the necessity of large-scale improvements to the European rail system and thus, most importantly, its infrastructure – thereby advancing efficiency, safety, and interconnectivity within the European rail network.

It is therefore worth focusing particularly on the infrastructure improvements unfolding along train routes dedicated to medium- and long-distance travel, i.e., intercity travel. Intercity travel ranges from journeys of only some dozen kilometers to distances covering hundreds or even thousands of kilometers. Hence, it directly competes with both flights and road traffic which underlines its important role in sustainable travel (Vickerman, 2021). Intercity travel therefore represents an enormous potential for transport-related emission reductions, which is further corroborated by the fact that around 50% of all passenger kilometers represent trips reaching beyond 100 km (Rich & Mabit, 2011). Moreover, intercity travel is often associated with touristic journeys. As a matter of fact, transportation is currently responsible for half of all emissions sourced from tourism (Lenzen et al., 2018). This signifies the relevance of a modal shift since CO_2 emissions associated with tourism in particular are being expected to grow by up to +164% between 2010 and 2050 (Gössling & Peeters, 2015).

1.2 – Research Gap

Rail travel is by any means no new field of research. Mainly thanks to the clear environmental benefits of train travel, various analyses have already centered around the importance of modal shifts toward rail transportation. The replacement of air travel by high-speed rail has thereby received particular attention. Usually, the research focus is in that case dedicated to selected city-to-city corridors with very high air travel volumes and particularly efficient high-speed rail. For instance, the very popular Barcelona-Madrid and Paris-London links have already been subject to extensive research (e.g., Behrens & Pels, 2012; Pagliara et al., 2012). Besides this, another much more recent field of train-related research has come up around the continuous re-emergence and gain of popularity of night trains across Europe (e.g., Kantelaar et al., 2022). Such research is highly valuable and meaningful since it highlights the potential of high-speed rail and overnight services to replace air travel between certain cities where ideal preconditions are met. However, the seemingly preferred focus on "prestige" high-speed rail lines leads to only few authors addressing other air routes (e.g., Avogadro et al., 2021). Additionally, of equal importance, the train replacement of passenger road traffic on medium- and long-distance routes appears to be somewhat neglected. This is substantial since the latter is, as introduced previously, an essential contributor to Europe's greenhouse gas emissions. To sum up, in the context of a sustainable mobility shift, literature appears to be failing to treat the European rail network as an interconnected system of countless potential travel corridors. Instead, research so far mainly treats the European rail network as an inconsistent and fragmented collection of a limited number of excellent high-speed connections.

When aiming at a sustainable mobility shift, it is therefore essential to investigate the European rail network as a whole without preference for certain prestige corridors. Fortunately, there already exist a few spatial analyses for Europe's rail infrastructure as an entirety. Most notably, Calzada-Infante et al. (2020) completed extensive topological analyses for the European rail network. In addition to a general network centrality analysis, the authors focused on the connectivity in terms of realistic passenger transfers. Supporting the urgent need for large-scale rail network analyses, they highlight that network research on a continental level is very rare while mostly regional analyses were performed. Meanwhile, Martí-Henneberg (2013) spatially analyzed the historical developments that the European rail network has experienced since 1840. He revealed that "[...] around 70% of lines currently in service had already been established by 1900 [...]" and that "[...] the national level has always been the one at which the most decisions relating to rail networks have been taken, and this remains the case today" (Martí-Henneberg, 2013, p. 126).

Besides this, using another mode of transportation, Condeço-Melhorado et al. (2014) assessed how new highway infrastructure in the Netherlands affects the overall national highway network. Similar research is however scarce for rail infrastructure, especially on a European scale. Furthermore, the current status quo reveals a research gap concerning a view into the future. Meanwhile, multiple rail infrastructure projects are as of today either in planning or construction stages, some even close to completion. Examples range from prestigious projects such as the Rail Baltica program to local improvements or even minor small-scale track refurbishments. Accompanying the planning and construction stages, many of these projects have already been subject to research regarding their anticipated local economic, environmental and rail operational impacts (e.g., Lupi et al., 2020). Yet, approaches dedicated to the combined outcomes of all currently projectable infrastructure improvements are not to be found. Overall, the current literature so far only represents a set of thematic puzzle tiles whereas some essential pieces remain missing in order to complete and understand the picture of the European intercity rail network's future.

1.3 – Research Objectives

1.3.1 – Goals of Research

As of now, the literature is lacking an overall analysis that combines the entire variety of all planned projects. This highlights the urgent need for a full-scale future-oriented perspective of the projects' impacts on a continental level. This reconnects to the issue previously raised by Martí-Henneberg (2013) who points out that both the existing rail network and planned infrastructure projects tend to be strongly bound to a local, usually national level. The problem resulting from a local scope of research is the potential negligence of a phenomenon that

Condeço-Melhorado et al. (2014) describe as distributive effects. This commonly also refers to network effects and spatial spillovers. In a geographic and infrastructure-centered context, this means that local changes to the network might also affect regions beyond the particular parts that were transformed (Laird et al., 2005). Simply put, Condeço-Melhorado et al. (2014, p. 96) summarize it as follows: "When an investment is made to improve the transport infrastructure of a region, its benefits are spread to many other regions".

Thus, the impacts and benefits of rail infrastructure projects might translate across larger parts of the European rail network and also cross international borders – given that these regions are appropriately linked to each other. According to Vrána et al. (2023), the European rail network in terms of efficient medium- and long-distance connections is still not designed for international services. This strongly relates to the previously introduced findings by Martí-Henneberg (2013). With the goal of an interconnected European rail network of efficient domestic and international passenger services, this issue therefore represents a major point of criticism. However, certain border-crossing projects now aim to (at least partially) overcome such territorial and topographical boundaries. Consequently, it makes sense to address the research gap concerning continental-scale rail network analyses from a future perspective. In return, resulting from the research context at a European scale, it is meaningful to limit the focus of attention to intercity connections and the sections of infrastructure serving those.

In combination with the climate impact of passenger travel, this brings up the question of how these projects and the resulting improvements contribute to promote a modal shift toward rail travel. This specifically concerns a reduction of travel times and increases in connectivity and frequencies. It is thereby worth to focus particularly on the changes in travel times only since they were identified to be the most important factor regarding modal choices for travel across longer distances (Nordenholz et al., 2017). Moreover, changes in connectivity and especially frequency are very complex to predict due to numerous underlying factors such as for instance the infrastructure's parallel use for freight transportation. However, the actually operated train travel times are defined by timetables and not only by infrastructure properties. This means that they are subject to political and economic variables (among others) as well as the available rolling stock. For instance, the use of tilting trains on curvy routes enables shorter travel times in comparison to conventional carriages while services routed to call at certain intermediate stations might increase the travel times again. Therefore, travel times can change while the infrastructure remains constant – or vice versa. Hence, as an attempt to uniformly identify the core European intercity rail network, it is meaningful to use potential travel times that are solely the result of infrastructure properties, i.e., maximum velocity (Vmax) per track segment length.

Subsequently, this thesis aims to address the research gap concerning the European-scale analysis of the continent's future rail network. While focusing on intercity routes, this means that every single (realistic) project that can currently be anticipated will be included in order to generate a future scenario with the help of realistic (timetable-based) and potential (infrastructure-based) travel times. The overall goal is therefore to develop and model two intercity rail network scenarios: a current and a future one. This allows for investigating the eventual impact of distributive effects and hence provides an overview of which regions will benefit to what degree from those projects. This might provide an insight to which projects are of particular importance in a European context. It might further help to identify patterns, e.g., of topographic or territorial kind, which define the current dynamics of rail infrastructure project planning. Certain projects will serve as case studies to provide additional insight to the variety of project backgrounds and resulting impacts. Overall, thanks to the European scale of research and the consequently complex spatial structure of the rail network, this analysis will involve a geovisual component. This is ideal for gaining a better understanding of the spatial and topological complexity of the current and future European intercity rail network. The secondary aim of this thesis is to serve as a starting point to further research of intercity train travel within all of Europe.

1.3.2 – Research Questions

In order to address the research goals, the following research questions (RQ) will be guiding through this thesis' work process and eventually be answered:

Within the context of travel time improvements resulting from infrastructure upgrades to the European intercity passenger rail network, ...

RQ1: *Which regions and cities benefit the most from the completion of upgrades in terms of reachability and accessibility/connectivity?*

RQ2: *How do distributive effects change the cities' and regions' European-scale relevance within the network and how are passenger transportation patterns shifted?*

RQ3: *Which projects make for the greatest overall operational impact on a European scale?*

RQ4: *Which political, topographical, and topological patterns do the spatial distribution, location, and arrangement of infrastructure projects indicate?*

RQ5: *How do the infrastructure projects vary in their nature and what implications could the particular characteristics addressed in the case studies pose to intercity rail planning on a European scale?*

2 – Theoretical Background

2.1 – Development of European Rail Infrastructure

2.1.1 – History of Railways in Europe

Nearly two centuries ago, on September 27, 1825, the world's first steam-powered passenger railway began operating between Stockton and Darlington, marking the start of a new era in transportation (Cottrell & Ottley, 1975; Simmons, 1980). Before this, railways were primarily used for transporting goods like coal, with wooden tracks dating back to the 16th century in German mines. Iron rails replaced wooden ones in the late 18th century, offering greater efficiency despite initial durability issues (Fremdling, 2003). In 1830, the Manchester-Liverpool line became the first rail service exclusively dedicated to passenger use. Its success led to the spread of passenger railways across Europe and beyond, with some calling it "[...] Britain's greatest gift to the world" (Donaghy, 1966; Jarvis, 1998). In the following decades, the total length of rail lines grew substantially. Around 180'000 km of rail lines[1] had been built across Europe by 1900 (Martí-Henneberg, 2013). However, connectivity challenges arose due to a lack of standardization; rail widths consequently ranged from 1000 mm to 2134 mm (Puffert, 2002). Only toward the end of the 19th century, the adaptation of the 1435mm standard gauge began to spread (Puffert, 2009). The expansion of railways created an unprecedented contraction of space, disrupting local time systems and prompting the need for time synchronization. Along with the telegraph, railways played a key role in establishing standardized time zones (Wenzlhuemer, 2010).

During the 20th century, the growth rate of the European rail network declined drastically. While the total line length had already surpassed the 200'000 km mark by 1910, it peaked in 1960 with only a slightly larger total length of around 230'000 km (Martí-Henneberg, 2013). Especially throughout the First but also the Second World War, railways played an essential role in various logistical operations of both military and civil kinds (Mierzejewski, 2002; Stevenson, 1999). The interwar years provided a glimpse into the future of European railways. Although plans for transcontinental rail corridors aimed to reorganize the post-war continent, they were never realized (Anastasiadou, 2009). Instead, the rise of automobiles, supported by favorable economic policies, posed a growing threat to railways after World War II (Fremdling, 2003). Moreover, air travel became more accessible, competing with rail on longer routes (Pender & Baum, 2000). This led to widespread rail line closures from the 1940s to the 1980s. Since 1980, the total length of railways has stabilized at around 200'000 km (Martí-Henneberg, 2013; Martí-Henneberg, 2021). By the 1980s, increasing rail closures contrasted with the steady total length of railways, indicating that new tracks were built while others were closed. Fremdling (2003, p. 220) refers to this as "revival of the railways in Europe", driven by road congestion and emerging environmental concerns. However, in a less enthusiastic tone, this can be seen as the construction of new infrastructure at the cost of older, often regional and less profitable high-maintenance lines (Seidenglanz et al., 2021). A key factor supporting this revival narrative is the development of high-speed rail.

Already in 1964, Japan's Tokaido Shinkansen high-speed rail line began linking Tokyo and Osaka at speeds up to 210 km/h (Suyama, 2014). Europe's high-speed rail progress started with the French TGV project, which launched its first line between Paris and Lyon in 1981[2].

[1] The term "rail lines" is herein not equal to the actual length of tracks. For instance, one kilometer of a double-tracked rail line is composed of at least two km of tracks.

[2] Even before the French high speed rail lines were completed, trains already operated at regular speeds of up to 220 km/h between Rome and Florence in 1977 (Fremdling, 2003). However, this rather represented more of an incremental improvement on a section of existing services rather than a complete rethinking of long-distance high-speed rail travel at a larger scale. This is why the French TGV project is commonly perceived to be the epicenter of European high-speed rail travel.

With speeds reaching up to 270 km/h and optimized routing, travel times were reduced from around four hours to just over two. The TGV's success led to a significant modal shift from air travel, with flight demand dropping over 50% within three years (X. Chen, 2011). Inspired by France's success, other European countries began developing high-speed rail networks. By 1993, France, Spain, Germany, and Italy operated 2,202 km of high-speed lines. The following year, the Channel Tunnel added 52 km to the network (Fremdling, 2003). Additionally, tilting trains and minor infrastructure upgrades allowed for higher speeds without entirely new tracks (e.g., Andersson et al., 1995). High-speed rail also spurred international infrastructure projects, such as the Oresund Bridge and the Perpignan-Figueres line, enhancing cross-border connectivity (Francisco et al., 2021; Knowles, 2006).

The increasing concern for international connectivity shifted the focus to another, commonly neglected aspect of rail infrastructure. While a standardization of rail gauges succeeded with some exceptions, the European rail network found itself as a patchwork of signaling and (given that the tracks are electrified in the first place) electrification technologies (Fabre et al., 2021; Ferrari et al., 2022). Even though certain rolling stock is capable of switching between selected electrification systems, interconnectivity is not always guaranteed – especially due to signaling incompatibilities. This has led to the establishment of the standardized European Rail Traffic Management System (ERTMS) in the early 2000s. This system's components, besides enhancing connectivity, seek to improve safety and increase both capacities and travel times (Rosberg et al., 2021; Smith et al., 2012). However, the system has been and still is implemented only gradually and along certain preferred highly frequented corridors.

2.1.2 – Status Quo of European Rail Infrastructure

As of 2022, the European rail network's lines total to a length of around 235'000 km (Eurostat, 2024)[3]. If matched with actual geodata, this translates to a track infrastructure length of roughly 487'800 km (OSM, 01.03.2024). Meanwhile, as Figure 3 illustrates, the network is particularly dense in and around Central Europe. The highest rail line densities can be found in Switzerland (133.8 m/km^2), the Czech Republic (123.3 m/km^2), Belgium (118.8 m/km^2), and Germany (109.9 m/km^2). On the opposite, the lowest densities are located in more rural countries such as Albania (7.3 m/km^2), Norway (10.7 m/km^2), Greece (15.3 m/km^2), and Montenegro (18.4 m/km^2) (Eurostat, 2024). Figure 3 furthermore tells that Germany, France, Poland, and the United Kingdom represent the countries with the largest absolute rail lengths. The only countries without relevant operable railways are the island states Iceland, Cyprus, and Malta, as well as the dwarf states Andorra and San Marino.

While the total rail length has experienced a slight overall decrease during the past decades, high-speed lines prominently expanded at the cost of less profitable routes. As of today, around 3.56% of the rail network are capable of speeds equal to or exceeding 230 km/h, most prominently in France, Germany, Spain, and Italy. Belgium, Switzerland, Sweden, Austria, the Netherlands, the United Kingdom, or Turkey are equipped with sections of high-speed rail, too. In a wider sense, 13.22% of all tracks allow for speeds between ≥ 160 km/h and < 230 km/h. This sums up to a total fraction of 16.78%, i.e., roughly one sixth of Europe's rail infrastructure, which is capable of hosting speeds of 160 km/h or more. The resulting corridors of higher-speed sections to some degree visually reflect the major rail transportation axes and topographic patterns. Among the countries interconnected by the European rail network, only nine do not exceed speeds of 160 km/h: Estonia, Latvia, Lithuania, Moldova, Bosnia and Herzegovina, Montenegro, Kosovo, Albania, and North Macedonia (OSM, 01.03.2024).

[3] Despite being higher than the 200'000 km proposed by (Martí-Henneberg, 2013), this does not indicate an increase in rail lines. Instead, the European statistics include countries which had not yet been part of Marti-Henneberg's analyses. This is particularly relevant for countries emerging from the Soviet Union or in the Balkan region.

In contrast to the usually electrified high-speed lines, the national rail electrification rates vary enormously. At the lower end, Albania, Moldova and Kosovo show no electrification at all, followed by Ireland (2.6%) and the Baltics (7.9% to 11.9%). At the upper end stand Switzerland (99.8%), Luxembourg (96.7%), Montenegro (90.5%), and Belgium (88.0%). A more uniform pattern can be found in the European rail gauge widths. The only countries currently operating major components of their rail network on other gauges are Portugal and Spain (1'668 mm), Ireland (1'600 mm), Finland (1'524 mm), as well as Estonia, Latvia and Lithuania (1'520 mm). Additionally, some regional lines throughout Europe are constructed with a narrow gauge, for instance along the Spanish Atlantic coast or in the Swiss Alps (Eurostat, 2024).

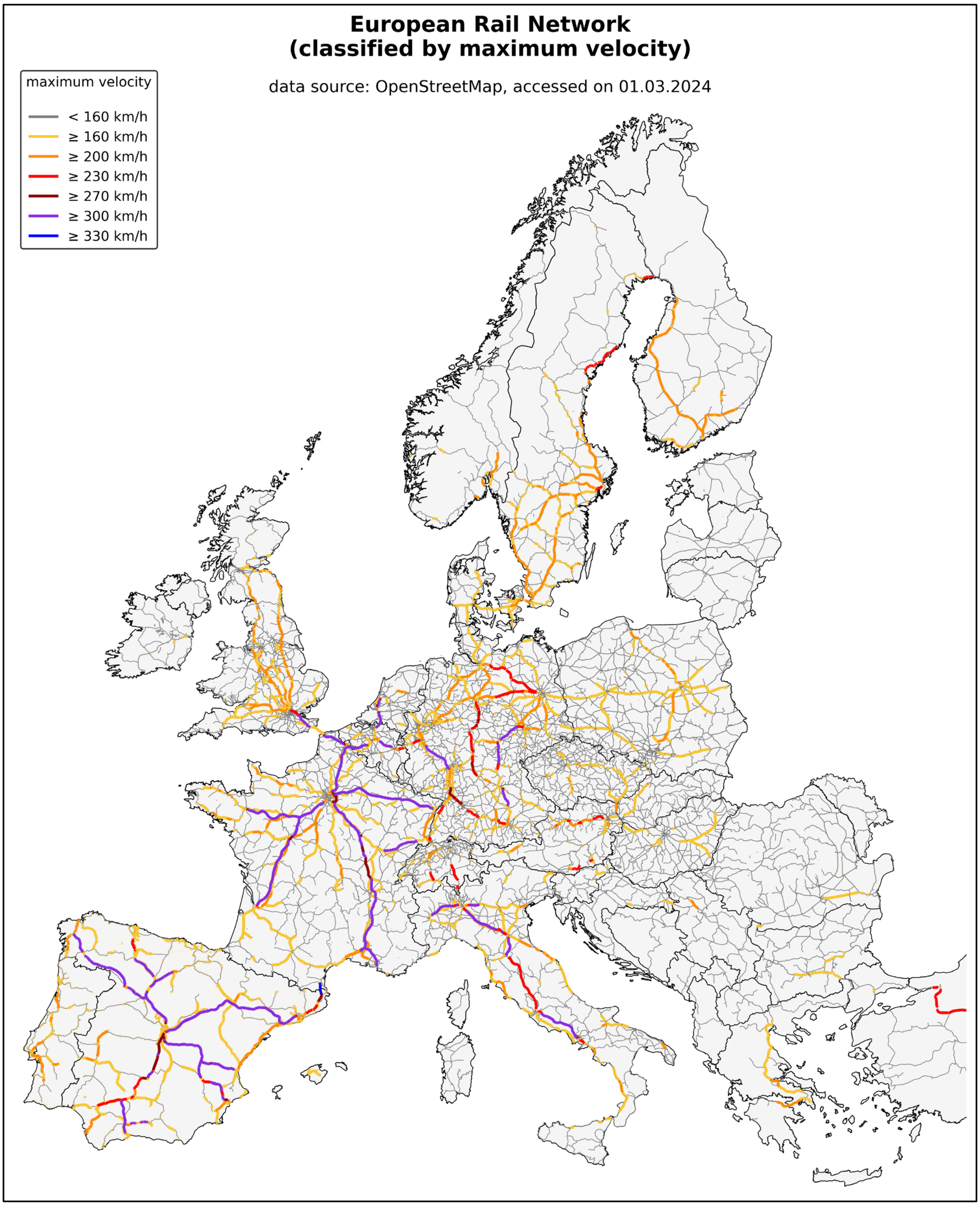


***Figure 3**: European rail infrastructure network, classified by Vmax, data from OSM (01.03.2024). Source: own illustration.*

It is worth noting that the effective infrastructure differs depending on whether it is viewed from a passenger or freight transportation perspective. Since freight trains physically behave differently from passenger trains, most notably due to being heavier, they cannot use tracks to the same extent as passenger trains. In particular, freight trains move slower and require more time to accelerate and slow down. Due to the different modes of operation, freight trains can usually use older, less maintained tracks (Mattsson et al., 2022). As a consequence, certain rail lines can be dedicated to freight or passenger use only, not allowing for mixed use. This is especially common in high-speed rail lines.

2.2 – Rail Infrastructure as Limiting Factor

As the differentiation between freight and passenger operations indicates, infrastructure is an essential aspect of how fast, frequent, and overall efficient trains can operate. The interaction between all involved components such as tracks, rail path structure and geometry, signaling systems, and electrification type can be deemed to be the most crucial factor in terms of railway operations (Stenström et al., 2016). Safety concerns, reliability issues, and capacity bottlenecks are usually the consequence of infrastructure that is outdated, has been poorly planned, overused, and/or neglected in maintenance. As a result, various attributes of rail infrastructure can be identified as major limiting factors for improvements in rail operations – especially in terms of passenger travel times.

Rail line geometry: The most obvious and also most striking limitation for improvements in rail operation speeds is the spatial structure or track layout of existing rail lines. Generally said, straighter lines enable higher velocities while curvatures reduce the maximum operable speed. An ideal track should therefore follow a straight path with only wide, smooth curves (Bhardawaj et al., 2021). However, major parts of the European rail infrastructure are remnants from the early 20th century when lower speeds could be achieved (Martí-Henneberg, 2013). Consequently, curvatures could be built relatively narrow which still today slows down trains. Straightening rail lines hereby eliminates too narrow curves and also reduces the overall path distance.

Signaling and communication technologies: In order to follow operation schedules and avoid potentially catastrophic crashes, track clearance must be reliably guaranteed for every section that a train wants to enter. This involves some form of communication between the train and the responsible control center. While this nowadays usually happens digitally and is fully automated, older systems still involve an analogue and manual component (e.g., the hand-over of a physical token) (Clark, 2012; Pachl, 2021). By reducing the lag between status updates and operation commands, modern systems allow for trains to run faster and more frequent on the same lines. In return, sections with less efficient systems implemented restrict train operations significantly (Goverde et al., 2013).

Corridor design: Smooth train operations necessitate minimizing potential disruptions, including interactions with humans and wildlife. Higher risks of human or environmental interference usually lead to slower speeds. For instance, level crossings – still numbering 94,000 across the EU (Eurostat, 2024) – can slow trains. Train stations pose similar risks, requiring trains to reduce speed unless separated bypasses are in place. Additionally, higher speeds necessitate proper vegetation clearance along the rail corridor (Hoerbinger et al., 2020). In essence, more physically isolated rail lines, such as those on viaducts or behind noise barriers, allow for higher speeds, while more exposed sections require slower speeds.

Physical stability: Higher speeds generate greater physical forces that infrastructure must withstand. Lower material quality or structural integrity can reduce the operable speeds. Key factors include not just the rails, but also welds, fastenings, sleepers, foundations, and the substructure (Pucillo et al., 2018). Older infrastructure is more prone to stability issues, which can limit speed. This can be due to age or natural factors, such as soil stability affecting the trackbed (Jankowski & Sołkowski, 2022). Tunnels must be designed to handle aerodynamic pressures at higher speeds, with both the entrance design and tunnel lining needing to endure these pressures (Du et al., 2021). Otherwise, trains must slow down before entering to maintain tunnel stability.

Maintenance: Over time, infrastructure material deteriorates due to operational stress and exposure to the elements. Common issues include trackbed failures and rail weld fatigue (Liu et al., 2021; Musgrave, 2015). Extreme weather events, exacerbated by climate change, cause severe impacts such as material deformations from high temperatures, trackbed instability from permafrost thaw, and damage from floods, droughts, storms, wildfires, landslides, or avalanches (Palin et al., 2021). Vegetation growth can further complicate these issues. Vandalism also affects track quality and safety. All these problems can reduce operational efficiency or cause disruptions if not properly maintained, with gradual deterioration often neglected. Consequently, poorly maintained tracks are a critical risk factor for slowing down train operations, especially in the long term.

In the meantime, the previously introduced interoperability issues and the resulting lack of continuous infrastructure uniformity can be seen as less of a limitation. Appropriate rolling stock can in theory overcome most of the respective limitations. For example, the Spanish manufacturer Talgo has successfully pioneered in trains that can automatically switch between gears within a matter of few seconds. Similar technologies could be expanded to match standard gauge with other kinds of wider gauges (Yuxing et al., 2018). Further technological progresses enable seamless operations between certain electrification systems (Lacôte, 2001). As an alternative to multi-voltage units, locomotives can be switched at the respective borders, even though this process is a little less efficient. Moreover, hybrid trains such as hydrogen-powered units or locomotives can provide a linkage between electrified and non-electrified infrastructure (Deng et al., 2022; Yerpes et al., 2012).

It therefore becomes clear that technological innovations and progresses in the field of rolling stock development can compensate for certain flaws in the infrastructure. In contrast, however, the previously mentioned physical limitations can hardly be overcome by rolling stock adjustments. Infrastructure sections characterized by slow signaling and communication systems on the controller end, critical human or wildlife intersections, poor physical stability, and neglected maintenance will therefore continue to slow down trains regardless. Only the rail line geometry can in some limited cases be partially compensated by tilting trains. In a general sense, it can therefore be concluded that the highest operable velocity on a track segment as well as the corresponding operation frequency are the immediate result of the infrastructure's quality. Insufficient infrastructure is therefore the most compelling limiting factor in terms of travel times.

2.3 – Continental Rail Corridors and Upgrade Plans

For this exact reason (and due to the neglect of railways after the Second World War), efforts of tackling infrastructure deficiencies have gained increasing attention during recent decades. Especially the standardization of infrastructure across the continent as well as the cross-border connectivity have herein piqued particular interest. Besides this, several countries have been developing comprehensive national strategies for rail travel which are usually tied to infrastructure upgrades too. This section briefly targets the idea and scope of these plans and strategies but not yet dive into their respective project specifics.

Established by the EU in 1990, the Trans-European Transport Network (TEN-T) is central to European transportation development. It includes railways, inland waterways, sea routes, and roads, aiming to link urban nodes, shipping ports, and airports for efficient goods and passenger transport. The framework consists of three layers with completion targets for 2030, 2040, and 2050. Rail receives special attention due to its low emissions and the urgent need for infrastructure upgrades (Öberg et al., 2018). The nine core network corridors, depicted in Figure 4, guide numerous rail projects aimed at meeting EU standards, including speed upgrades and signaling standardization. Specifically, passenger trains are to achieve a minimum speed of 160 km/h on all lines, and all tracks should be equipped with ERTMS. The Connecting Europe Facility supports these goals through funding (European Commission, 2024). While some TEN-T projects focus on freight, improvements generally benefit both passengers and goods, with nearly all European rail projects linked to the TEN-T framework.

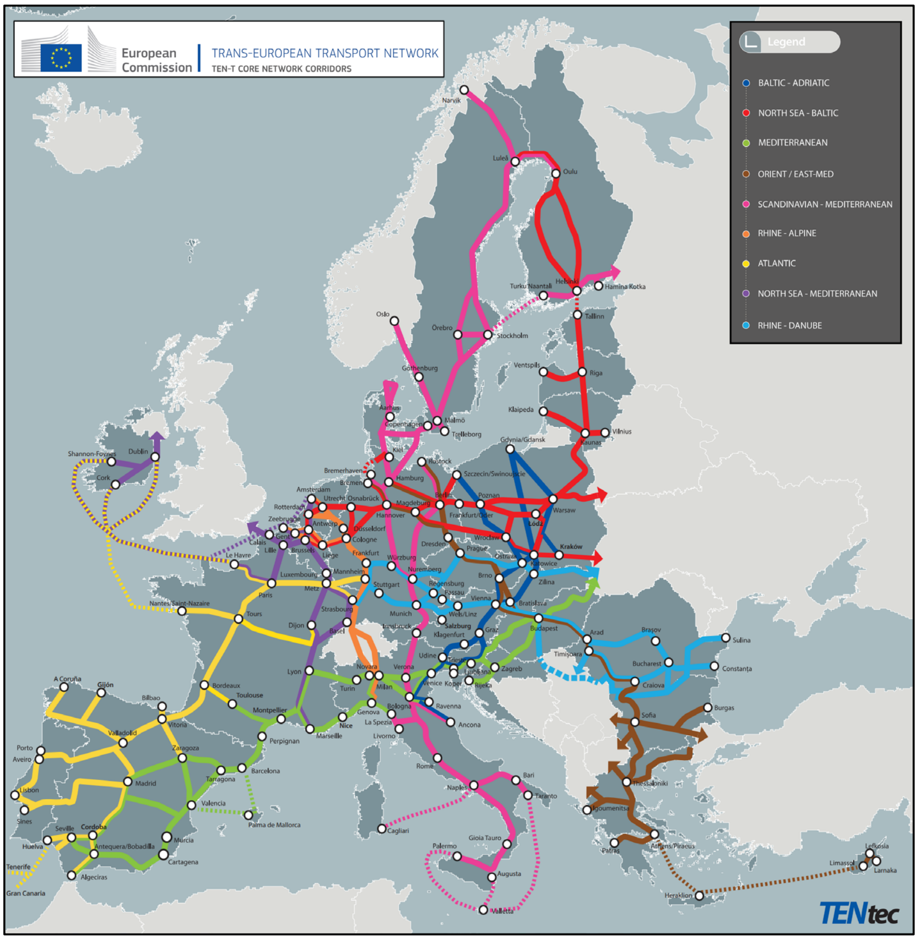


***Figure 4**: The nine core corridors of the TEN-T program's core network.*
Source: European Commission (2024).

However, infrastructure projects can also be driven by smaller-scale frameworks. In Germany, the 'Deutschlandtakt' aims to create a synchronized timetable system inspired by the Swiss 'Taktfahrplan'. This clock-faced scheduling would ensure trains arrive at and depart from major nodes at fixed intervals (e.g., on the hour or half-hour), enhancing connectivity, reducing wait times, and simplifying travel planning. For this to work, travel times between nodes must be short enough to fit the schedules, necessitating infrastructure upgrades to improve efficiency and reduce travel times. In Germany, these projects are legally mandated (Mitusch, 2023). Yet, immediate implementation is not always assured due to funding issues, political changes, land acquisition difficulties, and personnel shortages. Recent projections now expect the 'Deutschlandtakt' to be completed by 2070, rather than the original 2030 target (Sommer et al., 2023).

The United Kingdom's rail sector has faced a different fate with the High-Speed 2 (HS2) project, introduced in 2009 to enhance rail connections from London to major cities in the Midlands and north. The plan included a new Y-shaped high-speed line from London to Birmingham (Phase 1), splitting toward Manchester (Phase 2a) and Leeds (Phase 2b). However, due to environmental concerns, public backlash, and budget overruns, Phases 2a and 2b were canceled between 2021 and 2023, leaving only a delayed Phase 1. Similarly, high-speed and long-distance projects like Northern Powerhouse Rail and the Transpennine Route Upgrade faced substantial budget shortages in 2021 (Seidu et al., 2023). In response, the Integrated Rail Plan for the North and Midlands was introduced in late 2021, consolidating and coordinating the reduced projects to cut costs and improve efficiency. Funds were also redirected from large-scale projects to regional upgrades, highlighting the uncertainties and political influences affecting major rail initiatives (Chen, 2023; Cooke, 2024).

The Rail Baltica project exemplifies the intersection of immense political importance and the urgent need for improved rail connectivity. As a top priority of the TEN-T's North Sea-Baltic corridor, it aims to link Estonia, Latvia, and Lithuania to the remaining European network. A major challenge is addressing the prevalent Russian gauge to improve connectivity. While it will enhance passenger travel, the project's primary focus is on efficient goods transportation, including military material. Increased geopolitical tensions with Russia have elevated the project's military significance. Improving connectivity across the Suwalki Gap, which borders Poland and Lithuania between the Russian exclave Kaliningrad and Belarus, would enhance NATO's response time to incidents in the Baltic States (Bankauskaité & Šlekys, 2023; Kamiński & Śliwa, 2023; Schneider, 2020). Despite high costs, the EU has allocated €425 million to expand dual-use transportation infrastructure, demonstrating how regional rail projects are influenced by diverse political interests (CINEA, 2022).

The list of rail transportation strategies across Europe is extensive. In Switzerland, known for its dense rail network, expansion is managed through a national strategic development program, with projects organized by timelines (e.g., 'Ausbauschritt 2025' and 'Ausbauschritt 2035') or themes (e.g., noise reduction) (BAV, 2024). Austria's strategy, 'Zielnetz 2040', outlines the future rail network and necessary infrastructure, implemented by Austrian Federal Railways (ÖBB) within an annually updated framework (BMK, 2024). Denmark's goal to cut travel times between its four largest cities to one hour has faced political support issues, leading to only partial completion (Grunfelder et al., 2020). Norway's InterCity project aims to enhance rail connections around Oslo and to major cities in Norway and Sweden (Olsson & Klakegg, 2023). Portugal's national infrastructure program focuses on domestic intercity rail upgrades between its metropoles and better connectivity to Spain (Infraestruturas de Portugal, 2023), while Spain and Italy target advanced high-speed rail infrastructure as part of their national transportation strategies (Rothengatter, 2020).

However, major infrastructure and transportation expansion plans, even with political backing, do not guarantee completion. As seen with HS2, the 'Deutschlandtakt', and Denmark's One-Hour-Model, the extended timelines for such projects commonly clash with short-term political cycles. Large-scale mobility concepts, particularly costly high-speed rail plans, often remain speculative rather than concrete. New ambitious proposals frequently fail to reach construction, and those that do are often delayed and/or scaled back significantly. Consequently, the results of these infrastructure improvements often fall short of their original, ambitious goals, delivering only a fraction of the aspired benefits.

While many of the aforementioned rail expansion programs go hand in hand with the EU's TEN-T framework, intercontinental influences on the European rail network are also gaining increasingly more relevance. In particular, the Chinese Belt and Road Initiative aims to improve connectivity between the Far East and Europe via different modes of transportation – including railways. Even though this particularly addresses freight shipping, passenger travel will also benefit from the newly constructed or upgraded rail lines (Dunmore et al., 2019). More specifically, the current focus of investments lies especially in the Balkan region. The main corridor prone to such improvements is the rail line between the Greek port city Piraeus and the Hungarian capital Budapest as well as different branches connecting to and feeding into this corridor. As a result, construction projects have been or are still present in Hungary, Serbia, Montenegro, North Macedonia, and Greece – and possibly will emerge in further places, too (Fardella & Prodi, 2017; Sokołowski, 2018; Tonchev, 2022; Yang et al., 2018).

2.4 – Intercity Train Travel in Europe

The improvement of rail infrastructure resulting from the various projects and expansion frameworks benefits both freight and passenger transportation on rails. As has been introduced earlier, this is essential for expanding passenger rail travel across Europe since rail infrastructure can be seen as the most limiting factor restraining rail operations. The extent of passenger rail services across Europe are therefore to some degree tied to the available infrastructure. However, further aspects such as economics, (geo-) politics, and societal tendencies play a critical role in determining the patterns of rail travel across Europe – especially in terms of medium- and long-distance services (Seidenglanz et al., 2021).

Following the rapid expansion of Europe's rail network in the mid-19th century, interregional passenger services grew significantly. By the late 19th century, a broad network of long-distance trains was established, expanding throughout the 20th century (Wolmar, 2011). Even before the formation of European communities, cross-border services were crucial to the continent's rail network (Martí-Henneberg, 2017). Trains were a highly efficient, comfortable, and luxurious mode of travel, particularly before the advent of affordable flights and well-equipped cars (Seidenglanz et al., 2021). However, the rise of cheap flights and versatile cars led to intense competition for medium- and long-distance train travel. Cars offered individualistic travel, while planes excelled in speed on longer routes. This competition resulted in significant changes in the train network. As an example, Kuster (2003) observed that from 1960 to the 21st century, the number of international destinations from Hamburg decreased, with services to places like southern France and Italy disappearing. In contrast, connections to other German cities and neighboring countries increased. This shift exemplifies a broader European trend toward more frequent short- and medium-distance connections on well-equipped corridors, accompanied by a reduction in other services (Seidenglanz et al., 2021). This has led to a more fragmented rail network, where major cities remain connected but often require multiple train changes. Smaller cities have been neglected or excluded from intercity connections, leaving them underserved. The rise of high-speed rail has further intensified the focus on major city links, making smaller towns and cities less relevant within the European intercity network.

In the meantime, political influences add complexity to changes in intercity rail travel. For instance, the Schengen Agreement's removal of border controls sped up international travel, but historically, such formalities were not major barriers to international rail connections[4] (Martí-Henneberg, 2017). Politics, particularly domestic and economic, significantly impact European train services. The liberalization of rail in the early 2000s, while increasing competition and improving efficiency overall, has led to controversial outcomes. On the positive side, it has expanded service to new destinations, particularly in tourist-heavy areas. However, the focus often remains on profitable, efficient lines, leaving less profitable routes underserved. This concentration on specific corridors, driven by competition and privatization, results in the neglect of potentially important but less frequented lines (Lerida-Navarro et al., 2019; Seidenglanz et al., 2021).

A notable aspect of current intercity rail connections is the revival of night trains. Despite severe declines across Europe over several recent decades – due to high operational costs and competition from budget airlines – night trains are making a comeback, even though the same challenges remain today. This dynamic is particularly driven by a growing awareness of the need for climate-friendly travel options (Curtale et al., 2023; Kantelaar et al., 2022). Therefore, night trains are now aiming to bolster long-distance services and furthermore provide a counterbalance to the fragmentation and modularization of intercity rail services.

[4] This should not be confused with the infrastructure network's layout – which indeed is highly defined by territorial means. Yet, considering the rail network as a given entity, the establishment of international rail services (in case that there are rail connections) is not significantly affected by cross-border formalities.

Despite the aforementioned issues, medium- and long-distance services remain operating across Europe and even benefit from increased efficiencies along certain stretches. While the infrastructural restraints limit cross-border connections, the majority of inner-European borders are crossed by at least one rail service. A large set of cities is linked to medium- and long-distance services forming a relatively dense web of intercity connections across Europe. Spanning from the Arctic Circle down to Sicily, from Portugal's Atlantic coast all the way to the Black Sea – today's intercity rail services reach across the entire continent.

In conclusion, the evolution of intercity rail travel in Europe mirrors the dynamic interplay between infrastructure development, economic pressures, political influences, and emerging environmental concerns. Throughout recent decades, intercity rail travel has been forced to compete with automobiles but also, and most particularly, aviation. In return, the focus on the most efficient corridors has led to the continuous marginalization of smaller and less strategically located cities. The continuously growing popularity of high-speed rail and its associated expansion thereby bear the risk of aggravating the marginalization problem. At the same time, sustainable intercity mobility is further promoted along an increasing set of major rail axes by tackling short- and medium-distance flights. This leaves the status quo and outlook on intercity rail travel to be quite controversial, hosting major travel time improvements on one hand while experiencing significant accessibility shortfalls on the other hand. However, it is advisable to not lose sight of the rail network as a whole, rather than seeing it as a substitute to only some specific air or highway corridors.

2.5 – Geovisualization

2.5.1 – Definition and Origin of Geovisualization

The large scale of the European rail network encompasses a sophisticated spatial complexity of relevant information. The geographic extent and structure of Europe's intercity rail network poses a significant challenge to appropriately comprehending the information behind it. The same is true for countless other scientific fields dealing with geospatial data. An approach to overcoming such challenges and thereby supporting the research and analysis of complex geographic data is the field of geovisualization (short for "geographic visualization").

Common definitions describe geovisualization as the follows:

- Geovisualization is "[...] the use of concrete visual representations; whether on paper or through computer displays or other media; to make spatial contexts and problems visible, so as to engage the most powerful of human information-processing abilities, those associated with vision." (MacEachren et al., 1992, p. 101)
- "Geovisualization [...] concerns the visual representations of geospatial data and the use of cartographic techniques to support visual analytics" (Laurini, 2017, p. 225).

Overall, geovisualization is a valuable concept of reducing the complexity of geospatial data by utilizing the cognitive benefits from the interpretation of visual illustrations. It simplifies an abstract set of location names and/or coordinates and thereby allows for communicating multiple layers of associated information in a spatially organized manner.

While technological advancements continuously add new tools for geospatial visualization, its origins trace back to the pre-digital era. An early example is John Snow's 1854 cholera map, which plotted cholera deaths and water pump locations in Soho, England. By identifying spatial clusters of deaths, Snow traced the outbreak to a contaminated well, helping to halt the epidemic by convincing authorities to close the pump. This marks one of the first instances of geospatial analysis (Maciejewski, 2021). A few years later, Charles Minard's 1861 visualization of Napoleon's 1812-1813 Russian campaign depicted troop losses alongside geospatial and statistical data, illustrating the devastating human toll of war (Kraak, 2009).

2.5.2 – Common Methods of Geovisualization

Thanks to modern technologies, today's palette of geovisual tools is seemingly endless and appears to be restricted only by an author's boundaries of imagination and creativity. Furthermore, the borders between geographic visualization and general scientific visualization are rather gradual and vary with the wide concepts of (geographic) space. However, there is a set of methods and concepts that are most commonly applied and thereby represent the cornerstone of geovisualization.

Standing behind the different geovisualization tools is the concept of visual variables, introduced by Slocum et al. (2023). In short, visual variables stand for a geographical object's properties that can be changed to visually differentiate from other objects. The core visual variables (such as size, color, and shape) are schematically presented in Figure 5. Nonetheless, these eight enlisted variables are only the most common and basic ones which have proven to be most effective. Yet, there are several more options that are used less prominently.

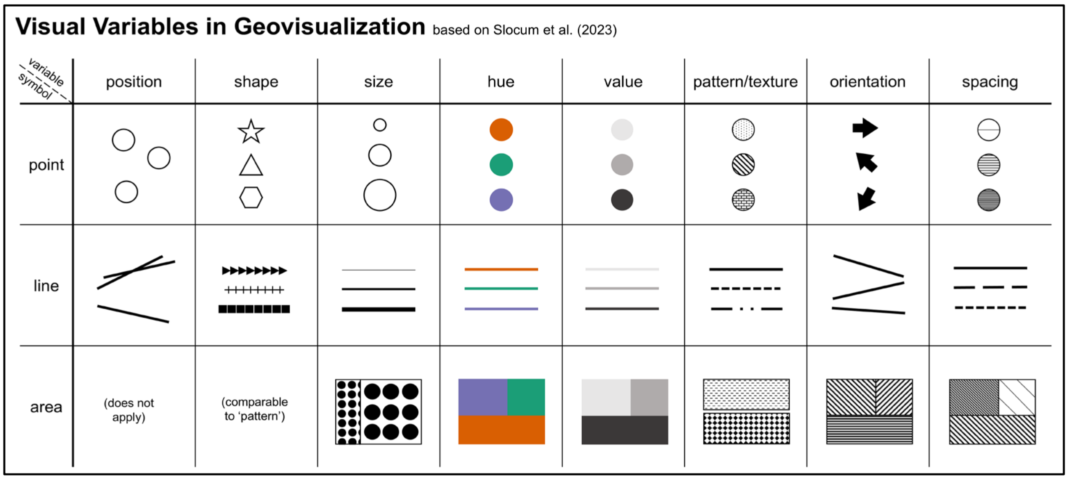
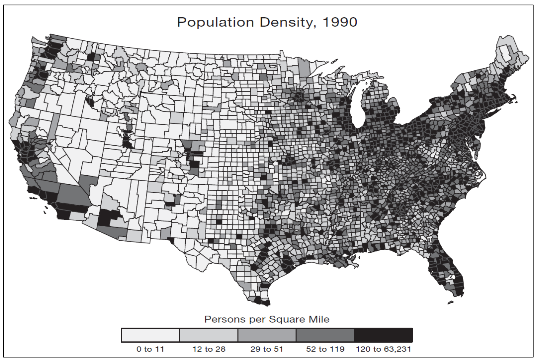


Figure 5: The most important visual variables of geovisualization, based on Slocum et al. (2023). Source: own illustration.

With use of the numerous visual variables, a wide set of maps can be produced to transfer the spatial data in a visual way. The focus of these so-called thematic maps is on their associated properties in the context of their spatial distribution. Among the diverse kinds of thematic maps exist typical mapping methods which are described in Table 1. Yet, further map types exist as well; combinations between different types are common, too. In recent decades, interactive maps gain increasingly more popularity since they allow for customized data exploration. Additionally, statistical visualizations (e.g., Histograms) often accompany geovisual research.

Table 1: Overview of most common mapping techniques, based on Slocum et al. (2023) and Maciejewski (2021).
Figures 6 a-f: Examples of various map types. Source: Slocum et al. (2008).

Illustrative Example	Map Description
	**Choropleth Maps**: Varying color values or hues represent the magnitude of a variable aggregated over a geographic area (e.g., countries, states, municipalities). For avoiding misinterpretations, the values should be normalized, for instance by the unit's population or area. The meaningfulness of choropleth maps is highly dependent on the layout and structure of the selected basis units. *Figure 6a: Choropleth map of the population densities in US counties as of 1990. Source: Slocum et al. (2008).*

Proportional (Point) Symbol Maps:

Symbols (typically points/discs) of varying sizes represent the data associated with different locations. The size (e.g., height, area, ...) matches the variable's magnitude. The symbols can thereby serve as additional layer of information, for instance in the function of a pie chart. In contrast to choropleth maps, this technique is ideal for mapping absolute values.

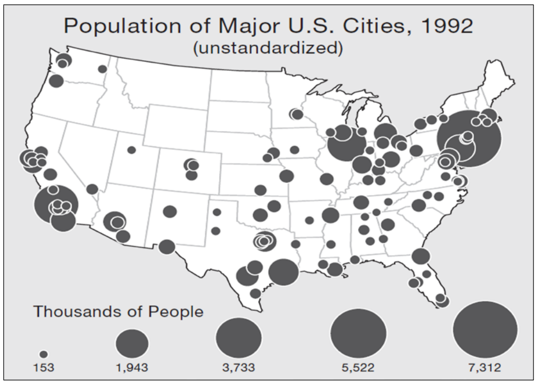


Figure 6b: Proportional point symbol map of the USA's cities' population in 1992. Source: Slocum et al. (2008).

Dot Maps:

Small dots are placed over a certain space to indicate the spatial distribution of a specific phenomenon. The positions of the dots represent the exact locations of a single instance (dot distribution map). Alternatively, aggregated data can be visualized by randomly placing dots in the region of the aggregated unit for each single instance (dot density map).

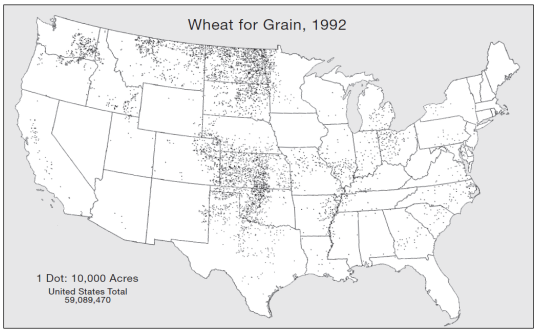


Figure 6c: Dot map of wheat sourcing locations in the USA in 1992. Source: Slocum et al. (2008).

Cartograms:

Geographic space is distorted based on a selected variable. The map features (typically areas or distances between locations) are then proportionally scaled to match the variable's magnitude. For example, a country's area then proportionally equals its population.

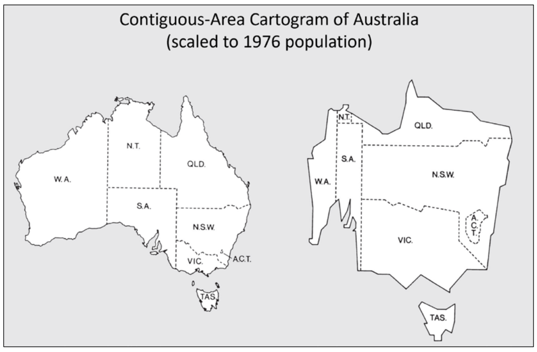


Figure 6d: Area cartogram of the 1976 populations of Australia's territories. Source: Slocum et al. (2008).

Isarithmic, Isopleth, Isoline, or Contour Maps:

Continuous quantitative fields (e.g., precipitation, elevation) are used to divide space into a set of regions. Each region thereby represents a constant range of values from that field. This concept can also be applied to non-physical fields such as travel times, in which case one speaks of isochrone maps. Point data can be turned into continuous fields by different interpolation methods.

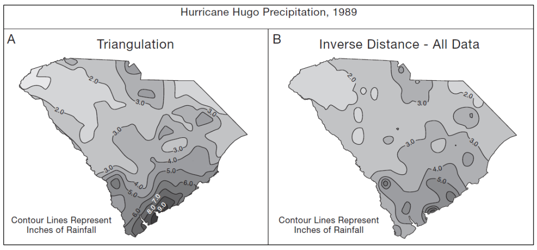


Figure 6e: Isoline map of precipitation associated with 1989 Hurricane Hugo in South Carolina, with two different interpolation methods. Source: Slocum et al. (2008).

Flow Maps:

Line symbols or arrows are used to display relationships or movements between places. This often refers to the fields of mobility and economic transactions. They can also simply be used to show non-directed connections between locations. These connections can further be enhanced by visual variables (e.g., width or color) to represent the magnitudes of values.

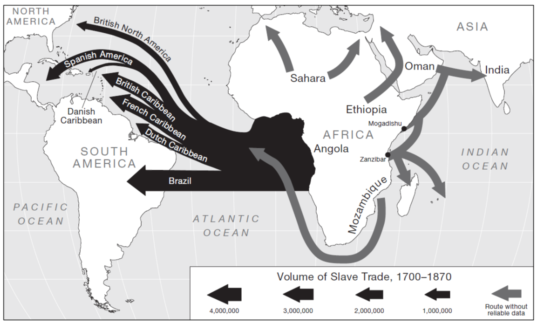


Figure 6f: Flow map of the slave trade out of Africa from 1700 to 1870. Source: Slocum et al. (2008).

2.5.4 – Examples of Applications of Geovisualization in the Field of Mobility

Among the field of mobility planning, analysis, and research, geovisual tools have proven to be particularly valuable. The integration of geographic information systems (GIS), statistical datasets, and analytical models provides comprehensive insights into movement patterns and urban dynamics while allowing for exploring transportation systems simultaneously. Stakeholders, the broad public, and scientific researchers alike benefit from meaningful geovisual tools which thereby contribute to a better understanding and further improvements of transportation systems all around the world at different scales. While the potential applications of different kinds of thematic maps and other geovisual methods appear to be seemingly endless, a few interesting examples serve to represent and corroborate the importance of geovisualization for the field of mobility (with a particular focus on railways).

Accessibility analyses therein are a very prominent discipline. Generally speaking, this usually addresses the spatial concentration of public services such as medical facilities, supermarkets, or public transport stops, but can also target specific locations (e.g., the country's capital). Accessibility is then defined as the ability to reach these services or places with appropriate efforts. Depending on the scope of research, the mode of mobility for reaching the desired places can vary. For instance, Rossetti et al. (2020) used geovisual tools to assess the pedestrian accessibility to public transport in urban areas in Brescia, Italy. In the case of Germany, Neumeier and Kokorsch (2021) identified spatial patterns of supermarket accessibility by foot, bicycle, and car. Similar studies have been conducted all across the world with varying focuses of research. What makes geovisual tools particularly useful is the ability to comprehensively illustrate complex spatial relationships which most likely would be hard to detect and understand in the raw data.

The same advantages also unfold in combination with other geographic disciplines such as risk assessment and management. Mobility-related infrastructure is critical to a functioning society. As a consequence, the potential risks associated with disruptions or full destruction of roads and railways are of severe significance. Depending on the geographic region and terrain, threats by natural hazards are of particular importance. Critical high-risk locations are commonly found through geovisual means. This often goes hand in hand with the communication of the respective risks which is significantly eased by appropriate visualizations. The local population, authorities, and decision-makers can all benefit from geovisual approaches toward risk management thanks to its ability to unify complex spatial variables into simple and more easily understandable displays (Lagadec et al., 2018; Saint-Marc et al., 2018).

Lastly, and in this thesis' context, most importantly, geovisualization serves as an ideal concept of analyzing and simplifying rail networks as well as respecting their impacts to the society. As an example of interactive geovisualization, Fairbairn (2005) addresses that geovisualization techniques could become closely coupled to applications in journey planning. On a more analytical note, Wang et al. (2022) used cartograms to visualize regional differences in how the improved high-speed rail network in China reduced travel times to the Chinese capital. Zhiyuan et al. (2017) applied different geovisual techniques to illustrate and research passenger flows in the Shanghai metro system. Meyer de Freitas and Blum (2024) used geovisual methods to assess the current TEN-T rail corridors and a modelled medium-speeds scenario in terms of connectivity to European metropolitan regions. Vrána et al. (2023) applied various types of geovisual tools in their research on current international high-speed rail connections in Europe which helped to easily identify patterns of services. The vast set of potential applications consequently underpin the enormous potential of geovisual (research) approaches, especially in the field of mobility and railways in particular.

3 – Methods I: Building the Network

3.1 – Analysis Framework

Throughout the analysis of the future European intercity rail network, the versatility of geovisual tools and methods will significantly support the research. The core idea of this research setup is to identify a realistic network of intercity rail links that spans across all of Europe's rail network and can be analyzed accordingly. As Figure 7 illustrates, a set of cities will be defined by mixed hard and soft criteria. In parallel, raw infrastructure data will be retrieved for all of Europe. With the help of a self-made routing tool and network identification algorithm, the basis network (based on potential travel times) will be computed. This current scenario will be updated with realistic timetable-based travel times. Next, the impacts of the infrastructure projects will be included. This will eventually result in two basic scenarios, a current and a future one, thereby acting as the core of analysis. With geovisual tools, network metrics, and by the help of case studies and specific thematical focuses, the research questions will eventually be addressed.

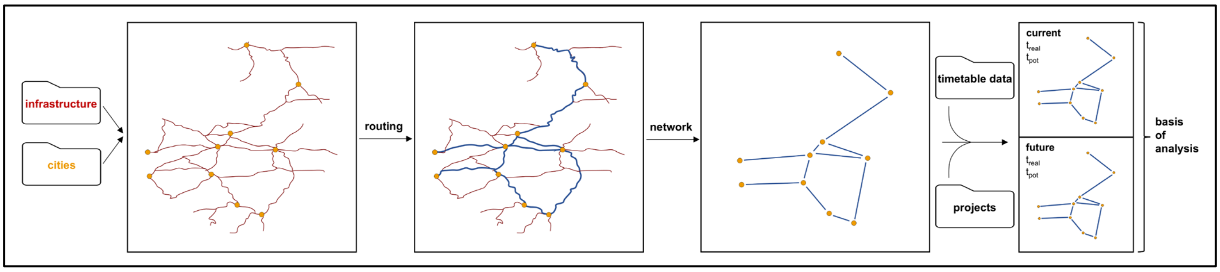


Figure 7*: Sketch of this research's methodological steps.*
Source: own illustration.

The spatial context of this work is marked by the extents of the European rail infrastructure as it is the goal to analyze as many connections across the continent as possible. However, there are different understandings of how far Europe reaches. In combination with the spatially uneven distribution of infrastructure and political conflicts, it therefore makes sense to clarify the spatial extent of this thesis. For obvious reasons, countries without any (operable) rail infrastructure are excluded. This concerns Iceland, Malta, Cyprus, Andorra, and San Marino. In the same sense, it should be noted that Monaco, being crossed by a major rail line, is in this case treated as a part of the French rail network. In the Southeast, the network includes Turkey, but only until reaching the Bosporus as this aligns with the outlines of the European continent. Toward the east, the European rail network is ending at the borders of Russia, Belarus, and the Ukraine due to the ongoing war. Since military conflicts are very destructive, especially regarding critical infrastructure, there is no certainty about how intact the Ukrainian rail network will be once the Russian attacks end. Meanwhile, the political relationships between the EU and Russia are highly confined including strict sanctions. The resulting discontinuation of international trains to Russia and Belarus will likely prevail in the near future.

The type of research will thereby be a mixed-methods approach. Besides the quantitative network analysis (i.e., changes in travel times and network metrics), the case studies and thematic focuses provide a qualitative component to this work. It is furthermore important to understand that this thesis represents only a snapshot of the dynamics surrounding rail infrastructure development. Due to the uncertainties associated with the completion of proposed expansion plans, projects might be cancelled in the near future or only be completed partially and/or with delays. However, new projects might also emerge continuously. This highlights the importance of the qualitative component of this research since it allows for identifying patterns of change. The entire methodological part of this thesis is based on publicly and openly accessible data and tools, thereby allowing for being reproduced. The technical basis of this analysis is Python (version 3.12).

3.2 – City Selection

The cornerstones of this research are formed by the cities that are being included. They determine the layout and structure of the resulting intercity rail network. Consequently, a meaningful selection of cities is crucial to substantiating the explanatory power of the analysis results. The challenge is thereby to find an adequate selection approach that represents the rail network appropriately, includes a large fraction of urban populations, and respects the local contexts of places. The first approach was therefore to develop a set of hard criteria (e.g., a fixed population threshold). These attempts however did not produce satisfying results. Therefore, it was decided to establish a combination of hard and soft criterions that would guide the city selection procedure accordingly. Listed below are the criteria which are based on a similar methodologic approach as in Wang et al. (2022).

- Every country with operable rail infrastructure must host at least three cities.

  Exceptions: small countries with very limited rail infrastructure (i.e., Liechtenstein, Luxembourg, Albania, Kosovo, and Montenegro) may host only one or two cities.
- Capitals must be included.

  Exception: Turkey, since Ankara is not part of continental Europe.
- The biggest cities (in terms of population) of every country must be taken into consideration if being linked to the rail network.
- The rail network should be captured in its full extent; the outermost cities should therefore be included if possible and meaningful.
- Different areas of a country should be covered by selected cities; they should (as far as their setting allows for it) be relatively evenly distributed across space.
- The structure of the rail network should be appropriately represented.
- In polycentric urban areas (e.g., the German Rhine-Ruhr region), only the major cities should be selected in accordance with the rail network's structural layout.
- If reducing the network's complexity, interchange locations may be added to the network despite being of minor importance as a city itself.

To sum up, it can be said that the cities were selected in order to represent the country's geography, match the layout of its rail infrastructure, and address the largest possible part of Europe's population while keeping the resulting network's complexity as low as possible. Eventually, a total of 335 cities were selected and included into the dataset forming the spatial basis of this research. This directly covers ca. 135 million inhabitants. In addition to each city's name, further attributes such as the population size or the respective country were stored. Most importantly, the coordinates of each city's major rail station were retrieved. This had to be done manually since it was essential to strategically pick a very specific location on the tracks at the main station for the routing operation (for more details, view the routing methodology). Hereby, cities with multiple different stations connecting to different parts of the rail network posed a special challenge. Prominent examples are Paris, London, or Budapest. However, there are also instances where stations differ by track gauges, for instance in northern Spain. In such cases, each station was listed separately with a specific attribute for later identification, totaling in 366 entries. This differentiation is essential for the routing operation and consequent network generation in order to avoid misleading results. However, the resulting network will only feature the 335 cities as such. The differentiation between stations will eventually only remain relevant for the computed connections. An overview of the cities and the connections can be found in Figure 11. The full city selection can be found in Appendix A.

3.3 – Infrastructure Data

3.3.1 – Data Source and Acquisition

The physical basis of this thesis is formed by rail infrastructure data. Publicly accessible and regularly updated data is available at OpenStreetMap (OSM). OSM is a collaborative database providing free and open geographic data that is contributed and updated by a community of volunteers. The platform covers a wide range of geographic features beyond railways, for instance roads, buildings, natural landscapes, and amenities. Its community-based characteristic enhances regular updates, therefore providing ideal up-to-date geodata. Furthermore, OSM uses a tagging system which assigns descriptive attributes to map elements by using key-value pairs. The key represents a specific characteristic (e.g., "highway") while the value specifies the type or name of that characteristic (e.g., "residential" or "pedestrian"). The raw data can be downloaded from OSM through different methods.

In this case, the Overpass API (https://overpass-api.de/api/interpreter, with help of the python package `requests`) was used. This method takes an input query that indicates the preferred file type, the spatial frame in which the data should be downloaded, and the desired geometries. For this work, the data was downloaded for each country individually by defining the countries outlines as spatial frame. This included maritime territories which enabled full infrastructure connectivity between the United Kingdom and France as well as Sweden and Denmark where infrastructure crosses the ocean. Furthermore, it was specified that within the key "railway" only the geodata with the values "rail" and "narrow_gauge" should be acquired. This ensured that abandoned tracks as well as local transit infrastructure such as light rails, monorails, subways, trams, and funiculars were not included in the dataset. Eventually, this results in a downloaded file for each country which, once unpacked, contains a set of all rail infrastructure elements. Each infrastructure element is then composed of a set of nodes which together represent a formation of linear segments capturing the element's geometry. Furthermore, each element is associated with tags that indicate track properties. Figure 8 presents an example of the infrastructure data's layout and structure.

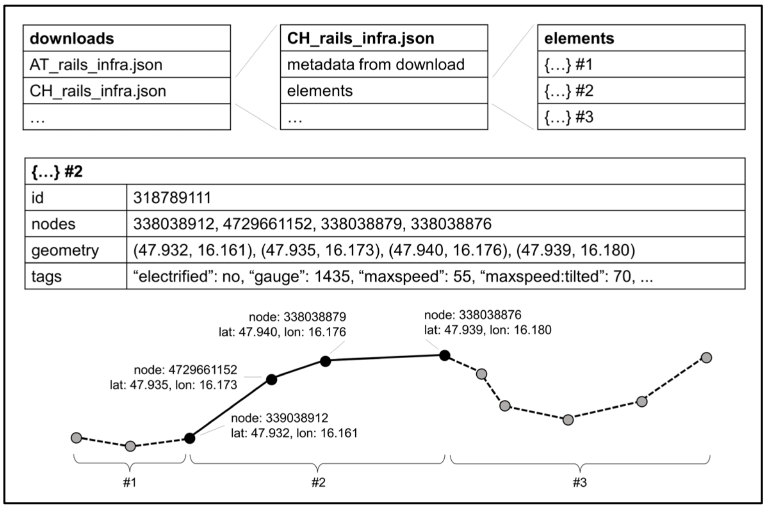


***Figure 8**: Simplified example of the rail infrastructure's data structure. Source: own illustration.*

3.3.2 – Data Pre-Processing

The datasets for all countries were downloaded on 01.03.2024 (from OSM). However, before the data can be analyzed adequately, it must be pre-processed in several aspects. This preparation is essential for enabling an efficient and accurate network generation and were conducted for every country's network file. First off, the elements need to be unpacked from the downloaded file, i.e., the elements are extracted from the nested structure.

Next, each infrastructure element is broken up into its segments. Each segment thereby is assigned with the attributes of the element they were part of. At that point, each infrastructure entry consists of only one single segment spanning between exactly two nodes. For each segment, the physical length, i.e., the geodesic distance, is calculated based on the nodes' coordinates. Furthermore, the Vmax is retrieved from the tags. In the OSM tag structure, the Vmax values are indicated by the key "maxspeed". Since the Vmax values can be further differentiated (e.g., "maxspeed:tilting" for tilting trains), the highest value of all keys containing "maxspeed" is selected as the Vmax to proceed with. However, not every element is equipped with the same tags. This means that information on the Vmax may not always available. In that case, the segment is assigned with the country's average Vmax as its own Vmax. This value is calculated as the average of all segments equipped with a "maxspeed" key, weighted by the segment's respective length. The relevant segments are then also marked with an additional attribute to clarify the value's origin. Lastly, the time needed to travel along each segment is calculated based on the segment's length and Vmax. This value, the (potential) travel time per segment, will be the most important attribute for the later stages of network generation.

However, the splitting-up of the elements multiplies the number of single elements significantly. This would dramatically slow down the network generation process due to high inefficiencies during routing. Therefore, a data re-simplification is applied to re-merge as many segments as possible (belonging to the same original element) into one single section of infrastructure. In order to maintain interconnectivity between the elements, an intersective approach is chosen which is illustrated in Figure 9. For each newly merged element, the joined segments' travel times and lengths are summed up. Consequently, the resulting elements represent no more exact real-world geometries but are equipped with attributes containing their exact physical properties. Overall, this reduces the number of elements by around 87.8% while still accurately maintaining its physical properties and interconnectivity within the infrastructure network.

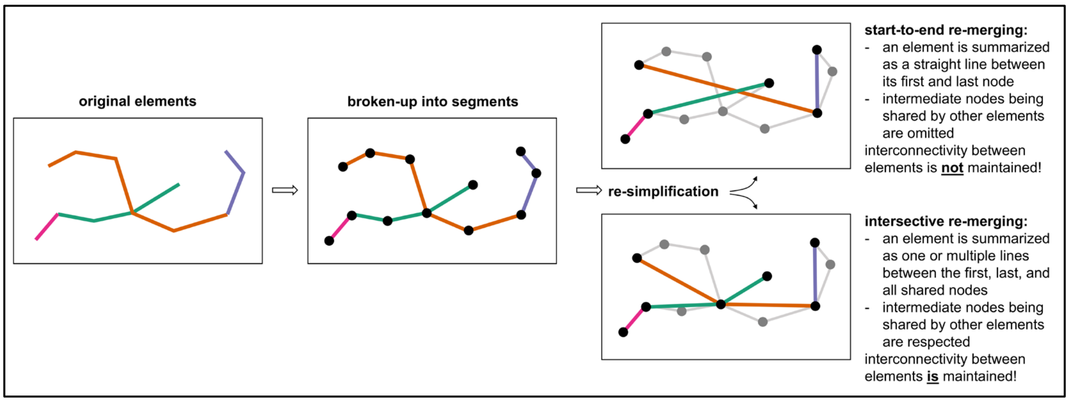


***Figure 9**: Example illustration of intersective re-merging of infrastructure segments.*
Source: own illustration.

3.3.3 – Data Quality

The infrastructure data from OSM is generally said to be accurate and regularly updated. OSM data is therefore considered to be a valid source for any kinds of research and analyses which has also been corroborated by specific studies on that matter (e.g., Mooney & Minghini, 2017). This has also become evident throughout this thesis' work. Comparisons with recent track disruptions (e.g., on the German island Fehmarn) help to confirm and validate the data's accuracy. However, while the track geometries seem to be very accurate in any instance, there are shortfalls regarding the indication of associated operational properties. In particular, large fractions of the infrastructure elements are not equipped with any information on the respective Vmax. This overall concerns around 32.74% of all tracks which is a substantial fraction. Fortunately, a more detailed assessment reveals that this mainly concerns smaller, less frequently used tracks which are not part of the main lines. Opposing this, main lines typically come with very accurate indications of their operative properties. This observation represents a parallel to the findings of Kounadi (2009) who claims that bigger streets are more accurate than smaller ones. Since main lines usually are the ones with the highest velocities and are predominantly used for intercity services while this thesis centrally focuses on intercity travel times, the OSM data quality can be deemed appropriate for this specific scope of research. Nonetheless, it must be acknowledged that data quality differs throughout Europe. Especially in Ireland, Moldova, northeastern Romania, and western France, some limitations do occur. Overall, the later computed network will include around 4.80% of tracks that initially did not have any Vmax values and therefore had to use the respective country's average velocity.

3.4 – Intercity Network Generation

3.4.1 – Routing

Once the infrastructure data has been pre-processed, it can be used for the computation of a web of intercity rail connections. Following the pre-processing, the infrastructure data is from now on treated as a theoretical network graph. Every simplified infrastructure element is represented as an edge spanning between two nodes. The edges are thereby weighted with different resistances which in this case are the potential travel times computed earlier. It is herein important to remind that this thesis desires to base the intercity network construction on these potential travel times for maintaining a uniform approach. This assumes that every infrastructure element is (to its full extent) traversed with the highest designated velocity. Only during later stages, these connections will be expanded thematically by adding a layer of real-world timetable-based travel times. In order to identify the potential travel times for a pair of cities, it is essential to establish an efficient routing tool. This tool should take two input coordinates, find the respective closest nodes in the network (acting as entry points), and identify the path through the infrastructure network requiring the shortest total potential travel time.

The first step is therefore to produce a method that takes any input location (in the format of latitude/longitude coordinates) and finds the closest node in the infrastructure network. Due to the high number of nodes, it is most meaningful to implement a k-dimensional tree (KD-tree) into this function. Simply put, a KD-tree is a binary search tree which allows for efficiently identifying the closest neighbor. However, due to the binary nature of this tree, the identified closest neighbor might not actually the closest point to the input coordinate. Therefore, a second verification search is implemented to find the actual, real closest neighbor. For that, the distance between the input location and the preliminary identified node is calculated. This distance is then doubled and used as diameter for constructing a square frame surrounding the original input coordinates. This square structure parallel to the latitudes and longitudes allows for an efficient binary identification of all nodes lying within the frame. Then the haversine distances from the input location to every point within the frame are calculated. The node with the shortest distance eventually represents the true closest node to the input location. For accurate routing results, it is essential that the true closest node is found. Otherwise, sidings or dead-end tracks might be targeted which would distort the routing results – which is why the input coordinates were carefully chosen manually in the first place.

Once the two start and end nodes are identified, the shortest path between them has to be found, if there is one. The term "shortest" herein refers to the topological distance which is the potential travel time (i.e., the shortest path is the one with the smallest potential travel time). For this purpose, the Dijkstra algorithm is chosen. This algorithm continuously explores the shortest paths to all other nodes and in this case terminates once it has reached the desired end node. One can thereby specify different metrics defining the topological distance (e.g., the number of edges along the way), which in this case is the edges' respective potential travel times. Once the shortest path has been found, the sum of the weights can be retrieved, thereby marking the overall potential travel time along the shortest path. It is herein important to remark that the resistances, i.e., the infrastructure elements' potential travel times, are treated as non-directed. This means that the journey travel times from A to B and from B to A are assumed to be identical. The routing results are therefore to be treated as non-directional, too. While the Dijkstra algorithm can be inefficient for larger and more complex networks, it provides reliable results and finds the true shortest paths which means that no further operational verifications must be made.

These overall routing operations are being implemented with the help of some publicly available python packages. For the KD-tree, the package `scipy.spatial.KDTree` was used. For treating data as network graphs, the `networkx` package and its extensions were applied. This also includes the application of the Dijkstra algorithm to identify the shortest paths.

3.4.2 – Domestic Routes

With the help of this routing approach, it has now become possible to freely calculate potential travel times between two places which is the key component of the desired goal to generate a network of intercity connections. In order to increase the efficiency of this procedure, it is most meaningful to start off with computing every country's domestic connection network only. This allows for using only the domestic infrastructure network (instead of the entire European data set) and also reduces the overall number of iterations.

Therefore, the following procedure is pursued for each country individually. First, the respective pre-processed rail network is loaded to form the basis for computation. One exception is made in the case of Austria where the southeastern German network section is also loaded. This is the only instance where a major domestic intercity connection runs through another country. Once this is successfully completed, the connections between all pairs of cities are routed and the travel times are stored accordingly. City pairs consisting of locations within the same place (e.g., between Paris Gare de Lyon and Paris Gare du Nord) are thereby not taken into consideration. Lastly, in the case of Italy, one manual addition is undertaken: an 85-min link between Messina and Villa San Giovanni. Through those two places, Italy's mainland is connected with Sicily by a boat transporting passenger trains – which is indicated to take 85 min from station to station, according to online sources. Even though no fixed infrastructure exists, this link is part of the Italian rail network.

Once all domestic network lines have been computed, the multiple stations are dealt with. Through an implemented function, all travel times running between the same cities but calling at different stations are compared from which eventually only the shortest travel time is being stored. In that case, an additional attribute remarks the station for clarity. The entire procedure also handles special cases where both cities are operating with multiple major stations, for example London and Liverpool. Here, the travel times are computed for all station pairs, but eventually only the fastest link (here: London Euston to Manchester Piccadilly) is kept.

Following this, the network is further simplified to represent only meaningful connections which also match the structure of regular intercity operations. Specifically speaking, this targets routes over longer distances that run through or very closely bypass other cities along the way. In that case, it is more realistic to split the lines into segments taking the intermediate cities into consideration as well. In particular, two thresholds were defined: if there is a route besides the most direct one, i.e., via one or multiple other cities, and the new travel time is less than 10% or 5 min longer than the original one, the indirect version should be preferred. Hereby, the larger of both values represents the effective decisive threshold. The final relative threshold of 10% was selected as a result of manual experiments and was identified as an ideal approximation to capture the non-directiveness with multiple stops that typically characterizes intercity rail services in Europe. The 5-minutes absolute threshold was established to also address sections with shorter travel times where the relative approach would not provide any satisfying results. Furthermore, five to ten minutes (depending on the country) mark the thresholds for train delays in Europe (Grechi & Maggi, 2018). This means that deviations from schedule of up to five minutes are widely deemed acceptable/tolerable which further supports the threshold selection. At the end of the simplification (a visualization of this process is available in Figure 10), the domestic network is complete. For Luxembourg and Liechtenstein where only one city was included, no domestic connections were calculated.

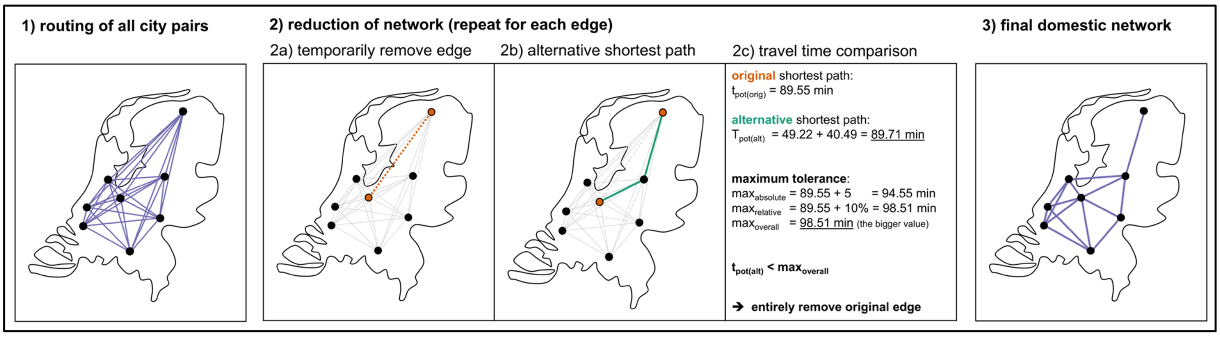


Figure 10*: Example sketch showcasing the simplification process of the domestic network (here: Netherlands). Source: own illustration.*

3.4.3 – International Routes

In in order to complete the network, the next step is to compute all international connections between the different countries. This means that all links between neighboring countries must be taken into consideration. However, simply pairing all cities from one country with every city from its neighboring country would be very resource demanding and hence inefficient. Besides that, international connections are also possible between countries that do not share a physical border with each other (e.g., Croatia to Italy through Slovenia, if certain cities in Slovenia were not included in the network). Consequently, to address all possible international connections, a specific system was manually set up. For every possible country pair, a distance threshold was implemented (which is available in Appendix M). Every international city pair between the two respective countries with a distance shorter than the threshold is then computed. The thresholds were selected manually and were set large enough to cover all international connections between the access points to the different sections of the respective domestic networks. This however is significantly dependent on the selected cities. Therefore, every threshold was, if necessary, equipped with one or multiple additional requirement cities.

If all the required cities for a specific country pair are present in the network, the threshold method is applied, i.e., connections are only computed for international city pairs with a distance below the threshold. Otherwise, all international city pairs are to be evaluated. Through this method, it is also possible to address the few potential special cases of international connections passing through a third country. Once all the required international connections are computed, the resulting network had to be simplified again. Thereby the exact same procedures as in the domestic networks are applied. Besides that, issues regarding multiple stations re-emerging from the international computations are also dealt with prior to the structural simplification. The eventual result is a simplistic rail network based on the potential (infrastructure-based) travel times. It consists of 683 connections. For a better understanding of the routed paths and the spatial structure of the connections, Figure 11 shows the physical paths of the routed intercity rail connections. A more abstracted visualization of the rail network will be illustrated in Figure 18.

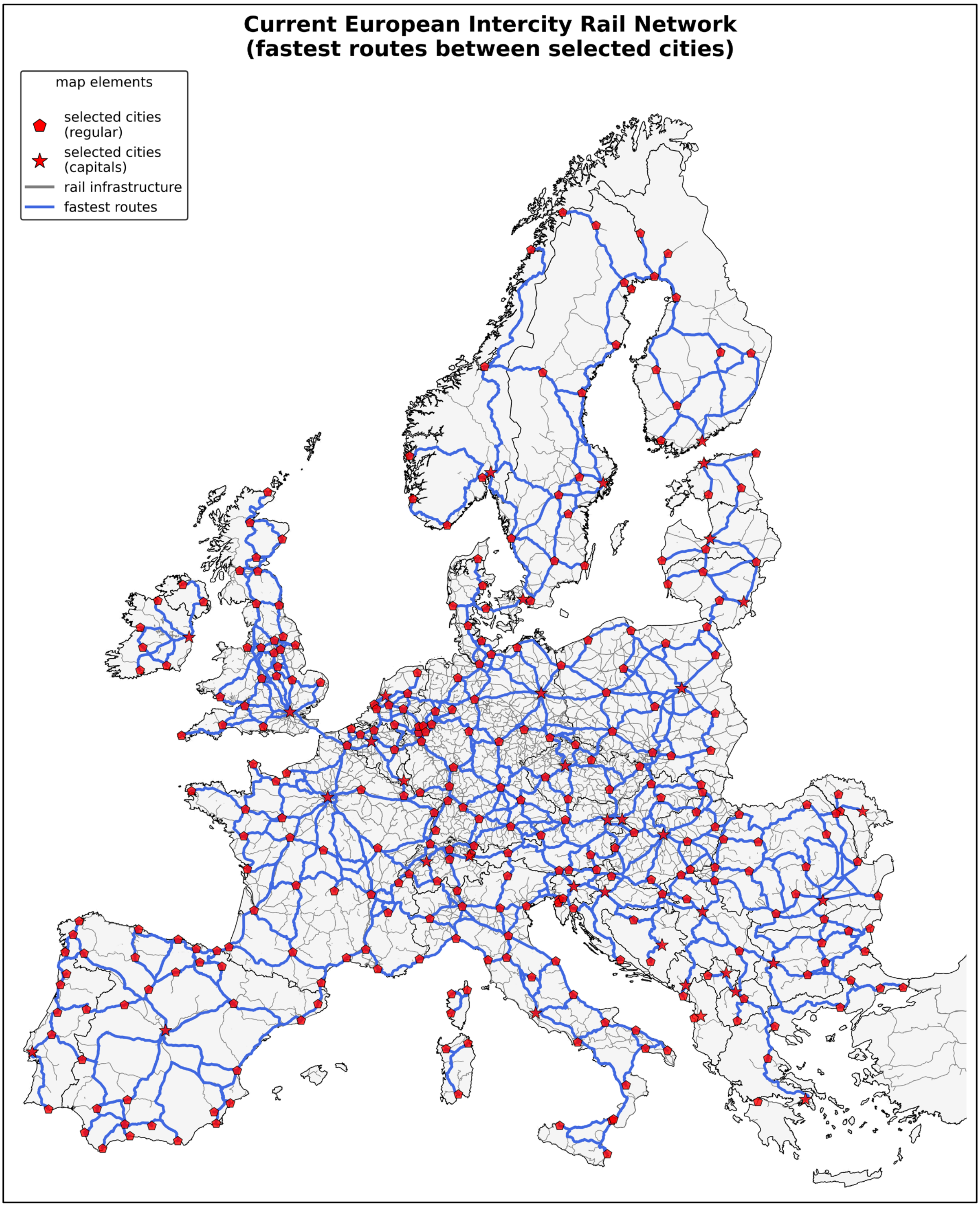


***Figure 11**: Overview of the selected cities and the corresponding network connections (fastest routes). Source: own illustration.*

3.5 – Timetable Data and Regression

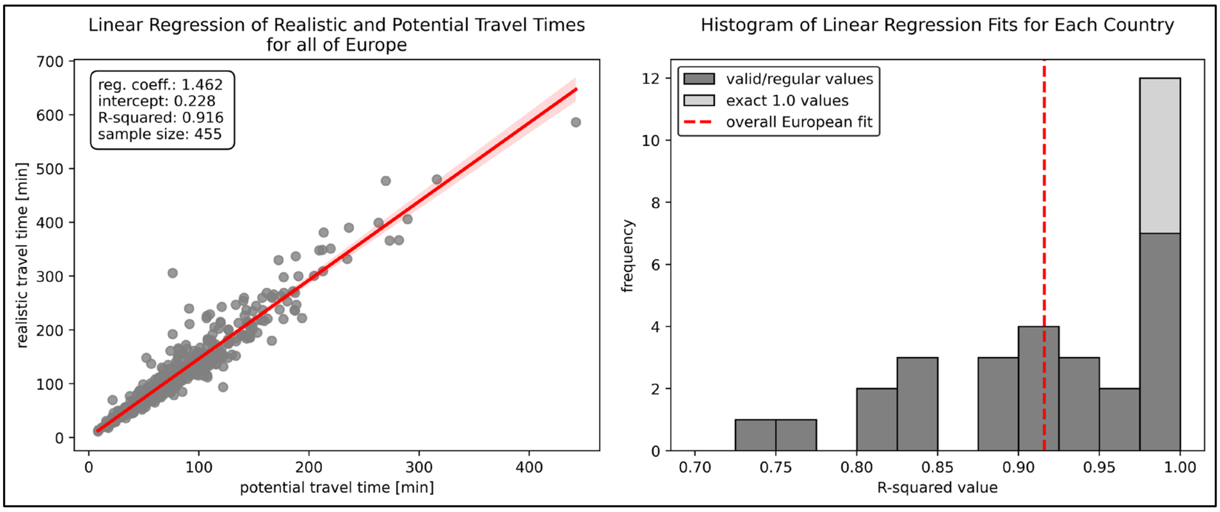
For full comparison and analysis, it makes sense to not only rely on potential travel times, but to also include the realistic equivalent. This means that each connection should (if available) be equipped with information on its timetable-based travel times. These are manually retrieved by the following approach:

- Timetable data must be accessed through a fixed order of travel planner applications: (1) Interrail/Eurail rail planner, (2) Rome2Rio, (3), local train websites, (4) rail.cc form. Only if one option does not provide realistic results, the next one in line is to be used.
- Period of travel is the first full week of May, i.e., 06.05.2024 to 12.05.2024. Any day within that timeframe would be viable.
- Both directions are checked: from city A to city B and vice versa from city B to city A.
- For cities with multiple major stations, connections to each one of them are checked.
- For each pair of cities, the very fastest connection (i.e., at any given time within the frame, with no regards to the direction or station) is proceeded with.

The travel times are then stored in a table for each connection. In addition, it is always remarked whether the connections were direct or not. For indirect connections, the intermediate stops are noted as well. Certain instances with no current operations (despite technically being connected by infrastructure) are marked separately. In three specific cases, the connections are temporarily disrupted and re-routed or significantly slowed down due to certain incidents. This concerns the links Zurich-Lugano (derailment), Turin-Lyon (landslide), and Hanover-Hamburg (track work). Since these limitations are not present in the infrastructure data (therefore not affecting the routing and potential travel times) and are to be sorted out throughout the year, the original (hence shorter) travel times are used. This results in a full-scale European network of intercity train connections which represents the current situation.

Prior to assessing the infrastructure projects, it is important to determine the relationships between potential and realistic travel times. This will later prove to be essential for analyzing the impacts of the infrastructure projects and further enable a wider understanding of how infrastructure correlates with travel times. For this purpose, the goal is to compute linear regressions between the two values. One major limitation that was undertaken is that only direct timetable connections are included. This is due to the fact that indirect ones usually come with transfers of varying durations which would distort the results. Furthermore, it was decided to compute regressions for every single country as well as for the entire rail network as a whole. In the first case, only domestic connections are used in order to avoid distortions from varying track properties per country. Therefore, no regressions can be computed for countries with less than two direct domestic connections.

On a European scale, the sample size is a total of 455 connections. The regression produces an R-squared value of 0.916 which indicates a very good fit (1.0 would indicate a perfect fit while 0 would mean that the regression has no explanatory value at all). A visual insight to the European regression is provided in Figure 12a. Among the specific regressions for each individual country, the R-squared values vary between 0.744 and 1.0 (see Figure 12b). This means that all regressions are at least fairly accurate. The majority of R-squared values are above 0.85 which corroborates the linear relationship between the realistic and potential travel times. However, the perfect fits marked by R-squared values of 1.0 are only of limited explanatory power since they all result from countries exactly two single domestic connections, which is why the regression could be fit perfectly. These calculations are realized with help of the `sklearn` package in python. The full regression results are available in Appendix B.



***Figures 12 a-b**: (a) regression between realistic and potential travel times for the full European sample; (b) distribution of the linear regression's R-squared values for every individual country.*
Source: own illustration.

This computation of regressions also serves as validation for the routing approach used during the network generation. The high regression fits indicate that the paths between cities are/were routed in an appropriately constant manner. This allows for the conclusion that the routing tool produces results that, despite not being equal, are confidently proportional to how train schedules are operated. This further corroborates the importance of infrastructure properties as the (obvious) basis for train travel times.

3.6 – Infrastructure Projects

3.6.1 – Criteria for Included Projects

Next, to enable a comparison between the current situation and the future of intercity rail travel in Europe, the changes to the infrastructure must be captured. Consequently, the next step of this thesis is to gather a list of all ongoing and bindingly planned infrastructure projects as well as their consequences to existing and new rail connections. The most challenging part in this is to clearly define which projects should be included and which ones should not. Implementation time scales and focuses of improvements (e.g., local vs. interregional services) vary drastically. Moreover, the speculative nature of such projects makes it difficult to identify to which degree the projects will be completed – if at all. This therefore also must be taken into consideration when developing a clear framework of criteria on which projects should be included:

- The project must be scheduled to be completed by 2050.
- The project must benefit intercity rail travel in terms of travel time reductions.
- The project must at least have entered the stage of legally binding designing or have been legally corroborated including the definite allocation of funds.

The temporal frame is set to be spanning until 2050 since this year marks the ambitious but necessary goal of the EU but also other European countries including Switzerland to reach climate neutrality. Since sustainable mobility is a crucial component to reaching this ambitious goal, the expansion of rail operations is part of countless sustainability strategies (Bäckstrand, 2022). Consequently, it can be expected that the climate neutrality deadline also represents the major framework for the completion of rail expansion work.

Moreover, it was decided to leave out projects that only tackle capacity expansions. Even though capacities, i.e., the frequency and number of trains being able to run along a section of tracks, are essential for rail operations, the focus of this work is on travel times only. However, capacity upgrades in some instances also enable shorter travel times (e.g., by reducing waiting times for track clearance or similar). Whenever it is indicated that projects benefit both, they are included in the overall project selection. Lastly, projects are excluded if they are surrounded by too much uncertainty regarding their completion. Only if the legally binding designing phase (i.e., the fixation of a route in accordance with property acquisition and environmental studies) has been progressed, the project is to be taken into consideration. Alternatively, if the project is corroborated by officially and legally binding memorandums or agreements, it is respected if the funding is secured already. Project plans that have been discontinued are also excluded due to the unclarities of their revival.

3.6.2 – Project Information Gathering

Based on the criteria above, the projects are then manually gathered in a table. However, the identification of projects and reliable information, especially regarding the reduction of travel times, proves to be a major challenge. The problem herein is the reliability of information, i.e., the quality of sources. For some projects, most remarkably in Germany, Italy, and Austria, detailed and accurate (official) documentations are made publicly available. However, other projects, for instance in Spain, Bulgaria, or Turkey, are not accompanied by any informative detailed publications. In that case, the information is gathered from secondary information outlets such as newspaper articles or non-scientific rail journals. Even though the data is being double-checked, and only reliable/verifiable information is used, this bears the risk of limiting the information's quality and level of detail. The last update on project information was made on 01.05.2024.

The spatial resolution of the project impacts thereby bases on the existing city selection and the previously computed network. This means that one single infrastructure improvement can impact multiple lines if different connections pass through this section of infrastructure – which is why the routed paths displayed in Figure 11 are so important. For every single affected line, another entry is made to the overall table. Each entry indicates a set of relevant attributes explaining the project's impacts. Herein, the most important element is the reduction of travel times. It is herein important to keep in mind that the changes in travel times here typically refer to realistic (timetable-based) travel times. The new travel times are indicated by either a relative reduction (e.g., "5 minutes faster") or by an absolute value (e.g., "travel times are cut to 1 hour"). At least one, but ideally both of these values are to be extracted from the project information sources and stored in the table. Furthermore, the planned completion dates, the new Vmax (if available), the overall project title, and the current implementation status are noted. The latter is classified into different categories, as presented in Table 2. Additionally, all relevant sources are stored. An example of the project table can be found in Table 3; the full table, including sources, is available in Appendix C.

***Table 2**: Overview of classification for infrastructure project stages.*

status	description
"corroborated"	the project has been officially agreed upon in a legally binding framework with a clear timeline and a secured allocation of funds
"legal design"	the project is approved, and the construction plans are being developed, which includes the design of the traces, environmental studies, and land acquisition
"tendering"	certain portions of the project are already being tendered for implementation/construction (while other parts might still be designed)
"in partial construction"	some first phases of the project are being in construction while other phases are still stuck in earlier stages
"in construction"	the project is mainly being constructed; the design has been completed

Table 3: Simplified example of the infrastructure project table (full version available in Appendix C).

affected city #1	affected city #2	new direct connection	new time [min]	reduction [min]	implementation status	completion date
Valladolid	Santander	no	-	60	in construction	2030
Sheffield	Leeds	no	40	-	corroborated	2041
Dresden	Prague	no	60	-	legal design	2045
Vilnius	Riga	yes	114	-	in partial construction	2030
Perpignan	Toulouse	no	-	16	tendering	2045
...	...	...	...	...	...	...

However, some infrastructure projects do not indicate the exact travel time reduction in advance but rather make it dependent on the infrastructure's upgraded properties. This usually centers around electrification and signaling improvements. For example, the Estonian rail network is to be partially electrified, thereby also increasing the Vmax. In these cases where no quantified travel time reductions are published, the improvements are computed with the help of the infrastructure-based routing tool. For each infrastructure section (either a full city-to-city connection or a shorter stretch along a route) that is to be upgraded, the routed paths are retrieved. The idea is then to adjust the Vmax of the infrastructure segments to match the new upgraded speed.

Yet, it would in most cases be wrong to increase the Vmax for absolutely all infrastructure segments along the path since slow passing points inevitably remain after the upgrades. This is due to external limiting factors such as track geometry and curvature or level crossings that are not improved by signaling or electrification. Hence, it must be decided which infrastructure segments should be adjusted. Therefore, the frequencies of all Vmax (weighted by segment length) are cumulated in ascending order. Then, a 0.3333 threshold is applied to retrieve threshold velocity above which the tracks are to be upgraded. Thus, tracks belonging to the slowest third will remain unchanged while the Vmax of all other tracks are set to the new improved value. The selection of the 0.3333 threshold is based on visual investigations of the spatial distribution of track velocities (by the help of a similar but more detailed map as the one in Figure 3). Based on the updated infrastructure track data, the routing is then simply repeated. The new travel time can then be deducted from the original one for the same section in order to identify the relative reduction. Figure 14 visualizes this process. It is important to note that this method of retrieving travel time reductions affects potential travel times, and not realistic travel times. This is therefore clearly indicated in the collection of reductions so that it can be handled accordingly during later analyses.

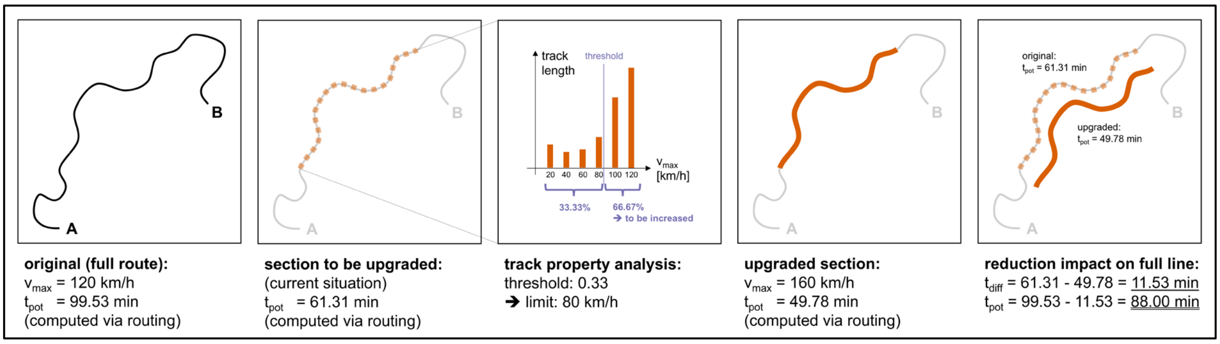


***Figure 13**: Visualization of the infrastructure-based computation of travel time reductions. Source: own illustration.*

3.6.3 – Impact Implementation

Once all projects and corresponding impacts on travel times are collected, they have to be added to a new version of the network. In other words, the original (current) travel times of each connection affected by infrastructure projects has to be updated with the new one – and new connections have to be added wherever necessary. Here, it is preferred to use the absolute new travel times if possible. If no absolute value is indicated, the relative reduction is applied. At this point, the different types of travel times come into play since only the same travel time types can be compared, replaced, and deducted from each other. This means that only one out of the realistic and potential travel times associated with each connection can be adjusted initially. For instance, the Dresden-Prague connection indicates a new realistic travel time of 60 min. Therefore, the original realistic travel time of 133 min is being replaced. Meanwhile, the 96 min of original potential travel time remain unchanged at first.

Yet, in order to enable full comparability of the current and future scenario, an adjusted (new) potential travel time has to be determined too. This reconnects to the regressions computed earlier. With the help of the stored regression values, the future potential travel time can be calculated form the future realistic travel time – and vice versa. For domestic connections, the domestic regression is applied if available. Otherwise, the European overall regression is used. For international connections, the average regression equations of all involved countries are used. If one or multiple of the involved countries has no regression value, only the average of the remaining ones is used. If no regression is available for any of the country, the European average is applied. In the previous Dresden-Prague example, the average of the German and Czech regressions is used, resulting in a future (regressed) potential travel time of 37 min.

By this procedure, every existing connection is updated with both the new potential travel time and the new realistic travel time. It is however important to be aware that the estimated value (computed via regression) can be a potential source of uncertainty; outliers may occur. Nonetheless, this method is preferred over the pure relative reduction of travel times (e.g., the realistic travel time for Dresden-Prague is reduced by 54.88%, therefore the potential travel time would be reduced by the same fraction to a new 54.68 min). Due to the relatively high goodness of fit of the regressions as well as the appropriate sample size leading up to it, the relative approach is deemed less accurate. For cities with a new direct connection, no current direct travel times are available. There, it is remarked that the connection has been newly established, and no direct link existed prior to that. Furthermore, the connections without current services (i.e., no current realistic travel time) but with existing infrastructure (i.e., existing potential ravel time) are also equipped with a future realistic travel time through the same regression-based method. This is justified by the assumption that rail services in a future scenario will be re-established on links with existing infrastructure due to clear environmental benefits.

This eventually results in two main networks: one containing only the current links and one consisting of all future connections, equipped with current and realistic travel times for both the current situation and future scenario. These two fully comparable networks in combination will eventually represent the very core of the following analysis. Thereby, the analysis will particularly compare the realistic travel times of the current and future scenario since these are the least abstract ones. The potential travel times are thereby only of secondary relevance for the actual analysis, but instead play an important role in generating the network and implementing the project-related changes of travel times. The exact values for each network connection can be found in Appendix D.

4 – Methods II: Analyzing the Network

For the comparison of the two scenarios, i.e., the two networks, different methods are applied depending on the specific focus of analysis. This involves a palette of different approaches that are a result of an interplay between various quantitative applications and geovisual tools. The following section provides a general explanation (and potentially a technological insight) into the various method components that will be referred to in the results section. It is important to note that, unless indicated differently, the analysis will generally address realistic travel times.

4.1 – Isochrones

A powerful tool for visualizing changes in accessibility and travel times are isochrones. They are a type of isopleth map, which means they illustrate regions of equal values – in this case, equal travel times from an origin point. For example, an isochrone representing a one-hour travel time would encompass all locations reachable from the origin within one hour. Isochrone maps are particularly useful for showing accessibility changes on a larger scale. In comparing the current and future scenarios, they provide an overview on the rough magnitude of change.

For this thesis, raster-based isochrones are generated with the help of Delaunay triangulation interpolation. A regular raster is set up across the entire continent and a set of non-overlapping (Delaunay) triangles are calculated. For each specific input city (i.e., origin), the fastest travel times to all other cities are calculated. The destination locations and travel times then serve as input points for the interpolation. Every raster grid cell thereby receives a value, based on linear interpolation between the values at the containing triangle's vertices. This results in a continuous field which can be clipped to Europe's outlines. For visualization purposes, the travel times are then classified into hourly values (e.g., travel times up to 60.0 min are categorized into the "reachable within one hour", and so on). This entire procedure, sketched in Figure 14, can then be applied to all desired origin cities, for both realistic and potential travel times.

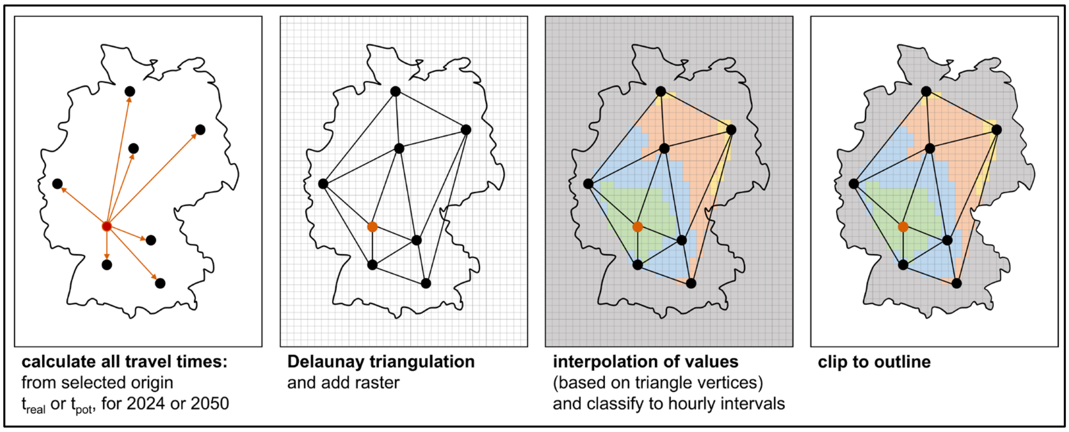


Figure 14: *Example visualization of the Delaunay triangulation travel time interpolation process. Source: own illustration.*

The Delaunay triangulation interpolation is chosen over other approaches (such as regular grid interpolation) as it is said to be most advantageous for cases where the input points and values are not exactly distributed evenly across space (Chen & Xu, 2004) which is the case for this particular city selection. The python package `LinearNDInterpolator` is used for the technical implementation. However, Chen & Xu (2004) also point out that this method's accuracy is highly dependent on the prior triangulation result and hence relies on a profound triangulation algorithm. Furthermore, values can only be interpolated within the extent of the triangulation, as is sketched in Figure 14. Extrapolation is thereby not recommended due to high uncertainties. Besides this, there is a conceptual shortfall associated with the spatially continuous visualization of a non-continuous property. The interpolation results with travel times even for regions that are very far from any rail lines – such as islands, larger water bodies, or remote rural areas. Also, locations along high-speed lines might appear as rapidly accessible which in reality is not the case. Despite the limited quantitative information content, isochrones provide valuable qualitative insights into the spatial extents of accessibility and are appropriate tools for visually grasping the dynamics of change.

4.2 – Cartograms

4.2.1 – (Centered) Distance Cartograms

Of more quantitative value are centered distance cartograms. In this application, they bend space around a selected origin to match the corresponding travel times. Cities with more efficient connections move closer, slower connections shift apart. These more abstract visualizations help to identify specific patterns of change. The following approach is inspired by Tom Carden's London Tube Map (Carden, 2005). Since no exact methodology is presented, this implementation is the result of trial and error. The basic concept is to select one city as center of the graph around which all other cities are to be positioned whereas their distance to the origin is proportional to the shortest travel time between both locations. Furthermore, the spatial arrangement of nodes should maintain the geographic structure as far as possible.

This means that the shortest paths from one selected input city to all other nodes are computed first. Additionally, the bearing (i.e., angle of orientation) is determined for every city (check Figure 15 for a better understanding). The cities' new positions are calculated via trigonometry whereas the sine and cosine of the bearing represent the relative proportions of the x- and y-axes. These are then multiplied with the travel time in order to identify the actual coordinates. Edges can then be reconstructed either fully or by only including those being part of a shortest path. This procedure is uniform and can be equally applied for all desired input origin nodes as well as potential and realistic travel times. Yet, this approach poses the risk of loss of geographic context due to the abstraction of spatial relationships. Nonetheless, it benefits from its dedicated focus on the pure network itself and avoids misleading outliers. The exact matching of visual and topological distances allows for precise quantitative analyses with a particular focus on the network's structure and functionality itself. These cartograms therefore mainly serve to enhance the author's understanding of the changes in city connection patterns and play a substantial background role for interpreting the quantitative results.

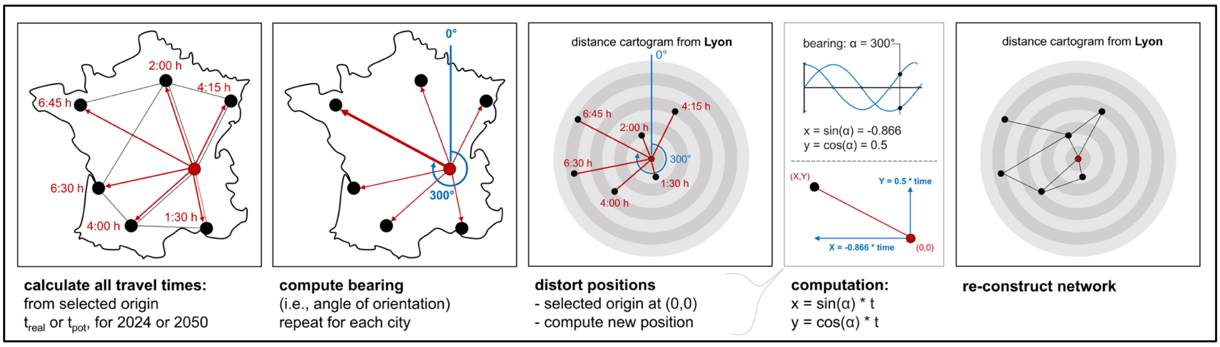


***Figure 15**: Illustration of the process of producing distance cartograms, including the position distortion. Source: own illustration.*

4.2.2 – Time-Space Cartograms / Contiguous Area Cartograms

In addition to the centered approach, non-centered cartograms help for understanding the full-European rail connectivity. The basic principle is very simple: all nodes are rearranged to match mapped distances with actual travel times. The resulting city distortion vectors are interpolated which allows for distorting an entire map extent (Spiekermann & Wegener, 1994). However, topological distances do not follow the laws of geometry which poses a challenge to the implementation, especially for complex networks. Nonetheless, there are approaches that manage to provide decent approximations, for instance via multi-dimensional scaling (e.g., Shimizu & Inoue, 2009). One common problem in multi-dimensional scaling and other optimization algorithms is, however, that topography is not necessarily respected which potentially leads to confusing misplacements. Solutions to this problem have been developed, for instance by a step-wise approach (Shimizu & Inoue, 2009). Yet, these conventional methods are not appropriately applicable within the limited scope of this thesis due to the network's topological complexity.

Instead, a self-developed approach is implemented which aims to approximate time-space cartograms with an alternative method. As is summarized in Figure 16, the idea is to compute Voronoi/Thiessen Polygons (i.e., spatial units containing all points closest to the corresponding edge) around the network edges. These then serve as spatial units for being inflated or deflated based on the corresponding edges' travel times. To avoid topological faults, intersecting edges are first split up. Their travel times are recomputed based on the fractional length[5] of the intersected edges, thus preserving the topological accuracy. For computing the edge Voronoi polygons, a high number of points are sampled along each edge. Voronoi polygons are then computed for the points and afterwards merged by edge, before clipping them to Europe's outlines. For computing cartograms, an absolute value is needed for each polygon which eventually decides on how inflated/deflated it should be. It was decided to transform each edge's area by the edges' velocity in relation to the overall average velocity[6]. To enhance the contrast between efficient and slow nodes, the ratio is squared and multiplied by the polygon's area. This ensures that the Voronoi polygon's nature of uneven spatial extent (especially in edge cases) is taken into account, which avoids misleading outcomes. The eventual result then represents the area to which each polygon is to be deflated/inflated. Deflated areas stand for more efficient connections; inflated areas represent less efficient edges.

The computation is done with the help of the python `cartogram 0.0.2` package which is based on the well-respected algorithm proposed Dougenik et al. (1985). The algorithm's age might however also imply that more sophisticated ones exist by now. Furthermore, the overall Voronoi-based cartogram concept comes with limitations due to the linear nature of network edges and the clipping to the country outlines. For instance, connections such as the Channel Tunnel, Oresund Bridge, or Messina Ferry are not represented ideally. In general, this method's accuracy is highly dependent on the layout and level of detail found in the network. It therefore serves no quantitative measures but provides a qualitative overview that allows for roughly comparing the connectivity and efficiency within the rail network in different regions of Europe.

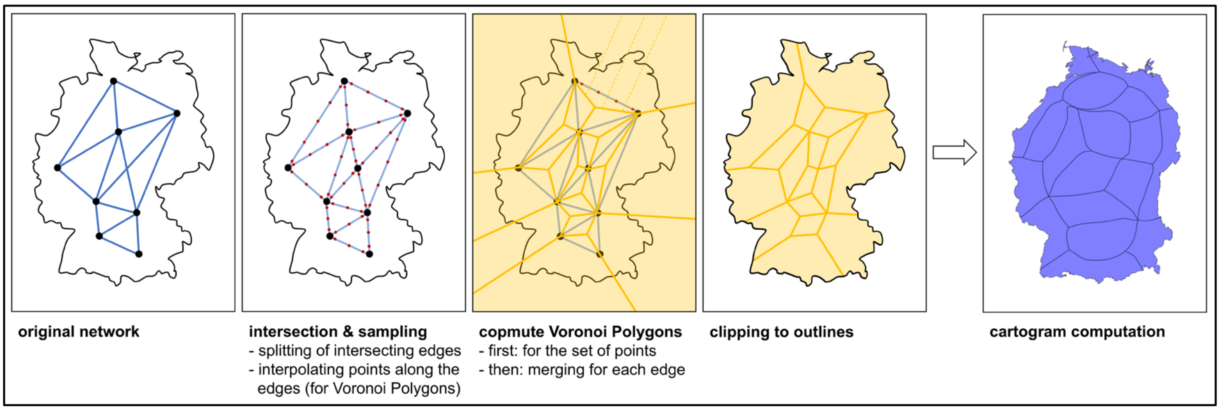


Figure 16: Schematic example visualization of the self-made Voronoi cartogram production. Source: own illustration.

[5] In this particular context, Euclidean distances based on the selected coordinate reference system are used instead of real-world metric distances. Since the transformation is analyzed visually only, it makes sense to assess the travel times in relation to the "visual" (i.e., Euclidean) distances.
[6] This refers to "visual velocities", i.e., visual distances (Euclidean distance in the coordinate system) divided by the travel time. The visual velocity's unit is coordinate units per minute.

4.3 – Network Metrics

Besides the application of visual methods, the two (current and future) networks also allow for quantitative assessments with the help of network metrics. Such metrics can provide valuable information about the structure, behavior, and functionality of the network as a whole, but also highlight the importance of individual edges or nodes. There are countless different metrics at the node, edge, and network level. Yet only a limited selection of these metrics are actually useful for this research's specific type of network(s). The reason for this lies within the network's structure which is inherently influenced by the initial city selection rather than by organic network formation. Since not all possible connections are represented, this might skew metrics that predominantly address the network's topology. Presented in Table 4 is a description of the most basic and popular metrics with an assessment of meaningfulness for this thesis' scope.

***Table 4**: Overview of selected network metrics (not) considered for work, with comment on relevance within the context of this thesis. It is important to note that metric names may vary depending on the author and context.*

level	metric name	description	relevance
node	node degree	the number of edges connected to a node, indicating its immediate connectivity	none
node	node closeness centrality	indicates how close a node is to all other nodes in the network, based on the shortest paths	high
node	node betweenness centrality	indicates the extent to which a node lies on paths between other nodes, showing its role as a connecting bridge	high
node	eccentricity	the maximum shortest path distance from a node to any other node in the network, representing its farthest reach	moderate
node	eigenvector centrality	a measure of a node's influence, taking into account the number of direct connections and the centrality of the connected nodes	low
edge	edge betweenness centrality	the number of shortest paths passing through an edge, indicating its importance in information (i.e., traffic) flow	high
edge	edge connectivity	the minimum number of edges that must be removed to disconnect the network, reflecting its robustness	none
network	average shortest path length	the average distance between all pairs of nodes, representing the network's navigability and interconnectivity	high
network	network diameter	the longest shortest path between any two nodes, indicating the maximum distance in the network	moderate
network	network density	the ratio of the number of edges to the total possible edges, indicating how dense the network is	low
network	clustering	the degree to which nodes in the network tend to cluster together, forming tightly interconnected groups	none
network	modularity	measures the strength of division of the network into modules or communities, where nodes are more densely connected within modules	none
network	network centralization	measures the degree to which the network is centered around a few highly connected nodes	low
network	resilience	the ability of a network to maintain or quickly restore its functionality and performance after facing disruptions, failures, or attacks	low

As a result, only very few of the more common network metrics remain of particular interest for this thesis' context. The most relevant metrics applied in this thesis will be the average shortest path length (ASPL), network diameter (NDim), edge betweenness centrality (EBC), node betweenness centrality (NBC), and node closeness centrality (NCC). The full dataset of computed EBC and NBC/NCC values are listed in Appendix E-F. The aforementioned issue is also present in the literature surrounding transportation networks. Consequently, several authors have proposed new measures that fit their network type and are tailored to their specific scope of research (Almotahari & Yazici, 2021; X. Chen et al., 2024). However, since this thesis only focuses on the travel times and does not address the frequencies and capacities of nodes and edges, these transportation-specific network metrics usually are not applicable either. Therefore, only the few most informative network metrics are applied and compared between the networks. They are either computed manually or with the help of the respective `network` package's functions in python. In certain cases, such as the ASPL, the metrics can only be applied to a fully interconnected network. Since the selected European cities do not enable a full network interconnection, the largest connected part (i.e., the full network excluding Ireland, Northern Ireland, Corsica, Sardinia, and Albania) is used whenever necessary. Relating to this, a problem arises from connections that are currently not operated but are assumed to run in the future (with travel times computed via regression). This must be taken into consideration during the interpretation of the results.

4.4 – Further Analysis Approaches

4.4.1 – Relative Travel Time Reductions per Edge

Among the slightly more complex analyses is the computation of the relative change of travel times for each affected edge. The complexity sources from the fact that, as was introduced earlier, the changes in travel times were originally only available for one type (either infrastructure or timetable-based) while the other type was computed via regression. Hence, for comparability reasons, it was decided that relative reductions would only be computed for the travel time type in which the project impact was originally indicated. For instance, this means that if the project's impacts are announced as timetable-based improvements, only the current and future realistic travel times are compared to each other. For the actual computation, every edge affected by any project is worked through. Edges that currently are not operated but receive a realistic travel time in the future scenario thanks to the regression are thereby highlighted separately, but no change in travel time is computed for them. For each link affected by projects, the current travel time is retrieved. This is done through finding the shortest path between the two cities within the current network, which in most cases would simply be the original direct edge. Wherever projects represent a new direct connection, the shortest current path involves more than one edge from the current network. The current and future travel times are then used to compute a ratio of reduction which eventually results in values between 0 (no improvement) and 1 (entirely new link). The full results are listed in Appendix G. A value of 1 is thereby only achieved by links between city pairs that were not connected at all earlier. These resulting reductions can then be analyzed, for instance by flow/line maps and in relation to the topography – which might provide insights into clusters and topographical patterns of impacts.

4.4.2 – Specific/Individual Project Impacts

Furthermore, it also makes sense to analyze the impacts of individual projects to the full network. This particularly addresses distributive effects and serves to identify critical edges and projects within the network. For this purpose, two different kinds of approaches are chosen. First, the impacts every single upgraded edge alone are assessed. While iterating through each affected edge, the current network is updated with only the respective edge's improved travel times; the rest remains unchanged. For this new network, network metrics are retrieved and compared to the ones corresponding to the original (current) ones. In this case, due to the

European context, the ASPL is used (in terms of realistic travel times). The relative change between the current and simulated ASPL thereby stands for the impact that the particular project alone would have. This reveals lots of information about the project's individual importance on a European scale. Similar to this procedure, each edge's inverse impact is analyzed as well. This means that all project impacts are implemented, apart from the specific one which is to be analyzed. Again, the ASPL of the future scenario (with all projects being implemented) can be compared to the value resulting from the simulated version (where exactly one project is not implemented, but all other ones are). The relative change of the ASPL thereby represents the dependency on the edge currently analyzed and hence showcases vulnerability. The results are then ideally visualized with flow maps for adding a spatial component. All computed values are available in Appendix G.

4.4.3 – Focus on Certain Cities (Specific Network Components)

As a further attempt of adding a sociodemographic layer to the observed spatial patterns of change, the network can be limited a smaller version based on a certain set of cities. In particular, this refers either to capitals only, or to cities with a specific population size. In both cases, the procedure to generate a new analyzable network are identical: first, the relevant cities are selected. Next, for every pair amongst the remaining cities, the shortest paths within the existing network are computed (based on realistic travel times). All edges being part of one of the shortest are kept (and optionally summarized into a new direct edge) while all remaining ones are discarded. The result can be computed from both (current and future) input networks. The resulting networks can then be treated exactly the same way as the other ones. In addition, these high-focus cities are also assessed in terms of accessibility from the remaining cities. Herein, the current and future travel times to the capital and closest metropole are computed and analyzed in their relative changes. The exact resulting values are available in Appendix H.

4.4.4 – Implications for Travelers

For analyzing how the rail network affects travelers, the focus is furthermore shifted toward travel times from certain cities. Besides the comparison of the NCC, the reachability was of major interest. Reachability is herein definable as the number of cities that can be reached within a certain time from a particular city. For every single city, this number is therefore computed for a predefined threshold, for both the current and future scenario. The difference (in detail available in Appendix I) then reveals the increase of reachable cities.

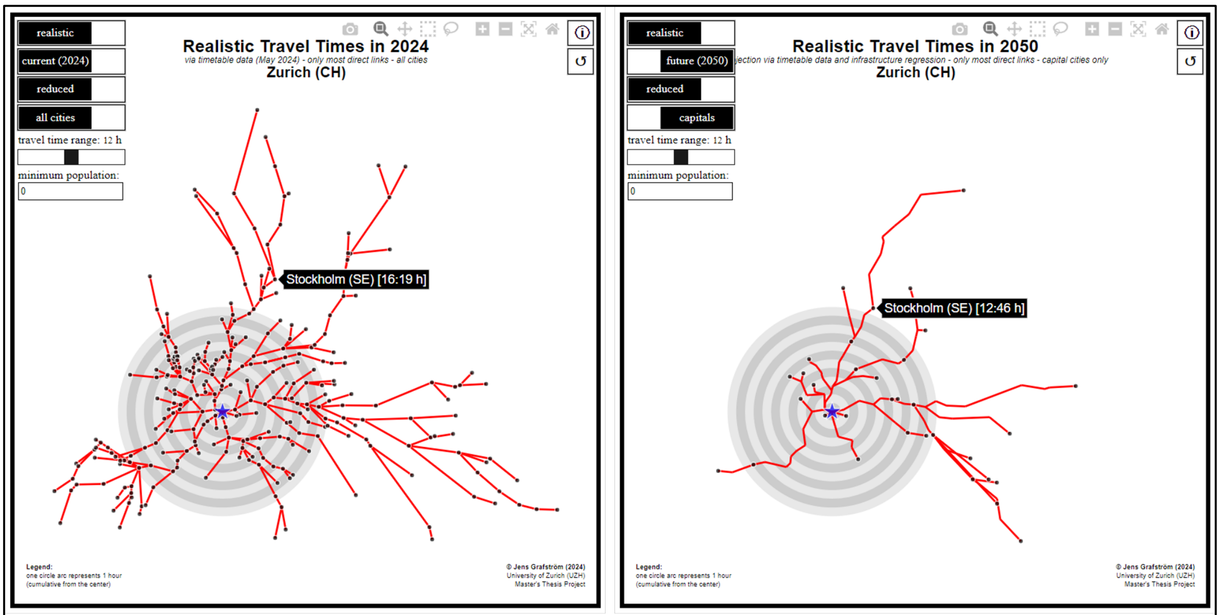
Furthermore, the changes in travel times are analyzed in comparison to Europe's most popular air routes since this aligns with the thesis' relevance of promoting a shift toward sustainability. Europe's most popular air routes are retrieved from Eurostat (2020), based on 2019 records. The pre-pandemic dataset contains a set of all recorded air routes within Europe (i.e., from airport to airport) and their passenger volumes. Turkey is however not included. These flights are then summarized to city-to-city routes, i.e., without differentiating between airports. For instance, the flights between London Heathrow and Paris Orly as well as London Gatwick and Paris Charles de Gaulle would count into the same record for Paris-London flights. From this, the top 1000 most popular flights are selected for the analysis. It can then be assessed how long air routes currently take to be travelled by train – and how this will change in the future. The full dataset, including the analyzed changes, is available in Appendix J.

4.4.5 – Case Studies

Lastly, it is meaningful to pick a few specific projects which serve as case studies representative of certain dynamics and processes surrounding the development and impacts of rail infrastructure upgrades. The different case studies are selected for very particular individual reasons which are elaborated later on. Each project is assessed in its pure individual impacts, its role within the European rail network, the differences between local/regional and continental outcomes, and the strategic project background. They therefore represent a thematic extension to the mainly data-based full-scale overall analysis of Europe's railways. This allows for illustrating different types of projects and outcomes and further supports a better understanding of the complex nature of rail infrastructure expansion.

4.4.6 – Interactive Component

Due to the high number of cities and connections, it was furthermore decided to implement the visualizations in an interactive manner. This means that it should be possible to dynamically switch between visualizations for different cities and scenarios. This is mainly implemented for the cartogram and isochrone visualizations with the help of a python `flask` web app. Besides that, more basic illustrations are created in the format of simple web maps, with the help of python `folium` / `leaflet` packages. While the interactive component is not essential to the written paper as such, it is highly useful for enhancing the author's understanding of the complex dynamics involved in rail upgrades. The interactive version therefore serves the author to interpret the results, especially the quantitative ones. Furthermore, the interactive tools might also be helpful for communicating the results. Yet, this is not the main target of this thesis which is why the interactive components are rather rudimentary and (as of hand-in date) will not be majorly published as such – even though the technical components are being shared publicly at the aforementioned GitLab repository (see section below). The geovisual use of such methods for a better understanding of such topics might instead be part of future work.



a) current scenario, all cities b) future scenario, capitals only

***Figures 17 a-b**: Screenshots of interactive linear cartogram web app. The pop-up appears when hovering across any given city. Cities can be clicked to visualize their respective cartograms. Different scenario combinations are possible: realistic vs. potential travel times, current vs. future scenario, reduced vs. full network, capitals vs. all cities, as well as population thresholds. The number of time ranges (i.e., circles) can be varied as well. Source: own illustration.*

4.4.7 – Publication of Technological Component

The code and the most relevant files are publicly available at:

https://gitlab.uzh.ch/giva/public/masters/euro_train_expansion_jens_grafstroem.git

In case of any errors or other issues during accessing the data, please contact the author.

5 – Results I: Full-Network Impacts

5.1 – Projects and Their Overall Network Changes

Before adding any project-related changes, the original intercity network forming the basis of this analysis consists of 683 connections. Their potential travel times sum up to 1'051 h 36 min (or 63'095 min). 26 of all connections are currently not actually served by trains. The realistic travel times on the remaining connections sum up to 1'574 h 45 min (or 94'485 min) in total. This already shows the contrast between potential and realistic travel times; the latter being around 49.74% higher than their potential pendants.

Meanwhile, the gathered infrastructure projects will affect 139 of the 683 connections within the current network. If weighted by track length, this corresponds to a fraction of 20.44% of the network that will be at least partially improved. Adding to this are 22 new network connections. These emerge either from entirely new lines being built or from upgrades on existing lines that improve the connections enough for them to become a shortest path within the network. In total, 180 of the 335 cities are part of at least one affected connection. As becomes evident in Figure 18, the overall 161 new/improved connections serve almost every included country; the few exceptions being Montenegro, Kosovo, Bosnia and Herzegovina, Moldova, Liechtenstein, and Ireland.[7] However, this does not mean that construction will actually be ongoing in all other countries since rail projects on international connections benefit both countries even if only one of the two is carrying out track work. Despite this share being highly dependent on the network's scale and city selection, it is interesting to observe that 36 of the 161 affected connections (i.e., 22.36%) are international. This closely relates to the ratio of international connections in the current network (22.55 %) and thereby indicates that international connections do not receive particular interest but also are not neglected neither.

From a temporal perspective, it is highly interesting to see that construction on 112 of the 164 projects (three lines come with multiple separate projects) is planned to be completed by 2030. In the meantime, only a mere 26 of the currently known projects are scheduled to be completed between 2040 and 2050. Whether they will actually be finished according to current schedules (which in some cases already had to be adjusted) remains unclear. What gives hope is that 103 projects are currently in the "in construction" stage while another 28 are in the "in partial construction" phase. Nonetheless, rail projects usually remain very time- and resource-consuming. However, the completion of multiple projects by 2030 would certainly contribute positively to the corroboration of further projects – which would be very valuable in terms of sustainable mobility.

A more technical insight into the planned projects reveals an interesting tendency regarding the planned Vmax (i.e., design speed) of the 161 upgraded/new lines. As can be seen in Figure 18, the new Vmax is equal to or greater than 350 km/h on 14 connections. Speeds of 300 km/h or more will be realized on another 28 lines, i.e., 42 lines in total. In a wider sense, a total of 93 of all 161 affected lines are going to host Vmax of 230 km/h or more. Additionally, 200 km/h or more are realized on 119 connections. Only three connections are to be operating at a new Vmax of 120 km/h which represents the lowest project design speed observed within this thesis' context. This reveals a clear tendency toward higher-speed and high-speed rail for intercity connections. However, the presence and importance of higher-speed and high-speed rail could be anticipated in advance since this thesis focuses only on travel time improvements and generally neglects pure capacity expansion projects.

[7] Nevertheless, relevant rail projects are currently being discussed or even close to initialization in all of these countries, except for Liechtenstein (where "only" track maintenance is planned which does not affect travel times). Though, these projects were not yet corroborated as of the deadline of this thesis' project information gathering.

When comparing the future network to the current one, the sum of the potential travel times is reduced by 2'818 min (46 h 58 min) which corresponds to a reduction by 4.47%. However, this also includes new edges; the absolute difference is therefore of only minimal informative value. This is even more obvious when analyzing the changes of realistic travel times: due to the addition of values to currently non-operated edges (via regression), the sum increases by 1'113 minutes. The absolute changes of overall travel times are therefore not as indicative of the actual changes – but this will be resolved later.

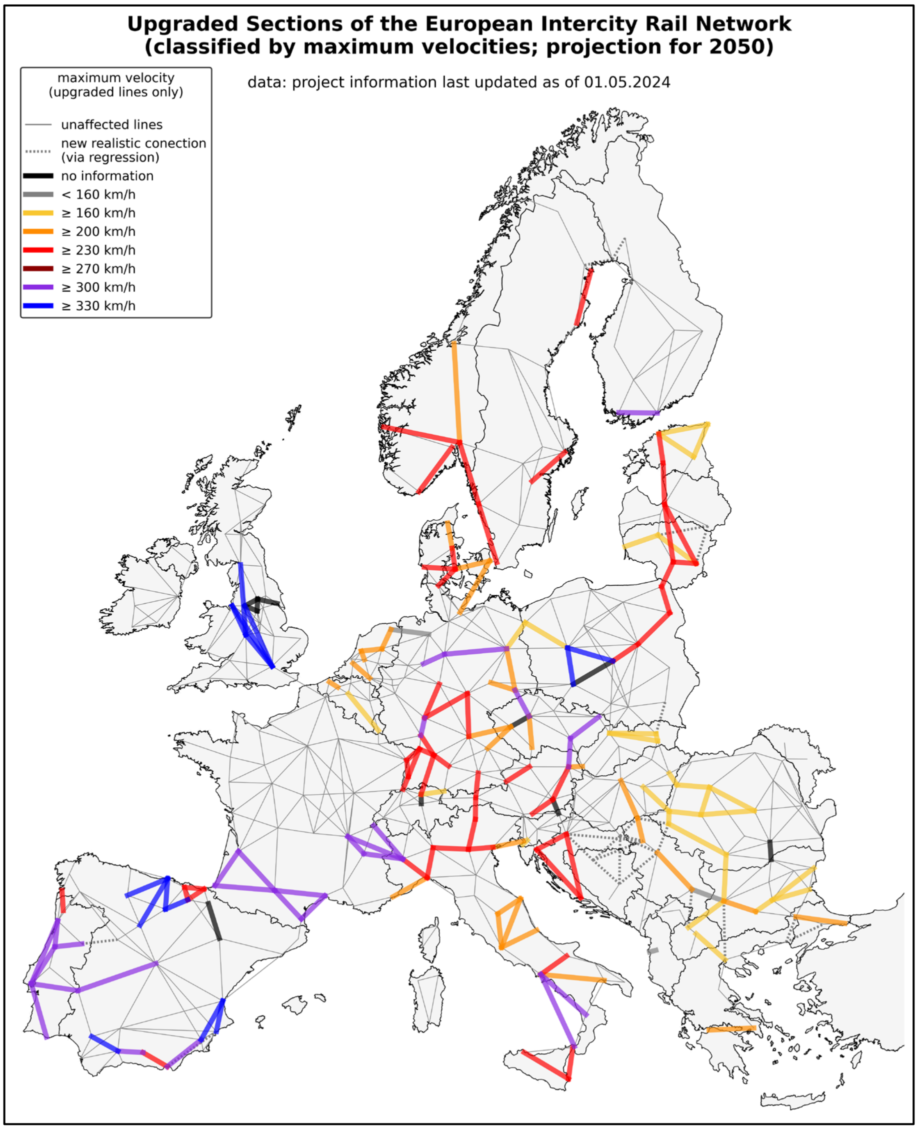


***Figure 18**: Visualization of impacted lines in the European intercity rail network's projected future scenario, classified by planned Vmax along the lines. Source: own illustration.*

The impacts differ significantly from project to project. Standing out are connections that overcome current gaps in the rail network. Thanks to those improvements, cities that had not been connected by rail at all or only via extensive detours will be reachable efficiently. This particularly concerns southeastern Europe (e.g., Sofia-Skopje, Patras-Athens, Durres-Tirana and Subotica - Novi Sad) but is also present in the Baltics (e.g., Pärnu-Riga and Tallinn-Pärnu) as well as the Iberian Peninsula (e.g., Murcia-Almería, Braga-Vigo). Significant reductions are also achieved along existing connections which so far have only been operable at slow speeds due to poor track quality or challenging terrain. Meanwhile, other connections which already are relatively well-equipped see improvements too. In contrast to previous examples, the resulting travel time reductions are usually not as substantial – even though exceptions do occur (e.g., on the Frankfurt-Kassel/Erfurt line or between Lisbon and Porto). In such cases, the relatively small reductions are typically desired in order to allow for tighter scheduling or similar operational improvements. Overall, the average reduction is 34.45% while the median indicates a slightly lower 28.99% (see Figure 19; full data available in Appendix G). Interestingly, the histogram shown below reveals that most projects group in a range of 5% to 40% of relative reduction. A brief correlation analysis indicated no potential relationship between relative travel time reductions and covered distances. This means that – at least in this particular study framework – the potential of relative reductions is not dependent on the connection's length.

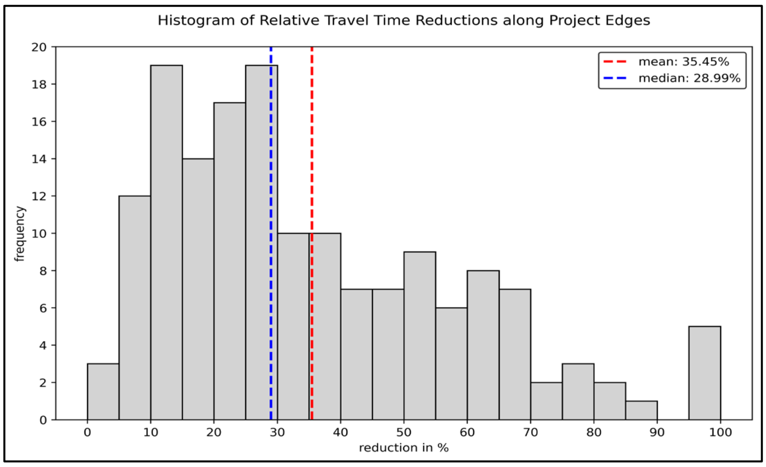


Figure 19: Relative Travel Time Reductions (full data available in Appendix G).
Source: own illustration.

A more substantial insight into the actual benefits of travel time reductions to the full European context can be provided by network metrics. The ASPL between all city pairs is projected to be reduced by 17.57% for potential travel times and by 10.81% for realistic travel times, as is illustrated in Table 5. Again, it must be kept in mind that the value for the latter now also includes additional links that were not operated before. This explains the lower relative reduction. Nonetheless, the reductions of both the realistic and potential travel times diverge significantly from the raw changes in the sum of travel times addressed earlier. This provides a first hint toward distributive effect: the benefits of a project can reach far beyond the pure travel times reductions between the directly involved cities. In a similar manner, the NDim is reduced significantly for both the realistic and potential travel times. This shows that the network is contracted which indicates that remotely located regions move much closer to the core and are likely better integrated into the network.

When focusing only on capital cities, the reductions of the ASPL between all pairs of capitals are even bigger at 22.26% (realistic) and 14.24% (potential). This in return indicates that there is a tendency that projects are particularly located along corridors connecting the administrative centers of all countries. Slightly lower reductions (though still higher than for the full network) are observed along the corridors between all cities of at least 500'000 inhabitants. There, the ASPL are reduced by 19.79% (potential) and 12.42% (realistic). However, all is surpassed by the changes observed between cities of one million inhabitants or more: here, the ASPL is reduced by 22.92% (potential) and 28.64% (realistic). Especially the last example showcases how the improvements particularly lay on the corridors linking major cities to each other. Especially among the cities of more than one million inhabitants also stand out with a high reduction of the NDim. The current and future longest connection, between Madrid and Istanbul, is reduced by over a third which is a substantial improvement on such a cross-continental line. This all could somehow be anticipated since the highest passenger demands could be expected between such cities which often also serve as important destinations for administrative and economic reasons – and hence are most likely to be considered for rail projects.

***Table 5**: Changes of overall network metrics between current and future scenarios: average shortest path length (ASPL) and network diameter (NDim). Note that realistic travel times might be slightly skewed (as explained above).*

scale	metric	travel time type	current [min]	future [min]	absolute change	relative change
full network	ASPL	potential (infrastructure)	855.38	705.08	- 150.30 min	- 17.57 %
		realistic (timetable)	1130.23	1008.05	- 122.18 min	- 10.81 %
	NDim	potential (infrastructure)	2756.31	2292.22	- 464.09 min	- 16.84 %
		realistic (timetable)	4118.00	3321.24	- 796.76 min	- 19.35 %
capitals only	ASPL	potential (infrastructure)	932.48	724.92	- 207.56 min	- 22.26 %
		realistic (timetable)	1188.03	1018.91	- 169.12 min	- 14.24 %
	NDim	potential (infrastructure)	2712.58	2135.90	- 576.68 min	- 21.26 %
		realistic (timetable)	3103.00	3145.24	+ 42.24 min	+ 1.36 %
population > 500'000	ASPL	potential (infrastructure)	693.86	556.58	- 137.28 min	- 19.79 %
		realistic (timetable)	899.61	787.84	- 111.77 min	- 12.42 %
	NDim	potential (infrastructure)	2712.58	2135.90	- 576.68 min	- 21.26 %
		realistic (timetable)	3555.00	3145.24	- 409.76 min	- 11.53 %
population > 1 Mio	ASPL	potential (infrastructure)	643.78	496.24	- 147.54 min	- 22.92 %
		realistic (timetable)	979.79	699.16	- 280.63 min	- 28.64 %
	NDim	potential (infrastructure)	1898.15	1350.11	- 548.04 min	- 28.87 %
		realistic (timetable)	3072.00	2006.83	- 1065.17 min	- 34.67 %

5.2 – Spatial Project Patterns and Project Distribution

5.2.1 – Geographic Patterns

Even though many parts of the network benefit from the expansion and upgrade of rail infrastructure, it can be assumed that the spatial distribution of project sites and the consequent impacts vary across Europe. This is the result of various factors such as the topography and geography, economic structure, and historical and political developments of/within a country. Of particular interest are herein territorial boundaries and topographic hindrances, as was already teased in the introduction. Figure 20 thereby visualizes the relative travel time reductions along each edge affected by projects and provides an additional topographic and territorial layer for identifying patterns.

A first striking observation can be made in the alpine region. Mountainous terrain is well-known to be a common factor slowing down rail operations. Therefore, the construction of tunnels and viaducts can significantly reduce travel times. As a consequence, it is no surprise that some of the most drastic travel time reductions are to be expected around the Lyon-Turin line, the Graz-Klagenfurt section, and the Munich-Innsbruck-Verona connection. Besides that, Figure 20 reveals further instances where particularly mountainous topography is overcome by infrastructure projects. To be specific, this concerns the connection in southern Norway, between North Macedonia and Bulgaria, the Italian links across the Apennine mountains, and the northern and southern parts of Spain. This interesting pattern reveals how much potential for travel time improvements are hidden in large-scale challenging terrain. Yet, said projects are usually only realizable with high financial investments – which most likely is the reason why so much potential remains in the first place.

Meanwhile, no clear pattern can be found regarding larger bodies of water. The only instances where such projects are being constructed are the Third Tagus Crossing in Portugal, and the Fehmarn Fixed Link between Denmark and Germany. While these two projects are expected to allow for significant travel time improvements, they require particularly high financial investments, too. Furthermore, Europe's geography provides only few locations besides the already well-established Channel Tunnel and Oresund Bridge where such projects could possibly make sense to be implemented. Occasionally, though, spectacular mega-projects emerge, for instance a bridge-tunnel combination between Helsinki and Tallin is regularly discussed vividly (Peda & Vinnari, 2022). However, in the current setting of corroborated projects, sea-crossing rail infrastructure only represents a tiny fraction. Nonetheless, as the Fehmarn Fixed Link illustrates, such projects can come with a high potential for travel time improvements on local but also (potentially) continental scales – in case they are actually being implemented.

These large-scale topographic hurdles can however also crucially limit travel times on smaller scales which may not have become as apparent from a continental perspective. For instance, Switzerland is home to two smaller tunnel projects improving connections from Zurich toward the east and south. Along Italy's Ligurian coast, a tunnel will improve travel times between Genoa and Nice. On the line from Dresden to Prague, a tunnel will be constructed as well. Between Bremen and Groningen, a bridge will be (re-) built across a river for improved cross-border connectivity. The list of projects particularly overwinding medium- or small-scale topography goes on much further. Obviously, topography at all scales is one major reason to why rail lines are not yet smooth and (relatively) straight and therefore require improvements for achieving shorter travel times. Hence, it is unsurprising that most projects to some degree involve improved track layouts and replace older lines limited by the surrounding topography.

The second main reason for suboptimal track layouts or network disruptions is anthropogenic. Besides human settlements this also includes political and territorial boundaries. Figure 20 hints toward the assumption that newly constructed or upgraded international connections may come with particularly high relative travel time reductions. The average relative reduction on the 36 affected international connections is 41.70%; the median lies at 40.86%. This is clearly higher than the mean and median reductions (33.65% and 27.77%) of the domestic affected connections. This substantiates the theory that the currently relatively poor cross-border connectivity and the predominantly national focus of rail planning have resulted in a distinct potential to improvements which is now slowly being exploited. However, this does not necessarily mean that construction work actually takes place on both sides of the border. Instead, significant improvements can already result from designated efforts of one country improving their connections toward the border. In these cases, the potential of travel time reductions along international corridors consequently could likely be even further taken advantage of.

5.2.2 – Clusters of Projects

Besides the arrangement of projects in relation to geographic features, it is also worth focusing on how projects interact with and relate to each other. Thanks to geovisual methods, it is possible to manually identify projects which might be part of a corridor or some greater strategy without necessarily being officially designated as such. Those project clusters can also be interpreted as an abstract visualization of political and economic schemes surrounding railway planning and operation at various scales. Table 6 provides an insight into the identified clusters and gives a short excurse to its backgrounds and basic impacts.

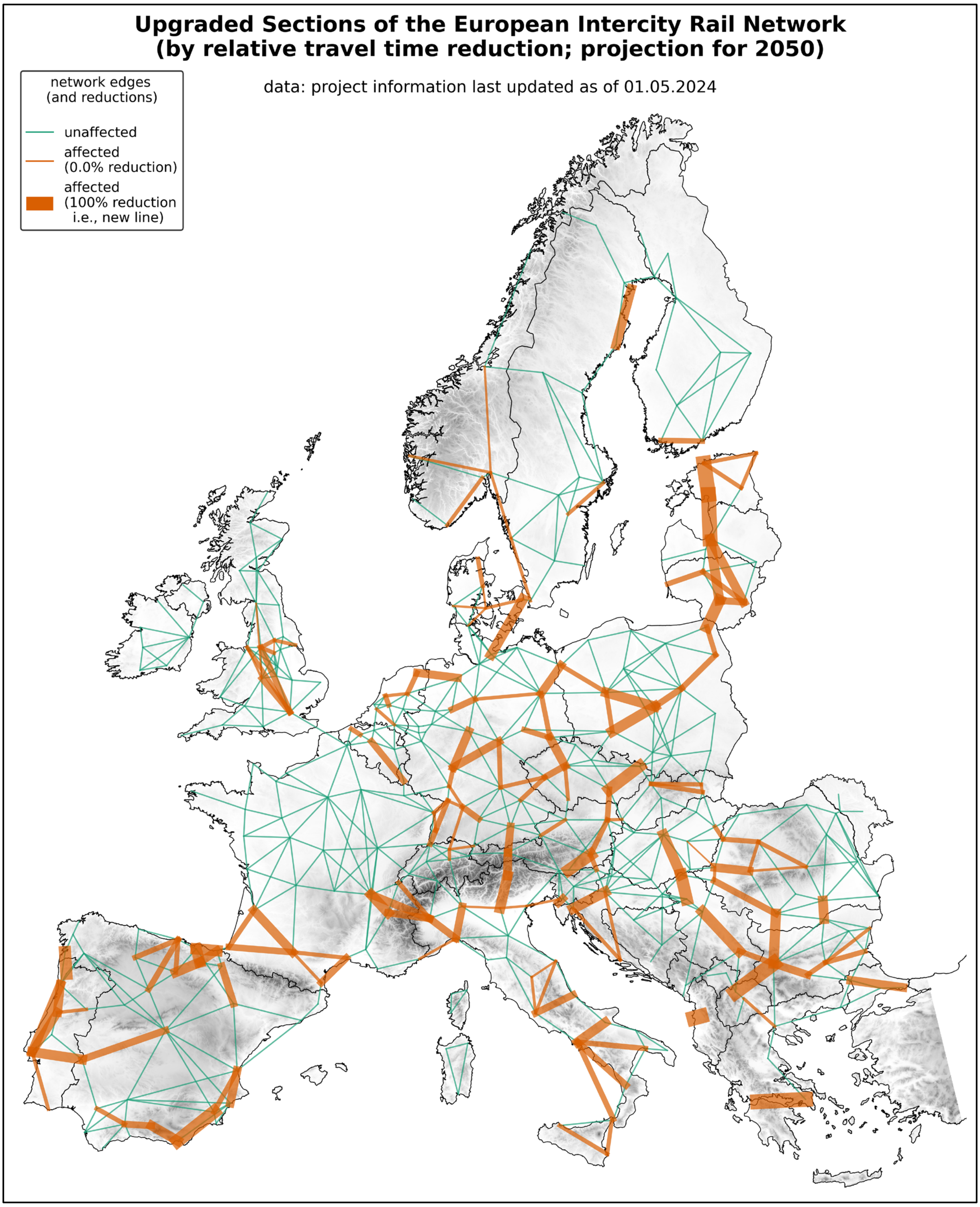
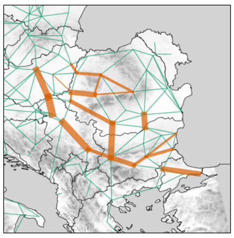
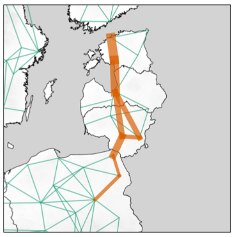
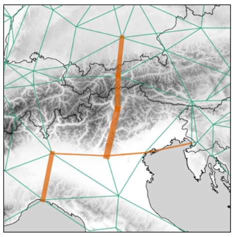
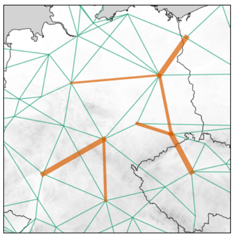
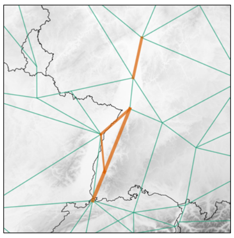
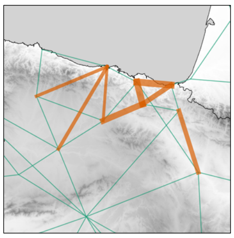
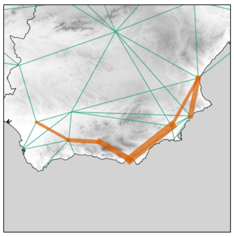


Figure 20*: Relative travel time reductions of upgraded intercity rail network sections.*
Background: topographic map of Europe, depicting altitude/elevation.
Source: own illustration.

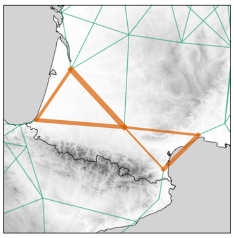
***Table 6**: Overview of Major Identified Project Clusters/Corridors. Note that the figures are not to scale.*
***Figures 21 a-o** (not labeled): Visualizations of referred project segments. Source: own illustration(s).*

visual snippet	project name and description
	**Black Sea - Hungary Corridor(s)** *(Romania/Bulgaria/Turkey – Budapest)* This assembly of rail projects improves the connectivity across the Balkan region and provides enhanced access to Turkey and the European Black Sea ports. Most significantly, there are two competing rough corridors toward Budapest, which acts as a gateway from Southeastern to Central, Western, and Northern Europe: one via Romania (EU member state) and one through Serbia (no EU member state). This political controversy is especially present in the financial supports for projects in the respective political regions. The most notable travel time reductions are found on the Nis – Belgrade – Budapest corridor (up to 80%). More information: section 6.1.
	**Rail Baltica** *(Warsaw – Bialystok– Kaunas/Vilnius – Riga – Tallinn)* Rail Baltica is a high-speed normal-gauge rail project connecting the Baltics via Warsaw to the rest of Europe, particularly the Central and Western parts. It is of high geopolitical relevance in its function to provide rapid access to the EU and NATO’s borders with Russia. Travel times will be reduced by around 30% in the Polish section and up to 80% between the Baltic metropole regions. More information: see section 6.2.
	**Brenner Tunnel + Extended Feeder** *(Munich – Verona, Genoa – Trieste)* The Brenner Tunnel particularly attempts to relieve road traffic on the transalpine route through Austria. However, this only works if suitable feeder infrastructure is constructed. It therefore makes sense that tangential connections toward Italy’s major northern cities and ports are improved simultaneously. Even though it consequently particularly addresses freight traffic (and mainly aims to improve capacities), passenger connections also significantly benefit by travel time reductions of 45-65% across the Alps. More information: section 6.3.
	**North-East German Upgrades** *(links toward northeastern Germany)* A series of rail projects roughly cluster around/toward Berlin. Even though this could imply some kinds of ties to Germany’s divided past, the main reason likely lies within the importance of Berlin as a metropolitan area and rail hub. These projects act as further improvements to well-established high-speed routes. Also, the currently rather slow but well-demanded links toward the Czech Republic and Poland are to be improved. These cross-border connections experience the greatest travel time reductions (over 50%), even though the Erfurt-Frankfurt connection is significant, too (50.4%).
	**German Rhine-Main Corridor** *(Basel – Mannheim – Frankfurt)* The corridor between Basel and Mannheim/Frankfurt is an infamous bottleneck for the transportation of both goods and passengers. Located on the Rhine-Alpine TEN-T corridor, this route serves as example of issues resulting from national planning and project implementation in the context of continental transportation. Even though corridor improvements mainly address freight traffic, passengers will also benefit of desirable travel time reductions of up to around 30% along these segments.
	**Northern Spain Patch** *(toward Santander and Bilbao/San Sebastian)* A set of rail projects group around the northeastern region of Spain. This region is one of the few not yet accessible by continuous high-speed rail. Consequently, the lines toward Santander and the Basque region are supposed to help connect these places to the rest of the country, particularly Madrid and Barcelona. These projects become even more interesting in the context of domestic politics since both the Basque Country and Cantabria experience strong separatist movements. Thus, the reduction of travel times by 30-70% might serve more than just economic and logistical purposes – especially regarding the “Basque Y” section in the Northeast.



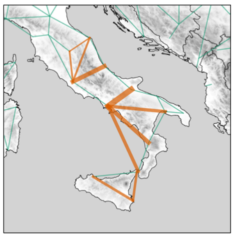
Spanish Southern Mediterranean Corridor *(Sevilla – Murcia – Valencia)*

In southern Spain, projects aim to improve transportation parallel to the coast, connecting multiple major cities and ports. This aims to expand the initially centralistic layout of Spain's high-speed rail (i.e., spokes coming together in Madrid). These sections are part of the TEN-T Mediterranean Corridor and – despite being planned as high-speed rail lines – will also benefit freight transportation. Most outstanding is the section between Murcia and Almeria where travel times will be reduced by nearly 80%.



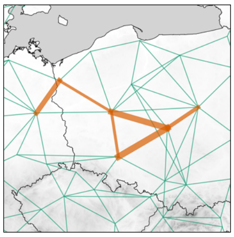
Southern France Corridor *(Montpellier/Narbonne – Toulouse – Bayonne/Bordeaux)*

Similarly, a gap in high-speed rail is to be filled in southern France, parallel to the Pyrenees. While most major locations in France are well interconnected by high-speed rail, Toulouse remains a major location that is not reachable as efficiently as others. Unsurprisingly, the air corridor between Paris and Toulouse is one of the busiest in Europe (Eurostat, 2020). Additionally, the connections toward Spain are improved as well. The reduction of travel times between Toulouse and Bordeaux (the fastest gateway toward Paris) are around 55%.



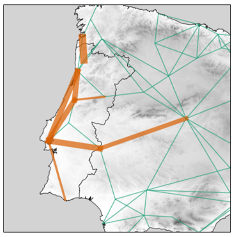
Central/Southern Italy Patch *(Rome – Ancona/Pescara, Naples – Bari/Taranto/Sicily)*

As an addition to the Italian high-speed rail system, which is particularly extensive in the country's north, connections from Rome toward the south and Adriatic coast are planned. This aligns with structural and demographic differences between the south and north which are now being overcome (at least partially). Being part of the TEN-T Baltic-Scandinavian corridor, major port towns as well as southeastern Italian tourism locations will benefit from improved connectivity. The reductions range from around 20% on Sicily to 40-60% along routes traversing the Apennines.



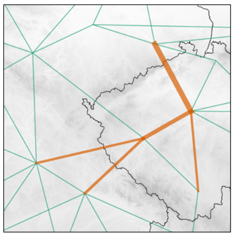
Western Poland Upgrades *(Szczecin – Poznan – Wroclaw – Lodz – Warsaw)*

As a part of a larger national plan aiming to improve sustainable mobility within Poland, a y-shaped high-speed network will link major western Polish cities to Warsaw. These sections are part of the TEN-T North Sea-Baltic Corridor which also includes the earlier mentioned Rail Baltica project. What makes this case interesting is that the full plan foresaw a spoke-like network of high-speed rails leading toward Warsaw – but is regularly debated and changed. The only corroborated remnants are of limited extent but will nonetheless reduce travel times by up to valuable 65%.



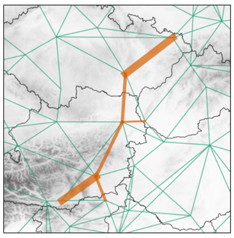
Portuguese Upgrade + Madrid Link *(Faro – Lisbon – Porto – Vigo; Lisbon – Madrid)*

Portugal's national infrastructure program plans on establishing high-speed rail along its densely populated Atlantic coast, but also toward the south and neighboring Spain. This includes an efficient link from Madrid toward Lisbon as well as a connection from Vigo toward Braga and Porto. Especially the links from Lisbon to Madrid and Porto are considered highly valuable due to their presence in the TEN-T Atlantic Corridor. Along these stretches, travel time reductions reach around 45-65%.



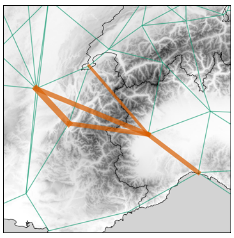
Western Czech Republic Patch *(Dresden – Prague – Budweis/Plzen – Bavaria)*

While being home to the EU's densest rail network, desires are high to improve operations in terms of efficiency. Besides the prestigious connection from Prague to Dresden, the relatively slow links to the country's Southwest and its German neighbor are to be upgraded. This is of particular relevance in terms since the TEN-T Rhine-Danube Corridor and the Orient/East-Med Corridor merge/split paths in Prague. Furthermore, Prague acts as an exceptional touristic center of gravity in this region which explains why travel time the expected reductions of 20-55% are highly desirable.



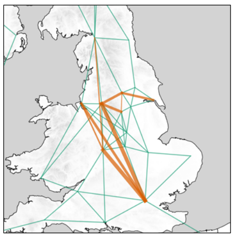
Trans-Austrian Corridor *(Ostrava – Vienna/Bratislava – Klagenfurt/Maribor)*

The Koralm Tunnel between Graz and Klagenfurt will represent a new cornerstone of rail connections from Austria, the Czech Republic, Poland, and Slovakia toward Italy. In combination with other major rail projects along this corridor, which is part of the TEN-T Baltic-Adriatic Corridor, a seamless and efficient corridor is established. This is of particular relevance considering the rather disrupted and ineffective layout resulting from the missing connection between Graz and Klagenfurt. Travel times are being reduced by 30-80% which substantially benefits rail travel in this particularly touristic area.



Euroalpin Tunnel + Feeder *(Genoa – Turin – Lyon/Geneva/Grenoble)*

Another transalpine tunnel is being constructed across the French-Italian border. This project stands out as the fourth transalpine tunnel (following the Lötschberg, Gotthard, and Brenner Tunnels). It acts to reduce climate vulnerability since natural hazards are commonly disrupting the existing mountainous route. Furthermore, it interconnects two major metropolitan regions efficiently and improves southern France's access to the Italian port of Genova. Travel times are reduced by up to 50% along the transalpine route and its extensions.



Network North *(London – Manchester/Liverpool, Manchester – Sheffield/Hull)*

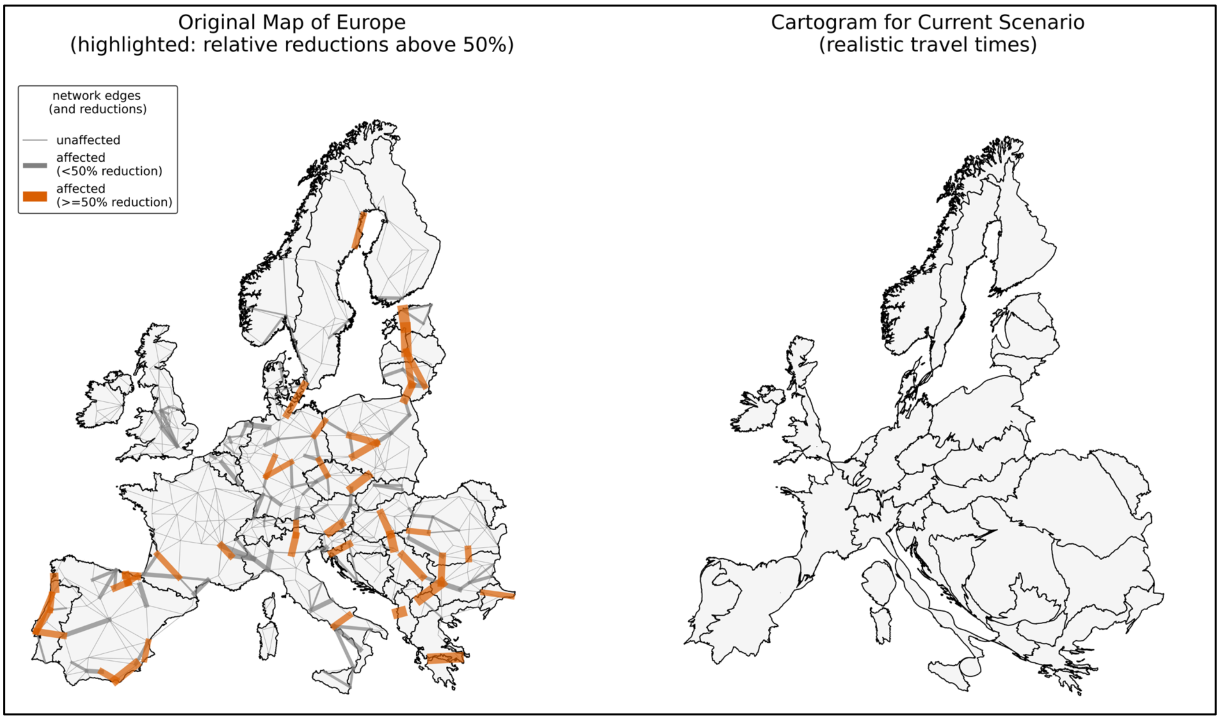
Following the partial cancellation of the ambitious HS2 project, its remnants have been joined with the Network North program which aims to improve connections from London to Birmingham, Manchester, Liverpool, and from Manchester to Sheffield as well as Leeds and Hull. What makes it special is the uncertainty it is surrounded by. Over the course of recent years, multiple project phases have been announced, cancelled, and rephrased. It is therefore an ideal example of how long-term rail projects struggle due to short-term political legislature periods. Once completed, the link between Manchester and Leeds will experience most travel time reductions (by ca. 55%). From London to Manchester, Liverpool, and Birmingham, reductions of 20-35% are projected.

5.3 – Distributive Effects and Impacted Regions

5.3.1 – Directly Impacted Regions

As the earlier sections revealed, the infrastructure projects scatter across almost all regions of Europe. Of particular interest herein are especially those segments with the highest reductions. For instance, reductions of over 50% are predominantly found in central and eastern Europe, as well as around the Iberian Peninsula. To some degree, this invertedly reflects the status quo of intercity connections in Europe. Wherever solid infrastructure prevails and allows for efficient connections, the potential for travel time reductions is rather limited. Instead, exceptionally high reductions and improvements can be achieved between cities that currently host no connections at all or can only provide rather slow links due to poor track quality or external factors such as challenging terrain. The most significant improvements are therefore found wherever gaps and choke points in the current network are overcome.

This is supported by a quick view at the contiguous area cartogram displayed in Figure 22b. The graph highlights regions of faster and slower rail connections by visually inflating the less efficient regions and deflating the more efficient ones. Unsurprisingly, the majority of Spain and France are significantly contracted. Northern Spain (including its border to Portugal) and the country's southern coastal region as well as Frances' southwest thereby represent an exception: these are the few remaining sections of the network that are not equipped with high-speed rail. This therefore matches nicely with the observation that some of the most significant travel time reductions will occur right there. Similarly, Latvia among the Baltic States appears to be rather inflated – which also is experiencing extraordinarily high travel time reductions. These dynamics are furthermore identifiable in the southeastern European countries which appear as most strikingly inflated. This is particularly true for Serbia, Romania, Bulgaria, and Croatia. This bears an enormous potential for travel time reductions through infrastructure upgrades. Many of the projects in exactly these regions are meanwhile also showing a particularly high travel time reduction. However, this is not always exactly comparable. For instance, high reductions are also found in central Germany which however does not stand out in the cartogram. This shows that travel time reductions can also be valuable in regions that already are above the European average in terms of rail operation efficiency but in a local context act as relatively inefficient connections, thereby showing high potential to substantial travel time improvements.



***Figures 22 a-b**: (a) all project edges with relative travel time reductions above 50%; (b) contiguous are cartogram (based on edge-Voronoi computation) of Europe. The cartogram is scaled by realistic travel times. Connections slower than the European average expand space, faster ones contract space.*
Source: own illustration.

Another glimpse into distributive effects can be observed when differentiating the impacts more specifically per country. Despite only a certain fraction of all its connections being affected, an entire country can benefit from travel time improvements since some improved sections might be part of the most efficient paths to other locations. This impact can be nicely assessed in the case of Serbia. As can be seen in Figure 22b, this country is one of the most visually outstanding due to its high inflated area, i.e., relatively low connections. For assessing the specific distributive effects, the ASPL within all cities inside of or directly linked to Serbia is used (i.e., direct international links to neighboring countries are included). In the future scenario, the ASPL is reduced by 23.78%. This is a substantial reduction which can mainly be addressed to the Belgrade-Nis corridor's upgrade (with a relative reduction between the two cities of nearly 70%). All connections between the south and north pass through it which makes it an essential improvement for all north-south journeys. Therefore, the benefits reach far beyond the upgraded link – an ideal representation of network effects.

5.3.2 – Identifying the Most Important Network Edges

Distributive effects may therefore be particularly expected whenever edges that are of particularly high strategic relevance within the network are changed (ideally in a positive way). This strategic relevance of edges (or nodes) in the context of a full-scale network is commonly understood as betweenness or betweenness centrality. To be specific, the EBC refers to the percentage of fastest routes (among all shortest paths) running through a particular edge. While the results slightly differ between realistic and potential travel times, the following observations are based on the realistic ones; the results are also visualized in Figure 23 and can be studied more detailed in Appendix E. It must be kept in mind that the current scenario of realistic travel times features non-operated connections which are only actively interconnected with the network in the future scenario. This might cause certain metric distortions which have to be taken into consideration. Yet, it realistically serves as an outlook of how the network might change following the revival of existing connections.

In accordance with Figure 23a, it becomes clear which network edges currently act as vital veins. In the current situation, the highest frequented edge is between Budapest and Gyor which is passed by 18.39% of all shortest paths within the network. The second and third most in-between edges are Vienna-Linz (18.35%) and Vienna-Gyor (16.55%). This paints the picture of the corridor Linz-Vienna-Gyor-Budapest being the major backbone of connections between Western and Eastern Europe. The fourth-ranked edge is Strasbourg-Karlsruhe (14.97%) which indicates that this stretch acts as an important entry into France, especially toward Paris and beyond. This is followed by the edges Lyon-Avignon-Montpellier (14.93% and 14.16%). This shows how the main pathway from central Europe toward the Iberian Peninsula runs along the Mediterranean coast instead of the alternative path along the Atlantic coast. Unsurprisingly, other edges of high betweenness seamlessly add to the two main corridors above. The Budapest-Szolnok link (13.97%) extends the Linz-Budapest corridor toward the east, while Montpellier-Perpignan-Girona-Barcelona (13.68%, 13.44%, 13.05%) confirms the mediterranean corridor's significance.

Besides this, two further corridors are indicated by the currently most in-between edges. The series of connections along the Hamburg-Padborg-Odense-Copenhagen-Malmö route achieve betweenness values from 10.74% to 13.26%. This is due to its role as a bottleneck linking Scandinavia with the rest of Europe. Since no other path is available, all shortest paths between the Nordics and the remaining continent have to cross this particular corridor. The same phenomenon can be observed for connections between the United Kingdom and mainland Europe. Since the only rail connection leads to the Channel Tunnel, it is unsurprising that the Lille-London stretch is ranked twelfth in terms of betweenness with 12.50% of all shortest paths passing this section. Lille-Brussels (11.74%) represents the most in-between extension to the Channel, thereby highlighting this link's importance for northbound connections.

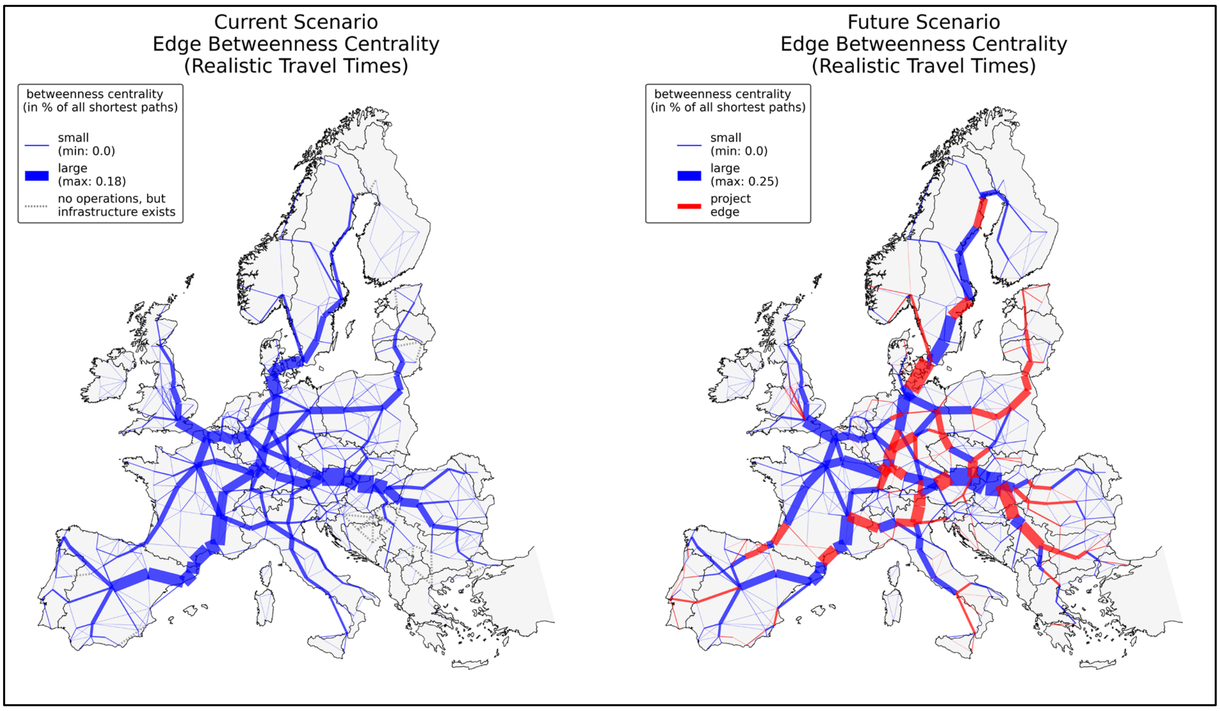


***Figure 23**: European intercity rail network classified by edge betweenness centrality, based on realistic travel times, for (a) the current scenario and (b) the future scenario, including emphasis on project edges. Raw data of edge betweenness centrality is available in Appendix E.*
Source: own illustration.

It might therefore be assumed that edges of high betweenness can be understood as edges that come with a particularly high potential for improvements since their improvements could reach far beyond the project's physical scale. This is however only partially true, as is being addressed in section 5.3.4. Instead, when quantitatively analyzing the future upgraded scenario, the first observation is that the values generally tend to be higher (now ranging up to 24.69%). This is due to the assumption that currently (temporarily) non-operated lines will be revived by 2050. Most importantly, this re-connects Finland via Sweden to the remaining network. What however remains unchanged is that the Linz-Vienna-Gyor-Budapest corridor is at the very top regarding betweenness; hosting values from 18.37% to 24.69%. Most interestingly, this is now directly followed by the edges along the Malmö-Hamburg route which now runs more directly via Copenhagen and Lübeck (instead of Odense and Padborg). These three edges come with betweenness centralities from 16.41% to 16.90%. This highlights how beneficial the Fehmarn Fixed Link might become, as it reduces travel times along a crucial corridor.

However, when shifting the focus away from such core bottlenecks, the future scenario nicely exemplifies how line upgrades can lead to the emergence of new fastest corridors. Somehow surprisingly, the Linz-Salzburg link is now ranked seventh in terms of betweenness with a value of 15.43%. A brief glance at the current scenario reveals that the Budapest-Linz corridor does a y-intersection continuing via Regensburg-Nuremberg and via Salzburg-Munich. While both paths are of relatively equal relevance in the current scenario, the future scenario reveals a clear shift toward the southern route via Salzburg. This change must of course be interpreted in the context of the entire upgraded network, which also includes altered traffic flows thanks to the Brenner Base Tunnel. As a result, the most efficient corridor from the Southeast to the southwest will in the future scenario run through the Brenner Base Tunnel, traverse northern Italy and continue via the Euroalpin tunnel instead of passing through southern Germany. Standing out in a similar way are developments in southeastern Europe. In the future scenario, the new Budapest-Subotica line is highly ranked (13.52%) together with the Subotica-Novi Sad and Novi Sad-Belgrade links (12.65% and 12.53%). In combination, this corridor now represents the main access toward the West Balkans, Bulgaria, Greece, and Turkey. Earlier, the most efficient route had led through Romania. As can be seen in Figure 23b, further examples of newly emerging key corridors can be found along the Biscay Atlantic coast which now takes over a substantial share of the most efficient routes leading from France into Spain at cost of the Mediterranean route. Similarly, a new corridor linking Northern Europe with the Southeast emerged between Berlin and Vienna, most importantly thanks to the Berlin-Dresden-Prague route upgrades, which most likely are also responsible for the Nuremberg-Linz line's downfall.

5.3.3 – Identifying the Most Important Network Nodes

While the EBC features some significant changes, this implies that the edges' nodes will be affected in a similar way. Analogue to edges, the betweenness centrality can also be computed for nodes as well and thereby provide interesting insights into the consequences of projects for different cities. In particular, this allows for identifying current and future major rail hubs and simultaneously assessing how these roles might change.

Standing out at the very top are Vienna, Linz, Gyor, and Budapest where 19.37% to 18.53% of all current shortest paths run through. This closely relates to the EBC patterns discovered before. Unsurprisingly, Karlsruhe and Lyon as well as Lille and Strasbourg (18.48% to 15.55%) follow up closely in the ranking – which all are cities that were heard of already before. However, the NBC's unique characteristic is that it is non-directional (in contrast to an edge). Therefore, Frankfurt and Paris (15.51% and 14.91%) also enter the top ten of in-between cities. Even though their significance is well-known, the latter have not particularly been part of any emphasized edge. This is due to the reason that the connections from/to these cities are not necessarily the very most in-between ones of Europe. Instead, multiple edges of relatively high in-betweenness come together in these hubs. The full set of values is available in Appendix F.

The observed changes in NBC generally go alongside the changes in EBC. Some cities are however worth emphasizing in particular. For instance, Vienna, Budapest, and Gyor remain at the very top in the future scenario since they are passed through by 28.04% to 24.66% of all shortest paths. Standing out is thereby that Vienna, as can be seen in Figure 24, is one of the cities experiencing strong increases. This is likely due to the new emerging corridor from Berlin to Vienna via Prague and Brno (which also show a high increase). Again, remember that the connection of inactive lines generally increases the values. Meanwhile, Linz is now only found at the sixth position (18.39%) behind Hamburg (20.17%) and Karlsruhe (20.04%). While all places were highly relevant earlier already, they have simply experienced less of an increase in relevance, compared to other nodes. The opposite is observable for the Danish cities (apart from Copenhagen) which represent an example of locations that have significantly lost relevance in terms of betweenness since the shortest paths now follow other upgraded or new corridors. Their losses, most particularly present in Padborg and Odense, are captured by Lübeck's increase in betweenness as it is now ranked 10th (with a new value of 16.62%). As Figure 24 corroborates, Lübeck is the city with the largest increase in NBC. Similar examples of locations gaining in relevance are Verona (with a new value of 13.71%), Subotica (13.15%), Novi Sad (12.58%), and Innsbruck (12.19%) while places such as Arad (4.38%), Deva (2.45%) have in return lost significance. These changes illustrate how the project implications come with severe impacts on cities' roles in the network. Such findings might help to understand how political interests in projects can be highly controversial from region to region.

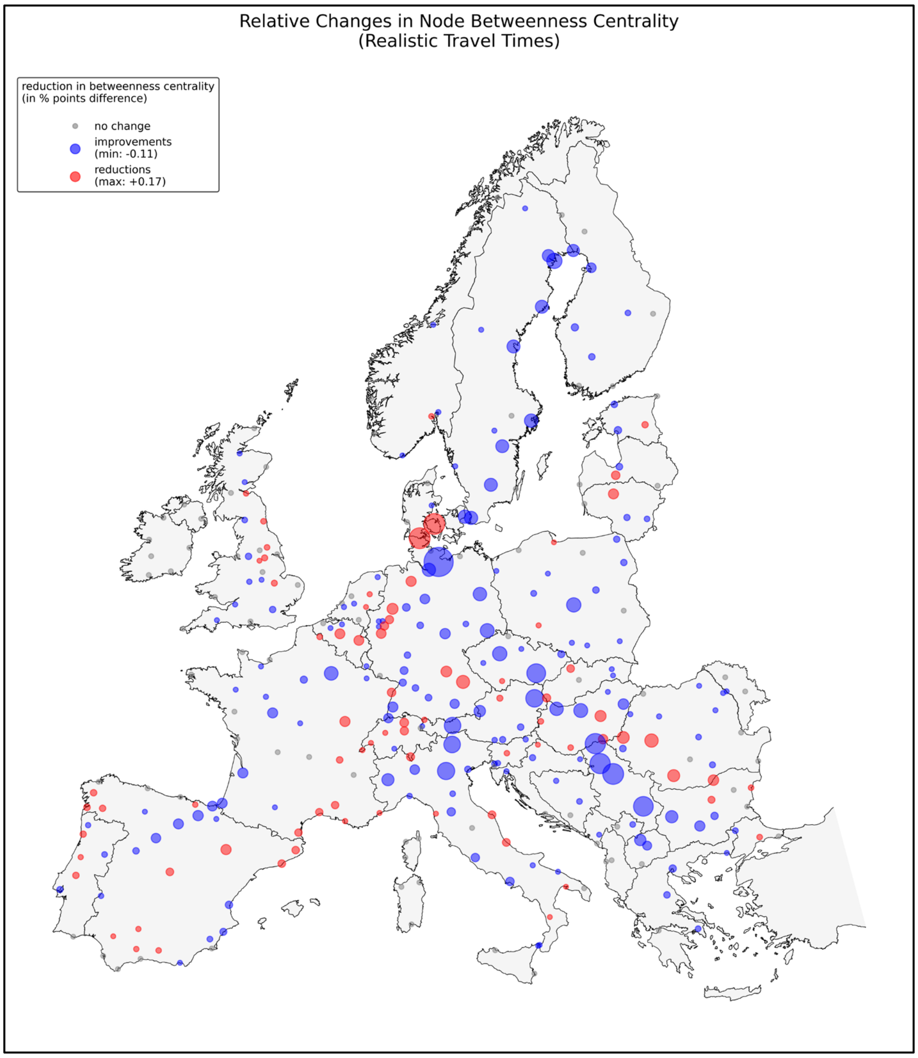


Figure 24: *Absolute changes in node betweenness centrality (realistic travel times).*
The full dataset of changes is available in Appendix F.
Source: own illustration.

Nonetheless, a node does not only benefit from being located along more paths through the network. Instead, it is also essential to assess a node's connectivity and accessibility to the overall network. This is referred to as the NCC. That value is defined as the inverse of the ASPL from one node to all other nodes (not to be confused with the full-network's ASPL which is based on all possible city pairs). For simplicity reasons, the ASPL will be referred to when speaking of the NCC.

Figure 25 thereby reveals a very clear pattern: the locations that benefit the most in terms of closeness centrality are located toward the outskirts of the European rail network. This makes sense since the shortest paths from the outermost locations to all other nodes in the network have the greatest chance to accumulate travel time reductions. In this case, this particularly concerns the Baltics, Scandinavia, Portugal, and the Balkan. However, there are very distinct differences between those regions. Particularly speaking, the improvements in the Baltics and in southeastern Europe are significantly greater than elsewhere. For the Baltics, this can mainly be attributed to the Rail Baltica project. Since every in- and out-bound route leads through the current Baltic bottleneck, improvements in this region will improve every single connection exiting or entering the Baltics. The assumption that Rail Baltica is the major contributor to these improvements can be supported by comparing the connections north and south of the Suwalki Gap. South of this section, the difference in NCC is clearly smaller than north of it. This stands in a slight contrast to the patterns of improvement in southeastern Europe. There, no specific bottleneck prevails in the current scenario. Instead, the various existing connections are relatively slow. The development of more efficient infrastructure, particularly through Serbia, provides new corridors which will outperform the current paths. Therefore, Bulgaria, Turkey and Serbia are the major benefiters in this region. observations are also supported quantitatively: the top four reductions of the ASPL are projected for Istanbul (reduction by 1227 min), Narva (1213 min), Tallinn (1211 min), and Plovdiv (1138 min).

Yet, it should not be neglected that every other region benefits as well – apart from Ireland and Northern Ireland, and Corsica and Sardinia. For instance, besides the primarily disconnected cities in Finland and the Balkans, the northernmost train station in Europe, Narvik, experiences a reduction of 525 min. Lisbon benefits by a reduction of 492 min, Chișinău's ASPL is reduced by 374 min, and Palermo sees a 358-min reduction. Even the more central locations are not unaffected: Zurich (127 min), London (119 min), Paris (128 min), Prague (241 min), Amsterdam (125 min), Munich (140 min), Budapest (184 min), and Zagreb (193 min) are examples of more central cities that still benefit considerably. Nonetheless, there is a clear pattern stating that the smallest reductions are found in cities around the Dutch-German-Belgian border region. In fact, Brussels shows the lowest ASPL reduction of only 114 min. Values for further cities can be retrieved from Appendix F.

To visually underpin how these cities' NCC values specifically change in Europe, a set of isochrones were mapped. They show the differences in spatial accessibility within a full day (i.e., 24 hours) between the current and future scenario. Figures 26 and 27 visually exemplify the changes for Istanbul and Tallin, two of the most affected cities. Besides these two examples, isochrones for all remaining previously mentioned cities can be found in Appendix K.

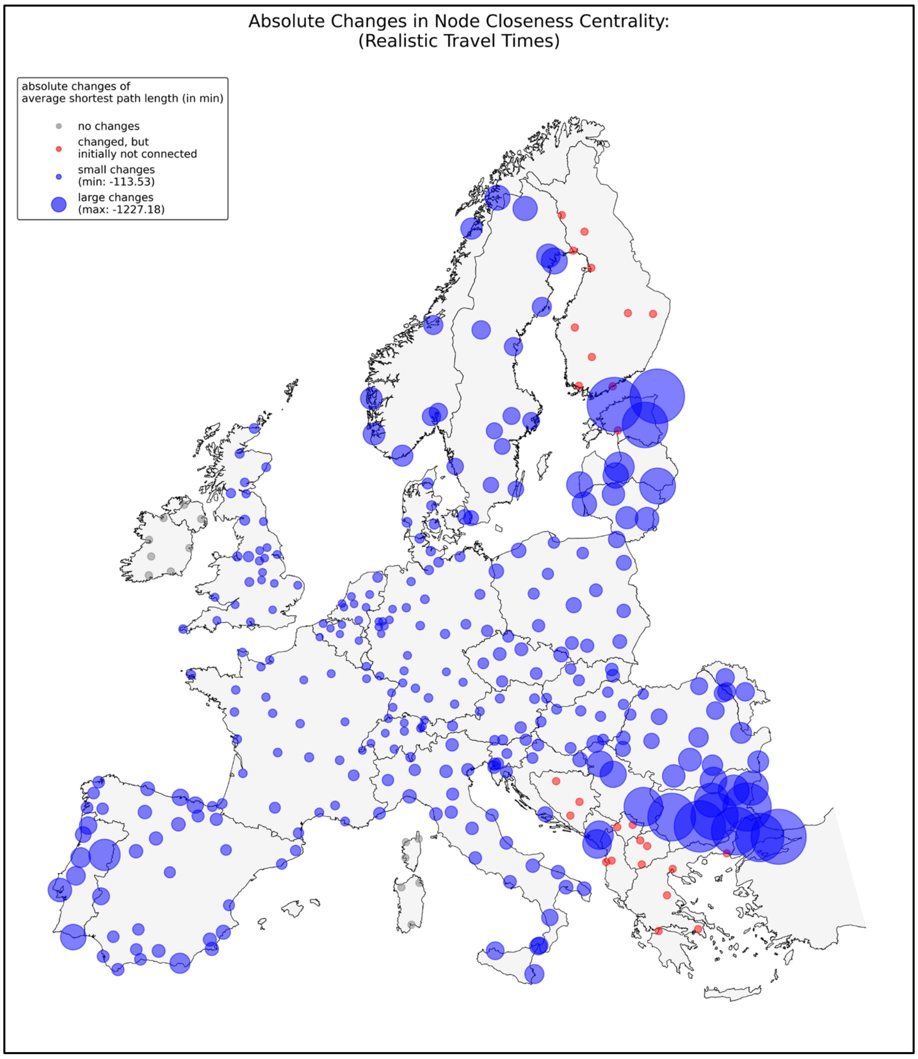
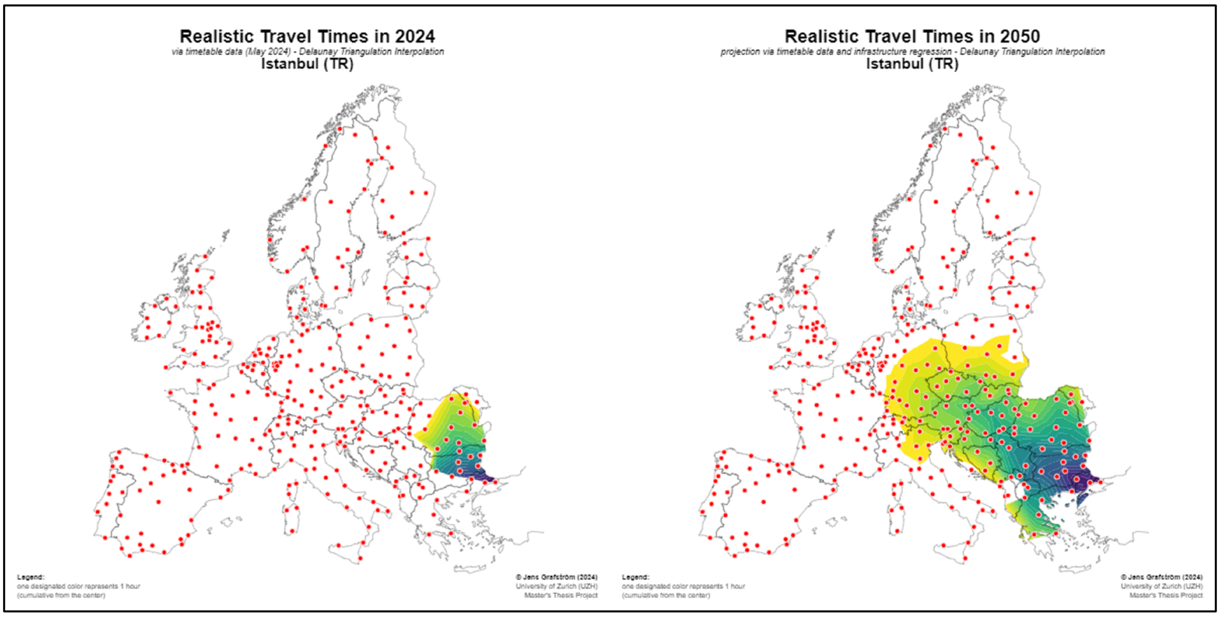
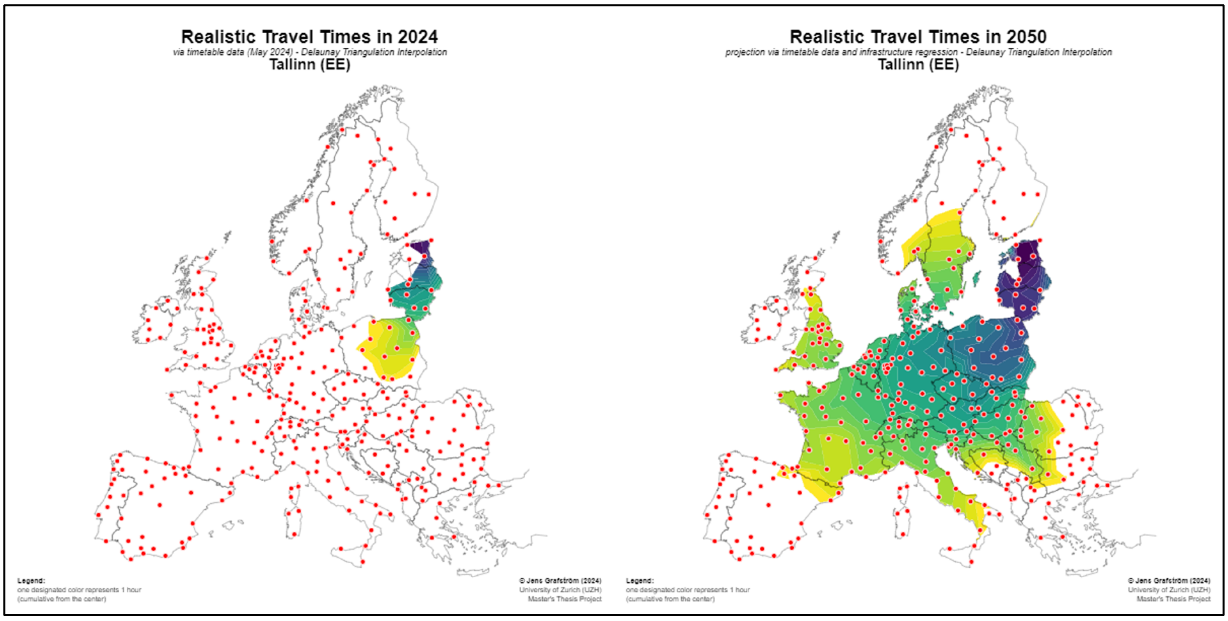


***Figure 25**: Changes in node closeness centrality between current and future scenario.*
Full dataset of changes is available in Appendix F.
Source: own illustration.



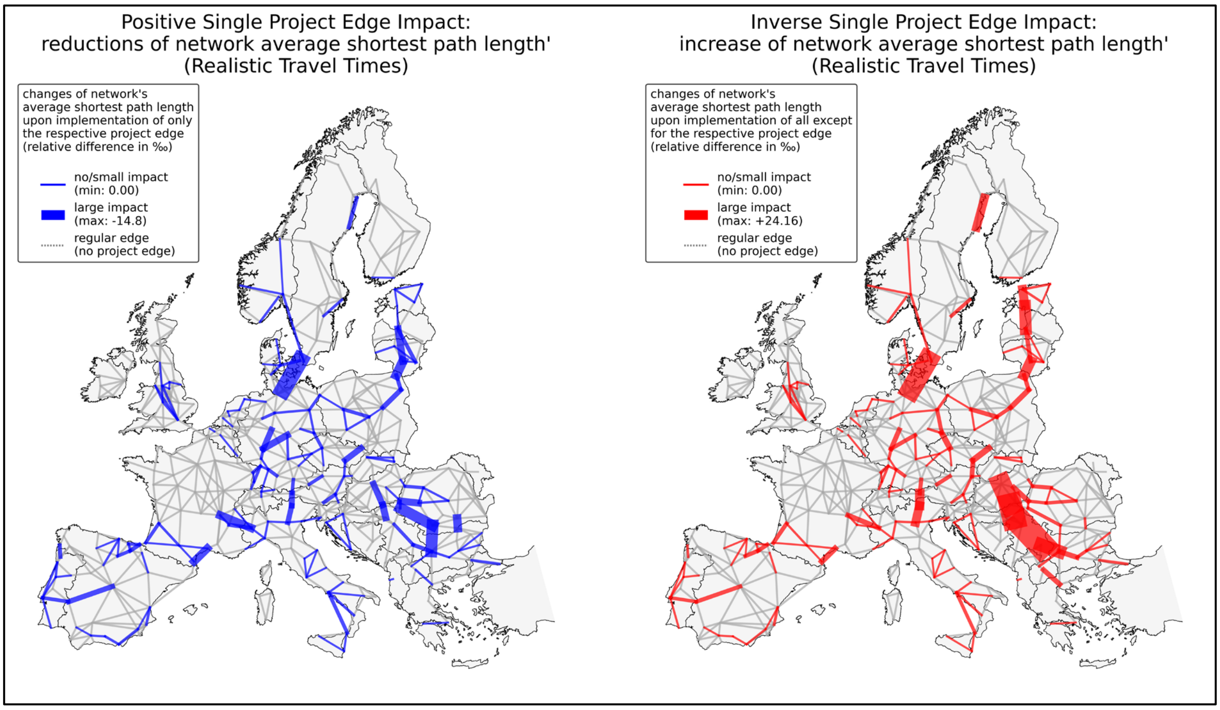
***Figures 26 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Istanbul.*
Source: own illustration.



***Figures 27 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Tallinn. Source: own illustration.*

5.3.4 – Valuing the Projects Individually

Even though it could already be clearly seen how important the projects are and how they as a whole can affect different regions of the network, both directly and indirectly, it remains to be identified which projects are the most important ones. This is where the single impact analysis comes into play. As a reminder, this encompasses the changes in full-network ASPL for a simulated scenario where either only one specific project edge is implemented or all but that one are being implemented. The results of both approaches are visualized below in Figure 28 and can be accessed in Appendix G.



***Figures 28 a-b**: Impacts of individual project edges: (a) relative reduction of ASPL after implementation of a specific project only; (b) relative increase of ASPL after re-setting only the specific project but keeping all others. The exact values for each connection can be found in Appendix G. Source: own illustration.*

Figure 28a immediately draws attention to two regions: the Balkans and the link between Denmark and Germany. In a scenario where only the Fehmarn Fixed Link is implemented, the ASPL is reduced by 14.80‰ (i.e., 1.48%). Following behind are two links in the Balkan. Upon further inspection, it however becomes clear that these are not part of the previously regularly mentioned Budapest-Belgrade-Sofia corridor. Instead, they are connecting Sofia to Craiova and Craiova to Timisoara and come with reductions of 10.06‰ and 9.05‰, respectively. Further highly ranked edges are Kaunas-Suwalki, Ruse-Bucharest, Lyon-Turin, Montpellier-Perpignan, Riga-Kaunas, Arad-Deva, and Subotica-Novi Sad (with reductions from 7.71‰ to 5.17‰). Project connections with high scores can herein be interpreted as overcoming current bottlenecks through which many connections pass.

It might therefore be assumed that that the relative reduction in ASPL by the implementation of a single project correlates with the edges' betweenness centralities. Following a brief linear regression (including all upgraded edges already existing in the current scenario), this thought must however be rejected due to an extremely low R-squared value of 0.131. Even though edges of high betweenness have a high potential to reduce the network's ASPL upon their upgrade, they are often (though not always) already well-equipped and leave little space for realistic optimization. Instead, a large fraction of upgrades is made along edges that currently are relatively inefficient and therefore often come with low betweenness centralities. These upgraded lines might then gain in betweenness and therefore have a great impact on the reduction of the network's ASPL. Consequently, no clear relationship between EBC and single project impact can be identified in this thesis' framework.

In Figure 28b the stark contrast regarding emphasized edges stands out. In a setting where all projects are implemented but one is left out, the Balkans are again in the center of focus. However, it is no Bulgarian-Romanian link that ranks highest. Instead, the Belgrade-Nis connection increases the ASPL the most, by 23.59‰ (i.e., 2.36%), if being undone. Among the top five, an additional three connections lay along the same corridor. This includes the Subotica-Novi Sad, Budapest-Subotica, and Sofia-Nis connections (with reductions between 21.27‰ and 11.38‰). The only unrelated connection ranked as high is between Copenhagen and Lubeck, with a value of 18.23‰. Ranks six to ten are occupied by Pärnu-Riga, Kaunas-Suwalki, Innsbruck-Bolzano, Tallin-Pärnu, and Verona-Bolzano (with values between 10.12‰ and 6.97‰). Connections that scored highly during the inverse analysis can herein be interpreted as edges of high vulnerability. If they were to be reset to the current status (or even worse: disrupted entirely), time-consuming detours would have to be undertaken.

More complex is the interpretation of the differences between the edges' relevance in the two analyses. Edges that receive high values in the first analysis but not in the second one can be understood as local bottlenecks. Upgrading them leads to immediate improvements, as is characteristic for bottlenecks. However, their upgrade's relevance is reduced in the context of the full-network upgrades. This means that their role as bottleneck does not apply on a larger scale anymore, most likely due to being undercut by another upgraded section. This applies to the aforementioned Bulgarian- Romanian edges in particular. In contrast, edges that rank highly in the inverse second analysis but not in the first one represent a different characteristic. They resemble newly established corridors or serve as crucial paths of access to other critical upgraded network components. If disrupted, other improvements cannot be (fully) benefitted from either. This is particularly relevant for the Budapest-Belgrade-Sofia corridor. The reset or disruption of one edge along this corridor would immediately reduce the benefits of the other upgrades as well. Edges that score relatively high in both analyses represent upgraded core edges. They are large-scale bottlenecks or corridors of high efficiency and frequency. This is especially applying to the Copenhagen-Lübeck connection. Similar tendencies can for instance be found in the Suwalki-Kaunas, Madrid-Badajoz, or Frankfurt-Kassel connections.

When comparing the single project impacts between domestic and international connections, another interesting observation is made. Domestic projects on average reduce the ASPL by 0.72‰ if they are implemented as the only project. Meanwhile, international projects come with a reduction of 1.23‰. Regarding the inverse analysis, a domestic project increases the ASPL on average by 1.06‰ if being the only one not implemented. In contrast to that, international projects record an increase by 2.94‰. In both cases, the average impacts of single projects are greater for international projects than for domestic ones. This reconnects to the observation made earlier stating that international projects have a greater relative impact at the full European scale than domestic ones. This relative contrast is even more striking for the inverse analysis. International connections can be seen as more vulnerable than domestic ones which supports the claim by Marti Henneberg (2013 & 2017) that international rail connectivity is relatively poor in Europe.

Overall, the results emerging from the most significant impacts of single projects indicate that the Fehmarn Fixed Link between Germany and Denmark is the one connection that on its own has the highest potential impact on the full European rail network. Its strategic location allows for it to act as a new gateway for north-south connections to/from Scandinavia. When taking grouped projects into consideration, Rail Baltica acts in a similar manner as the Fehmarn Fixed Link by improving all links from the Baltics to Europe. The most interesting pattern has however been revealed along the corridor between Hungary and the Black Sea. While the projects between Sofia, Craiova, and Timisoara are of major importance for improving the currently most efficient pathway along this route. The most striking change can be expected upon the completion of the Budapest-Belgrade-Sofia route. It will undercut the Romanian path significantly and attract most of the shortest paths toward the Southeast, metaphorically speaking. Yet, it is highly vulnerable since the full-scale benefits are only unfolded if all sections of these projects are completed. If only one section along this path is delayed or suffers from other issues preventing it from being completed, the European ASPL will increase dramatically. This consequently is an ideal example of why the European scale of analysis is so valuable – since a local analysis would not have grasped the interregional importance and dynamics of this particular corridor.

6 – Results II: Case Studies

Following the previous section, there are certain projects that stand out in terms of full-scale European relevance. While those particular impacts have already been addressed before, it is worth to explore the different nature of these projects. This particularly concerns their technological, political geographical, and rail-operational backgrounds. The following case studies are thereby selected specifically to serve as examples for the different directions in which the complex dynamics and processes surrounding the project implementation are headed.

6.1 – Black Sea - Hungary Corridor(s)

The likely most unexpected outcome of the previous analyses concerns the projects in southeastern Europe. From a technical perspective, this group of upgrades features four main components: (1) sectional upgrades to 160 km/h in Romania, (2) improvements of Bulgarian cross-border connections, (3) sectional upgrades to 160km/h along Bulgaria's core corridor (4) construction and upgrades to establish a continuous efficient corridor from Budapest via Belgrade to Sofia. Overall, these projects mainly use existing tracks which are to be upgraded. Between Subotica and Novi Sad, an entirely new connection is built; partially new constructions are planned between Belgrade and Nis. The terrain is particularly challenging in southern Serbia, western Bulgaria, and central Romania due to the mountainous landscapes.

What makes this case stand out is the complex web of political interests involved. On the one hand, multiple lines, especially in Romania and Bulgaria, are part of two TEN-T corridors. This underpins these sections' high importance to the EU. This goes alongside with political and hence financial support sourcing from the EU. Upon completion, the projects in Romania and Bulgaria as such have a significant impact on travel times connecting eastern Europe toward the western rest of the continent. As was identified earlier, the path through Romania currently represents the major (but passable) bottleneck between southeastern and central Europe. In the meantime, this current bottleneck, despite significant improvements, is going to be undercut in terms of travel times and bypassed in Serbia – who is not part of the EU.

Consequently, the EU plays no substantial role in funding these specific projects. Instead, the required projects are funded as a part of the Chinese Belt and Road Initiative which foresees the installation of strategic corridors enhancing trade toward China. Thus, in the context of political patterns and existing infrastructure in the Balkan region, Serbia provides ideal conditions for external involvement (Csapó, 2021; Stojanović et al., 2022). However, Chinese funding also occurs in EU-member states. In this particular context, the connection from Budapest to the Serbian border is upgraded and constructed with a major fraction of funding sourcing from China, too (Rogers, 2019). Once the corridors passing through Romania are undercut in terms of operational efficiency, the Serbian corridor has the potential to create new dependencies and will therefore likely become an irreplaceable component of the continent's transportation networks. While the Chinese involvement is commonly criticized (mainly due to high loans and losses in infrastructural independence) (Csapó, 2021), it allows for the construction of ambitious projects which regular travelers and the local population can majorly benefit from.

In this particular case, these travel time improvements themselves have become a political tool as well and are a substantial reason for Hungary's support of this corridor. Among the inhabitants of Serbia exists a recognized national minority of Hungarians. In certain northern municipalities they even represent a majority. These foreign Hungarians are able to obtain Hungarian citizenship and can then participate in votes in Hungarian elections. Especially in recent years, there have been major Hungarian investments, particularly in infrastructure, in northern Serbia in order to maintain relationships with the foreign Hungarians. The Budapest-Belgrade railway can thereby be considered as another such investment, at least from a Hungarian perspective (Rémenyi et al., 2021). This is further manifested by the connection's route layout in Hungary:

the new rail line from Budapest directly approaches Subotica without connecting to any other major city. As an example, Szeged (Hungary's third largest city, located near the Hungarian-Serbian border), is bypassed even though its link to Budapest could benefit from speed upgrades or improved track paths. This underpins the new connection's pure intention to provide improved access toward Serbia.

The outcomes of this series of overall projects are significant. The overall travel time between Belgrade and Budapest is reduced form 7 h 41 min to 2 h 30 min which corresponds to an overall reduction of 67.46%. Passing through the same corridor, Sofia is connected to Budapest in 7 h 22 min instead of 20 h 45 min– reducing travel times by 64.51%. In contrast, Bucharest still lies 11 h 8 min away from Budapest which is "only" a 22.33% reduction from the current 14 h 21 min. Even though a reduction by almost one fourth is remarkable, it clarifies how Romania's improvements are relatively seen lagging behind its neighbors. Furthermore, Istanbul will be reached from Budapest in 14 h 55 min which is 50.78% less than the current 30 h 18 min and hence makes this city pair perfectly connectable by night trains. Meanwhile, Budapest will expand its status as an essential hub for travel toward southeastern Europe. Similar pattern will most likely emerge for freight traffic whereas the Hungarian capital might turn into an operational and logistical center at the intersection between central and eastern Europe – which might provide the main economic benefits of its investments in the new line.

To conclude, it can be said that the project results from a patchwork of both opposing and aligning (geo-) political interests, and logistical as well as trade-economical desires. While the political dimension of this series of projects might spark controversies, the outcomes for regular everyday passengers are substantial. Major international hubs in southeastern Europe will be reached conveniently from Budapest. While all improvements are beneficial on a local scale, the projects along the Serbian corridor clearly outpower the Romanian ones one a European level, as the previous sections' analyses revealed. Yet, this new pathway is also highly vulnerable since disruptions along any of its sections could not be compensated in terms of travel times.

6.2 – Rail Baltica

Somewhat familiar to the previous case, the Rail Baltica project is also of high political relevance. Yet, it also features interesting technical and geographical features which should not be left out. Simply put, Rail Baltica is an EU-backed project that is supposed to improve rail connectivity within the Baltic States – Lithuania, Latvia, and Estonia – as well as to Poland and hence remaining Europe. The project will thereby predominantly encompass newly built tracks. The project is laid out in standard gauge which differs from the Russian gauge currently present in the Baltics. In a nearly straight line from Kaunas via Riga to Tallinn, speeds reaching up to 249 km/h will be realized. Additionally, a branch line will connect the Lithuanian capital Vilnius via Kaunas to the main line. The remaining infrastructure will however remain in Russian gauge. This shows how the project is clearly addressing journeys to and between the major Baltic cities – at least in terms of passenger travel.

In reality, this project's relevance goes far beyond simply improving travel times. The project has profound strategic implications, particularly in the context of regional security and geopolitical dynamics. Currently, the only land-based route connecting the Baltics to the rest of the EU runs through the Suwalki Gap, a narrow 65-km stretch of Lithuanian-Polish border nestled between Belarus and the Russian exclave Kaliningrad. This corridor is a critical and vulnerable chokepoint, especially in the context of rising tensions between NATO and Russia. The existing infrastructure crossing the Suwalki Gap includes just two highways and a single rail line that switches from Russian to Standard gauge in Lithuania, hence making it a logistical bottleneck. In the hypothetical event of a crisis, this could severely limit the ability to move troops, equipment, and supplies quickly into the Baltic region, leaving it potentially isolated and vulnerable.

By providing a direct, high-speed rail connection from Poland to the Baltic capitals, Rail Baltica aims to significantly strengthen the EU's and NATO's ability to maintain access to the Baltics, thereby enhancing the region's strategic security and deterring potential aggression (Montrimas et al., 2021). The most important aspect herein is likely the elimination of track gauge differences. Even though gauge-switching passenger trains are well established in certain regions of Europe, this technology can be applied only to a very limited extent to freight traffic due to the immense potential weight of the cargo. This is especially problematic in a military context where goods are particularly heavy. Therefore, the current infrastructure would slow down mobilization and supply processes by requiring a transfer to fitting rolling stock. Rail Baltica would consequently significantly facilitate traffic flows toward the Baltic States – which also is of high non-military interest.

All geopolitical aspects aside, Rail Baltica also stands out for its massive scale. No other European rail project currently directly involves four countries at once. Overall, around 870 km of electrified track will be built, including rail stations and cargo terminals. This all happens in a region of particularly low population sizes and densities. The main Baltic cities included in the project (Riga, Vilnius, Tallinn, Kaunas, Panevezys, Pärnu) together account for only around two million inhabitants. The project is consequently highly ambitious and commonly discussed. The extent of how far ambitions reach is symbolically represented by regularly re-occurring proposals for a tunnel linking Tallinn with Helsinki, as mentioned earlier. This would act as a northbound extension of Rail Baltica and provide a new direct link from Helsinki toward mainland Europe (Jegelevicius, 2019; Peda & Vinnari, 2022). While the tunnel is yet far from being corroborated, the regular sections of Rail Baltica face constant implementation delays as a result of its ambitious scale. Besides that, it is safe to assume that the coordination between four different countries is far from straight-forward.

Nonetheless, Rail Baltica's implications upon completion are massive, thanks to its ambitious scale. Unsurprisingly, the cross-border link between Suwalki and Kaunas has gained most attention during earlier analyses in this thesis. Since there is no other way of bypassing the bottleneck on land, this stretch's upgrade is most vital in a full-scale European context. In contrast to the Kaunas/Vilnius-Riga connection, the greatest impact is caused by the link between Riga and Tallinn via Pärnu. This is due to the fact that the Lithuanian and Latvian metropolitan regions are already relatively well connected while Estonia is only accessible through a very slow connection. The travel times from Tallinn to Vilnius is minimized from 14 h 29 min to 3 h 20 min which corresponds to a massive reduction by 75.37%. Warsaw, the Baltic's closest and thus most important hub on the way toward the rest of Europe, can now be reached within 6 h 36 min from Tallinn, 4 h 56 min from Riga, 4 h 2 min from Vilnius, and 3 h 24 min from Kaunas. This translates to reductions of 68.35%, 54.04%, 47.51%, and 48.48%, respectively. As a result, the Baltics will drastically move closer to the rest of Europe. Due to the bottleneck structure, every single connection from or to the Baltics will benefit which underpins the project's importance for this region.

As a conclusion, Rail Baltica is a megaproject requiring high investments, but also providing essential benefits at various levels and scales. It enhances efficient and sustainable mobility within the Baltics and brings this rather remote region of Europe closer to each other, but also closer to the remaining continent. Moreover, it structurally strengthens the EU and reduces the topological remoteness of these three states while adding another backbone to the EU and NATO's defensive agility. The project therefore is an ideal, yet unique example of how civil infrastructure investments can serve a military purpose and thereby expand their benefits from a regional and European scale even further to an intercontinental level. Still, it should be hoped that the significantly reduced travel times will remain to be the only aspect ever to be actually put to test.

6.3 – Brenner Base Tunnel

An entirely different geographic and contextual setting is found surrounding the Brenner Base Tunnel project including its feeder infrastructure. Here, the key element is to improve an existing transalpine route. Currently, Verona and Innsbruck (extending to Munich/Salzburg) are connected by a mountainous hence curvy and high-gradient route crossing the Brenner pass. Forming one of the main international transportation corridors in Europe, both regarding passenger and freight as well as by road and rail, the corridor is running close to capacity. To increase capacities and improve travel times, the world's longest rail tunnel is being built between Innsbruck and Bolzano. By straightening the path and reducing the slope gradients, the tunnel alone will cut travel times in half between these two cities and simultaneously increase freight capacities from currently 66 to 225 trains per day (Herrenknecht, 2020).

This project's special nature is its clear dedication to freight usage. Despite being designed for mixed use, its major importance lies in freight traffic improvements. Overall, roughly 80% of trains along this section are planned to be freight trains (Bergmeister, 2014). Consequently, the rail project mainly serves as improvement of a European-scale freight transit route rather than as a pure end-to-end connection. Hence, the success of improving this corridor does not rely on the tunnel's completion alone. Instead, it is highly dependent on its feeder infrastructure as well. The reason is simple: in terms of frequency and capacity, chokepoints must be improved entirely; partial upgrades are only of minimal benefits. If the sections at one or both ends of the upgraded part remain unchanged, the number of trains reaching the upgraded section will stay constant as well, or the higher number of trains will not be able to continue beyond the upgraded section – or both. This represents a key difference to travel time upgrades. Reduced travel times along one section benefit every connection passing through it, regardless of the route's previous or following properties. This provides a first shallow dive into the deep field surrounding the complexity of high-frequency rail operations and corresponding improvements.

In the Brenner context, this dependence on feeder infrastructure is not just an operational, but also a political challenge. Since this choke point stretches across three countries, three different political decision-making and project implementation processes are followed. As a consequence, there is a risk of getting stuck in co-dependency. Since one project is only beneficial on a larger scale if the others are also implemented, one might only want to start the highly expensive constructions once the other projects are also being progressed. Such a scenario bears the risk of significant implementation disruptions or delays and might even to some degree arise political tension, also on smaller scales. Most prominently, this has been the case in Germany and bordering regions in Austria. Germany has long struggled to present a committing and realistic plan for its feeder access from Munich toward Innsbruck. Even now as such a project has been corroborated, the plans foresee a completion not earlier than 2040 which is (according to current schedules) at least eight years later than the Brenner Base Tunnel itself will be completed. As a result, fears are that freight traffic at the northern end will remain road based. Austrian municipalities therefore worry that the currently intense heavy truck traffic, a severe source of air and noise pollution, will not be alleviated or might even be intensified along the tunnel feeder pathways due to the project delays in Germany (Hawlin & Miebach, 2024; Houben, 2024).

Despite the major focus being on freight traffic, passengers will also significantly benefit from the route upgrades' completion. Traversing the Alps, the connection from Munich to Verona will be covered in 2 h 20 min instead of the current 5 h 17 min. This is a significant reduction of 55.84%. In a European context, the Brenner Base Tunnel and its feeder lines will provide another highly efficient transalpine connection. As Figure 23 indicates, it thereby has the potential to re-route the fastest/shortest east-west paths through northern Italy instead of southern Germany which is further supported by the Euroalpin tunnel toward France. While the cities in northern Italy benefit most directly, the remaining part of the country can expect much more rapid connections in the northeastern direction. Italy thereby becomes a more integrated part of the European rail network. Especially in terms of touristic journeys, given the high number of popular destinations in all of Italy, this project alone might represent a massive incentive for a shift toward sustainable mobility – which is even more substantial when combined with all additional upgrades.

The complex situation surrounding the Brenner Base Tunnel therefore acts as an impressive example of how capacity upgrades differ from pure travel time improvements. This case shows how capacity upgrades must be part of a larger upgrade scheme and target the full bottleneck since they otherwise might not be much beneficial. This issue can lead to political challenges, especially in such a multinational case. Nonetheless, the Brenner Base Tunnel represents an important improvement in overwinding restricting topography – in this case, the Alps – which allows for significant travel time improvements and might even enhance another shift in European-scale passenger travel corridors.

7 – Results III: Practical Outcomes and Implications for Rail Travel

7.1 – Reachability Ranges

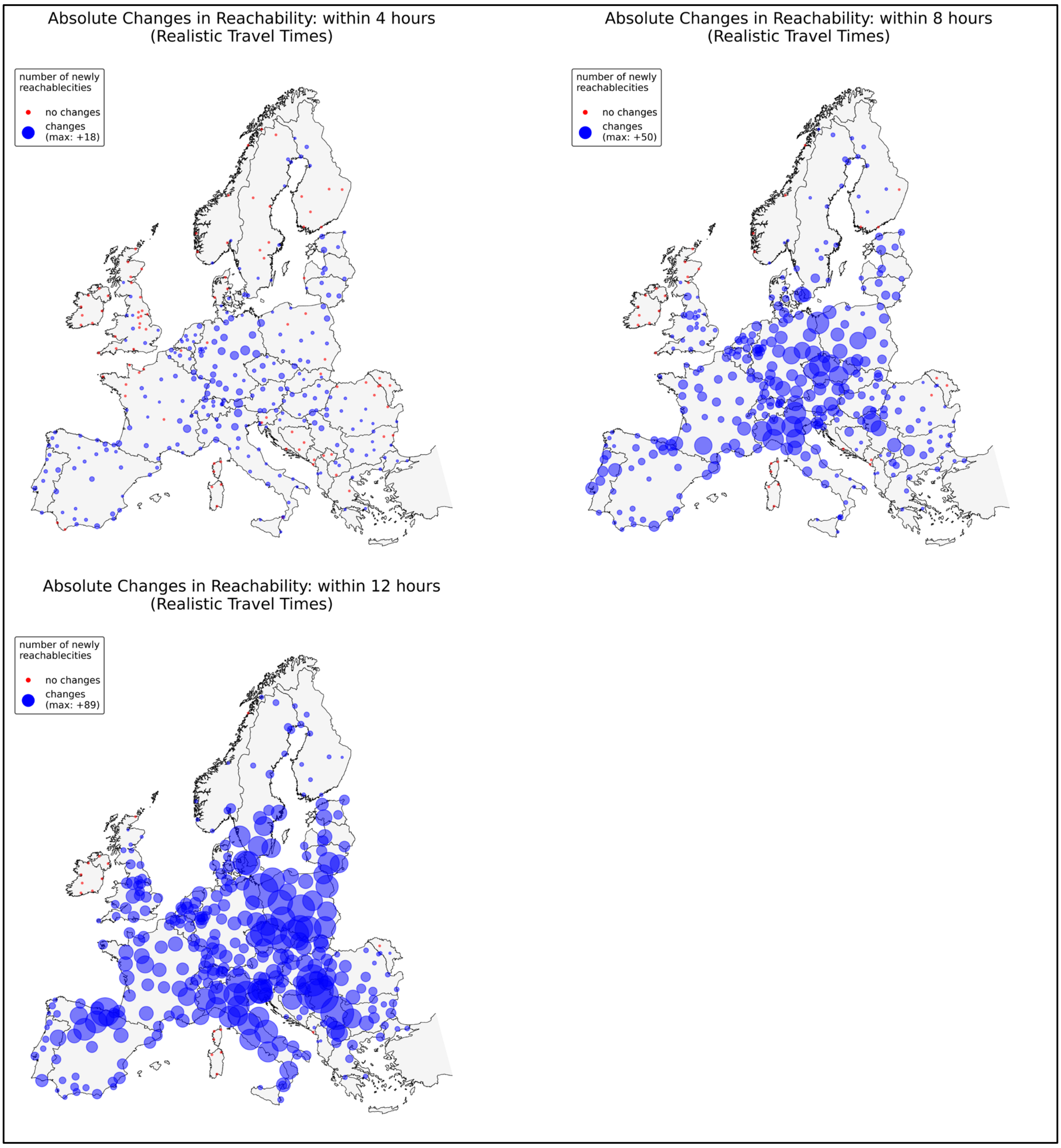
So far, insights into travel time changes have been provided on multiple occasions. However, these were usually limited to the directly impacted paths, or only provided in a full-European context. Similarly, the typical network metrics operate on the full network scale. Nearby impacts might therefore be overlooked. This would however be crucial since railways are an especially promising means of transport for short- and medium-ranged journeys, but not particularly aim to move people across the entire continent at once. Therefore, with keeping this research's motivation in mind, it is essential to identify how the entirety of full-network improvements transform the scope of feasible rail journeys from/to each city. Prominently discussed is the replacement of air travel by rail journeys. Thereby, travel time thresholds have been identified below which railways might be advantageous and preferred. A commonly agreed-upon threshold is 4 hours. However, depending on the respective studies' frameworks, 6-8 hours are present as well (Kroes & Savelberg, 2019; Reiter et al., 2022) Furthermore, one might argue that rail journeys within one day are reasonable. Therefore, 4 hours, 8 hours, and 12 hours were used as thresholds to analyze changes in reachability.

Figure 29 shows how every city's number of reachable locations within the network change between the current and future scenario (exact values are available in Appendix I). This means that all network nodes accessible within travel times below the respective thresholds are counted and compared. Interestingly, the main beneficiaries within the 4-hour threshold are predominantly very central cities. The top five improvements are recorded for Leipzig, Innsbruck, Erfurt, Bolzano, and Grenoble with 18, 17, 16, 14, and 14 newly reachable cities, respectively. Furthermore, places with ten or more newly reachable cities are Dresden, Kassel, Szczecin, Berlin, Hanover, Verona, Munich, Subotica, Basel, and Stuttgart. The dominance of German locations is herein explainable by the high NCC of German nodes. Due to the central location in Europe, these places can potentially benefit from improvements in all directions.

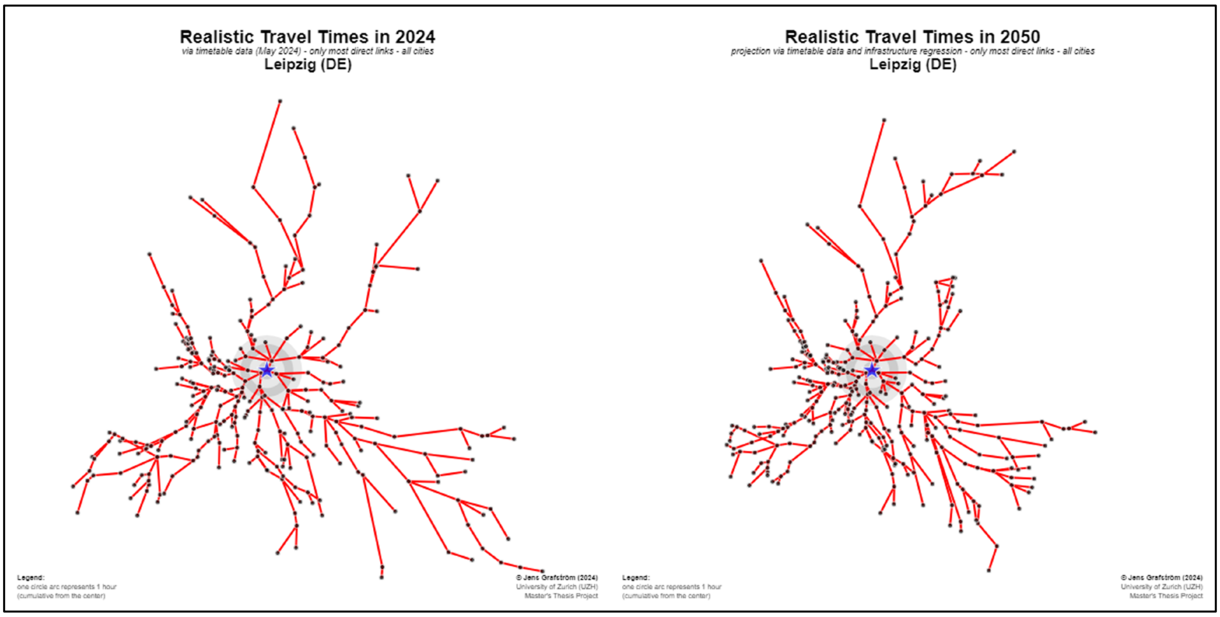
Within the 8-hour threshold, the patterns of benefit start to change. Ranking at the very top is Szczecin with a value of 50 newly reachable nodes. This is thanks to its ideal location allowing it to benefit from the Polish, Baltic, German, and Czech upgrades at once. It is next followed by Bolzano (49), Genoa, Prague, and Verona (all 47). The most striking observance is the high abundance of cities from Italy's north – especially when taking into consideration that Turin (45), Milan (42), and Bologna (41) also join the top ten ranked cities. This must clearly be attributed to the Brenner Base Tunnel and the Euroalpin Tunnel which significantly reduces travel times across the Alps. Overall, the pattern of highest impacts now resembles an arch following the German-Polish Border down to the Czech Republic and continuing via Austria, northern Italy and the Pyrenees toward Portugal's Atlantic coast, with a branch along the Budapest-Belgrade-Sofia corridor.

This again changes when applying a 12-hour threshold. Suddenly, the top five are dominated by the four Serbian cities Novi Sad, Belgrade, Nis, and Subotica (with 89, 80, 78, and 74 newly reachable nodes, respectively). This means that, thanks to the major improvements along the Budapest-Belgrade-Sofia corridor, access to other regions and further improvements is enabled. On rank six follows Bilbao (67) which underpins how important the Basque Y project is for granting this northern Spanish region access to appropriately reachable long-distance destinations. The following ranks are uninterruptedly occupied by a group of Czech and Polish cities: Ostrava, Lodz, Hradec Kralove, Krakow, Katowice, Poznan, and Prague (with 66 to 57 newly reachable cities). Furthermore, Figure 29c indicates that under this threshold, southern Italy joins its northern part in terms of recorded changes. Also, southern Scandinavia and the southern Baltics see relatively high benefits thanks to their bottleneck-overwinding projects. In the meantime, even though important improvements in reachability are also present, some regions of central and western Europe are impacted only relatively little. Now, the greatest impacts are found along a block spanning from southern Sweden to Serbia, as well as in Italy and northeastern Spain.

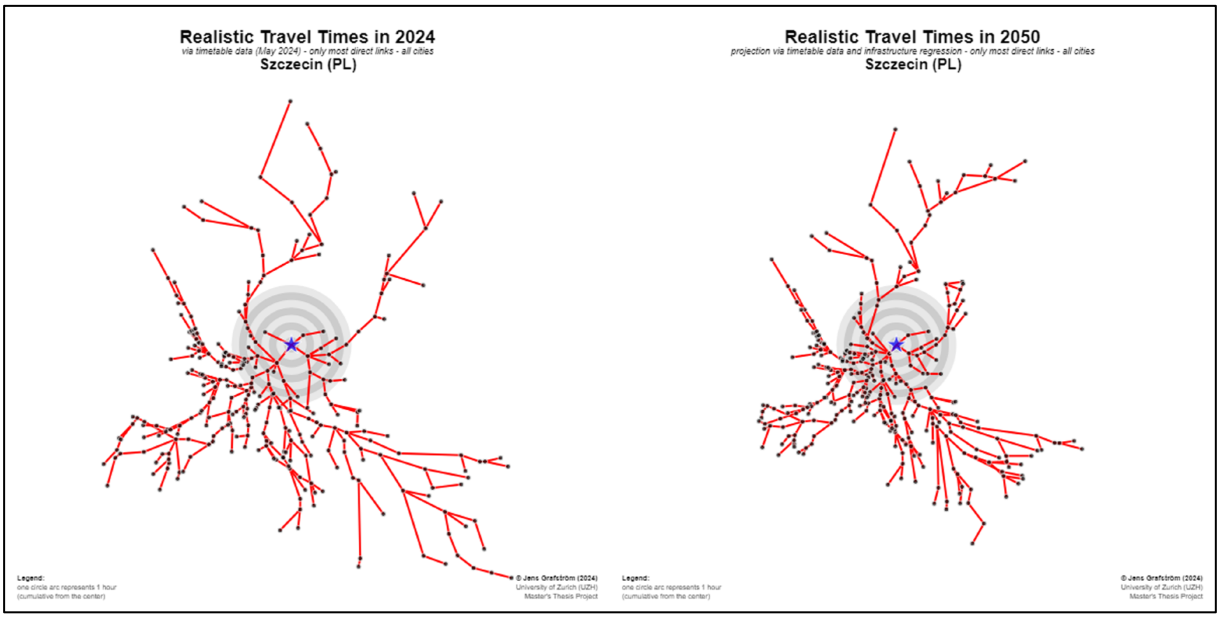
In order to clearly showcase the specific impacts for the three most-benefitting cities from each scenario, cartograms are shown in Figures 30-32. They serve to illustrate how the shortest paths from each city to its reachable locations change and how certain locations move closer in terms of travel times. For further insights, cartograms for the top five differences of each scenario are made available in Appendix L.



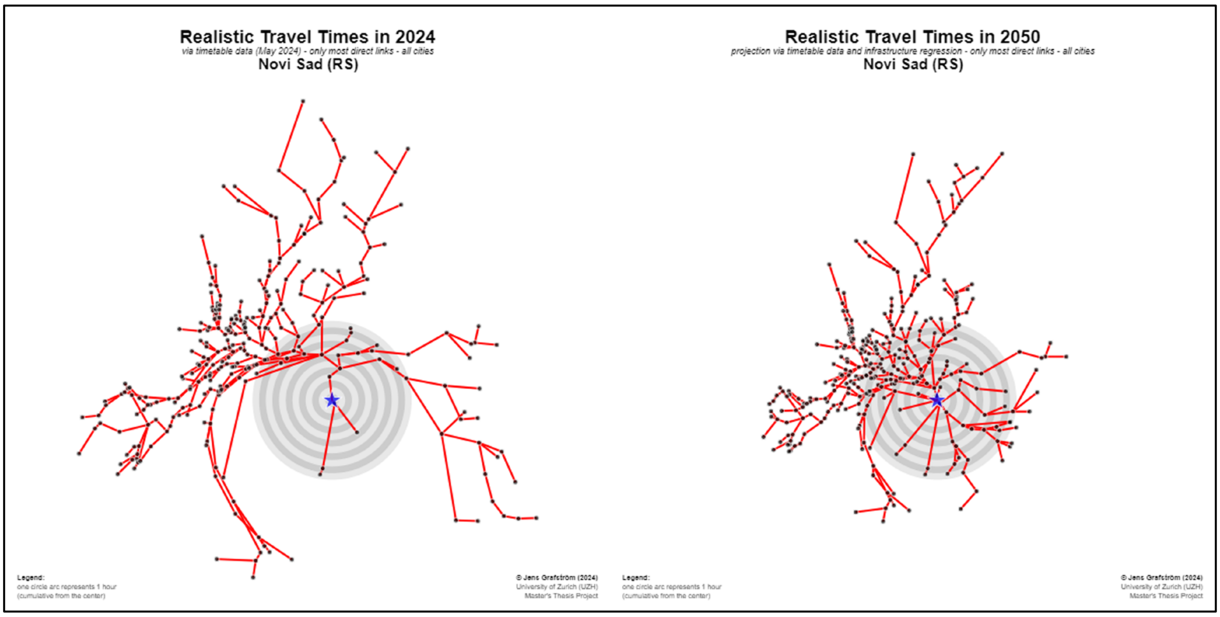
Figures 29 a-c*: Changes in the number of reachable cities within (a) 4 h, (b) 8 h, and (c) 12 h of realistic travel times from origin. Comparison between current and future scenario; continuous scale. Exact values: Appendix I. Source: own illustration.*



***Figures 30 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Leipzig.*
4-hour range highlighted for reachability context.
Source: own illustration.



***Figures 31 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Szczecin.*
4-hour range highlighted for reachability context.
Source: own illustration.

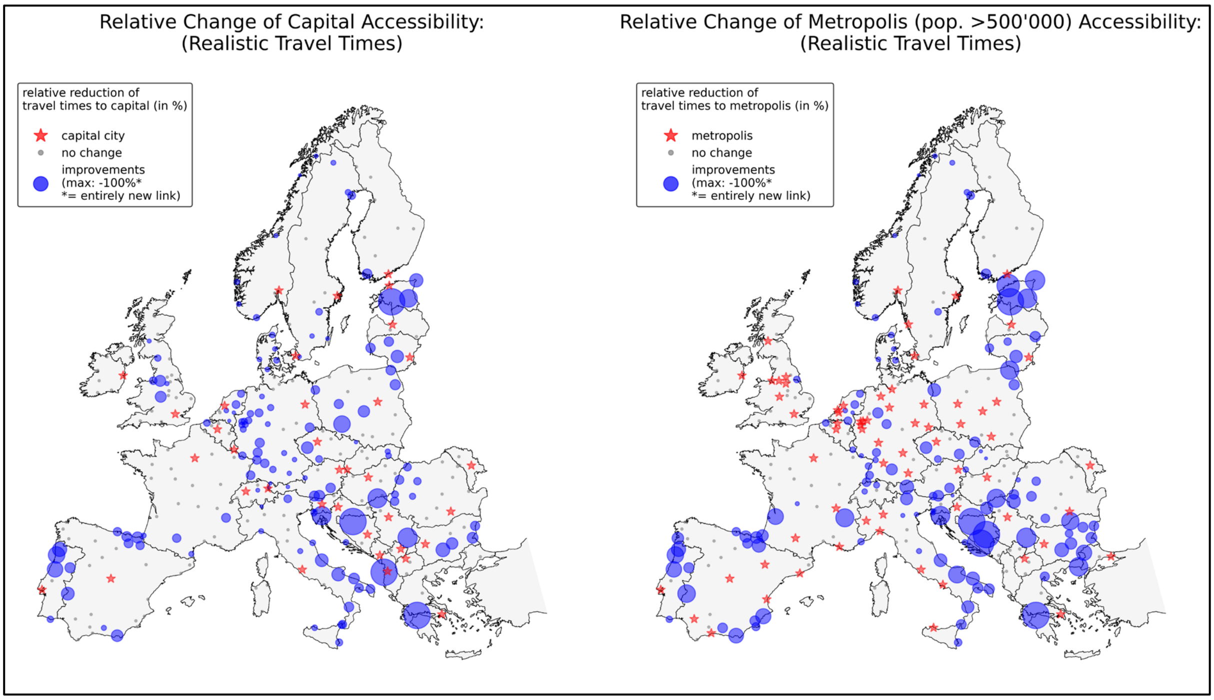


***Figures 32 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Novi Sad. 4-hour range highlighted for reachability context. Source: own illustration.*

7.2 – Accessibility and Connectivity to Major Cities

To the changes in reachability can be added another dimension of relevance, thus transforming it into a matter of accessibility and connectivity to the network. Specifically speaking, it might be of major importance to identify whether certain regions benefit from improved access to their respective capital city or to the closest city of major population sizes. Especially the access to its capital can be of particular relevance since capitals often represent important economic and administrative places which usually are visited frequently and might also be accompanied with high amounts of travels between each other. These regions are also profiting above average, as was already indicated in Table 5. As a brief reminder, the ASPL is reduced by 10.52% in the full network. For connections between capitals only, the reduction is higher (at 14.24%). Cities of population sizes above 500’000 see similar improvements (12.42%) while the values almost doubles for cities above one million (28.64%).

However, besides these already well-known observations, the benefits are clearly not limited to only those major cities. Instead, these places of high relevance will be reached more easily from other cities. Interestingly, the improvements show similar categories regarding accessibility to both respective capital cities and cities of metropolitan characteristics with at least 500’000 inhabitants, as Figure 33 shows.



Figures 33 a-b*: Relative changes of cities' accessibility to (a) their capital and (b) the closest metropolitan city. Full data for both cases are available in Appendix H. Source: own illustration.*

At first sight, the patterns appear to be of relatively similar nature. In both analyses, the Balkans, Baltics, and some regions around the Iberian Peninsula as well as southern Italy stand out. The pattern is therefore relatively clear: the major improvements are found at the outskirts and/or rather poorly equipped regions of the European rail network. Regarding the access to capital cities, four connections stand out as they have gained an entirely new access: Pärnu, Durres, Patras, and Banja Luka. The latter is however not part of any new project, but only a result of the inclusion of a currently not operated route. Following behind are Nis, Subotica, and Rijeka with travel time reductions of 69.88%, 69.05%, and 66.91%, respectively. Completing the top ten are Tartu (63.41%), Wroclaw (58.82%), and Porto (58.56%). Overall, 129 of the 335 cities are experiencing a reduction of travel times toward their respective capital. Taking into consideration that 36 of the 335 cities are capitals themselves, this means that 43% of the remaining 299 cities somehow benefit from the improvements. Regarding access to metropolitan regions, the cities gaining entirely new access to a metropolitan are similar. Banja Luka, Mostar, Patras, Pärnu, and Sarajevo are now newly connected to a city with a population above 500'000. The top ten are completed by Tallinn (reduction by 83.53%), Narva (70.79%), Nis (69.88%), Tartu (68.006%), Rijeka (66.91%), and Alexandroupolis (66.55%). Again, it must be noted that some of these locations (i.e., Mostar, Sarajevo, and Alexandroupolis) also benefit from the assumption that existing but non-operated lines will be in service again in the future scenario. Overall, a total of 118 out of the 267 non-metropolitan cities are experiencing improvements, which corresponds to a share of around 44%. For more detailed information, see Appendix H.

Upon a closer look, some interesting sights can be found. In southern Spain, only Almeria sees particular improvements in connecting toward the capital. Meanwhile, all places at the Spanish south coast show clear reductions in their metropolitan access. This discrepancy reveals how Spain's high-speed rail network evolved around a highly centralistic approach, forming a spoke-like structure linking toward Madrid, while tangential connections were less prioritized. In Spain's north, it becomes clear how significant of an upgrade the Basque Y project is for the entire region, serving to improve access to the capital and also the closest major metropolitan areas. As well on the Iberian Peninsula, the cluster of high reductions surrounding Portugal corroborates the meaningfulness of the country's rail upgrade plans in terms of improving accessibility. Meanwhile, the German upgrades did well to improve the connectivity between Germany's western region to its capital, Berlin. Similarly, southern Italy benefits from improved access toward Rome. One example where the impacts differ slightly between capital and metropolitan access is found in Bulgaria. There, improvements regarding connectivity to the capital is found along the directly impacted edges concerning the Sofia-Plovdiv-Stara Zagora-Burgas/Varna corridor. Meanwhile all Bulgarian cities benefit from improvements in terms of connecting to the closest metropolitan area which in this case showcases the significant improvements in international connectivity since no other Bulgarian city besides Sofia is home to at least 500'000 inhabitants.

7.3 – Replacement of Specific Air Corridors

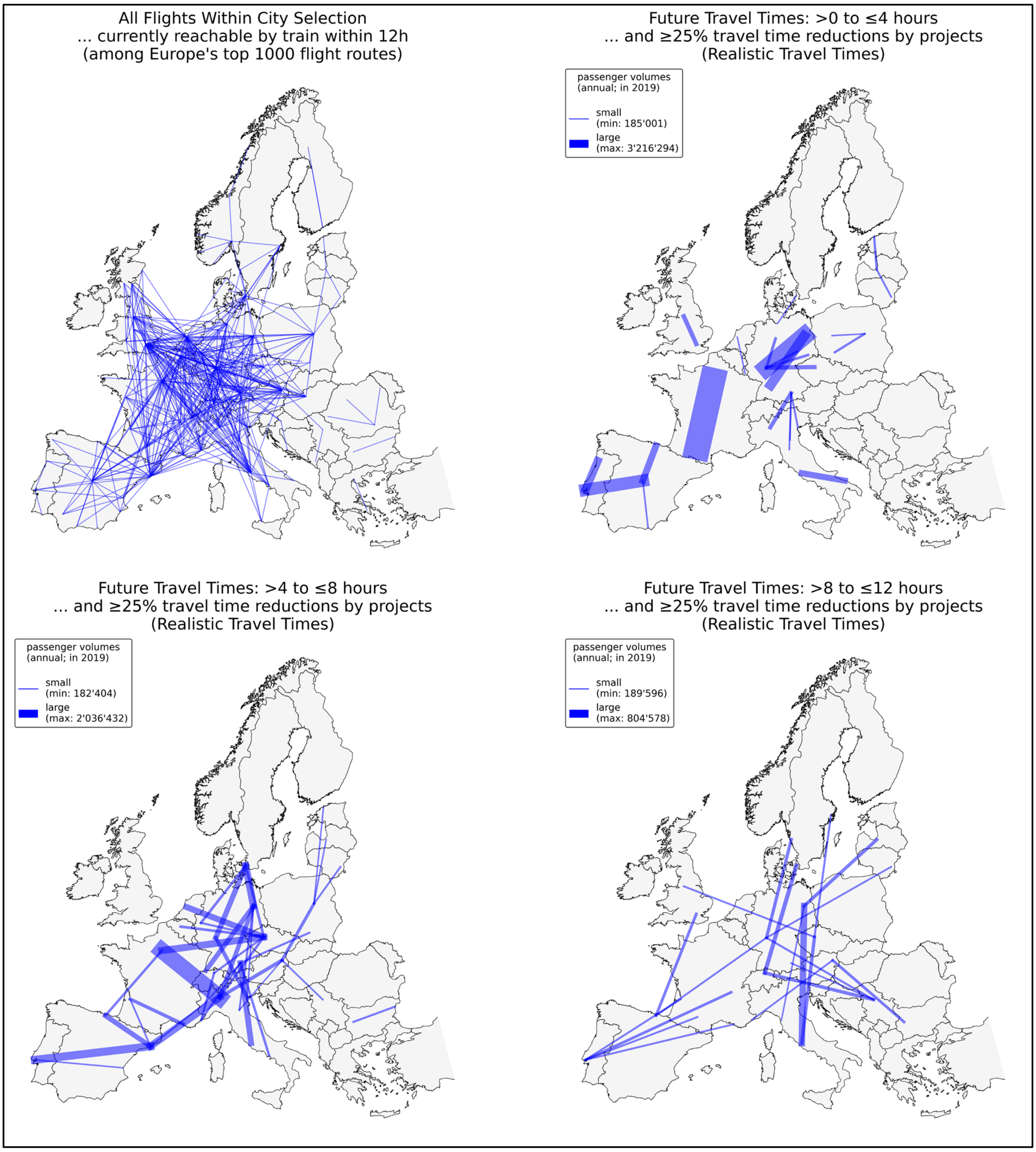
This overall tendency, the improvement of reachability and accessibility, can be directly compared to specific flight routes as well. Among the 1000 flight routes within Europe that in 2019 hosted the highest number of passengers, 666 corresponding city pairs are currently connected by rail (Eurostat, 2020). This sums up to a total of over 369 million passengers that travelled by air on these corresponding routes in 2019. In the future scenario, the rail network will encompass 49 more of the 2019 air connections, adding another 21 million passengers to the total count (the full dataset, including the results below, is available in Appendix J). This alone represents an enormous potential of reducing CO_2 emissions by accomplishing a mobility shift toward rail travel. Of course, not all flight connections can realistically be replaced by rail services – but some are replaceable already today and more will follow in the future.

A first glimpse into the potential of replaceability is found among the top 20 air routes with most passenger volumes, as shown in Table 7. While only two routes are not connected by rail, only five of the remaining 18 routes are not scheduled to experience improvements regarding rail travel times. Besides London-Malaga, all rail connections currently take less than twelve hours. Three connections (Amsterdam-London, Barcelona-Madrid, Berlin-Frankfurt) even come with current rail travel times below the four-hour threshold. Another one, Paris-Toulouse, will follow in the future. This indicates that a significant gap in the French high-speed rail network will be filled – which is of immense environmental relevance due to it being the fifth most frequented air corridor in Europe. The impressive reduction of travel times by over 25% is only surpassed by the Berlin-Frankfurt route's rail upgrades. This German example is of particularly high interest since the travel times were below the four-hour threshold already before and are reduced even further. The potential of air replacement by rail is therefore very high. However, this example also showcases a common issue surrounding replaceability of popular European air routes. It is likely that many of these connections particularly serve as connective flights to longer journeys. Frankfurt is for instance a well-known hub and interchange airport; the same is true for London and other larger airports. This means that flights from/to such airports are often part of a longer journey which imposes the question whether passengers would want to replace a flight by rail travel if it only represents one leg of the full journey.

Yet, there are clear reductions in rail travel times surrounding the most popular flights. Even though the reductions in some instances are not as drastically high, it likely is a very positive contributor to sustainable mobility, nonetheless. An insight into the most pressing travel time reductions is provided by Table 8 where the air routes with the highest relative reductions in travel times are listed. Standing out the most are connections from and to the Baltics. Thanks to the Rail Baltica project, inter-Baltic connectivity and links to remaining Europe are improved significantly. While long-range journeys such as to Sweden or Germany may not be realistically in favor of rail travel, despite the large reductions, a shift toward rail travel can be expected from flights between Baltic cities as well as to Poland. Further clear improvements are found regarding Portugal. From Lisbon, rail connections to Porto and Madrid will be accelerated significantly. The projected rail travel times are furthermore also particularly low while the passenger volumes on the corresponding flights are substantial. This hosts ideal preconditions for a drastic shift toward rail travel in the future. Similarly, connections from Germany toward Italy will likely experience significant changes in favor of rail travel upon completion of the Brenner Base Tunnel and its feeder links. Likely less relevant will the connections toward Sofia be. Even though the Bulgarian Capital acts as a significant hub in southeastern Europe and rail travel times will be reduced by a large fraction, they remain relatively extensive. However, this might unveil potential for some new night train connections as accepted travel times can usually be longer than for regular day services.

Figure 34 helps to identify the most promising air corridors in terms of rail replaceability resulting from rail infrastructure upgrades. Shown in Figure 34b are all air corridors that in the future scenario can be travelled within four hours by rail and (!) have seen travel time reductions by at least 25%. This reduction threshold is essential since multiple instances of well-researched high-speed corridors have shown that a reduction of travel times by around 25% can be sufficient to convince passengers to prefer rail over air travel (e.g., Sweden: Nelldal, 1998). Since multiple high-demand air corridors are already reachable in relatively short times by rail, the component of reduction is of particular importance to further promote a mobility shift. It can therefore be projected that Portugal, Spain, France, and Germany are regions of very high potential, as Figure 34b indicates, due to the high passenger demands along their corridors of high improvements. Also, as indicated earlier, the rail projects' completion is particularly beneficial in the Baltics and traversing the Alps, but also while connecting Manchester to London and Hamburg to Copenhagen. This all corresponded to a total of around 15.6 million passengers in 2019, thereby representing a large amount of potentially avoidable CO_2 emissions.

In a range between four and eight hours of future rail travel time, air corridors with rail travel times reduced by over 25% are especially centered around Copenhagen, Prague, Berlin, Munich, Milan, Barcelona, and Vienna. Standing out is the Paris-Milan route due to its high passenger demand. Thanks to the Euroalpin Tunnel between Lyon and Turin, rail travel is accelerated significantly between Italy and France. Other notable high-demand routes are Lisbon-Barcelona, Barcelona-Milan, Copenhagen-Berlin, Paris-Prague, and Munich-Rome. Overall, the routes present in Figure 34c is currently flown around 17.2 million annual passengers. Another 6.57 million annual passengers travel on the routes present in Figure 34d. Again, these connections will see rail travel time reductions of over 25% and will be travelable by rail in eight to twelve hours in the future. Standing out is the link from Berlin to Rome and vice-versa. However, these routes in general represent air corridors of relatively low demand, yet high rail travel times. Their potential of replaceability is therefore limited. However, they might represent interesting options for new night train routes – which would be an ideal contribution toward sustainable mobility across the continent.



***Figures 34 a-d**: (a) routes travelable by train among Europe's top 1000 most popular air routes; air corridors that experience relative train travel time reductions by ≥ 25% and are reachable in (b) 0-4 h, (c) 4-8 h, and (d) 8-12 h. Exact values and passenger volumes can be retrieved from the raw data in Appendix J. Source: own illustration.*

***Table 7**: Top 20 most frequented air corridors (both directions, 2019) and corresponding realistic travel times by rail in the current and future scenarios. The full dataset is available in Appendix J. Data source: Eurostat (2020).*

air route (both directions)		passengers	$t_{current}$	t_{future}	$d_{relative}$	$d_{absolute}$
Dublin	London	5107690	-	-	-	-
Amsterdam	London	4925746	219 min	219 min		
Barcelona	London	3387482	562 min	523 min	- 6.94%	- 39 min
Edinburgh	London	3374774	256 min	256 min		
Paris	Toulouse	3216294	302 min	226 min	- 25.17%	- 76 min
Nice	Paris	3178806	361 min	361 min		
London	Madrid	3147547	720 min	658 min	- 8.61%	- 62 min
Berlin	London	2838644	482 min	442 min	- 8.30%	- 40 min
Barcelona	Paris	2690832	417 min	378 min	- 9.35%	- 39 min
Barcelona	Madrid	2572893	158 min	158 min		
Madrid	Paris	2561787	575 min	513 min	- 10.78%	- 62 min
Geneva	London	2524519	374 min	374 min		
London	Milan	2503822	522 min	418 min	- 19.92%	- 104 min
London	Rome	2392594	718 min	614 min	- 14.48%	- 104 min
Belfast	London	2375583	-	-	-	-
Glasgow	London	2296483	301 min	281 min	- 6.64%	- 20 min
London	Malaga	2276567	888 min	826 min	- 6.98%	- 62 min
Berlin	Frankfurt	2248716	222 min	159 min	- 28.38%	- 53 min
Paris	Rome	2247612	573 min	469 min	- 18.15%	- 104 min
Copenhagen	London	2227971	718 min	594 min	- 17.27%	- 124 min

***Table 8**: Top 20 air corridors (nondirectional) with the highest projected relative reductions of realistic rail travel times. The full dataset is available in Appendix J. Source: Eurostat (2020).*

air route (both directions)		**passengers**	$t_{current}$	t_{future}	$d_{relative}$	$d_{absolute}$
Riga	Tallinn	289702	607 min	100 min	- 83.53%	- 507 min
Tallinn	Warsaw	191102	1251 min	396 min	- 68.35%	- 855 min
Warsaw	Wroclaw	294171	255 min	105 min	- 58.82%	- 150 min
Lisbon	Porto	1008951	181 min	75 min	- 58.56%	- 106 min
Sofia	Vienna	347550	1388 min	585 min	- 57.87%	- 803 min
Riga	Vilnius	229468	262 min	114 min	- 56.49%	- 148 min
Riga	Warsaw	191772	644 min	296 min	- 54.05%	- 348 min
Frankfurt	Tallinn	280602	1791 min	830 min	- 53.66%	- 961 min
Lisbon	Madrid	1558588	483 min	231 min	- 52.17%	- 252 min
Belgrade	Vienna	213021	604 min	293 min	- 51.49%	- 311 min
Munich	Sofia	258896	1619 min	804 min	- 50.35%	- 815 min
Berlin	Sofia	223520	1809 min	933 min	- 48.43%	- 876 min
Munich	Venice	239201	377 min	195 min	- 48.28%	- 182 min
Bologna	Munich	206028	369 min	192 min	- 47.97%	- 177 min
Vilnius	Warsaw	233666	461 min	242 min	- 47.51%	- 219 min
Milan	Munich	502803	390 min	208 min	- 46.67%	- 182 min
Rome	Sofia	224999	2036 min	1093 min	- 46.32%	- 943 min
Stockholm	Tallinn	288763	2225 min	1197 min	- 46.20%	- 1028 min
Frankfurt	Sofia	456935	1755 min	951 min	- 45.82%	- 804 min
Florence	Munich	209195	406 min	229 min	- 43.60%	- 177 min

8 – Discussion

8.1 – Interpretation & Synthesis of Results

In accordance with the results presented above, it is possible to answer the research questions guiding through this thesis:

Within the context of travel time improvements resulting from infrastructure upgrades to the European intercity passenger rail network, ...

RQ1: *Which regions and cities benefit the most from the completion of upgrades in terms of reachability and accessibility/connectivity?*

Assuming that the current infrastructure remains existent, and projects do not go at the cost of other relevant tracks, every city connected to the core network (excluding Ireland, Corsica, Sardinia) benefits form improved accessibility and connectivity to the network. The ASPL from one city to all other within the network is most significantly reduced in the Baltics, southeastern Europe, and Portugal. Standing out the most are Istanbul, Narva, Tallinn, and Plovdiv. Besides Turkey, Estonia, and Bulgaria, other countries worth mentioning are Serbia, Montenegro, Latvia, and Portugal. These countries are (at least in some parts) benefitting the most form moving much closer to the rest of the network. Additionally, Norway and Sweden, as well as southern Italy and coastal Spain see moderate yet substantial improvements. Besides that, gaps in the rail network will be closed and allow multiple formerly isolated cities to access the remaining rail network. This particularly concerns Macedonia and Greece. The lowest improvements in this sense are meanwhile found around the German-Dutch-Belgian border region whereas Brussels shows the smallest reduction among all cities connected to the core network. The patterns of greatest improvements are partially explained by the regions' peripheral location. However, other rather remote regions such as Scotland or the eastern parts of Poland, Slovakia, and Hungary do not see equally substantial improvements. This highlights the dependence on certain improved key corridors that strategically target specific peripheral regions and accelerate journeys toward the rest of Europe.

At a local scale and within a demographic context, over 40% of all cities will benefit from more efficient access to their capitals and the closest metropole (cities with more than 500'000 inhabitants). Again, southeastern Europe will see the most striking relative reductions of travel times, alongside with Estonia, southern Italy, Portugal, and coastal Spain. These generally more peripheral regions make up for the majority of the reduction in the full network's ASPL of 10.81% for realistic travel times and 17.57% for potential travel times. If narrowed down to only capitals or metropoles, these reductions are even higher, ranging up to 28.64%. These two findings allow for concluding that rail upgrades particularly target connectivity from/to/within capitals and metropoles which are cities of distinctly high socio-economic and political relevance. Moreover, the changes in reachability for short journeys (below four hours) will be most prevalent in central Europe (e.g., Leipzig, Innsbruck, Erfurt, Bolzano, Grenoble). For journeys below eight hours, the major benefits are expected in regions along an arch spanning from the German-Polish border via the Czech Republic and northern Italy to the Pyrenees. Standing out are especially the northern Italian cities. Within a twelve-hour threshold, the increases in reachability will expand toward the East with Serbia, Poland, and the Czech Republic standing out. Italy, northeastern Spain, and southern Sweden represent the few western exceptions. This allows for concluding that central Europe will particularly benefit from strategic local bottleneck upgrades while eastern Europe and the central and western periphery will mainly benefit from improved accessibility across major bottlenecks to the more central and more efficiently connected parts of the network as such.

RQ2:	*How do distributive effects change the cities' and regions' European-scale relevance within the network and how are passenger transportation patterns shifted?*

With the upgraded network implemented, the most efficient European-scale transportation corridors will be reshaped which was particularly quantified by using the EBC – which visualized the distributive effects of the series of implemented projects. Most notably, the main access corridor toward southeastern Europe will be re-routed through Serbia instead of Romania. This particularly benefits Subotica, Novi Sad, Belgrade, and Nis, but goes at the expense of Szeged, Arad, and Craiova's relative network relevance. Northern Italy will gain particular relevance in two ways simultaneously. Lugano, Arth-Goldau, and Zurich as parts of the Swiss transalpine corridor will be of less relevance on a European scale while Italy's transalpine connections toward France and Austria will significantly benefit. Furthermore, the northern Italian cities will be a part of more efficient north-east connections which currently are dominated by the southern German corridor. This means that Turin, Milan, Verona, Bolzano, as well as Innsbruck and Salzburg will gain in relevance. The German cities Nuremberg and Regensburg will lose relevance due to a newly emerging corridor for connections between the North and Southeast which then will run via the Berlin-Dresden-Prague-Brno-Vienna path. Especially the Czech cities will thereby gain particular relevance. Coming from the north, the Danish cities Padborg and Odense will be bypassed by the direct connection between Copenhagen and Lubeck. The northern German city will thereby gain substantial relevance in its role as a gateway toward Scandinavia. In the southwest, an Atlantic corridor from France toward Spain will emerge, hence benefitting Bordeaux, Bayonne, San Sebastian, Vitoria-Gasteiz, and Burgos. At the negative end, this will slightly reduce the relevance of the cities along the Mediterranean path, i.e., Barcelona, Girona, Perpignan, and Montpellier. As a general conclusion, it can be said that the greatest relative loss of network relevance occurs in regions of high current relevance. Newly emerging most efficient corridors thereby compete with their pendants. However, distributive effects, i.e., the interplay of the network's structure and other project impacts, cause these patterns to be not always as straight-forward as would be expected. This is especially present in the Berlin-Prague-Vienna and southern-Alpine corridors, and was also further corroborated by the fact that no correlation between the EBC and individual impact could be found.

RQ3:	*Which projects makes for the greatest overall operational impact on a European scale?*

The most important single project edge is the Fehmarn Fixed Link on the route between Lubeck and Copenhagen. It alone will manage to reduce the full network's ASPL by 1.48% which is substantial for a relatively small project. Yet, its position along such a crucial bottleneck allows for its high importance. The Suwalki-Kaunas section of the Rail Baltica project serves a similar purpose, though shows a less striking reduction by 0.77%. Of considerable relevance is also the Lyon-Turin connection (0.64%). Standing out are the Timisoara-Craiova and Sofia-Craiova edge upgrades (1.01% and 0.91%, respectively). Meanwhile, other projects unfold their full power especially in combination with further upgrades. The projects along the Budapest-Belgrade-Sofia line are herein most dominant. This is especially corroborated by the high vulnerability in a simulated reset of only one single section. The disruption of only one upgraded line would in the future scenario cause an increase in the full-network's ASPL of up to 2.36%. Similarly high values are only found for the Copenhagen-Lubeck link (1.82%), the Innsbruck-Bolzano-Verona sections (up to 0.77%) and the Rail Baltica segments along the Riga-Pärnu-Tallinn and Kaunas-Suwalki lines (up to 1.01%). This confirms the particularly high importance of the Serbian corridor, the Fehmarn Fixed Link, sections of Rail Baltica, and the Brenner Base Tunnel. Nonetheless, it must be addressed that especially the projects attracting new efficient rail corridors throughout Europe are highly important as well, especially in a local and economic context. This for instance concerns the Berlin-Dresden, Dresden-Prague, and Brno-Vienna line, the Basque Y project together with the Bordeaux-Bayonne improvements, the Frankfurt-Kassel/Erfurt lines, as well as the Lisbon-Badajoz-Madrid upgrades. Moreover, it shall not be forgotten that every project affects at least two cities directly and is therefore automatically relevant on a local scale, too. In general, it was observed that the impacts of international project edges were notably higher than those of domestic ones.

> ***RQ4:*** *Which political, topographical, and topological patterns do the spatial distribution, location, and arrangement of infrastructure projects indicate?*

The identified groups and clusters of projects appear to either be part of a specific transportation corridor, or a regional improvement patch. Interestingly, multiple project groups align with specific corridors of the TEN-T network established by the EU. This makes sense due to the funding mechanisms dedicated to the implementation of the TEN-T network. From a topographical perspective, it becomes clear that hilly and mountainous terrain is the dominant hurdle being overwound by projects. Larger water bodies are thereby only of secondary relevance due to only little meaningful potential remaining to be exploited. While there is no particular focus on international connections, they are not neglected neither. Instead, specific political patterns could be observed in a few instances. Generally speaking, projects are in some instances used to provide improved access to structurally neglected regions (e.g., southern Italy) or more autonomous regions (e.g., northern Spain). Interestingly, however, projects are not necessarily dedicated to network sections that already are of high European-scale relevance. Instead, they appear to rather fill remaining gaps. Overall, the clearest pattern is that projects are particularly present in regions of high local relative (inefficiencies) of rail services. This indicates an overall tendency that the current European rail network has in certain regions reached a (possibly temporary) optimum. This optimum covers maximum operation velocities above 200 km/h for core lines and above 160 km/h for secondary main lines. The currently planned projects thereby reflect a desire to improve suboptimal infrastructure sections to match the temporary optimum instead of further advancing the already well-equipped connections – which is exactly what the TEN-T project was set up for.

> ***RQ5:*** *How do the infrastructure projects vary in their nature and what implications could the particular characteristics addressed in the case studies pose to intercity rail planning on a European scale?*

The key finding is that infrastructure projects are a political tool that plays into socio-economic fields as well. In many instances, problems are part of a greater strategy aimed at strengthening the connectivity and/or relevance of one region to/within the remaining network. The political involvements can however also become much more complex, as the projects along the Hungary-Black Sea Corridor have shown. In this instance, the EU's interests oppose Chinese desires that in return match Hungary's approach to commit domestic and foreign politics on both sides of the Hungarian-Serbian border. Less of a patchwork is the Rail Baltica instance where geopolitics and military interests mix with infrastructural development. Since politics are potentially capricious, it can be concluded that additional such projects might emerge, but also likely will disappear again before full completion. From a pure rail network and passenger travel perspective, ignoring the implications of political involvement, it can be hoped that passenger travel will benefit from a sort of arms race of infrastructure expansion in underdeveloped regions – which, however, is a highly optimistic thought.

Furthermore, it was emphasized that the dynamics of rail projects concerning travel time improvements on a European scale significantly differ from projects targeting frequency and capacity upgrades. The main difference is that capacity upgrades must cover the full bottleneck in order to unfold its large-scale benefits. Meanwhile, sectional travel time reductions are not of minor value, even if other bottleneck sections remain unchanged. For frequency-targeted projects, this results in a co-dependency which unfortunately tends to rather slow down project implementations instead of the opposite. The same also applies to multinational projects, such as the Rail Baltica project, since coordinative efforts and different economic and political situations might interfere with a synchronous project completion. It is therefore particularly helpful for projects to be controlled and advanced by a superior authority.

8.2 – Limitations

8.2.1 – Conceptual Limitations

The most defining conceptual aspect of this thesis is the core network's structure. It is the result of infrastructure data, a routing and simplification approach, and a series of input cities. While each component has its own limitations, which will be addressed, the city selection is worth a particular focus. Changes in the city selection would eventually result in a differently structured network which hence also behaves differently. In return, the quality of analysis would potentially be affected too. As a consequence, the previously introduced results are strictly dependent on the current city selection. Since no hard criteria could be set up to sufficiently capture the general structure of the full European rail network, the application of predominantly soft criteria might be interpreted differently and could hence lead to diverging results. In return, despite the careful choice of cities in accordance with the predefined soft criteria, relevant cities might have been left out. For instance, smaller cities with disproportionately high numbers of rail connections could be unintentionally overlooked since it usually requires high local knowledge to be aware of such locations. Even though additional research (e.g., in timetables or specific online forms) was conducted and multiple improvements and city additions were made based on the intermediate network results, some essential network nodes might remain undetected.

Another issue relates to the fact that the city selection was based on the current network. This means that, upon inclusion of planned projects, there is a chance that cities suddenly become relevant without being noticed before. As the results have shown, this already occurred among the selected cities – and could therefore also happen to previously excluded cities. For instance, cities without any current relevant rail infrastructure might in the future be connected to the intercity rail network and thereby play a more important role. Even though the city selection process took place in close correspondence with the project network research – which allowed for anticipating and including such cities (e.g., Pärnu along the Rail Baltica line between Tallinn and Riga) – the risk of omitting respective places could not be fully alleviated.

This relates to a very general limitation of this work: the current status quo literally represents nothing more than a snapshot of the never-ending dynamics constantly surrounding the field of railways in Europe. This concerns not only the infrastructure data (retrieved on 01.03.2024), but also the general pattern of current rail operations (retrieved for 06.05.2024 - 12.05.2024). This means that temporary disruptions or operational alterations might have gone undetected. Even though this was specifically looked out for in the data gathering stages, there remains a risk that such inaccuracies might have been included unknowingly. This has the potential to make the work and results slightly less representative, depending on the magnitude of the possible oversights. On the other hand, using this current snapshot as a reference for creating the future scenario and comparing the resulting model calls for the assumption that the current situation is preserved at least. This means that the potential decommissioning of existing infrastructure is not foreseen (unless being replaced by a project, in which case the future situation would be covered in the scenario).

Furthermore, the realistic travel times retrieved from timetables are potentially subject to minor inaccuracies of one or two minutes. This is due to the simple reason that timetables tend to vary throughout the year. Since the realistic travel times were retrieved for early May, current journey times might have been slightly altered already because of the snapshot-like character of data retrieval. Besides that, such minor uncertainties might also be the reason of the non-directional travel time retrieval. This means that the realistic travel times might be correct in one direction but may be off by one or two minutes in the opposite direction. Due to simplicity reasons and the European scale of research, this error is overall negligible but might still cause minor uncertainties or lead to slight confusion.

During the computational generation of this network, one further conceptual limitation arises besides the difficulties surrounding the routing as such (which is addressed further below). In particular, the problem is centered around the simplification process which is undertaken to eventually represent only meaningful connections that also match the structure of regular intercity operations. As was indicated in the methods section, direct connections were removed whenever there was an alternative path present taking less than 10% or 5 min more time than the direct one. While this worked very well to establish a realistic structure, there were certain instances in which the fastest route within the resulting network diverges from and is slower than what is realistically being operated. For instance, journeys between Stuttgart and Zurich are in the resulting network routed via Karlsruhe and Basel which adds up to 3 h 13 min while the actually fastest service takes 2 h 58 min and runs via Singen near Lake Constance. This means that a few very distinct journeys are in reality operated more efficiently than this thesis' base network allows for. However, this only applies to a limited number of examples. The simplification thresholds were therefore selected to optimally balance the trade-off between realistic accuracy and modelled comprehensiveness.

Additionally, the network's structure being based on potential travel times bears the risk of a resulting mismatch with realistic travel times. The aforementioned network simplification might remove edges/connections where the thresholds would not actually apply in terms of realistic travel times. This is due to the reason that potential and realistic travel times may show a linear relationship but are not directly proportional. Fortunately, a manual check has indicated that issues resulting from this behavior are very rare and are especially of no major relevance due to this thesis' focus on the future development train travel. Nonetheless, one striking example worth mentioning is the connection between Klagenfurt and Graz. Here, potential travel times indicate that the fastest route (after applying the 10%- and 5-min simplification) runs via Maribor, thereby replacing the alternative route through Bruck an der Mur. In reality, however, the variant through Maribor takes a total of 3h 33 min while the originally replaced alternative route would take 2 h 53 min – which is far more than a difference of 10% or 5 min. Yet, since the emphasis of this thesis is on the changes between the current and future, this issue is less problematic. If no project lies between two such cities, there will not be any changes. And if a project were to be implemented, the new travel times would have been added to the network, and change would be detected. Nonetheless, the change might in such an instance be slightly overexaggerated which is why this issue must be kept in mind during interpretation.

Speaking of infrastructure projects, it must be mentioned that they are surrounded by multiple limitations. The most defining problem, especially during information acquisition, was the severe uncertainty of completion. As is listed in the methodology, measures were undertaken to obtain a set of realistic infrastructure projects. Despite these clear criteria, project completion can never be guaranteed in advance. Besides this, the project information data quality was of very mixed quality. Hence, information might in some cases be not perfectly exact, most particularly in terms of travel time improvements. For instance, travel times are rather indicated in rounded values (e.g., "cut travel times to below one hour"). Therefore, if necessary, underestimated improvements were used which in return means that the travel time reductions may be slightly higher in reality. Lastly, it must be noted that it is difficult to be sure that all currently relevant projects were included. Since there is no summarized overview of all projects, there is a tiny chance, that some project might have been overlooked. To avoid this, different online forms and specific magazines/journals were checked. Furthermore, the selection of projects again represents only a snapshot. It includes all known and relevant projects as of 01.05.2024. Consequently, new projects could already have emerged by the completion of this thesis.

What also must be clearly addressed is the issue surrounding connections that currently are not operated but exist in terms of functional infrastructure. It was decided to exclude these connections from the current network in terms of realistic travel times, but to include them for the future scenario. The future travel times are then – unless the connection is affected by a project – computed via the linear regression. As a result, the differences (in terms of realistic travel times) between the current and future networks go beyond the implementation of projects. While this approach is justifiable by the assumption that the infrastructure's potential will be fully exploited, it brings complications to the interpretation of changes. Due to the new connections and the network's substantial expansion, the comparison of certain network metrics (e.g., ASPL or NDim) is skewed. This has been emphasized multiple times and must be understood in order to interpret changes appropriately.

Relating to the computation of travel times via regression, it must again be clearly pointed out that the future scenario is a patchwork of direct and indirect travel time projections. Based on the type of project impact, the travel time improvements of the other type were computed based on the linear regression. This method however comes with uncertainties regarding the result's accuracy. Firstly, even though coming with high R-squared values, the regressions obviously are not exactly accurate. Secondly, the use of mixed regressions (for international connections) or the European instead of local regressions (for countries without regressed samples), increases the inaccuracy. Additionally, the upgrade of infrastructure might change the relationship between infrastructure and operated travel times. The indirectly computed travel times therefore serve as an appropriate approximation but cannot provide an entirely unerring result.

The last major conceptual limitation concerns the interoperability of trains within the European rail network. As was introduced earlier, this thesis' context assumes that differences in track gauge, signaling systems, and electrification do not pose any hurdle to train operations. This was also justified by specific technological innovations. Unfortunately, this theoretical ideal of European interoperability does not fully exist (yet) in reality. Cross-border connections often involve locomotive changes, switching rolling stock, and/or passenger transfers for overcoming the technological differences of infrastructure. In order to fulfill this thesis' projections to a full extent, a series of strategic implementations (including infrastructural upgrades and rolling stock adjustments) would have to be undertaken by 2050. Since it is unclear whether this will actually happen, there remains a degree of uncertainty. In case this will not be fully implemented, it must be expected that travel times on affected routes (in particular: cross-border operations) might be slightly longer than projected in this ideal scenario.

8.2.2 – Computational Limitations

On the computational side, the limitations start at the coordinate inputs of the selected cities. As was described in the methodology, the coordinate input was needed to find the closest node of the infrastructure network which would then be used as origin or destination during routing. However, an unfortunate coordinate selection could lead to the closest node being part of the sidings or lie on some dead-end track with very low operational velocities. In such cases, the routed travel times would be particularly high. Therefore, the coordinate inputs were carefully picked with the help of satellite maps, in order to identify ideal spots. These were usually near switches (since this typically indicates that an infrastructure element ends there, i.e., a node is nearby) along the main tracks in or right in front of the respective station. However, unexpected data structures or inaccurate satellite map referencing could in certain occasions still lead to misplacements. Therefore, the immediate routing results were manually checked for outliers and otherwise outstanding results which would indicate such an incident. Furthermore, the outliers of the regression were checked, too. While certain misplacements could be identified and were cleaned out accordingly, there is a risk for undetected routing inaccuracies resulting from such instances.

During routing, further limitations occur. Most notably, the routing algorithm is only a very simplistic and somewhat idealistic approach toward accurate routing. To be specific, this version assumes that every edge can be travelled to the full extent at its Vmax. This would mean that trains accelerate or slow down instantaneously which obviously does not resemble reality. Furthermore, this Vmax corresponds to the most efficient category of trains, for instance tilting trains that can go faster on curvy tracks – which cannot be fulfilled by regular trains. The differentiation of tracks dedicated to certain uses (e.g., freight traffic only) is not respected neither. Adding to this is that frequencies and capacities are neglected, and that full interoperability across all infrastructure is seen as given. Additionally, the routing itself allows for sharp turns that technically are not operable on rails. These aspects all together lead to far too optimistic resulting travel times. More ideal routing algorithms would involve methods that approach realistic operations more closely. Therefore, the network being built based on these potential travel times brings along a certain degree of uncertainty which reconnects to the issues mentioned earlier. Nonetheless, since this thesis' focus is on infrastructural upgrades, the potential travel times represent a fair approximation to actual rail operations – which has been validated by the regression's high goodness of fit.

The necessity of basing the network generation on realistic travel times lies in the absence of optimal data gathering methods for realistic travel times. If it were possible to retrieve high quantities of accurate timetable-based travel times across international borders, the network generation logic could have been applied in an analogue manner. However, there is no single travel planner or data source that accurately covers the full European extent (which is why the manual retrieval of realistic travel times had to involve multiple different sources). Besides this, the most pressing hurdle would be the automatic gathering of data. The automated access to travel planning websites can potentially violate the user guidelines. In an instance where this is not the case, a brief trial experiment revealed issues at the server side which eventually led to unsuccessful requests and hence produced no usable outcomes. Consequently, the network generation purely based on realistic travel times might be feasible on a smaller scale but could not (yet) be implemented for entire Europe. Therefore, the infrastructure-based network generation allowed for an ideal alternative approach to generate a network following a clear and consistent logic.

Nonetheless, the infrastructure data itself is also tied to certain limitations. While the general data quality could be seen as suitable for this thesis, it comes with certain gaps regarding the Vmax. This vital information is missing in some cases which represents a major problem since the travel times per infrastructure segment rely on just exactly that particular value. As a solution, the affected elements were assigned with the weighted average velocity of all other elements within the same country. This allowed for smooth routing operations. However, this potentially reduces the accuracy of the results. Since these gaps seemed to mainly have affected tracks of secondary relevance for intercity travel, there is a chance that the used average values are higher than what the tracks would allow for in reality. In return, some shortest paths could have been led through these sections. However, thanks to the same reason (i.e., that the affected tracks tend to be less relevant in comparison to the main lines which clearly operate above the average velocities), it is unlikely that any major error would have emerged from this problem – but the problem must nonetheless be made aware of.

Another issue relates to the computation of travel time reductions. Whenever the reductions were indicated in terms of specific infrastructure upgrades (e.g., Vmax increased from 120 km/h to 160 km/h), the reduction was computed following the procedure displayed in the methodology. This however relies heavily on the assumptions made surrounding the behavior of track upgrades. It is assumed that the slowest third of infrastructure remains constant while all other sections are upgraded to the new Vmax. Even though this assumption could in one instance be confirmed, it is uncertain whether it corresponds to reality. Therefore, there remains a minor uncertainty concerning the resulting travel time reduction.

A more general problem surrounding the computational section of this thesis is a relatively high inefficiency. In the current approach of network generation, a relatively high number of connections is computed before being reduced. While this works relatively fine for a smaller number of city inputs, this inefficiency might turn into a crucial issue – especially due to the routing algorithm being based off a simple Dijkstra algorithm. The latter becomes particularly relevant due to the infrastructure data set's high number of elements. Despite the simplification process summarizing elements as far as possible, it might be advisable to implement a more efficient routing algorithm. Furthermore, the conceptual approach might be improved to require the computation of fewer connections. To conclude, it can be said that the computational efficiency is acceptable for this thesis' exact scope but might become a challenge for future work.

The second last major computational limitation concerns the area cartograms. Their computation via the approach based on Voronoi polygons is time-consuming and the results are of limited use. This is mainly due to the used external algorithm (see the methods section) but is also a result of the self-developed conceptual approach. Most notably, on the algorithm side, the computed results try to maintain the overall extent of the polygons. This means that the outermost regions are set to remain outermost which in return leads to a slightly skewed product. On the conceptual side, the Voronoi polygon-based approach struggles with visualizing change. Since there are unlimited possibilities to reshape a polygon to result in a desired area, the contractions and expansions of space are not always visible as clearly as desired. Nonetheless, it serves well to indicate regions of more or less efficient rail operations. The aforementioned problem however becomes apparent when trying to visualize change. Again, this is mainly due to the algorithm's attempt to preserve the general layout of the polygons. Therefore, the self-developed cartograms are not yet ideal to replace common time-space maps and are therefore only of limited analytical value. Still, they are valuable for mapping and understanding the current status quo of rail operations.

To complete the computational limitations, it is also worth to emphasize that the created interactive web apps are only of rudimental functionality. In particular, this concerns the smoothness of use. The produced visualizations are always loaded/generated upon request (e.g., after selecting a city or changing the scenario). This means that there is a short delay between inputting the request and being returned with the result visualization. This is only of minor significance for the distance cartograms as the result is shown within less than a second. However, the isochrone visualizations take longer to load, around three to five seconds, due to the high-quantity data structure. This is already enough to reduce the effectiveness of this interactive experience. While being sufficient for private analysis-centered use, this tool would not be suitable for public use and would require the expertise of a skilled web app developer.

8.2.3 – Interpretational Limitations

During the interpretation of the results, there are further limitations that must be taken into consideration. One major aspect herein concerns how nodes are treated in the final current and future intercity rail networks. Currently, the nodes are all treated as through-stations allowing for seamless travel. In reality however, it is fairly common that the corresponding stations are laid out as terminus stations. Consequently, trains need to change directions which from an operational perspective usually requires a few minutes of setting up. Therefore, travel times in reality might be higher through such stations. In general, the computed travel times assume that nodes are passed through without stop or passenger transfer. In reality, trains (apart from dedicated express services) stop, thereby adding at least one or two minutes (sometimes even more) to the overall travel times. In the case of multiple stations per city (e.g., as in Paris, London, or Budapest), connections might realistically arrive and depart from different stations. This would require a transfer which depending on the city can be time-consuming. This means that even the resulting realistic travel times are to some degree only an idealization whenever the connection passes through one or more network node(s) besides the start and end.

Moreover, passenger transfers as a general concept represent another major interpretational limitation. Connections involving transfers between different trains usually translate to layovers at the station. While these can be of various lengths, it can commonly be said that one spends more time at a station if one has to transfer trains, in contrast to staying on the same train. This means that transfers increase the travel times even further than the stops as such already do. The magnitude of waiting times during a layover is thereby highly dependent on the integration of timetables and schedules. In some extreme cases, there might even be the risk that no trains connect to each other at all – which would result in hours of waiting times. This all is not taken into consideration (quantitatively) during this thesis. In return, every connection and computed travel time assumes that a train either travels directly through stations along the way or immediately connects to the next one, without any noticeable transfer times. This consequently underpins the importance of understanding that the produced scenarios only represent an optimal setting. In reality, travel times might therefore be slightly higher than the indicated values.

Another issue relates to the interpretation of network metrics. This has already been emphasized multiple times throughout the thesis: some metrics are only computable for a certain extent of the network while others might be distorted due to the inclusion (in the future scenario) of connections that currently are not operated. The first problem refers to metrics such as the ASPL and NDim. These values are only computed for the largest connected component of the network. This means that Ireland and other disconnected regions are not represented by the resulting values. For the same reason, these two metrics are also susceptible to the secondly mentioned problems. Due to the addition of currently non-operated lines, the network (when assessed in terms of realistic travel times) suddenly grows significantly. In return, more and longer connections are possible. This does not only skew the results of the ASPL, but also concerns the NDim, eccentricity, as well as the EBC/NBC or the NCC. This must therefore always be pointed out during analysis interpretation. Nonetheless, it can be argued that the addition of such connections is correct in the thesis' context and simply reflects a meaningful component of the modeled scenario – which is exactly why it was decided to stick with this approach.

The aforementioned problem however only occurs when basing the analysis and subsequent interpretations on realistic travel times. Despite this limitation, it makes sense to maintain the research focus on realistic travel times. The reason is simple: the potential travel times are only an approximation to realistic rail operations. Most interesting for travelers is the understanding of projected real-world changes in the field of intercity rail travel. The potential travel times are a valuable tool for generating a core network and furthermore help to quantify the impacts of infrastructure upgrades. However, they shall mainly remain a basis tool supporting and facilitating the analysis of realistic travel times. Nonetheless, one must be aware of the fact that the analysis focus on realistic travel times goes alongside the aforementioned limitations, especially during interpretation.

Lastly, it is worth to mention another limitation regarding the result interpretation; in this case concerning the isochrones and area cartograms. Before, it was already explained that the latter are suboptimal for visualizing changes but instead are fairly informative about the current operational efficiency. Yet, it must be emphasized that both instances make use of projecting the travel times across the entire map of Europe. This means that not every region is part of any relevant intercity rail connection or is even served by any trains at all. Nonetheless, they are part of the visualizations (either by being inflated/deflated or by being assigned to an isochrone range). Also, as was pointed out in the methods section, no particular respect is taken to major bodies of water which are not treated as a hindrance for travel. Consequently, the interpretation of the results is most meaningful for areas close to or between included cities. Yet, once being aware of these limitations, the isochrones and area cartograms can serve as a valuable tool for visualizing differences in accessibility on a continental scale.

8.2.4. – Excurse to Rail Operations as a Whole

Besides the thesis-specific limitations, there are also a few aspects that must be addressed when viewing this work in the context of sustainable mobility. Most importantly, it is important to emphasize that sustainable mobility by rail does not only require a well-functioning intercity network. Much more, the intercity network must be well-integrated with the local and regional rail system. However, the expansion of intercity rail infrastructure bears the risk of emerging imbalances if local and regional rail is being neglected – a potential issue pointed out by several researchers (e.g., Albalate & Bel, 2012). In Europe, this topic is being discussed particularly for Italy and Spain, two countries well-known for their extensive high-speed rail networks (Beria et al., 2018). While not being part of this thesis, it is crucial to understand that the improvement of Europe's intercity rail network should not take place at the expense of local and regional rail infrastructure. Unfortunately, though, this exact tendency has been dominant throughout the recent decades, as Seidenglanz et al. (Seidenglanz et al., 2021) observed.

Moreover, the pure existence of infrastructure does not automatically imply that it is used to its full potential. One central aspect herein is the cost of track access fees. Simply put, every train has to pay for the tracks it uses. How high these costs are and what further fees apply varies from country to country. However, claims are common that the costs are too expensive to allow for financial competitiveness of trains against airplanes (Donat, 2021). As a result, fewer trains might operate which in return could reduce transfer options to onward connections. This also relates to the complex field of economics and politics. The degree of liberalization and privatization of the rail system impacts how and at which costs railways are operated. Consequently, these circumstances play an important role in making use of the future potential for intercity rail travel. Furthermore, the mixed use of traces together with freight rail will additionally affect how rails are actually operated. Though being particularly excluded from this thesis, all these dynamics must at least be mentioned, too. It can therefore be said that this thesis simply produces an outlook on the projected potential for passenger travel – while reality will have to decide on how much of it will actually be exploited.

One last aspect worth mentioning is about the relevance of edges and nodes within the network. In general, an increase in relevance (e.g., due to the node/edge being part of additional shortest paths within the network) can be seen as a positive result. It provides new opportunities for both the affected region (e.g., increased touristic and/or logistical potential), as well as for rail operations in general (i.e., more efficient routes). However, this might also be viewed as a sort of burden in case of lacking facilities to handle the traffic such as insufficient noise protection. In return, the relative loss of relevance of a node or edge might also be interpreted as an alleviation from overused infrastructure. Besides this, a relative loss of relevance does not necessarily translate to fewer trains or similar shortages. In an optimistic scenario projecting an increase in rail usage, the rail services are not reduced but instead only expanded along the newly emerging corridors. In reality, however, it would not be surprising if less efficient routes (i.e., those losing relative relevance) would see fewer trains. Nonetheless, these exact dynamics cannot be fully projected yet, especially since no frequency and capacity analyses were conducted within this thesis. Again, it therefore rather serves to set up a framework in which a series of various influences (such as the ones listed above) will reshape how rail operations will look like in the future – which hopefully will be in a positive way.

8.3 – Recommendations

As was pointed out multiple times, this thesis can be understood as a gateway into the field of infrastructure-based improvements and changes surrounding European rail transportation. While this work provides a framework showcasing an idealized and simplistic future scenario, further work could dive into specific addressed aspects of this work to which the doors have been opened in the earlier paragraphs.

Most particularly, it would be valuable to come up with a methodology allowing for more flexible analyses regarding scale and temporal resolution. This could for instance involve an engineering perspective by creating an updated data set of raw infrastructure data – including planned projects and their exact traces and properties (if already designed). In combination with a more efficient routing and network generation approach, this would allow for generating a vast set of scenarios at flexible scales for analyses. Upon unwrapping this concept even further, a sophisticated project differentiation filter could be implemented. This would allow for selecting projects within a range of projected completion, and/or to choose them by their current implementation status. Much more generally, projects could be filtered by all their attributes (e.g., size, location, Vmax, etc.). In a similar way, the cities that should be considered could be selected upon a flexible input of criteria such as administrative relevance, population size, or economic status. This would result in a tool of efficient, yet fully flexible network generation and hence allow for particular analyses within different frameworks at varying scales.

Going alongside (but also being highly relevant individually) is the addition of travel-specific elements to the research. Particularly speaking, this refers to station stops, transfers, frequencies of connecting operations, and the resulting waiting times. The necessary data could for instance be approximately retrieved from an analysis of timetables. Overall, this would enable an (almost) fully accurate future scenario which in return is of high value for predicting actually resulting passenger journeys. This perspective on operational aspects is highly valuable but requires significant field-related expertise which is why it reaches beyond this thesis' scope.

Leading into a different direction is the optimization of the routing algorithm with the eventual goal of matching potential travel times to realistic travel times. This would provide several benefits. Most importantly, the network generation would produce more accurate results, thereby minimizing potential uncertainties. Besides that, an improved routing would allow for directly (accurately) comparing them to realistic travel times. For instance, infrastructure sections could be identified that are currently not yet operated to their full extent. Similarly, the comparison of realistic travel times with accurate potential travel times might help to identify spots where infrastructure upgrades would be particularly beneficial.

Moreover, it would be highly interesting to approach the future infrastructure's analysis from a multimodal perspective. This means that the infrastructure would also be equipped with attributes defining the capacities. Consequently, projects targeting capacity upgrades would become relevant as well. Furthermore, track properties such as slope and corridor width could be retrieved (if not yet available). This could then eventually be used to assess future rail operations as a whole, including the mixed-use sharing of tracks among passenger and freight trains. This would represent a high-detail and integrated analysis of the future rail operations as a whole. Eventually, this would be highly valuable in a context of sustainable transportation. Such an analysis approach would allow for modelling the exact number of passenger and freight trains in the future scenario. As a result, it could be estimated how many passengers might benefit from the improved travel times showcased in this thesis – and hence allows for precise models on the projected climate impact of rail infrastructure upgrades.

In a combined multimodal and fully infrastructure-based analysis, it would furthermore make sense to dive into the field of vulnerabilities. The disruption of certain infrastructure sections could thereby be simulated, and alternative pathways be computed. This would indicate parts of the network which might require additional protection or mitigation measures to minimize negative outcomes of potential disruptions. Most interestingly, this could be done in relation to natural hazards and climate impacts. With including future infrastructure projections and modelling a climate scenario, it might be possible to identify a prognosis of how vulnerability patterns will change between the current and future.

9 – Conclusion

For this thesis, the current and future European intercity rail networks were modelled. The anticipated changes induced by the projects' implementation until 2050 will affect nearly all sections of the network – apart from the fully disconnected regions. These implications must be differentiated in terms of accessibility/connectivity improvements and changes in the network's relevance. Assuming that existing infrastructure is at least maintained, no region will experience negative changes in accessibility. The lowest improvements are found in mainland Europe's Northwest while the greatest improvements are situated at the continent's outskirts. Southeastern Europe, the Baltics, and Portugal are the clear winners in this field. The changes in full-network relevance show a clear shift to newly emerging corridors in southeastern Denmark, Serbia, northern Italy, the Czech Republic, and northern Spain. This goes at the cost of western Denmark, Romania, southern and eastern Germany, as well as southern France and Spain. In combination, the most unexpected benefiter is Serbia, thanks to substantial infrastructure investments along a strategic corridor. This also makes the Budapest-Belgrade-Sofia corridor stand out as one of the most important series of upgrades. Thanks to their strategic overcoming of global bottlenecks, the Fehmarn Fixed Link and Rail Baltica project both deserve particular attention. Similarly, the Euroalpin Tunnel and the Brenner Base Tunnel significantly transform and improve the European rail network. Case studies on some of these projects have provided insights into the complexities surrounding the implementation of such infrastructural improvements. Even though this thesis represents only a snapshot of the highly dynamic situation surrounding rail infrastructure development, it provides an interesting and promising view into a field that has not yet been scholarly explored in an integrated continental-scale approach. It is therefore hoped that this work will soon be followed by even more substantial research, thereby capturing a new snapshot of the European transportation sector's path toward sustainability.

Bibliography/References

Albalate, D., & Bel, G. (2012). High-Speed Rail: Lessons for Policy Makers from Experiences Abroad. *Public Administration Review*, *72*(3), 336–349. https://doi.org/10.1111/j.1540-6210.2011.02492.x

Almotahari, A., & Yazici, A. (2021). A computationally efficient metric for identification of critical links in large transportation networks. *Reliability Engineering & System Safety*, *209*, 107458. https://doi.org/10.1016/j.ress.2021.107458

Anastasiadou, E. (2009). *In search of a railway Europe : transnational railway developments in interwar Europe*. Technische Universiteit Eindhoven. https://doi.org/https://doi.org/10.6100/IR658478

Andersson, E., Bahr, H. V., & Nilstam, N. G. (1995). Allowing higher speeds on existing tracks—design considerations of the X2000 train for Swedish State Railways. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, *209*(2), 93–104. https://doi.org/10.1243/PIME_PROC_1995_209_261_02/ASSET/PIME_PROC_1995_209_261_02.FP.PNG_V03

Antonowicz, M., & Kwarcinski, T. (2023). Rail Transport Infrastructure as a Factor Accessibility of Rail Transport on the Example of Poland. *European Research Studies Journal, 16*(4), 544–552. https://doi.org/10.35808/ersj/3305

Avogadro, N., Cattaneo, M., Paleari, S., & Redondi, R. (2021). Replacing short-medium haul intra-European flights with high-speed rail: Impact on CO2 emissions and regional accessibility. *Transport Policy*, *114*, 25–39. https://doi.org/10.1016/j.tranpol.2021.08.014

Bäckstrand, K. (2022). Towards a Climate-Neutral Union by 2050? The European Green Deal, Climate Law, and Green Recovery. In A. Bakardjieva Engelbrekt, P. Ekman, A. Michalski, & L. Oxelheim (Eds.), *Routes to a Resilient European Union* (pp. 39–61). Springer. https://doi.org/10.1007/978-3-030-93165-0_3

Bankauskaité, D., & Šlekys, D. (2023). Lithuania's Total Defense Review. *PRISM*, *10*(2), 54–77.

Behrens, C., & Pels, E. (2012). Intermodal competition in the London–Paris passenger market: High-Speed Rail and air transport. *Journal of Urban Economics*, *71*(3), 278–288. https://doi.org/10.1016/j.jue.2011.12.005

Bergmeister, K. (2014). The Brenner Base Tunnel – A railway line for the future. *Global Railway Review*, *4*.

Beria, P., Grimaldi, R., Albalate, D., & Bel, G. (2018). Delusions of success: Costs and demand of high-speed rail in Italy and Spain. *Transport Policy*, *68*, 63–79. https://doi.org/10.1016/j.tranpol.2018.03.011

Bhardawaj, S., Sharma, R. C., Sharma, S. K., & Sharma, N. (2021). On the Planning and Construction of Railway Curved Track. *International Journal of Vehicle Structures and Systems*, *13*(2). https://doi.org/10.4273/ijvss.13.2.04

BAFU Bundesamt für Umwelt. (2020). *Klimawandel in der Schweiz: Indikatoren zu Ursachen, Auswirkungen, Massnahmen*. www.bafu.admin.ch/uz-2013-d

BAV Bundesamt für Verkehr. (2024). *Eisenbahnausbauprogramme Bahninfrastrukturfonds (BIF): Standbericht 2023.*

BMK Bundesministerium für Klimaschutz, U. E. M. I. und T. (2024). *Zielnetz 2040: Das Bahnnetz der Zukunft - Fachentwurf*.

Calzada-Infante, L., Adenso-Díaz, B., & García Carbajal, S. (2020). Analysis of the European international railway network and passenger transfers. *Chaos, Solitons & Fractals*, *141*, 110357. https://doi.org/10.1016/j.chaos.2020.110357

Carden, T. (2005, May 15). *Travel Time Tube Map*. https://www.tomcarden.co.uk/p5/tube_map_travel_times/applet/

Chen, L. (2023). Stuck on infrastructure? Planning for the transformative effects of transport infrastructure. In *Planning in a Failing State* (pp. 138–159). Policy Press. https://doi.org/10.51952/9781447365075.ch009

Chen, L., & Xu, J.-C. (2004). Optimal Delaunay Triangulations. *Journal of Computational Mathematics*, *22*(2), 299–308.

Chen, X. (2011). Development impacts of high-speed rail: French experience and Chinese implications. *2011 5th International Association for China Planning Conference*, 1–8. https://doi.org/10.1109/IACP.2011.5982032

Chen, X., Ma, S., Chen, L., & Yang, L. (2024). Resilience measurement and analysis of intercity public transportation network. *Transportation Research Part D: Transport and Environment*, *131*, 104202. https://doi.org/10.1016/j.trd.2024.104202

CINEA European Climate, I. and E. E. A. (2022, April 8). *Transport infrastructure: projects receive EUR 425 million in EU funding to boost green mobility and to adapt the network for dual civil/defence use*.

Clark, S. (2012). A history of railway signalling (from the Bobby to the Balise). *IET Professional Development Course on Railway Signalling and Control Systems (RSCS 2012)*, 6–25. https://doi.org/10.1049/ic.2012.0040

Condeço-Melhorado, A., Tillema, T., de Jong, T., & Koopal, R. (2014). Distributive effects of new highway infrastructure in the Netherlands: the role of network effects and spatial spillovers. *Journal of Transport Geography*, *34*, 96–105. https://doi.org/10.1016/J.JTRANGEO.2013.11.006

Cooke, P. (2024). Competition in the 'body without organs': an assemblage perspective on the UK's fast train (HS2) cancellation. *European Planning Studies*, *32*(7), 1464–1477. https://doi.org/10.1080/09654313.2024.2341162

Cottrell, P. L., & Ottley, G. (1975). The Beginnings of the Stockton & Darlington Railway. *The Journal of Transport History*, *3*(2), 86–93. https://doi.org/10.1177/002252667500300202

Csapó, D. G. (2021). Funding of Transport Infrastructure in Serbia: China in Focus. *China Report*, *57*(2), 210–228. https://doi.org/10.1177/00094455211004257

Curtale, R., Larsson, J., & Nässén, J. (2023). Understanding preferences for night trains and their potential to replace flights in Europe. The case of Sweden. *Tourism Management Perspectives*, *47*. https://doi.org/10.1016/j.tmp.2023.101115

Deng, K., Fang, T., Feng, H., Peng, H., Löwenstein, L., & Hameyer, K. (2022). Hierarchical eco-driving and energy management control for hydrogen powered hybrid trains. *Energy Conversion and Management*, *264*. https://doi.org/10.1016/j.enconman.2022.115735

Donaghy, T. J. (1966). The Liverpool & Manchester Railway as an Investment. *The Journal of Transport History*, *7*(4), 225–233. https://doi.org/10.1177/002252666600700404

Donat, L. (2021). *Für die Renaissance des europäischen Bahnverkehrs - Was Deutschland jetzt tun sollte*. Germanwatch e.V. https://www.germanwatch.org/de/19851

Dougenik, J. A., Chrisman, N. R., & Niemeyer, D. R. (1985). An Algorithm to Construct Continuous Area Cartograms. *The Professional Geographer*, *37*(1), 75–81. https://doi.org/10.1111/j.0033-0124.1985.00075.x

Du, J., Fang, Q., Wang, J., & Wang, G. (2021). Influences of High-Speed Train Speed on Tunnel Aerodynamic Pressures. *Applied Sciences*, *12*(1). https://doi.org/10.3390/app12010303

Dunmore, D., Preti, A., & Routaboul, C. (2019). The "Belt and Road Initiative": impacts on TEN-T and on the European transport system. *Journal of Shipping and Trade*, *4*(1). https://doi.org/10.1186/s41072-019-0048-3

European Commission. (2022). EU Transport in Figures – Statistical pocketbook 2022. In *Statistical Pocketbook 2022*. https://data.europa.eu/doi/10.2832/216553

European Commission. (2024). Trans-European Transport Network (TEN-T). https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

Eurostat. (2020). Detailed air passenger transport by reporting countries and routes. https://ec.europa.eu/eurostat/web/transport/data/database

Eurostat. (2024). Length of railway lines by number of tracks and electrification of lines. https://doi.org/10.2908/RAIL_IF_LINE_TR

Fabre, J., Ladoux, P., Caron, H., Verdicchio, A., Blaquiere, J.-M., Flumian, D., & Sanchez, S. (2021). Characterization and Implementation of Resonant Isolated DC/DC Converters for Future MVdc Railway Electrification Systems. *IEEE Transactions on Transportation Electrification*, *7*(2), 854–869. https://doi.org/10.1109/TTE.2020.3033659

Fairbairn, D. (2005). Geovisualization Issues in Public Transport Applications. In J. Dykes, A. M. MacEachren, & M.-J. Kraak (Eds.), *Exploring Geovisualization* (pp. 513–528). Elsevier.

Fardella, E., & Prodi, G. (2017). The Belt and Road Initiative Impact on Europe: An Italian Perspective. *China & World Economy*, *25*(5), 125–138. https://doi.org/10.1111/cwe.12217

Ferrari, A., Mazzanti, F., Basile, D., & ter Beek, M. H. (2022). Systematic Evaluation and Usability Analysis of Formal Methods Tools for Railway Signaling System Design. *IEEE Transactions on Software Engineering*, *48*(11), 4675–4691. https://doi.org/10.1109/TSE.2021.3124677

Francisco, F., Teixeira, P. F., Toubol, A., & Nelldal, B. L. (2021). Is large technological investment really a solution for a major shift to rail? A discussion based on a Mediterranean freight corridor case-study. *Journal of Rail Transport Planning & Management*, *19*, 100271. https://doi.org/10.1016/j.jrtpm.2021.100271

Fremdling, R. (2003). European Railways 1825-2001, an Overview. *Jahrbuch Für Wirtschaftsgeschichte / Economic History Yearbook*, *44*(1). https://doi.org/10.1524/jbwg.2003.44.1.209

Gössling, S., & Peeters, P. (2015). Assessing tourism's global environmental impact 1900–2050. *Journal of Sustainable Tourism*, *23*(5), 639–659. https://doi.org/10.1080/09669582.2015.1008500

Goverde, R. M. P., Corman, F., & D'Ariano, A. (2013). Railway line capacity consumption of different railway signalling systems under scheduled and disturbed conditions. *Journal of Rail Transport Planning & Management*, *3*(3), 78–94. https://doi.org/10.1016/j.jrtpm.2013.12.001

Grechi, D., & Maggi, E. (2018). The importance of punctuality in rail transport investigation on the delay determinants. *European Transport/Trasporti Europei*, *70*(2), 1–23.

Grunfelder, J., Huynh, D., & Lidmo, J. (2020). *Transit-oriented development in the Greater Copenhagen Region*. https://doi.org/10.6027/R2020:15.1403-2503

Hawlin, A., & Miebach, E. (2024, July 27). Stau am Brenner: Wann enden die Geduldsproben? *ZDF*. https://www.zdf.de/nachrichten/wirtschaft/verkehr-stau-brenner-basistunnel-deutschland-oesterreich-italien-100.html

Herrenknecht. (2020, August 5). Mega project Brenner Base Tunnel: first milestone achieved with Herrenknecht tunnel boring machine. https://www.herrenknecht.com/en/newsroom/pressreleasedetail/mega-project-brenner-base-tunnel-first-milestone-achieved-with-herrenknecht-tunnel-boring-machine/

Hoerbinger, S., Obriejetan, M., Rauch, H. P., & Immitzer, M. (2020). Assessment of safety-relevant woody vegetation structures along railway corridors. *Ecological Engineering*, *158*, 106048. https://doi.org/10.1016/j.ecoleng.2020.106048

Houben, M. (2024, August 14). Neues Großprojekt der Bahn umstritten. *WDR*. https://www.tagesschau.de/wirtschaft/verbraucher/deutsche-bahn-grossprojekt-umstritten-brenner-100.html

Infraestruturas de Portugal. (2023). Programa Nacional De Investimentos 2030. https://www.infraestruturasdeportugal.pt/infraestruturas/investimentos/programas/planos-estrategicos/pni2030

International Energy Agency IEA. (2019). The Future of Rail: Opportunities for energy and the environment. www.iea.org/t&c/

Islam, D. M. Z., Ricci, S., & Nelldal, B. L. (2016). How to make modal shift from road to rail possible in the European transport market, as aspired to in the EU Transport White Paper 2011. *European Transport Research Review*, *8*(3), 1–14. https://doi.org/10.1007/S12544-016-0204-X/FIGURES/9

Jankowski, W., & Sołkowski, J. (2022). The modelling of railway subgrade strengthening foundation on weak soils. *Open Engineering*, *12*(1), 539–554. https://doi.org/10.1515/eng-2022-0053

Jarvis, A. (1998). James Cropper, Liverpool Docks and the Liverpool-Manchester Railway. *The Journal of Transport History*, *19*(1), 18–32. https://doi.org/10.1177/002252669801900103

Jegelevicius, L. (2019). Rail Baltica strives to stay on track. *New Eastern Europe*, *03+04* (37), 93–99.

Kamiński, M. A., & Śliwa, Z. (2023). Poland's Threat Assessment: Deepened, Not Changed. *PRISM*, *10*(2), 130–147.

Kantelaar, M. H., Molin, E., Cats, O., Donners, B., & Wee, B. van. (2022). Willingness to use night trains for long-distance travel. *Travel Behaviour and Society*, *29*, 339–349. https://doi.org/10.1016/j.tbs.2022.08.002

Knowles, R. D. (2006). Transport Impacts of the Øresund (Copenhagen to Malmö) Fixed Link. *Geography*, *91*(3), 227–240. https://doi.org/10.1080/00167487.2006.12094170

Kounadi, O. (2009). *Assessing the quality of OpenStreetMap data*. University College of London.

Kraak, M.-J. (2009). Geovisualization. In *International Encyclopedia of Human Geography* (pp. 468–480). Elsevier. https://doi.org/10.1016/B978-008044910-4.00033-X

Kroes, E., & Savelberg, F. (2019). Substitution from Air to High-Speed Rail: The Case of Amsterdam Airport. *Transportation Research Record: Journal of the Transportation Research Board*, *2673*(5), 166–174. https://doi.org/10.1177/0361198119839952

Kuster, H. (2003). Railways: Gateways Between East and West in Europe. *Promet*, *15*(4), 215–221.

Lacôte, F. (2001). 50 Years of Progress in Railway Technology. *Japan Railway & Transport Review*, *27*, 25–31.

Lagadec, L.-R., Moulin, L., Braud, I., Chazelle, B., & Breil, P. (2018). A surface runoff mapping method for optimizing risk assessment on railways. *Safety Science*, *110*, 253–267. https://doi.org/10.1016/j.ssci.2018.05.014

Laird, J. J., Nellthorp, J., & Mackie, P. J. (2005). Network effects and total economic impact in transport appraisal. *Transport Policy*, *12*(6), 537–544. https://doi.org/10.1016/J.TRANPOL.2005.07.003

Laurini, R. (2017). Geovisualization and Chorems. In *Geographic Knowledge Infrastructure* (pp. 223–246). Elsevier. https://doi.org/10.1016/B978-1-78548-243-4.50011-6

Lenzen, M., Sun, Y.-Y., Faturay, F., Ting, Y.-P., Geschke, A., & Malik, A. (2018). The carbon footprint of global tourism. *Nature Climate Change*, *8*(6), 522–528. https://doi.org/10.1038/s41558-018-0141-x

Lerida-Navarro, C., Nombela, G., & Tranchez-Martin, J. M. (2019). European railways: Liberalization and productive efficiency. *Transport Policy*, *83*, 57–67. https://doi.org/10.1016/j.tranpol.2019.09.002

Liu, Y., Tsang, K. S., Tan Zhi'En, E., Alagu Subramaniam, N., & Pang, J. H. L. (2021). Investigation on material characteristics and fatigue crack behavior of thermite welded rail joint. *Construction and Building Materials*, *276*. https://doi.org/10.1016/j.conbuildmat.2021.122249

Lupi, M., Pratelli, A., Conte, D., & Farina, A. (2020). Railway Lines across the Alps: Analysis of Their Usage through a New Railway Link Cost Function. *Applied Sciences 2020, 10*(9), 3120. https://doi.org/10.3390/APP10093120

MacEachren, A., Buttenfield, B. P., Campbell, J. B., DiBiase, D., & Mark Monmonier. (1992). Visualization. In R. F. Abler, G. M. Marcus, & J. M. Olson (Eds.), *Geography's Inner Worlds: Pervasive Themes in Contemporary American Geography* (pp. 99–137). Rutgers University Press.

Maciejewski, R. (2021). Geovisualization. In *Handbook of Regional Science* (pp. 1651–1670). Springer. https://doi.org/10.1007/978-3-662-60723-7_70

Martí-Henneberg, J. (2013). European integration and national models for railway networks (1840–2010). *Journal of Transport Geography*, *26*, 126–138. https://doi.org/10.1016/j.jtrangeo.2012.09.004

Martí-Henneberg, J. (2017). The influence of the railway network on territorial integration in Europe (1870–1950). *Journal of Transport Geography*, *62*, 160–171. https://doi.org/10.1016/j.jtrangeo.2017.05.015

Martí-Henneberg, J. (2021). From State-Building to European Integration: The Role of the Railway Network in the Territorial Integration of Europe, 1850–2020. *Social Science History*, *45*(2), 221–231. https://doi.org/10.1017/ssh.2021.7

Mattsson, K., Lee, J., & Ligmajer, O. (2022). *Handling increased need of maintenance to meet future freight demands: Deterioration and effective maintenance strategies for track system and rail vehicles*. Chalmers University of Technology.

Meyer de Freitas, L., & Blum, S. (2023). *High-speed rail in Europe: A review of ex-post evaluations and implications for future network expansion*. https://doi.org/10.3929/ethz-b-000593596

Meyer de Freitas, L., & Blum, S. (2024). An accessibility-based methodology to identify corridor speed upgrades in the European rail network. *Journal of Transport Geography*, *114*. https://doi.org/10.1016/j.jtrangeo.2023.103760

Mierzejewski, A. (2002). German Railroaders and the Holocaust. *Railroad History*, *186*, 65–67.

Mitusch, K. (2023). *Der Deutschland-Takt: Regulierung, Wettbewerb und Organisation auf der Schiene* (V. Stocker, F. Birke, G. Brunekreeft, & H.-J. Weiß, Eds.). Nomos Verlagsgesellschaft mbH & Co. KG. https://doi.org/10.5771/9783748937463

Montrimas, A., Bruneckienė, J., & Gaidelys, V. (2021). Beyond the Socio-Economic Impact of Transport Megaprojects. *Sustainability*, *13*(15). https://doi.org/10.3390/su13158547

Mooney, P., & Minghini, M. (2017). Mapping and the Citizen Sensor. In G. Foody, L. See, S. Fritz, P. Mooney, A.-M. Olteanu-Raimond, & C. C. Fonte (Eds.), *Mapping and the Citizen Sensor* (pp. 37–59). Ubiquity Press. https://doi.org/10.5334/bbf

Musgrave, P. (2015). Track bed total route evaluation for track renewals and asset management "a Network Rail perspective." *Construction and Building Materials*, *92*, 2–8. https://doi.org/10.1016/j.conbuildmat.2015.03.101

Nelldal, B.-L. (1998). The experience of the SJ X2000 tilting train and its effect on the market. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, *212*(1), 103–108. https://doi.org/10.1243/0954409981530715

Neumeier, S., & Kokorsch, M. (2021). Supermarket and discounter accessibility in rural Germany– identifying food deserts using a GIS accessibility model. *Journal of Rural Studies*, *86*, 247–261. https://doi.org/10.1016/j.jrurstud.2021.06.013

Nordenholz, F., Winkler, C., & Knörr, W. (2017). Analysing the modal shift to rail potential within the long-distance passenger travel market in Germany. *Transportation Research Procedia*, *26*, 81–91. https://doi.org/10.1016/J.TRPRO.2017.07.010

Öberg, M., Nilsson, K. L., & Johansson, C. M. (2018). Complementary governance for sustainable development in transport: The European TEN-T Core network corridors. *Case Studies on Transport Policy*, *6*(4), 674–682. https://doi.org/10.1016/j.cstp.2018.08.006

Office of Rail and Road ORR. (2023a). *Rail Emissions: April 2022 to March 2023*. https://www.gov.uk/government/statistics/rail-emissions-april-2022-to-march-2023

Office of Rail and Road ORR. (2023b). *Rail Infrastructure and Assets: April 2022 to March 2023*. https://www.gov.uk/government/statistics/rail-infrastructure-and-assets-april-2022-to-march-2023

Olsson, N. O. E., & Klakegg, O. J. (2023). A Resilience Perspective on Governance for Construction Project Delivery. In *Construction Project Organising* (pp. 85–100). Wiley. https://doi.org/10.1002/9781119813798.ch6

OpenStreetMap OSM. (2024, March 1). *OpenStreetMap*. https://www.openstreetmap.org/

Pachl, J. (2021). Railway Signalling Principles : Edition 2.0.

Pagliara, F., Vassallo, J. M., & Román, C. (2012). High-Speed Rail versus Air Transportation. *Transportation Research Record: Journal of the Transportation Research Board*, *2289*(1), 10–17. https://doi.org/10.3141/2289-02

Palin, E. J., Stipanovic Oslakovic, I., Gavin, K., & Quinn, A. (2021). Implications of climate change for railway infrastructure. *WIREs Climate Change*, *12*(5). https://doi.org/10.1002/wcc.728

Peda, P., & Vinnari, E. (2022). To build or not to build? Mobilization of uncertainty arguments in public decision-making on private megaprojects. *Journal of Public Budgeting, Accounting & Financial Management*, *34*(6), 235–262.

Pender, L., & Baum, T. (2000). Have the frills really left the European airline industry? *International Journal of Tourism Research*, *2*(6), 423–436. https://doi.org/10.1002/1522-1970(200011/12)2:6<423::AID-JTR240>3.0.CO;2-R

Pucillo, G. P., Penta, F., Catena, M., & Lisi, S. (2018). On the lateral stability of the sleeper-ballast system. *Procedia Structural Integrity*, *12*, 553–560. https://doi.org/10.1016/j.prostr.2018.11.064

Puffert, D. J. (2002). Path Dependence in Spatial Networks: The Standardization of Railway Track Gauge. *Explorations in Economic History*, *39*(3), 282–314. https://doi.org/10.1006/exeh.2002.0786

Puffert, D. J. (2009). Continental Europe. In *The Economic Dynamics of Standardization in Railway Gauge* (pp. 170–192). University of Chicago Press.

Reiter, V., Voltes-Dorta, A., & Suau-Sanchez, P. (2022). The substitution of short-haul flights with rail services in German air travel markets: A quantitative analysis. *Case Studies on Transport Policy*, *10*(4), 2025–2043. https://doi.org/10.1016/j.cstp.2022.09.001

Rémenyi, P., Pap, T., & Pap, N. (2021). The changing room for manoeuvre of 'Visegrad' Hungary in the Western Balkans. An extraordinary change in Hungarian-Serbian relations. *Politics in Central Europe*, *17*(s1), 791–819. https://doi.org/10.2478/pce-2021-0032

Rich, J., & Mabit, S. L. (2011). A Long-Distance Travel Demand Model for Europe. *EJTIR*, *12*(1), 1–20. https://doi.org/10.18757/ejtir.2012.12.1.2946

Ritchie, H. (2020). *Cars, planes, trains: where do CO2 emissions from transport come from?* https://ourworldindata.org/co2-emissions-from-transport

Ritchie, H. (2023). Which form of transport has the smallest carbon footprint? https://our-worldindata.org/travel-carbon-footprint

Rogers, S. (2019). China, Hungary, and the Belgrade-Budapest Railway Upgrade: New Politically-Induced Dimensions of FDI and the Trajectory of Hungarian Economic Development. *Journal of East-West Business*, *25*(1), 84–106. https://doi.org/10.1080/10669868.2018.1561589

Rosberg, T., Cavalcanti, T., Thorslund, B., Prytz, E., & Moertl, P. (2021). Driveability analysis of the european rail transport management system (ERTMS) - A systematic literature review. *Journal of Rail Transport Planning & Management*, *18*. https://doi.org/10.1016/j.jrtpm.2021.100240

Rossetti, S., Tiboni, M., Vetturi, D., Zazzi, M., & Caselli, B. (2020). Measuring Pedestrian Accessibility to Public Transport in Urban Areas: a GIS-based Discretisation Approach. *European Transport \ Trasporti Europei*, *76*, 1–12.

Rothengatter, W. (2020). Intermodal dimension of climate change policy. In *Aviation and Climate Change* (pp. 181–201). Routledge.

Saint-Marc, C., Villanova-Oliver, M., Davoine, P.-A., Pams Capoccioni, C., & Chenier, D. (2018). Mapping the narratives of natural disasters and their domino effects. The case study of floods impacting railways. *International Journal of Cartography*, *4*(1), 78–103. https://doi.org/10.1080/23729333.2017.1370862

Schneider, P. (2020). Military Mobility in Europa. *Internationales Verkehrswesen*, *72*(2), 18–21.

Seidenglanz, D., Taczanowski, J., Król, M., Horňák, M., & Nigrin, T. (2021). Quo vadis, international long-distance railway services? Evidence from Central Europe. *Journal of Transport Geography*, *92*, 102998. https://doi.org/10.1016/j.jtrangeo.2021.102998

Seidu, R. D., Robinson, H., Young, B. E., Ryan, M., & Fong, D. (2023). Infrastructure Development in the UK: Key Drivers and Implementation Challenges. *Journal of Infrastructure Policy and Management*, *6*(1), 33–51.

Shimizu, E., & Inoue, R. (2009). A new algorithm for distance cartogram construction. *International Journal of Geographical Information Science*, *23*(11), 1453–1470. https://doi.org/10.1080/13658810802186882

Simmons, J. (1980). Rail 150: 1975 or 1980? *The Journal of Transport History*, *1*(1), 1–8. https://doi.org/10.1177/002252668000100102

Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2023). *Thematic Cartography and Geovisualization* (4th ed.). CRC Press.

Slocum, T., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2008). *Thematic Cartography and Geovisualization* (2nd ed.). Pearson.

Smith, P., Majumdar, A., & Ochieng, W. Y. (2012). An overview of lessons learnt from ERTMS implementation in European railways. *Journal of Rail Transport Planning & Management*, *2*(4), 79–87. https://doi.org/10.1016/j.jrtpm.2013.10.004

Sokołowski, M. (2018). New Silk Road on the Balkans. Case of Macedonia and Serbia. *Polish Journal of Political Science*, *4*(2), 29–54.

Sommer, C., Ebert, T., Herget, M., Briegel, R., & Milbradt, J. (2023). ÖPNV Sofortprogramm: Das Maßnahmenpaket für die Verkehrswende bis 2025.

Spiekermann, K., & Wegener, M. (1994). The shrinking continent: new time - space maps of Europe. *Environment and Planning B: Planning and Design*, *21*(6), 653–673. https://doi.org/10.1068/b210653

Stenström, C., Parida, A., & Kumar, U. (2016). Measuring and monitoring operational availability of rail infrastructure. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, *230*(5), 1457–1468. https://doi.org/10.1177/0954409715592189

Stevenson, D. (1999). War by Timetable? The Railway Race before 1914. *Past & Present*, *162*, 163–194.

Stojanović, D., Jovičić, E., & Stanisavljević, N. (2022). *The Role and Significance of Chinese Investments in the Modernization of Railway Infrastructure in Serbia* (pp. 194–216). https://doi.org/10.4018/978-1-7998-8021-9.ch009

Suyama, Y. (2014). 50 Years of Tokaido Shinkansen History. *Japan Railway & Transport Review*, *64*.

Tonchev, P. (2022). *China's road: Into the western Balkans*.

Vickerman, R. (2021). Intercity modal competition. In C. Mulley, J. D. Nelson, & S. Ison (Eds.), *The Routledge Handbook of Public Transport* (pp. 61–71). Routledge. https://doi.org/10.4324/9780367816698

Vrána, M., Hlisnikovský, P., Surmařová, S., Pařil, V., & Kasa, M. (2023). High-speed rail in Europe: Analysis and typology of international connections. *Journal of Rail Transport Planning & Management*, *28*, 100419. https://doi.org/10.1016/J.JRTPM.2023.100419

Wang, L., Li, X., Ding, L., Yu, X., & Hu, T. (2022). Visualization and Analysis of Transport Accessibility Changes Based on Time Cartograms. *ISPRS International Journal of Geo-Information*, *11*(8), 432. https://doi.org/10.3390/ijgi11080432

Wenzlhuemer, R. (2010). The History of Standardisation in Europe. In *Europäische Geschichte Online*. Leibniz-Institut für Europäische Geschichte IEG.

Wolmar, C. (2011). Blood, iron, and gold: How the railroads transformed the world. *Public Affairs*.

Yang, D., Pan, K., & Wang, S. (2018). On service network improvement for shipping lines under the one belt one road initiative of China. *Transportation Research Part E: Logistics and Transportation Review*, *117*, 82–95. https://doi.org/10.1016/j.tre.2017.07.003

Yerpes, A., Manzano, R., Conejo, P., & Jimenez, E. (2012). Talgo Hybrid Train: Maximum interoperability in propulsion system. *2012 Electrical Systems for Aircraft, Railway and Ship Propulsion*, 1–5. https://doi.org/10.1109/ESARS.2012.6387458

Yuxing, W., Qiang, L., Binjie, W., Qingfeng, Q., & Jing, Z. (2018). Research on Dynamic Characteristics of Gauge Change Bogies. *2018 International Conference on Intelligent Rail Transportation (ICIRT)*, 1–5. https://doi.org/10.1109/ICIRT.2018.8641676

Zhiyuan, H., Liang, Z., Ruihua, X., & Feng, Z. (2017). Application of big data visualization in passenger flow analysis of Shanghai Metro network. *2017 2nd IEEE International Conference on Intelligent Transportation Engineering (ICITE)*, 184–188. https://doi.org/10.1109/ICITE.2017.8056905

Personal Declaration

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

Location; Date: Signature:

St. Gallen, 21.09.2024

Jens Grafström

A – City Selection

***Table 9**: City selection used for network generation.*

city name	iso code	coordinates	capital	population	multiple stations
Durrës	AL	41.31637676387685, 19.47717709929254	no	113249	no
Fier	AL	40.73020445258939, 19.55325911486487	no	120655	no
Tirana	AL	41.3471158124183, 19.77352596689944	yes	418495	no
Bregenz	AT	47.50295674927683, 9.73991957681453	no	29574	no
Feldkirch	AT	47.24001895101847, 9.60332204828015	no	35793	no
Graz	AT	47.073329984833755, 15.416460160465814	no	292630	no
Innsbruck	AT	47.26327521904431, 11.401015211822248	no	130585	no
Klagenfurt	AT	46.61604071611506, 14.318313453146175	no	104332	no
Linz	AT	48.289855406438924, 14.291620365214	no	210165	no
Salzburg	AT	47.81289914369519, 13.045310440195761	no	155021	no
Vienna	AT	48.1848319636155, 16.378370160946293	yes	1973403	no
Villach	AT	46.61864221817067, 13.848381300672845	no	65127	no
Banja Luka	BA	44.788662924823036, 17.212558558703577	no	185042	no
Mostar	BA	43.34944540230291, 17.813636254213936	no	126628	no
Sarajevo	BA	43.860307514971126, 18.39918585294584	yes	275524	no
Antwerp	BE	51.216243214386644, 4.420992853723842	no	536079	no
Bruges	BE	51.19749307665864, 3.2172101047094017	no	118509	no
Brussels	BE	50.83592003833151, 4.3362244635144895	yes	1218255	no
Ghent	BE	51.035078678919824, 3.713317680713317	no	265085	no
Liège	BE	50.62437509941582, 5.566697184344896	no	195278	no
Burgas	BG	42.49068280782946, 27.472786169477445	no	210813	no
Plovdiv	BG	42.13422905386565, 24.74122676238506	no	383540	no
Ruse	BG	43.83326285094041, 25.956391042908816	no	143325	no
Shumen	BG	43.27241500756297, 26.941970640952803	no	89092	no
Sofia	BG	42.71279588242656, 23.321381140151345	yes	1276956	no
Stara Zagora	BG	42.4161225207411, 25.629595823047485	no	136144	no
Varna	BG	43.198099031118204, 27.912308169062563	no	348594	no
Veliko Tarnovo	BG	43.07392957477432, 25.637734861563633	no	66797	no
Arth-Goldau	CH	47.048703251649954, 8.555293096015149	no	10480	no
Basel	CH	47.54707124129799, 7.58892075173689	no	173552	no
Bern	CH	46.94831544237606, 7.436315188309467	yes	134506	no
Brig	CH	46.319730459919526, 7.986517028649797	no	12162	no
Geneva	CH	46.2106508791602, 6.142546234304431	no	203840	no
Lausanne	CH	46.51775469880473, 6.6243257417467545	no	141418	no
Lugano	CH	46.00506876758176, 8.946728731182784	no	63185	no
Zurich (+1)	CH	47.378099165179805, 8.539146253831492	no	443037	Zurich
Zurich (-1)	CH	47.378148043193704, 8.541362493575344	no	443037	Zurich
Brno	CZ	49.1905791320434, 16.612676206368292	no	396101	no
České Budějovice	CZ	48.97438687517213, 14.488438004720038	no	96417	no
Hradec Králové	CZ	50.21464013174219, 15.810218732317747	no	92763	no
Liberec	CZ	50.76062024651525, 15.046770463089864	no	107309	no
Ostrava	CZ	49.850676949866056, 18.266521267010987	no	283504	no
Plzeň	CZ	49.74375328703533, 13.388474353184431	no	181240	no

Prague	CZ	50.08325740844486, 14.436218331489227	yes	1357326	no
Berlin (+1)	DE	52.52515130546339, 13.372283904306888	yes	3755251	Berlin
Berlin (-1)	DE	52.52699, 13.36799	yes	3755251	Berlin
Bielefeld	DE	52.028493135602886, 8.531416202816889	no	333786	no
Bremen	DE	53.08343322500673, 8.812582074041368	no	569396	no
Cologne	DE	50.94302605691282, 6.958592210446736	no	1084831	no
Dortmund	DE	51.517769002614784, 7.459280917872808	no	593317	no
Dresden	DE	51.040624299889366, 13.72946593633128	no	563311	no
Duisburg	DE	51.42940444867688, 6.776356808750952	no	502211	no
Düsseldorf	DE	51.21953036538851, 6.793477634657491	no	619294	no
Erfurt	DE	50.97238995532242, 11.038043155469884	no	214969	no
Essen	DE	51.45213793693594, 7.018727767965539	no	584580	no
Frankfurt	DE	50.1060395934853, 8.66113453825917	no	773068	no
Freiburg	DE	47.999156686807474, 7.842238771897548	no	236146	no
Hamburg	DE	53.5527933683336, 10.006738028266147	no	1892122	no
Hanover	DE	52.377040004242545, 9.741415255692775	no	552710	no
Karlsruhe	DE	48.99464857383276, 8.405099574291475	no	313092	no
Kassel	DE	51.31174428797717, 9.447391376216915	no	204202	no
Kiel	DE	54.31393039807236, 10.131431000439852	no	247717	no
Leipzig	DE	51.344574975717364, 12.380884634825689	no	625341	no
Lübeck	DE	53.867232741879704, 10.669404870255649	no	218095	no
Mannheim	DE	49.4794603928349, 8.46911765488034	no	315554	no
Munich	DE	48.14065420798882, 11.556150023221415	no	1512491	no
Münster	DE	51.95506139636848, 7.635678452580286	no	314319	no
Nuremberg	DE	49.44545103028204, 11.082476163697892	no	523026	no
Regensburg	DE	49.01174292538338, 12.09674085968242	no	157443	no
Rostock	DE	54.07830966914783, 12.131433914442342	no	209920	no
Saarbrücken	DE	49.2418853826737, 6.987390169563093	no	181959	no
Stuttgart	DE	48.78544077687866, 9.183201751413481	no	632865	no
Ulm	DE	48.39973956058877, 9.98279860003682	no	126329	no
Wuppertal	DE	51.254400489952204, 7.150073308128062	no	358876	no
Aalborg	DK	57.043196174439366, 9.916677386168168	no	113417	no
Aarhus	DK	56.14977426649749, 10.203747764096375	no	285273	no
Copenhagen	DK	55.67185147192673, 12.565668424458236	yes	644431	no
Esbjerg	DK	55.4678154640934, 8.458903635877034	no	115459	no
Odense	DK	55.401758670892, 10.3853025712738	no	180863	no
Padborg	DK	54.82304875201694, 9.35883721878989	no	4325	no
Narva	EE	59.368317912851964, 28.200544219893697	no	53875	no
Pärnu	EE	58.39527296392951, 24.587800004146874	no	51272	no
Tallinn	EE	59.440270198842775, 24.73671964901164	yes	461346	no
Tartu	EE	58.373636706870144, 26.70655729525739	no	97524	no
A Coruña	ES	43.352107917856735, -8.410592330655435	no	247376	no
Algeciras	ES	36.126535435688815, -5.449474471539967	no	123639	no
Alicante	ES	38.34484173986132, -0.49673256671804056	no	349282	no
Almería	ES	36.83453590276323, -2.4560128634494705	no	200578	no
Antequera	ES	37.06998106338044, -4.719621436832545	no	41154	no
Badajoz	ES	38.89079054926135, -6.981742659332291	no	150190	no
Barcelona	ES	41.379197783906406, 2.1405709458163344	no	1660122	no

Bilbao (regional/narrow)	ES	43.260284756996455, -2.9260795631405783	no	346096	Bilbao
Bilbao (interregional)	ES	43.26053113178843, -2.927912986233929	no	346096	Bilbao
Burgos	ES	42.37116938823483, -3.6664740518657517	no	174451	no
Cádiz	ES	36.52771836796025, -6.286755180326387	no	111811	no
Cartagena	ES	37.60528015892063, -0.9741155037660539	no	218050	no
Córdoba	ES	37.88837693979414, -4.789973540356829	no	325708	no
Gijón (regional/narrow)	ES	43.53761580820216, -5.675824132132513	no	268313	Gijón
Gijón (interregional)	ES	43.53776180192165, -5.676005280560825	no	268313	Gijón
Girona	ES	41.97933159643777, 2.8168372372093673	no	104320	no
Granada	ES	37.1837584799016, -3.608784964347275	no	232208	no
León	ES	42.595098760606845, -5.581386321318405	no	121281	no
Madrid (+1)	ES	40.402414921083036, -3.68536587707576	yes	3332035	Madrid
Madrid (-1)	ES	40.40427536459729, -3.6865662237122137	yes	3332035	Madrid
Málaga	ES	36.711207949603285, -4.433526237194415	no	586384	no
Murcia	ES	37.974492149282455, -1.1300017316297115	no	469177	no
Ourense	ES	42.35070236080785, -7.872845582074918	no	105505	no
Pamplona	ES	42.82552540377751, -1.6608607272042961	no	199066	no
Salamanca	ES	40.971718921298034, -5.64830055981371	no	143954	no
San Sebastián (interregional)	ES	43.317659643462584, -1.976592642294175	no	188743	San Sebastián
San Sebastián (regional/narrow)	ES	43.31298614273132, -1.9815061932682498	no	188743	San Sebastián
Santander (regional/narrow)	ES	43.45824391780236, -3.8111662291764103	no	172726	Santander
Santander (interregional)	ES	43.459259877317066, -3.8117909539794237	no	172726	Santander
Santiago de Compostela	ES	42.87075449517897, -8.544299037439748	no	98687	no
Seville	ES	37.393492964687475, -5.973210956880131	no	684025	no
Valencia	ES	39.459344407973084, -0.38128195670029447	no	807693	no
Valladolid	ES	41.642022795455794, -4.726911594801891	no	297459	no
Vigo	ES	42.23537816164509, -8.710694067571465	no	293652	no
Vitoria-Gasteiz	ES	42.84178437655222, -2.677084412300465	no	253672	no
Zaragoza	ES	41.65905395667392, -0.9112792857985567	no	682513	no
Helsinki	FI	60.17165041652153, 24.941566911864445	yes	664921	no
Joensuu	FI	62.59969982261569, 29.77655929132699	no	76334	no
Kolari	FI	67.34885847217133, 23.83635555452093	no	3875	no
Kuopio	FI	62.897199345215135, 27.680922679645946	no	121557	no
Oulu	FI	65.01126683215088, 25.484631108285935	no	201810	no
Rovaniemi	FI	66.49800241529823, 25.70506300993194	no	62420	no
Seinäjoki	FI	62.791873183946265, 22.844464449300006	no	64150	no
Tampere	FI	61.49845899486538, 23.77350049356692	no	231853	no
Tornio	FI	65.85087316234622, 24.182691243297302	no	21573	no
Turku	FI	60.45406378534739, 22.252817696013487	no	189669	no
Ajaccio	FR	41.92753805496737, 8.738977320209647	no	44070	no
Avignon	FR	43.92390008439339, 4.780328928843166	no	90330	no
Bastia	FR	42.702030910905606, 9.44758020472945	no	69378	no
Bayonne	FR	43.49704677796449, -1.470070008762129	no	49207	no
Bordeaux	FR	44.82608315759758, -0.5558039234809385	no	261804	no

Bourges	FR	47.09445746690047, 2.39432543122802	no	63702	no
Brest	FR	48.387871071311395, -4.479555044229427	no	139619	no
Caen	FR	49.17648463676137, -0.3488641817329554	no	106260	no
Calvi	FR	42.56440770095584, 8.755793359791626	no	5410	no
Cherbourg-Octeville	FR	49.63326074488161, -1.6210787407180691	no	35545	no
Clermont-Ferrand	FR	45.778708394785156, 3.1007091175995347	no	147327	no
Dijon	FR	47.323050396342715, 5.026964561388656	no	159346	no
Grenoble	FR	45.19126716835642, 5.71398836633718	no	157477	no
La Rochelle	FR	46.15270009395072, -1.1453586756924354	no	78535	no
Le Havre	FR	49.4927690055231, 0.12614702593788413	no	166058	no
Le Mans	FR	47.995429504169614, 0.1921528228238871	no	145004	no
Lille (Europe)	FR	50.63945853289013, 3.0762508930265136	no	236710	Lille
Lille (Flanders)	FR	50.63628837347249, 3.0714067349026464	no	236710	Lille
Limoges	FR	45.83628187444859, 1.267436960758757	no	129760	no
Lyon	FR	45.76032762866298, 4.860175402004224	no	522250	no
Marseille	FR	43.303666554752155, 5.381651546741638	no	873076	no
Metz	FR	49.10933941823257, 6.177818676831699	no	120874	no
Montpellier	FR	43.595318437052555, 3.9247478579198507	no	302454	no
Nantes	FR	47.21719653046198, -1.5424075283979215	no	323204	no
Nice	FR	43.70425919998589, 7.260701343558609	no	348085	no
Paris (Gare Saint-Lazare)	FR	48.876810415031116, 2.325304925277017	yes	2145906	Paris
Paris (Montpar-nasse)	FR	48.84065627737904, 2.3197564872898457	yes	2145906	Paris
Paris (Austerlitz)	FR	48.83903862403894, 2.3682922247878975	yes	2145906	Paris
Paris (Gare de l'Est)	FR	48.87741005595024, 2.359758259056418	yes	2145906	Paris
Paris (Gare de Lyon)	FR	48.84466453468429, 2.373822327768317	yes	2145906	Paris
Paris (Gare du Nord)	FR	48.88063211930947, 2.3548809242126163	yes	2145906	Paris
Perpignan	FR	42.696118604671575, 2.8793386377799455	no	119656	no
Reims	FR	49.259162637698324, 4.024286840249119	no	179380	no
Reims	FR	49.21625702794758, 3.9890541296480464	no	184076	no
Rennes	FR	48.1032964704555, -1.6715439677654829	no	225081	no
Strasbourg	FR	48.58494782839153, 7.733750893617865	no	291313	no
Toulouse	FR	43.61025695708779, 1.4544742983108103	no	504078	no
Tours (Centrale)	FR	47.3877159932701, 0.6959121646064983	no	137658	Tours
Tours (Saint-Pierre-Des-Corps)	FR	47.38449180442222, 0.7202784644619132	no	137658	Tours
Aberdeen	GB	57.14331645457981, -2.098741612814794	no	200680	no
Belfast (Great Victoria Street)	GB	54.594195937642795, -5.93756123229572	no	345006	Belfast
Belfast (Lan-yon Place)	GB	54.594954338685056, -5.91730226975501	no	345006	Belfast
Birmingham	GB	52.477910651918386, -1.8994045207045334	no	1137100	no
Bristol (Temple Meads)	GB	51.449571188519876, -2.580316971183325	no	472465	Bristol
Bristol (Parkway)	GB	51.513812475285754, -2.541904208996378	no	472465	Bristol
Carlisle	GB	54.89068591866715, -2.933378497870439	no	20144	no
Derry	GB	54.99262839936011, -7.313397998972563	no	85016	no

Doncaster	GB	53.52204176689714, -1.139796978651595	no	109805	no
Edinburgh	GB	55.95192581415101, -3.1894163380359988	no	488050	no
Exeter	GB	50.7291418706283, -3.5438242734819267	no	129801	no
Glasgow	GB	55.85935723228601, -4.25821292055751	no	635640	no
Inverness	GB	57.4799275486458, -4.223294341429295	no	47380	no
Kingston u. Hull	GB	53.74426118689597, -0.3464472816284624	no	260200	no
Leeds	GB	53.79364784723733, -1.5507942989190122	no	789194	no
Leicester	GB	52.631392312108225, -1.1238235146594402	no	357394	no
Liverpool	GB	53.407592478652965, -2.977826529505324	no	513441	no
London (Bridge)	GB	51.50529164318203, -0.0855039322821116	no	8799728	London
London (Euston)	GB	51.5289135777343, -0.1347287206973779	yes	8799728	London
London (King's Cross)	GB	51.532030726261134, -0.12314406206855928	yes	8799728	London
London (St Pancras)	GB	51.531293442671156, -0.12608904662649126	yes	8799728	London
London (Victoria)	GB	51.49435145576124, -0.14391979234488542	yes	8799728	London
London (Waterloo)	GB	51.50188259085412, -0.11381553493584233	yes	8799728	London
Manchester (Piccadilly)	GB	53.47605192521905, -2.2253859619856526	no	547627	Manches-ter
Manchester (Victoria)	GB	53.48720453654775, -2.2449705516066496	no	547627	Manches-ter
Newcastle u.Tyne	GB	54.96844338017993, -1.616756686168096	no	300196	no
Norwich	GB	52.62653106722053, 1.307382199142596	no	195971	no
Nottingham	GB	52.94737530473628, -1.1412610467337256	no	331297	no
Penzance	GB	50.121942367224726, -5.532621285893106	no	21168	no
Perth	GB	56.391620240031095, -3.438381506396406	no	47350	no
Peterborough (Interregional)	GB	52.57741511802135, -0.252192396428806	no	194000	Peterbor-ough
Peterborough (Regional)	GB	52.57732976742599, -0.25254904381321214	no	194000	Peterbor-ough
Sheffield	GB	53.37806475051299, -1.4618096145713155	no	584028	no
Southampton	GB	50.90740447098516, -1.41381361607332	no	271173	no
Swansea	GB	51.625451582287646, -3.9405465745977564	no	245508	no
Thurso	GB	58.590073768177874, -3.527729927059496	no	7610	no
York	GB	53.955779380062886, -1.096124201190496	no	208400	no
Alexandroupoli	GR	40.84789347348713, 25.89117530938814	no	73000	no
Athens	GR	38.06038823967672, 23.734309996801148	yes	643452	no
Larissa	GR	39.629459163596024, 22.422773647779756	no	148562	no
Patras	GR	38.249687109305746, 21.734771903585283	no	173600	no
Thessaloniki	GR	40.64389956901383, 22.931584001989528	no	309617	no
Osijek	HR	45.5527422340516, 18.683797296928788	no	96313	no
Rijeka	HR	45.33009420269459, 14.430260982075016	no	107964	no
Split	HR	43.504697602375764, 16.44302169970109	no	160577	no
Varaždin	HR	46.30569025987652, 16.346719580783706	no	42789	no
Zagreb	HR	45.80434990014418, 15.978989118666448	yes	767131	no
Budapest (Nyugati)	HU	47.51127945113849, 19.058282046015748	yes	1671004	Budapest
Budapest (Déli)	HU	47.49956611223871, 19.024995385244495	yes	1671004	Budapest
Budapest (Keleti)	HU	47.50050398953286, 19.085398114682835	yes	1671004	Budapest

Debrecen	HU	47.51988416086886, 21.62826861940479	no	201582	no
Győr	HU	47.681170352413446, 17.63233326451533	no	129301	no
Miskolc	HU	48.09883640292072, 20.811758771027545	no	145248	no
Pécs	HU	46.06601674405131, 18.223973173327746	no	141031	no
Szeged	HU	46.239873860962525, 20.143459393497782	no	158829	no
Szolnok	HU	47.17927670611352, 20.175713670941178	no	71285	no
Szombathely	HU	47.23632679853725, 16.633320856610684	no	78407	no
Cork	IE	51.901438380729594, -8.457937354490454	no	222333	no
Dublin (Con-nolly)	IE	53.35237692306594, -6.249003776414832	yes	592713	Dublin
Dublin (Heuston)	IE	53.34649077337974, -6.2933851762590445	yes	592713	Dublin
Galway	IE	53.27341663953856, -9.046604985689697	no	83456	no
Limerick	IE	52.65840906933754, -8.623244977244406	no	58319	no
Sligo	IE	54.27217221208001, -8.482244691225647	no	19199	no
Waterford	IE	52.266522987492195, -7.118260056530168	no	53504	no
Ancona	IT	43.60759190411532, 13.49767633120252	no	100696	no
Bari	IT	41.11780054771549, 16.870135868656536	no	316015	no
Bologna	IT	44.50629053828535, 11.343206969929586	no	387971	no
Bolzano	IT	46.49640559245234, 11.358670665060274	no	106107	no
Cagliari	IT	39.216690219576805, 9.107028573890675	no	148117	no
Cosenza	IT	39.31894438639433, 16.260659637157126	no	63760	no
Florence	IT	43.77702747163024, 11.247756388522763	no	360930	no
Foggia	IT	41.465751335999535, 15.555921510917754	no	145348	no
Genoa	IT	44.417366373984734, 8.920514035165517	no	558745	no
Lecce	IT	40.34542049082451, 18.165925484475483	no	94783	no
Messina	IT	38.18485560747073, 15.561172156742893	no	218786	no
Milan (Porta Garibaldi)	IT	45.48475916928917, 9.186769450233138	no	1354196	Milan
Milan (Centrale)	IT	45.48774293436178, 9.206244798882878	no	1354196	Milan
Naples (Centrale)	IT	40.852982824930436, 14.273180119993086	no	913462	Naples
Naples (Interchange)	IT	40.88520783188453, 14.323899234795485	no	913462	Naples
Olbia	IT	40.92480861316997, 9.498575609306675	no	61048	no
Palermo	IT	38.10893091197514, 13.36764417851799	no	630167	no
Perugia	IT	43.10392074618472, 12.37555760757073	no	166676	no
Pescara	IT	42.45758309791371, 14.212285144270789	no	118657	no
Pisa	IT	43.70822877907478, 10.398335633681537	no	88737	no
Rome	IT	41.90061399356659, 12.502663379723169	yes	2748109	no
Sassari	IT	40.729544902969515, 8.554223611079232	no	121021	no
Syracuse	IT	37.068958388994886, 15.28086928224865	no	116244	no
Taranto	IT	40.483644103694346, 17.224232877044322	no	188098	no
Trieste	IT	45.65876041528067, 13.77129778235539	no	198417	no
Turin	IT	45.06049401735347, 7.677162572375207	no	841600	no
Venice	IT	45.48232157443141, 12.231699561853524	no	250369	no
Verona	IT	45.428776566298495, 10.98271070438972	no	255588	no
Villa San Gio-vanni	IT	38.21668898235332, 15.634368514658572	no	12752	no
Vaduz/Schaan	LI	47.1685654034565, 9.508101088215607	yes	11489	no
Kaunas	LT	54.88623777465683, 23.931747441978235	no	305120	no
Klaipėda	LT	55.721137354635964, 21.134957492934337	no	158420	no

Šiauliai	LT	55.92263692476599, 23.31540562686701	no	101511	no
Vilnius	LT	54.66994560823776, 25.28463325438789	yes	581475	no
Luxembourg	LU	49.59994730251573, 6.134694030377752	yes	132780	no
Daugavpils	LV	55.8748178540611, 26.528068182102135	no	78850	no
Jelgava	LV	56.639511117315394, 23.73018214031282	no	55972	no
Liepāja	LV	56.525035365723696, 21.01850390697963	no	68945	no
Riga	LV	56.9464378474394, 24.12014803033064	yes	660187	no
Bălți	MD	47.76100077844809, 27.909952587065693	no	97930	no
Chișinău	MD	47.01290383373783, 28.860067280701394	yes	639000	no
Ungheni	MD	47.20015341903947, 27.79592517783435	no	25800	no
Bar	ME	42.08757170624869, 19.105588825401195	no	44054	no
Podgorica	ME	42.431777589616495, 19.269164029627543	yes	150977	no
Bitola	MK	41.0204271257066, 21.343064742577788	no	69287	no
Skopje	MK	41.9911946009942, 21.44608051211098	yes	526502	no
Veles	MK	41.72434397815813, 21.76943721664013	no	48463	no
Amsterdam	NL	52.37926771469527, 4.899141715344551	yes	921468	no
Arnhem	NL	51.984722725387975, 5.900578308196073	no	164096	no
Eindhoven	NL	51.44325529076439, 5.4811243108262655	no	235691	no
Groningen	NL	53.21072991067833, 6.5637849122522125	no	202900	no
Rotterdam	NL	51.9249126200891, 4.469780022528715	no	664311	no
The Hague	NL	52.06897905143204, 4.320262005756452	no	514861	no
Utrecht	NL	52.087499880308066, 5.111977589711167	no	367497	no
Zwolle	NL	52.505600092960286, 6.0892770706502874	no	123861	no
Bergen	NO	60.39007065741137, 5.333817716229017	no	267117	no
Bodø	NO	67.28656440207081, 14.392815980498	no	53259	no
Drammen	NO	59.74006979258713, 10.205321432579693	no	66214	no
Kristiansand	NO	58.145719212187394, 7.986736409111273	no	115569	no
Narvik	NO	68.44141969506587, 17.44475663242554	no	21515	no
Oslo	NO	59.9107654002489, 10.754456441305683	yes	711300	no
Stavanger	NO	58.96643480651651, 5.732573074554093	no	146011	no
Trondheim	NO	63.43645153086511, 10.398871511082033	no	212660	no
Białystok	PL	53.13408685427886, 23.13602819190044	no	294242	no
Bydgoszcz	PL	53.13507072355395, 17.992039393140615	no	337666	no
Gdańsk	PL	54.35683595716114, 18.64453700808109	no	486022	no
Katowice	PL	50.25760887182851, 19.01705009559095	no	285711	no
Koszalin	PL	54.19045475922263, 16.169667407017734	no	105883	no
Kraków	PL	50.06838508596897, 19.947353789798754	no	766683	no
Łódź	PL	51.757835466286025, 19.429934787545726	no	670642	no
Lublin	PL	51.2314239342606, 22.56906761062492	no	334681	no
Olsztyn	PL	53.78556331710419, 20.497693825663358	no	170225	no
Poznań	PL	52.402998946501526, 16.912856592955592	no	546859	no
Rzeszów	PL	50.043159973083604, 22.007805294531074	no	195871	no
Suwałki	PL	54.10462211186022, 22.948254061789456	no	69206	no
Szczecin	PL	53.418886968898285, 14.550462476142123	no	396168	no
Warsaw	PL	52.22881577757354, 21.003214089993563	yes	1860281	no
Wrocław	PL	51.098296503840025, 17.037115640598692	no	672929	no
Braga	PT	41.54787712554409, -8.434610730578335	no	193342	no
Coimbra	PT	40.224869546729835, -8.44048505421954	no	140816	no
Entroncamento	PT	39.4615499530507, -8.474081419014531	no	20141	no

Faro	PT	37.018773930838634, -7.9400556805601745	no	64560	no
Guarda	PT	40.55349916409098, -7.2400436876400835	no	40117	no
Lisbon (Oriente)	PT	38.76779191767734, -9.09912294954436	yes	545923	Lisbon
Lisbon (Rossio)	PT	38.71436170568904, -9.14149852199962	yes	545923	Lisbon
Porto	PT	41.14877621914789, -8.585000820743758	no	237591	no
Arad	RO	46.189960761951, 21.32552252366198	no	145078	no
Bacău	RO	46.565818183385424, 26.89481918564678	no	136087	no
Brașov	RO	45.66158409180138, 25.61395064056485	no	237589	no
Bucharest	RO	44.44701208821772, 26.07348246028291	yes	1716961	no
Cluj-Napoca	RO	46.78463194144769, 23.58695454844528	no	286598	no
Constanța	RO	44.168771735717016, 28.63163528050895	no	387593	no
Craiova	RO	44.3290150742757, 23.816981928495952	no	234140	no
Deva	RO	45.88406638735966, 22.910758370998632	no	53113	no
Galați	RO	45.44712673319686, 28.060280125296835	no	217851	no
Iași	RO	47.16539213879057, 27.56972991977809	no	271692	no
Oradea	RO	47.07147108169548, 21.93517221448622	no	183105	no
Pitești	RO	44.84919466926701, 24.884779423935846	no	141275	no
Satu Mare	RO	47.795397911007505, 22.893030242371168	no	91520	no
Suceava	RO	47.67040864693623, 26.266151769141374	no	84308	no
Timișoara	RO	45.7509778984045, 21.20748014427406	no	250849	no
Belgrade	RS	44.7929214536255, 20.455516127951267	yes	1378682	no
Niš	RS	43.31648242053823, 21.877318013048818	no	183164	no
Novi Sad	RS	45.281877, 19.795158	no	380000	no
Subotica	RS	46.10215764236732, 19.67109587041512	no	105681	no
Alvesta	SE	56.89907674126362, 14.557333942422492	no	8017	no
Boden	SE	65.82883807783816, 21.708332572577007	no	16830	no
Gothenburg	SE	57.709301621740146, 11.9739120125181	no	579281	no
Hallsberg	SE	59.067078457077706, 15.109689038777717	no	8525	no
Kalmar	SE	56.66134623025437, 16.35991939988837	no	41388	no
Kiruna	SE	67.86808944026757, 20.19948713837393	no	17513	no
Linköping	SE	58.416608579431355, 15.625413173963137	no	115682	no
Luleå	SE	65.58352376126376, 22.165703065511074	no	49123	no
Malmö	SE	55.610135763434336, 13.004024908952335	no	344166	no
Östersund	SE	63.17047353700136, 14.637326236878245	no	49806	no
Stockholm	SE	59.33006384702191, 18.05719770032102	yes	984748	no
Sundsvall	SE	62.38623219727761, 17.316059661700592	no	58807	no
Umeå	SE	63.83021338803353, 20.26683597500849	no	91916	no
Västerås	SE	59.6073394474996, 16.55230257525329	no	127799	no
Divača	SI	45.68074230036461, 13.968430343210333	no	1868	no
Koper	SI	45.539115827273434, 13.73874365957956	no	25913	no
Ljubljana	SI	46.058725101889856, 14.512796209430965	yes	284293	no
Maribor	SI	46.56208848732088, 15.658125939481506	no	96302	no
Banská Bystrica	SK	48.735017380230595, 19.163524751343207	no	78758	no
Bratislava	SK	48.15881983417699, 17.106482714640592	yes	475503	no
Košice	SK	48.72271677637954, 21.268872361703302	no	229040	no
Prešov	SK	48.98392083133166, 21.248922880086734	no	89872	no
Žilina	SK	49.227028856900496, 18.746529724657336	no	82656	no
Çorlu	TR	41.17754240013083, 27.78000187532291	no	279251	no

Edirne	TR	41.65529101446166, 26.57990553444446	no	180327	no
Istanbul	TR	41.01838998803094, 28.766647252799455	no	15462452	no
Peja	XK	42.66049452777952, 20.305026341054333	no	96450	no
Pristina	XK	42.658884045387374, 21.15096113310213	yes	207477	no

B – Regression Results (Domestic + Full Europe)

***Table 10**: Regression results between realistic and potential travel times for each country's domestic connections, as well as for all of Europe as once. Only connections with direct realistic travel times were used (no transfers).*

country	regression coefficient	intercept	R-squared	sample size
entire Europe	1.46215197	0.22774828	0.91552115	455
AT	1.37714818	-3.3606492	0.98244476	12
BA	0	115	-	1
BE	1.77045901	-10.581045	0.95200076	5
BG	1.27833186	22.714621	0.93398296	12
CH	1.76922281	-14.34038	0.83579644	10
CZ	1.12469653	28.8392599	0.80745674	8
DE	1.39397928	-1.256045	0.93755317	50
DK	1.82739826	-26.118286	0.8111082	7
EE	4.14020219	-273.5178	1	2
ES	1.56125453	6.89384671	0.74428211	48
FI	1.4810177	-6.2899841	0.93988789	12
FR	1.55698721	-7.3405113	0.88220264	49
GB	1.35204813	3.46521346	0.89666672	58
GR	2.118241	-47.745915	1	2
HR	1.22294124	49.8728221	0.99902486	3
HU	1.4840307	-7.492754	0.92496828	10
IE	0.91002557	42.2366823	0.76718811	5
IT	1.65099864	-6.9070269	0.91768332	35
LT	1.2745845	5.90416214	0.91509626	4
LV	1.34384283	18.1975365	0.84035053	3
MD	1.94073429	-142.38145	1	2
ME	0	59	-	1
MK	1.31919297	7.47066343	1	2
NL	1.1718341	6.29087839	0.84305524	12
NO	1.35876845	1.41407144	0.9838202	6
PL	1.5755905	-16.80397	0.91130592	32
PT	1.72175575	-6.7949887	0.99618673	6
RO	1.62253973	-0.1799967	0.89718864	27
RS	1.47843887	-8.3867889	0.99523067	3
SE	1.37368682	3.5221494	0.96342848	18
SI	1.29800591	-3.764682	0.98253772	3
SK	1.18658952	15.4499736	0.99113195	4
TR	-0.655899	174.169553	1	2
XK	0	116	-	1

C – Infrastructure Projects

C.1 – Infrastructure Project Specifications

***Table 11**: Gathered information on all used infrastructure projects. Status: COR = "corroborated", LD = "legal design", TD = "tendering", PCO = "in partial construction", CON = "in construction" (analogue to Table 2). Sources are available in section C.2.*

affected city (start)	affected city (end)	new direct	t_{new} [min]	t_{reduct} [min]	impact type	Vmax [km/h]	status	comp-letion	sources
Lisbon	Badajoz	yes	110	-	timetable	300	CON	2024	[1], [2], [3]
Ghent	Bruges	-	13.3	-	infrastructure	200	CON	2024	[4]
Deva	Brașov	-	156.89	-	infrastructure	160	CON	2024	[5]
Brașov	Cluj-Napoca	-	167.6	-	infrastructure	160	CON	2024	[5]
Deva	Cluj-Napoca	-	91.24	-	infrastructure	160	CON	2024	[5]
Bucharest	Ruse	-	80	-	timetable	?	CON	2024	[5], [6]
Drammen	Kristiansand	-	-	28	timetable	250	CON	2025	[7], [8], [9]
Vilnius	Šiauliai	-	98	-	timetable	160	CON	2025	[10], [11]
Šiauliai	Klaipėda	-	82	-	timetable	160	CON	2025	[10], [11]
Valencia	Alicante	-	60	68	timetable	350	CON	2025	[12], [13], [14]
Valencia	Murcia	-	-	68	timetable	350	CON	2025	[12], [13], [14]
Stuttgart	Ulm	-	27	-	timetable	250	CON	2025	[15], [16]
Stuttgart	Zurich	yes	171	7	timetable	250	CON	2025	[15], [16]
Karlsruhe	Stuttgart	-	35	-	timetable	250	CON	2025	[15], [16]
Mannheim	Stuttgart	-	33	-	timetable	250	CON	2025	[15], [16]
Graz	Klagenfurt	yes	45	-	timetable	250	CON	2025	[17], [18]
Vienna	Bratislava	-	40	-	timetable	200	CON	2025	[19]
Poznań	Szczecin	-	120	-	timetable	160	CON	2025	[20], [21]
Budapest	Subotica	yes	72	-	timetable	200	CON	2025	[22], [23], [24]
Subotica	Novi Sad	-	42	-	timetable	200	CON	2025	[22], [23], [24]
Szolnok	Arad	-	-	1	infrastructure	160	CON	2025	[5], [25]
Arad	Deva	-	55.93	-	infrastructure	160	CON	2025	[5]
Istanbul	Edirne	yes	120	-	timetable	200	CON	2025	[26], [27]
Thessaloniki	Veles	-	-	14.96	infrastructure	160	CON	2025	[28]. [29]
Aarhus	Aalborg	-	60	-	timetable	200	CON	2026	[30]
Murcia	Almería	yes	65	-	timetable	300	CON	2026	[31], [32], [33]
Antequera	Granada	-	-	23	timetable	300	CON	2026	[34], [35]
Seville	Antequera	-	-	24	timetable	350	CON	2026	[34], [35]
Bolzano	Verona	-	30	-	timetable	250	PCO	2026	[36], [37]
Berlin	Szczecin	-	90	-	timetable	160	CON	2026	[38], [39]
Maribor	Graz	-	45	-	timetable	?	PCO	2026	[40], [41]
Milan	Genoa	-	50	-	timetable	250	CON	2026	[42]
Turin	Genoa	-	60	-	timetable	250	CON	2026	[42]
Milan	Verona	-	-	5	timetable	250	CON	2026	[43]
Naples	Taranto	yes	210	30	timetable	200	CON	2026	[44], [45]
Venice	Trieste	-	-	10	timetable	200	PCO	2026	[46], [47]
Craiova	Timișoara	-	143.94	-	infrastructure	160	CON	2026	[5]
Timișoara	Arad	-	40.02	-	infrastructure	160	CON	2026	[5]

Debrecen	Oradea	-	47.23	-	infrastructure	160	CON	2026	[5]
Oradea	Cluj-Napoca	-	80.37	-	infrastructure	160	CON	2026	[5]
Niš	Belgrade	-	100	-	timetable	200	TD	2026	[50], [51]
Sofia	Craiova	-	180	-	timetable	160	PCO	2026	[52], [53]
Tirana	Durrës	yes	20	-	timetable	120	CON	2026	[54]
Athens	Patras	yes	110	-	timetable	200	CON	2026	[55]
Oslo	Trondheim	-	-	19	timetable	200	CON	2027	[56]
Vitoria-Gasteiz	Burgos	-	30	47	timetable	350	TD	2027	[57]
Zaragoza	Pamplona	-	60	-	timetable	?	CON	2027	[58], [59]
Žilina	Košice	-	107.48	-	infrastructure	160	CON	2027	[60], [61]
Žilina	Prešov	-	-	32.64	infrastructure	160	CON	2027	[60], [61]
Prešov	Košice	-	-	2.9	infrastructure	160	CON	2027	[60], [61]
Koper	Divača	-	-	18.58	infrastructure	160	CON	2027	[62], [63]
Naples	Foggia	-	65	-	timetable	250	CON	2027	[64]
Rome	Ancona	-	185	30	timetable	200	PCO	2027	[65]
Rome	Perugia	-	120	15	timetable	200	PCO	2027	[65]
Ancona	Perugia	-	150	15	timetable	200	PCO	2027	[65]
Sofia	Niš	-	133.97	-	infrastructure	120	CON	2027	[51], [66]
Tallinn	Narva	-	91.41	-	infrastructure	160	CON	2028	[67]
Narva	Tartu	-	106.17	-	infrastructure	160	CON	2028	[67]
Tallinn	Tartu	-	78.17	-	infrastructure	160	CON	2028	[67]
Odense	Esbjerg	-	-	5	timetable	250	CON	2028	[30]
Odense	Padborg	-	-	5	timetable	250	CON	2028	[30]
Odense	Aarhus	-	-	5	timetable	250	CON	2028	[30]
Bilbao	San Sebastián	-	55	103	timetable	250	CON	2028	[68], [69]
Vitoria-Gasteiz	San Sebastián	-	55	45	timetable	250	CON	2028	[68], [69]
Vitoria-Gasteiz	Bilbao	-	43	97	timetable	250	CON	2028	[68], [69]
Copenhagen	Lübeck	yes	110	-	timetable	200	CON	2029	[70], [71]
Copenhagen	Odense	-	60	-	timetable	200	CON	2029	[30]
Brussels	Luxembourg	-	120	60	timetable	160	CON	2029	[72]
Berlin	Dresden	-	80	-	timetable	200	CON	2029	[73]
Łódź	Warsaw	-	45	-	timetable	250	PCO	2029	[74]
Verona	Venice	-	-	5	timetable	250	CON	2029	[75]
Genoa	Nice	-	-	8.61	infrastructure	200	LD	2029	[76]
Tallinn	Pärnu	-	40	-	timetable	249	PCO	2030	[77]
Pärnu	Riga	yes	60	-	timetable	249	PCO	2030	[77]
Riga	Kaunas	yes	92	-	timetable	249	PCO	2030	[77]
Riga	Vilnius	yes	114	-	timetable	249	PCO	2030	[77]
Kaunas	Vilnius	-	38	-	timetable	249	PCO	2030	[77]
Kaunas	Suwałki	-	38	-	timetable	249	PCO	2030	[77]
Suwałki	Białystok	-	79	-	timetable	249	PCO	2030	[77]
Białystok	Warsaw	-	87	-	timetable	249	PCO	2030	[77]
Lisbon	Porto	yes	75	-	timetable	300	CON	2030	[78]
Lisbon	Coimbra	yes	51	39	timetable	300	CON	2030	[78]
Porto	Coimbra	-	30	45	timetable	300	CON	2030	[78]
Coimbra	Guarda	-	127	16	timetable	300	CON	2030	[78]
Braga	Vigo	-	30	-	timetable	250	TD	2030	[78]

Granada	Almería	-	65	96	timetable	250	CON	2030	[79]
Madrid	Badajoz	-	151	-	timetable	300	CON	2030	[80]
Amsterdam	Utrecht	-	14.74	-	infrastructure	200	CON	2030	[81]
Dresden	Leipzig	-	47	-	timetable	200	CON	2030	[82]
Frankfurt	Mannheim	-	29	9	timetable	300	LD	2030	[83]
Nuremberg	Erfurt	-	60	-	timetable	230	CON	2030	[84]
Vienna	Graz	-	110	-	timetable	230	CON	2030	[85]
Plzeň	Regensburg	-	-	36	timetable	200	CON	2030	[86]
Plzeň	Nuremberg	-	-	36	timetable	200	CON	2030	[86]
Prague	České Budějovice	-	80	-	timetable	200	CON	2030	[87]
Palermo	Syracuse	-	-	60	timetable	250	CON	2030	[88]
Messina	Syracuse	-	-	30	timetable	250	CON	2030	[88]
Rome	Pescara	-	120	-	timetable	200	PCO	2030	[89]
Naples	Cosenza	-	105	-	timetable	300	PCO	2030	[44], [45]
Naples	Villa San Gio-vanni	-	170	-	timetable	300	PCO	2030	[44], [45]
Zagreb	Rijeka	-	90	-	timetable	250	PCO	2030	[90], [91]
Zagreb	Split	-	-	39.25	infrastructure	250	PCO	2030	[90], [91]
Split	Rijeka	-	-	56.09	infrastructure	250	PCO	2030	[90], [91]
Plovdiv	Stara Zagora	-	-	35	timetable	160	CON	2030	[92]
Stara Zagora	Burgas	-	-	35	timetable	160	CON	2030	[92]
Stara Zagora	Varna	-	-	35	timetable	160	CON	2030	[92]
Sofia	Plovdiv	-	80	-	timetable	200	CON	2030	[93], [94]
Skopje	Sofia	yes	145	-	timetable	160	CON	2030	[95]
Valladolid	Santander	-	-	60	timetable	350	CON	2030	[96]
Burgos	Santander	-	-	60	timetable	350	CON	2030	[96]
León	Santander	-	-	60	timetable	350	CON	2030	[96]
Bremen	Groningen	yes	131	-	timetable	120	CON	2030	[97]
Helsinki	Turku	-	78	36	timetable	300	LD	2031	[98]
Oslo	Bergen	yes	354	50	timetable	250	LD	2032	[99]
Lyon	Turin	-	107	126	timetable	320	CON	2032	[100]
Grenoble	Turin	-	-	82	timetable	320	CON	2032	[100]
Geneva	Turin	-	-	82	timetable	320	CON	2032	[100]
Lyon	Grenoble	-	-	54	timetable	320	CON	2032	[100]
Bordeaux	Toulouse	-	60	-	timetable	320	CON	2032	[101]
Innsbruck	Bolzano	-	55	70	timetable	250	CON	2032	[37]
Malmö	Gothenburg	-	133	20	timetable	250	CON	2033	[102]
London	Birmingham	-	49	27	timetable	360	CON	2033	[103], [104]
Liverpool	Birmingham	-	-	7	timetable	360	CON	2033	[103], [104]
Birmingham	Carlisle	-	-	7	timetable	360	CON	2033	[103], [104]
Liverpool	London	yes	105	35	timetable	360	CON	2033	[103], [104]
London	Manchester	yes	100	26	timetable	360	CON	2033	[103], [104]
Oslo	Gothenburg	-	-	23	timetable	250	CON	2034	[105]
Berlin	Hanover	-	85	16	timetable	300	TD	2034	[106]
Brno	Vienna	-	60	-	timetable	320	CON	2034	[107]
Łódź	Wrocław	-	60	-	timetable	?	LD	2034	[108]
Łódź	Poznań	-	65	-	timetable	350	TD	2034	[109]
Poznań	Wrocław	-	80	-	timetable	350	LD	2034	[109], [110]
Stockholm	Linköping	-	65	30	timetable	250	CON	2035	[111]

Zurich	Arth-Goldau	-	-	6	timetable	?	LD	2035	[112]
Zurich	Bregenz	-	-	8	timetable	160	LD	2035	[113], [114]
Frankfurt	Kassel	-	39	13	timetable	250	LD	2035	[115]
Plzeň	Prague	-	51	-	timetable	?	COR	2035	[87]
Erfurt	Frankfurt	-	62	8	timetable	230	LD	2037	[115]
Munich	Innsbruck	-	55	-	timetable	250	LD	2040	[116]
Salzburg	Linz	-	56	-	timetable	250	LD	2040	[117]
Leeds	Kingston upon Hull	-	48	10	timetable	?	COR	2041	[104], [118]
Sheffield	Manchester	-	42	9	timetable	?	COR	2041	[104], [118]
Sheffield	Leeds	-	40	-	timetable	?	COR	2041	[104], [118]
Manchester	Leeds	-	-	11	timetable	?	COR	2041	[104], [118]
Karlsruhe	Freiburg	-	-	18	timetable	250	PCO	2041	[119]
Karlsruhe	Strasbourg	-	-	10	timetable	250	PCO	2041	[119]
Strasbourg	Freiburg	-	-	8	timetable	250	PCO	2041	[119]
Freiburg	Basel	-	-	13	timetable	250	PCO	2041	[119]
Bordeaux	Bayonne	-	-	30	timetable	320	LD	2042	[120]
Toulouse	Bayonne	-	125	-	timetable	320	LD	2042	[120]
Montpellier	Toulouse	-	-	27	timetable	320	TD	2045	[121]
Perpignan	Toulouse	-	-	16	timetable	320	TD	2045	[121]
Perpignan	Montpellier	-	-	39	timetable	320	TD	2045	[121]
Dresden	Prague	-	60	-	timetable	320	LD	2045	[122]
Drammen	Kristiansand	-	-	15	timetable	250	COR	2050	[7], [8], [9]
Oslo	Trondheim	-	-	11	timetable	250	LD	2050	[56]
Umeå	Luleå	yes	90	145	timetable	250	PCO	2050	[123]
Lisbon	Badajoz	yes	80	-	timetable	300	COR	2050	[2], [124]
Lisbon	Faro	-	-	30	timetable	300	COR	2050	[2], [124]
Amsterdam	Zwolle	-	37.52	-	infrastructure	200	CON	2050	[81]
Zwolle	Groningen	-	35.55	-	infrastructure	200	CON	2050	[81]
Eindhoven	Rotterdam	-	35.88	-	infrastructure	200	CON	2050	[81]
Hanover	Bielefeld	-	31	17	timetable	300	COR	2050	[106], [125]
Brno	Ostrava	-	36	-	timetable	320	PCO	2050	[107], [126]

C.2 – Infrastructure Project Information Sources

[1] radioelvas: "Portugal confirma alta velocidade entre Badajoz e Lisboa em 2024". Accessed on 20.04.2024. URL: https://radioelvas.com/2023/03/16/portugal-confirma-comboio-de-alta-velocidade-entre-badajoz-e-lisboa-em-2024/.

[2] Rádio Renascença: Terceira travessia do Tejo volta à agenda do PS". Accessed on 20.04.2024. URL: https://rr.sapo.pt/2019/07/18/pais/terceira-travessia-do-tejo-volta-a-agenda-do-ps/noticia/158323/.

[3] Sul Informação: "Railway Plan foresees crossing the Tagus that brings Algarve and Alentejo closer to Lisbon". Accessed on 20.04.2024. URL: https://www.sulinformacao.pt/en/2022/11/plano-ferroviario-preve-travessia-do-tejo-que-poe-algarve-e-alentejo-mais-perto-de-lisboa/.

[4] RailwayPro: "Infrabel approves EUR 1 billion loan for rail projects". Accessed on 21.04.2024. URL: https://www.railwaypro.com/wp/infrabel-approves-eur-1-billion-loan-for-rail-projects/.

[5] Compania Națională de Căi Ferate: "Stadiu Proiecte CFR Febr. 2024". Accessed on 19.04.2024. URL: https://cfr.ro/wp-content/uploads/2024/03/Stadiu-proiecte-CFR-febr-2024.pdf.

[6] Ruse Chamber of Commerce and Industry: "Modernization of the Bucharest-Gyurghevo railway line: new opportunities and benefits for the Ruse region". Accessed on 19.04.2024. URL: https://rcci.bg/en/%D0%BC%D0%BE%D0%B4%D0%B5%D1%80%D0%BD%D0%B8%D0%B7%D0%B0%D1%86%D0%B8%D1%8F-%D0%BD%D0%B0-%D0%B6%D0%B5%D0%BB%D0%B5%D0%B7%D0%BE%D0%BF%D1%8A%D1%82%D0%BD%D0%B0%D1%82%D0%B0-%D0%BB%D0%B8%D0%BD%D0%B8%D1%8F/.

[7] Government.no: "National Transport Plan 2022–2033". Accessed on 14.04.2024. URL: https://www.regjeringen.no/en/dokumenter/national-transport-plan-2022-2033/id2863430/?ch=8.

[8] Jernebanedirektoratet: "Helhetlig strategi for utvikling av togtilbudet". Accessed on 14.04.2024. URL: https://www.jernbanedirektoratet.no/content/uploads/2024/01/Helhetlig-strategi-for-utvikling-av-togtilbudet.pdf.

[9] BSR Transgovernance: "MESO case Eastern Norway County Area". Accessed on 14.04.2024. URL: https://www.ostlandssamarbeidet.no/wp-content/uploads/2016/11/ENCN_task-3_7_final_13_may_2014.pdf.

[10] LTG Infra: "Elektrifikavimas". Accessed on 14.04.2024. URL: https://ltginfra.lt/elektrifikavimas/.

[11] TV3 LT: "Trumpės kelionė iš Vilniaus į Klaipėdą". Accessed on 14.04.2024. URL: https://www.tv3.lt/naujiena/lietuva/trumpes-kelione-is-vilniaus-i-klaipeda-n985239.

[12] International Railway Journal: "Spain completes new line between Xátiva and La Encina". Accessed on 15.04.2024. URL: https://www.railjournal.com/passenger/main-line/spain-completes-new-line-between-xativa-and-la-encina/.

[13] Alicante Plaza: "La Junta Directiva de AVE visita La Encina: las obras del Corredor avanzan pero no al ritmo deseado". Accessed on 15.04.2024. URL: https://alicanteplaza.es/la-juntadirectivadeavevisitalaencinalasobrasdelcorredoravanzanperonoalritmodeseado.

[14] EuroWeekly News: "Alicante to Valencia One-Hour Train Journey Becomes a Reality with New Route". Acecssed on 15.04.2024. URL: https://euroweeklynews.com/2023/09/09/alicante-to-valencia-fastest-route-is-by-train/.

[15] Bahnprojekt Stuttgart-Ulm: "Reisezeiten: Regionalverkehr und Fernverkehr". Accessed on 20.04.2024. URL: https://www.bahnprojekt-stuttgart-ulm.de/mediathek/detail/media/reisezeiten-regionalverkehr-und-fernverkehr/mediaParameter/show/Medium/.

[16] Bahnprojekt Stuttgart-Ulm: "Aktuelles im Detail: Stuttgart 21: Für Fahrgäste stets stabiler Fahrplan oberstes Ziel bei Inbetriebnahme". Accessed on 20.04.2024. URL: https://www.bahnprojekt-stuttgart-ulm.de/presse/pressemitteilungen/newsdetail/news/1667-stuttgart-21-fuer-fahrgaeste-stets-stabiler-fahrplan-oberstes-ziel-bei-inbetriebnahme/.

[17] ÖBB Infra: "Koralmbahn". Accessed on 20.04.2024. URL: https://infrastruktur.oebb.at/de/projekte-fuer-oesterreich/bahnstrecken/suedstrecke-wien-villach/koralmbahn.

[18]: ÖBB Infra: "Koralmbahn Graz–Klagenfurt". Accessed on 20.04.2024. URL: https://infrastruktur.oebb.at/de/projekte-fuer-oesterreich/bahnstrecken/suedstrecke-wien-villach/koralmbahn/rund-um-den-bau/printproduktionen-kab/dokument?datei=Streckenkarte+Koralmbahn.

[19] ÖBB Infra: "Projekt-Information Streckenausbau Wien–Bratislava". Accessed on 20.04.2024. URL: https://infrastruktur.oebb.at/de/projekte-fuer-oesterreich/bahnstrecken/weststrecke-wien-salzburg/ausbau-marchegger-ostbahn/rund-um-den-bau/printproduktionen-wbr/dokument?datei=Projektbrosch%C3%BCre_Ausbau+Wien-Bratislava_DE+%28Marchegger+Ostbahn%29.

[20] PKP Polskie Linie Kolejowe: "O inwestycji". Accessed on 21.04.2024. URL: https://poznan-szczecin.pl/o-inwestycji/.

[21] Transinfo: "Nowe perony i nowy drugi tor na linii Poznań – Szczecin". Accessed on 21.04.2024. URL: https://transinfo.pl/inforail/nowe-perony-i-nowy-drugi-tor-na-linii-poznan-szczecin/.

[22] International Railway Journal: "Upgraded Belgrade – Budapest line now set for 2025". Accessed on 21.04.2024. URL: https://www.railjournal.com/infrastructure/speeded-up-rail-link-from-belgrade-to-budapest-by-2025/.

[23] Szabad Magyar Szó: "Szabadka központjába ért a Belgrád-Budapest gyorsvasút építkezése". Accessed on 18.04.2024. URL: https://szmsz.press/2023/06/06/szabadka-kozpontjaba-ert-a-belgrad-budapest-gyorsvasut-epitkezese/.

[24] Szabad Magyar Szó: "Tizenöt kilométernyi vasutat tettek le Újvidék és Szabadka között ". Accessed: 18.04.2024. URL: https://szmsz.press/2023/08/04/tizenot-kilometernyi-vasutat-tettek-le-ujvidek-es-szabadka-kozott.

[25] RailwayPro: "Hungary awards contract to double the connection with Romania". Accessed: 18.04.2024. URL: https://www.railwaypro.com/wp/hungary-awards-contract-to-double-the-connection-with-romania/.

[26] Ministry of Foreign Affairs Directorate for EU Affairs: "Construction of Çerkezköy-Kapıkule Section of Halkalı-Kapıkule Railway Line Project". Accessed on 222.04.2024. URL: https://ab.gov.tr/52172_en.html.

[27] Daily Sabah: "Halkalı-Kapıkule railway project to connect Türkiye, Europe". Accessed on 22.04.2024. URL: https://www.dailysabah.com/turkiye/halkali-kapikule-railway-project-to-connect-turkiye-europe/news.

[28] ergose: "Installation of a modern signaling system at Thessaloniki – Idomeni single railway line". Accessed on 22.04.2024. URL: https://www.ergose.gr/project/polykastro_eidomeni-2/?lang=en.

[29] ergose: "Polikastro – Eidomeni". Accessed on 22.04.2024. URL: https://www.ergose.gr/project/polykastro_eidomeni/?lang=en.

[30] Banedanmark: "Banedanmarks Anlægsplan 2030". Accessed on 22.04.2024. URL: https://www.bane.dk/da/Borger/Publikationer/-/media/D93AB7E0ACBE4C9FA6A808D372BC6C3B.ashx.

[31] Diario de Almería: "¿Cuándo llegará el AVE a Almería?". Accessed on 20.04.2024. URL: https://www.diariodealmeria.es/almeria/llegara-AVE-Almeria_0_1300970016.html.

[32] Murcia Today: "excavation of murcia almeria high speed ave train tunnel gets underway". Accessed on 20.04.2024. URL: https://murciatoday.com/excavation_of_murcia_almeria_high_speed_ave_train_tunnel_gets_underway_1818794-a.html.

[33] Railway Technology: "Murcia-Almería High-Speed Railway, Spain". Accessed on 20.04.2024. URL: https://www.railway-technology.com/projects/murcia-almeria-high-speed-railway-spain/?cf-view.

[34] Railway Gazette: "High speed rail bypass contract awarded". Accessed on 21.04.2024. URL: https://www.railwaygazette.com/infrastructure/high-speed-rail-bypass-contract-awarded/66130.article.

[35] Tecozam: "Riofrio Viaduct - Loja Bypass". Accessed on 21.04.2024. URL: https://www.tecozam.com/en/projects/riofrio-viaduct-loja-bypass.

[36] FS Italiane: "Brennero e Fortezza – Verona". Accessed on 18.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/it/opere-strategiche/brennero-e-linea-fortezza-verona.html.

[37] BBT Info: "Der Brenner Basistunnel". Accessed on 18.04.2024. URL: https://www.bbt-se.com/fileadmin/broschueren/2022/allgemeine-broschuere/.

[38] Rynek Kolejowy: "Rozpoczęła się modernizacja linii Berlin - Szczecin po niemieckiej stronie". Accessed on 19.04.2024. URL: https://www.rynek-kolejowy.pl/wiadomosci/rozpoczela-sie-modernizacja-linii-berlin--szczecin-po-niemieckiej-stronie-105682.html.

[39] DB BauInfoPortal: "Angermünde – Grenze D/PL (– Szczecin)". Accessed on 19.04.2024. URL: https://bauprojekte.deutschebahn.com/p/angermuende-stettin.

[40] Občina Žirovnica: "Državni prostorski načrt za nadgradnjo železniške proge Ljubljana—Kranj—Jesenice—državna meja v koridorju obstoječe proge -mnenja občanov". Accessed on 19.04.2024. URL: https://zirovnica.si/drzavni-prostorski-nacrt-za-nadgradnjo-zelezniske-proge-ljubljana-kranj-jesenice-drzavna-meja-v-koridorju-obstojece-proge-mnenja-obcanov/.

[41] International Railway Journal: "Slovenia Secures EU Funding for Maribor Sentilj Upgrade". Accessed on 19.04.2024. URL: https://www.railjournal.com/regions/europe/slovenia-secures-eu-funding-for-maribor-sentilj-upgrade/.

[42] FS Italiane: "Terzo Valico - Nodo di Genova". Accessed on 22.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/it/opere-strategiche/terzo-valico.html.

[43] FS Italiane: "Brescia-Verona-Padua HS/HC Line". Accessed on 22.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/brescia-verona-padua-hs-hc-line.html.

[44] FS Italiane: "Taranto - Metaponto – Potenza". Accessed on 22.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/taranto-metaponto-potenza.html.

[45] FS Italiane: "Expansion of the Salerno-Reggio Calabria railway line". Accessed on 22.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/expansion-of-the-salerno-reggio-calabria-railway-line.html.

[46] FS Italiane: "Venice-Trieste line". Accessed on 22.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/expansion-of-the-venice-trieste-line-.html

[47] InTrieste: "Railway Transformation: Cutting Travel Time from Trieste to Venice". Accessed on 22.04.2024. URL: https://www.intrieste.com/2023/11/25/railway-transformation-cutting-travel-time-from-trieste-to-venice/.

[50] RailwayPro: "Serbia obtains EU grant for Corridor X". Accessed on 19.04.2024. URL: https://www.railwaypro.com/wp/serbia-obtains-eu-grant-for-corridor-x/.

[51] International Railway Journal: "Terna to construct western Bulgarian line". Accessed on 19.04.2024. URL: https://www.railjournal.com/infrastructure/terna-to-reconstruct-western-bulgarian-line/.

[52] Mirela: "Construction of the new Sofia to Vidin railway". Accessed on 19.04.2024. URL: https://m.mirela.bg/en/bulgarian-real-estates/Construction-of-the-new-Sofia-to-Vidin-railway-offer6714.html.

[53] International Railway Journey: "€2.3bn Vidin-Sofia rail modernization plan outlined". Accessed on 19.04.2024. URL: https://www.railjournal.com/infrastructure/e2-3bn-vidin-sofia-rail-modernisation-plan-outlined.

[54] EBRD: "From Tirana to Durres by train in 20 minutes". Accessed on 19.04.2024. URL: https://www.ebrd.com/news/video/from-tirana-to-durres-by-train-in-20-minutes.html.

[55] RailwayPro: "Underground concept proposed for Patras railway link". Accessed on 20.04.2024. URL: https://www.railwaypro.com/wp/underground-concept-proposed-for-patras-railway-link/.

[56] Euronoise: "The InterCity Initiative – railway development in Norway". Accessed on 18.04.2024. URL: https://www.euronoise2018.eu/docs/papers/229_Euronoise2018.pdf.

[57] Diario de Burgos: "Las obras del AVE a Vitoria, como pronto en 2027". Accessed on 18.04.2024. URL: https://www.diariodeburgos.es/Noticia/Z69416026-DAB6-13B1-A1E5E824D5A9E7DF/202303/Las-obras-del-AVE-a-Vitoria-como-pronto-en-2027.

[58] Heraldo: "Nueva línea AVE Navarra-Zaragoza: el acceso por Plaza costaría un 41% menos que por Casetas". Accessed on 18.04.2024. URL: https://www.heraldo.es/noticias/aragon/2023/04/10/ave-navarra-zaragoza-alternativas-acceso-por-plaza-costaria-menos-que-por-casetas-1643863.html.

[59] Heraldo: "El AVE Zaragoza-Navarra se estrenará en 2027 con la mitad del viaje por vía convencional". Accessed on 18.04.2024. URL: https://www.heraldo.es/noticias/aragon/2023/01/07/el-ave-zaragoza-navarra-se-estrenara-en-2027-con-la-mitad-del-viaje-por-via-convencional-1622954.html.

[60] International Railway Journal: "Eastern Slovakia line upgrade contract awarded". Accessed on 20.04.2024. URL: https://www.railjournal.com/infrastructure/eastern-slovakia-line-upgrade-contract-awarded/.

[61] Želenice Slovenskej Republiky: "Annual Report 2022". Accessed: 20.04.2024. URL: https://www.zsr.sk/files/o-nas/vyrocne-spravy/annualreport2022.pdf.

[62] RailFreight.com: "Koper-Divaca rail line financing takes final and cheaper than expected form". Accessed: 20.04.2024. URL: https://www.railfreight.com/infrastructure/2023/05/31/koper-divaca-rail-line-financing-takes-final-and-cheaper-than-expected-form/.

[63] Total Slovenia News: "Breakthrough at First Koper-Divača Rail Track Tunnel". Accessed on 20.04.2024. URL: https://www.total-slovenia-news.com/business/10132-breakthrough-at-first-koper-divaca-rail-track-tunnel.

[64] FS Italiane: "Naples-Bari". Accessed on 21.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/napoli-bari-.html.

[65] FS Italiane: "Development of the Orte-Falconara". Accessed on 21.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/strengthening-and-development-of-the-orte-falconara.html.

[66] Railway Technology: "Nis-Dimitrovgrad Railway Line Rehabilitation, Serbia ". Accessed: 20.04.2024. URL: https://www.railway-technology.com/projects/nis-dimitrovgrad-railway-line-rehabilitation-serbia/?cf-view.

[67] Eesti Raudtee: "Electrification of Estonian Railways 2020-2028". Accessed: 18.04.2024. URL: https://www.evr.ee/files/Electrification-of-Estonian-Railways-2020-2028.pdf.

[68] Euskal Trenbide Sarea: "Nueva red ferroviaroa del pais vasco en el territorio historico de Gipuzkoa". Accessed on 20.04.2024. URL: https://www.ets-rfv.euskadi.eus/contenidos/informacion/etst_transparencia/es_oficinas/adjuntos/200630-Informe-trimestral-Cast.pdf.

[69] Railway Gazette: "Spain: 'Basque Y' inches ahead". Accessed on 20.04.2024. URL: https://www.railwaygazette.com/in-depth/spain-basque-y-inches-ahead/61348.article.

[70] Femern: "Faktenblatt zum Fehmarnbelt-Tunnel". Accessed on 22.04.2024. URL: https://femern.com/media/m0mhwglv/231024_faktenblatt_presse_fehmarnbelt-tunnel_oktober_2023.pdf.

[71] Femern: "Fakten zur Fehmarnbelt-Querung". Accessed on 20.04.2024. URL: https://www.femern.info/de/fakten-zur-fehmarnbelt-querung.

[72] Railway International: "A major Belgian rail link re-electrified using a technology never seen before in Europe". Accessed on 21.04.2024. URL: https://www.railway-international.com/news/57339-a-major-belgian-rail-link-re-electrified-using-a-technology-never-seen-before-in-europe.

[73] Berlin-Dresden: "Korridor Berlin–Dresden". Accessed on 19.04.2024. URL: https://www.berlin-dresden.de/home.html.

[74] RailwayPro: "STH releases investor variant for a new high-speed connection". Accessed on 19.04.2024. URL: https://www.railwaypro.com/wp/sth-releases-investor-variant-for-a-new-high-speed-connection/.

[75] FS Italiane: "Brescia-Verona-Padua HS/HC Line". Accessed on 21.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/brescia-verona-padua-hs-hc-line.html.

[76] FS Italiane: "Doubling Genoa-Ventimiglia". Accessed on 21.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/completion-of-the-track-doubling-for-the-genoa-ventimiglia-line-.html.

[77] Rail Baltica: "In brief". Accessed on 20.04.2024. URL: https://info.railbaltica.org/en/in-brief.

[78] Infrastruturas de Portugal: "Linha de alta velocidade Porto – Lisboa". Accessed: 18.04.2024. URL: https://www.infraestruturasdeportugal.pt/sites/default/files/inline-files/ApresentacaoProjetoAV_28Set2022.pdf.

[79] RailFreight.com: "Spain launches more tenders for Mediterranean Corridor upgrades". Accessed: 19.04.2024. URL: https://www.railfreight.com/corridors/2023/11/14/spain-launches-more-tenders-for-mediterranean-corridor-upgrades/.

[80] el Periodico: "Extremadura: AVE con destino a 2030". Accessed on 19.04.2024. URL: https://www.elperiodicoextremadura.com/extremadura/2021/01/03/extremadura-ave-destino-2030-43801239.html.

[81] ERTMS.nl: "Where will ERTMS be deployed?". Accessed on 22.04.2024. URL: https://www.ertms.nl/english/about-ertms/where/default.aspx.

[82] Leipzig-Dresden: "Sachsen kommt sich näher". Accessed on 22.04.2024. URL: https://www.leipzig-dresden.de/home.html.

[83] Frankfurt-Mannheim: "Projekt auf einen Blick". Accessed on 22.04.2024. URL: https://www.frankfurt-mannheim.de/auf-einen-blick.html.

[84] VDE8.1: "Der Streckenabschnitt VDE 8.1 Ausbaustrecke Nürnberg–Ebensfeld". Accessed on 22.04.2024. URL: https://www.vde8.de/de/projektabschnitte/ausbaustrecke-nuernberg-bamberg/ueberblick.

[85] ÖBB Infra: "Semmering-Basistunnel". Accessed on 21.04.2024. URL: https://infrastruktur.oebb.at/de/projekte-fuer-oesterreich/bahnstrecken/suedstrecke-wien-villach/semmering-basistunnel.

[86] Správa železnic: "Modernizace trati Plzeň - Domažlice ". Accessed on 21.04.2024. URL: https://www.spravazeleznic.cz/modernizace-trati-plzen-domazlice/casto-kladene-otazky.

[87] Správa železnic: "Praha-Beroun Přínosy projektu". Accessed on 21.04.2024. URL: https://www.spravazeleznic.cz/praha-beroun/prinosy-projektu.

[88] FS Italiane: "Palermo-Catania-Messina". Accessed on 19.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/palermo-catania-messina.html.

[89] FS Italiane: "Rome-Pescara". Accessed on 19.04.2024. URL: https://www.fsitaliane.it/content/fsitaliane/en/strategic-projects/rome-pescara-line-.html.

[90] RailFreight.com: "Croatia will construct new railway to port of Rijeka". Accessed on 20.04.2024. URL: https://www.railfreight.com/policy/2019/05/03/croatia-will-construct-new-railway-to-port-of-rijeka/.

[91] HZ Infra: "EU FONDOVI KARTA 30 1 2024 ENG". Accessed on 20.04.2024. URL: https://eng.hzinfra.hr/wp-content/uploads/2024/01/EU-FONDOVI-KARTA-30-1-2024-ENG-.pdf.

[92] Railway Technology: "Plovdiv-Burgas Railway Line Phase Two Rehabilitation Project, Bulgaria. Accessed on 22.04.2024. URL: https://www.railway-technology.com/projects/plovdiv-burgas-phase-two-railway-line-rehabilitation-project/?cf-view.

[93] Sofia Globe: "New railway line to cut Sofia – Plovdiv travelling time 'by an hour'". Accessed on 22.04.2024. URL: https://sofiaglobe.com/2019/06/11/new-railway-line-to-cut-sofia-plovdiv-travelling-time-by-an-hour/.

[94] National Railway Infrastructure Company: "Modernization of railway section Elin Pelin – Kostenetz". Accessed on 22.04.2024. URL: https://www.rail-infra.bg/en/251.

[95] EBRD: "Non-Technical Summary Railway Corridor VIII - Eastern section". Accessed on 22.04.2024. URL: https://www.ebrd.com/english/pages/project/eia/42921.pdf.

[96] Rail Target: "Adif AV Gives a New Boost to the Palencia-Santander HSL with the Contracting of the Palencia-Palencia Norte Stretch". Accessed on 19.04.2024. URL: https://www.railtarget.eu/technologies-and-infrastructure/adif-av-gives-a-new-boost-to-the-palenciasantander-hsl-with-the-contracting-of-the-palenciapalencia-norte-stretch-4222.html.

[97] Wunderlinie.nl: "Wunderlinie: the connecting link in the North Sea – Baltic Ten-T corridor". Accessed on 24.04.2024. URL: https://www.wunderline.nl/fileadmin/user_upload/wunderline/Wunderline_PositionPaper_apr24.pdf.

[98] Helsinki Times: "Berner: New rail link between Helsinki and Turku set to be completed in 2031". Accessed on 23.04.2024. URL: https://www.helsinkitimes.fi/finland/finland-news/domestic/15886-berner-new-rail-link-between-helsinki-and-turku-set-to-be-completed-in-2031.html.

[99] Regjeringen.no: "Statlig plan for Ringeriksbanen og ny E16 er vedtatt". Accessed on 23.04.2024. URL: https://www.regjeringen.no/no/dokumentarkiv/regjeringen-solberg/aktuelt-regjeringen-solberg/kmd/pressemeldinger/2020/statlig-plan-for-ringeriksbanen-og-ny-e16-er-vedtatt/id2695504/.

[100] TELT: "FAQ". Accessed on 21.04.2024. URL: https://www.telt.eu/en/multimedia-en/faq-lyon-turin/.

[101] International Railway Journal: "French Government commits €4bn to Bordeaux-Toulouse Project". Accessed on 21.04.2024. URL: https://www.railjournal.com/passenger/high-speed/french-government-commits-e4bn-to-bordeaux-toulouse-hs-project.

[102] Trafikverket: "The Varberg tunnel". Accessed on 23.04.2024. URL: https://bransch.trafikverket.se/en/startpage/projects/Railway-construction-projects/The-Varberg-tunnel/.

[103] Gov.uk: "PM redirects HS2 funding to revolutionise transport across the North and Midlands". Accessed on 18.04.2024. URL: https://www.gov.uk/government/news/pm-redirects-hs2-funding-to-revolutionise-transport-across-the-north-and-midlands.

[104] Gov.uk: "Network North". Accessed on 18.04.2024. URL: https://www.gov.uk/government/publications/network-north.

[105] Jernbaneverket: "InterCity: Ostfoldbanen". Accessed on 23.04.2024. URL: http://www.jernbaneverket.no/Prosjekter/Inter-City-/Ostfoldbanen/.

[106] BVWP Projekte: "Korridor Berlin – Hannover – Bielefeld". Accessed on 18.04.2024. URL: https://www.bvwp-projekte.de/schiene_2018/2-016-V02/2-016-V02.html.

[107] Vysokorychlostní tratě: "Praha - Brno - Ostrava a Brno - Břeclav". Accessed on 20.04.2024. URL: https://vrtky.cz/useky-a-mapy/praha-brno-ostrava-a-brno-breclav.

[108] CPK: "Nowa linia kolejowa Łódź – Sieradz – Wrocław. CPK przedstawia wariant inwestorski". Accessed on 19.04.2024. URL: https://www.cpk.pl/pl/aktualnosci-2/nowa-linia-kolejowa-lodz-sieradz-wroclaw-cpk-przedstawia-wariant-inwestorski.

[109] CPK: "Program wieloletni". Accessed on 19.04.2024. URL: https://www.cpk.pl/pl/inwestycja/program-wieloletni.

[110] Railway News: "Poland CPKs High-Speed Rail Tunnel in Lodz receives additional permit". Accessed on 19.04.2024. URL: https://railway-news.com/poland-cpks-high-speed-rail-tunnel-in-lodz-receives-additional-permit.

[111] Trafikverket: "The East Link, a new doubletrack railway". Accessed on 23.04.2024. URL: https://bransch.trafikverket.se/en/startpage/projects/Railway-construction-projects/ostlanken-east-link-project.

[112] SBB: "Zimmerberg-Basistunnel 2". Accessed on 18.04.2024. URL: https://company.sbb.ch/de/ueber-die-sbb/projekte/deutschschweiz/region-zuerich/zuerich-zug-luzern-studie-zimmerberg-basistunnel-2.html.

[113] SBB: "Nutzen für die Reisenden". Accessed on 18.04.2024. URL: https://company.sbb.ch/de/ueber-die-sbb/projekte/deutschschweiz/region-zuerich/bauprojekte-region-winterthur/zuerich-winterthur-bruettenertunnel/nutzen-fuer-die-reisenden.html.

[114] BAV: "Ausbauschritt 2035: Projekte und Nutzen". Accessed on 18.04.2024. URL: https://www.bav.admin.ch/dam/bav/de/dokumente/themen/fabi-step/as2035_faktenblatt_projekte_nutzen.pdf.download.pdf/Ausbauschritt%202035_Projekte%20und%20Nutzen.pdf.

[115] Fulda-Gerstungen: "Vorzugsvariante". Accessed on 20.04.2024. URL. https://www.fulda-gerstungen.de/vorzugsvariante.html.

[116] ÖBB Infra: "Bahnprojekt Brenner-Nordzulauf". Accessed on 20.04.2024. URL: https://www.brennernordzulauf.eu/newsreader/2022-07-13-meilenstein-beim-brenner-nordzulauf-gesamtverlauf-der-neubaustrecke-steht-fest.html.

[117] ÖBB Infra: "Projekt-Information: Streckenausbau Wien – Bratislava". Accesseed on 20.04.2024. URL: https://infrastruktur.oebb.at/de/projekte-fuer-oesterreich/bahnstrecken/weststrecke-wien-salzburg/ausbau-marchegger-ostbahn/rund-um-den-

bau/printproduktionen-wbr/dokument?datei=Projektbrosch%C3%BCre_Ausbau+Wien-Bratislava_DE+%28Marchegger+Ostbahn%29.

[118] NAO.uk: "The Transpennine Route Upgrade Programme". Accessed on 18.04.2024. URL: https://www.nao.org.uk/press-releases/the-transpennine-route-upgrade-programme/.

[119] Karlsruhe-Basel: "Ausbau- und Neubaustrecke Karlsruhe-Basel". Accessed on 20.04.2024. URL: https://www.karlsruhe-basel.de/home.html.

[120] Ceser: "Le Grand Projet ferroviaire du Sud-Ouest (GPSO)". Accessed on 20.04.2024. URL: https://ceser-nouvelle-aquitaine.fr/sites/default/files/2023-04/2023_04_19_Rapport_GPSO_Vot%C3%A9%20%26%20finalis%C3%A9%20%26%20ISBN2.pdf.

[121] LNMP: "Ligne Nouvelle Montpellier-Perpignan". Accessed on 20.04.2024. URL: https://www.ligne-montpellier-perpignan.com/.

[122] Dresden-Praha: "Chancen & Nutzen: Doppelt so schnell von Dresden nach Prag". Accessed on 20.04.2024. URL: https://www.dresden-praha.eu/de/chancen.

[123] Norrbotniabanan: "Norrbottniabanan: The North Bothania Line". Accessed on 23.04.2024. URL: https://norrbotniabanan.se/eng/.

[124] International Railway Journal: "Portugal to link largest cities with high-speed rail by 2050". Accessed on 19.04.2024. URL: https://www.railjournal.com/infrastructure/portugal-to-link-largest-cities-with-high-speed-rail-by-2050.

[125] DB InfraGO: "Bahnprojekt Hannover–Bielefeld". Accessed on 20.04.2024. URL: https://www.hannover-bielefeld.de/.

[126] Správa železnic: "VRT Moravská brána I". Accessed on 20.04.2024. URL: https://www.spravazeleznic.cz/vrt/moravska-brana.

D – Network Edges Raw Data

Table 12: Travel times (realistic and potential; current and future) of the core network's edges.

city 1 / start	city 2 / end	t_{real} [min] (current)	t_{pot} [min] (current)	t_{real} [min] (future)	t_{pot} [min] (future)
A Coruña	Santiago de Compostela	28	20.3938277	28	20.3938277
Aalborg	Aarhus	78	58.8812359	60	47.1261724
Aarhus	Esbjerg	140	78.9853135	140	78.9853135
Aarhus	Odense	92	65.5284013	87	61.9012768
Aarhus	Padborg	121	87.7663768	121	87.7663768
Aberdeen	Edinburgh	140	111.0684	140	111.0684
Aberdeen	Inverness	132	101.011521	132	101.011521
Aberdeen	Perth	92	78.3674723	92	78.3674723
Ajaccio	Bastia	226	107.09335	226	107.09335
Ajaccio	Calvi	309	158.218142	309	158.218142
Alexandroupolis	Çorlu	X	143.984849	168.489362	143.984849
Alexandroupolis	Edirne	X	112.258476	145.291959	112.258476
Alexandroupolis	Thessaloniki	502	264.656638	502	264.656638
Algeciras	Antequera	172	88.1398317	172	88.1398317
Alicante	Almería	X	268.259507	425.715217	268.259507
Alicante	Cartagena	148	52.2709344	148	52.2709344
Alicante	Córdoba	298	176.936683	298	176.936683
Alicante	Madrid	142	112.137795	142	112.137795
Alicante	Murcia	54	34.0866543	54	34.0866543
Alicante	Valencia	128	79.651809	60	34.0150516
Almería	Granada	166	81.1892545	65	37.2176043
Almería	Murcia	-	-	65	37.2176043
Alvesta	Gothenburg	155	110.039915	155	110.039915
Alvesta	Hallsberg	157	97.0659208	157	97.0659208
Alvesta	Kalmar	80	52.2277441	80	52.2277441
Alvesta	Linköping	84	67.1537184	84	67.1537184
Alvesta	Malmö	79	57.4927329	79	57.4927329
Amsterdam	Rotterdam	38	25.579039	38	25.579039
Amsterdam	The Hague	50	28.6237043	50	28.6237043
Amsterdam	Utrecht	26	20.3439998	23.5637131	14.74
Amsterdam	Zwolle	65	43.5845892	50.2580939	37.52
Ancona	Bologna	106	71.0416961	106	71.0416961
Ancona	Perugia	160	83.1362536	150	95.0376476
Ancona	Pescara	70	53.1921164	70	53.1921164
Ancona	Rome	215	119.587645	185	116.236938
Antequera	Cádiz	216	92.0691058	216	92.0691058
Antequera	Córdoba	32	23.6187905	32	23.6187905
Antequera	Granada	58	36.8181022	35	18.0022878
Antequera	Málaga	18	17.5538999	18	17.5538999
Antequera	Seville	99	49.4089233	75	43.6227099
Antwerp	Brussels	35	25.084123	35	25.084123
Antwerp	Eindhoven	92	45.657257	92	45.657257
Antwerp	Ghent	57	36.1296867	57	36.1296867

Antwerp	Liège	78	40.5959761	78	40.5959761
Antwerp	Rotterdam	32	28.3956711	32	28.3956711
Arad	Deva	132	122.081297	90.5686503	55.93
Arad	Oradea	145	98.3885647	145	98.3885647
Arad	Szeged	271	98.8258139	271	98.8258139
Arad	Szolnok	171	65.1372026	95.7869931	64.1372026
Arad	Timișoara	85	45.4267975	64.7540432	40.02
Arnhem	Duisburg	61	42.4122395	61	42.4122395
Arnhem	Eindhoven	80	46.1725531	80	46.1725531
Arnhem	Münster	165	74.5841423	165	74.5841423
Arnhem	Utrecht	34	25.3614792	34	25.3614792
Arnhem	Zwolle	60	39.8361855	60	39.8361855
Arth-Goldau	Basel	101	56.3529287	101	56.3529287
Arth-Goldau	Bern	100	62.8175759	100	62.8175759
Arth-Goldau	Lugano	69	48.2359715	69	48.2359715
Arth-Goldau	Vaduz/Schaan	144	66.374931	144	66.374931
Arth-Goldau	Zurich	40	29.9136224	34	27.3229461
Athens	Larissa	202	117.902503	202	117.902503
Athens	Patras	-	-	110	74.4702398
Avignon	Dijon	183	107.783429	183	107.783429
Avignon	Grenoble	116	66.6511872	116	66.6511872
Avignon	Lyon	63	51.9206479	63	51.9206479
Avignon	Marseille	34	21.1237678	34	21.1237678
Avignon	Montpellier	70	21.549143	70	21.549143
Bacău	Brașov	348	209.259789	348	209.259789
Bacău	Bucharest	247	188.547251	247	188.547251
Bacău	Constanța	349	212.098044	349	212.098044
Bacău	Galați	237	125.618302	237	125.618302
Bacău	Iași	117	97.0504344	117	97.0504344
Bacău	Suceava	100	81.3304824	100	81.3304824
Badajoz	Entroncamento	165	94.4330767	165	94.4330767
Badajoz	Lisbon	-	-	80	48.7056477
Badajoz	Madrid	266	167.855859	151	92.3015119
Badajoz	Seville	267	139.039549	267	139.039549
Bălți	Ungheni	94	121.800006	94	121.800006
Banja Luka	Novi Sad	X	240.248428	346.805825	240.248428
Banja Luka	Osijek	X	175.157183	264.079765	175.157183
Banja Luka	Sarajevo	X	228.942346	334.97625	228.942346
Banja Luka	Zagreb	X	162.754781	248.912355	162.754781
Banská Bystrica	Budapest	334	152.37253	334	152.37253
Banská Bystrica	Győr	438	146.040775	438	146.040775
Banská Bystrica	Miskolc	405	121.591241	405	121.591241
Banská Bystrica	Žilina	99	66.512543	99	66.512543
Bar	Podgorica	59	44.2686291	59	44.2686291
Barcelona	Girona	38	28.8970113	38	28.8970113
Barcelona	Valencia	172	111.782245	172	111.782245
Barcelona	Zaragoza	83	74.3682739	83	74.3682739
Bari	Foggia	57	43.9272405	57	43.9272405
Bari	Lecce	80	59.0938956	80	59.0938956

Bari	Taranto	80	43.4839921	80	43.4839921
Basel	Bern	58	40.9600901	58	40.9600901
Basel	Dijon	85	67.4784801	85	67.4784801
Basel	Freiburg	40	27.0202546	27	22.00189
Basel	Lausanne	133	83.6931362	133	83.6931362
Basel	Strasbourg	78	46.3011708	78	46.3011708
Basel	Zurich	53	41.2516845	53	41.2516845
Bastia	Calvi	259	135.651962	259	135.651962
Bayonne	Bordeaux	107	78.0484287	77	54.1690456
Bayonne	San Sebastián	82	31.8476608	82	31.8476608
Bayonne	Toulouse	203	149.03509	125	84.9978152
Belfast	Derry	121	90.4604939	121	90.4604939
Belfast	Dublin	125	94.3864116	125	94.3864116
Belgrade	Niš	332	234.633731	100	73.3116473
Belgrade	Novi Sad	36	33.6555234	36	33.6555234
Belgrade	Osijek	X	116.525929	178.133429	116.525929
Belgrade	Podgorica	587	472.440396	587	472.440396
Belgrade	Sarajevo	X	317.73812	461.369599	317.73812
Belgrade	Timișoara	X	119.912573	181.639768	119.912573
Bergen	Drammen	367	281.605385	367	281.605385
Bergen	Oslo	-	-	354	259.489341
Berlin	Dresden	110	78.0277784	80	58.2907121
Berlin	Erfurt	97	74.9656724	97	74.9656724
Berlin	Hamburg	104	82.5590127	104	82.5590127
Berlin	Hanover	101	72.5831273	85	61.877566
Berlin	Leipzig	73	54.8096023	73	54.8096023
Berlin	Lübeck	166	92.3750207	166	92.3750207
Berlin	Poznań	165	109.65927	165	109.65927
Berlin	Rostock	120	93.4160602	120	93.4160602
Berlin	Szczecin	185	76.1096264	90	66.696535
Bern	Brig	66	42.6470053	66	42.6470053
Bern	Lausanne	67	53.0037008	67	53.0037008
Bern	Zurich	56	47.7290107	56	47.7290107
Białystok	Olsztyn	235	148.686111	235	148.686111
Białystok	Suwałki	109	84.3934443	79	60.8051202
Białystok	Warsaw	129	84.5278624	87	65.8825817
Bielefeld	Bremen	116	71.2309715	116	71.2309715
Bielefeld	Dortmund	46	31.9474652	46	31.9474652
Bielefeld	Hanover	50	40.102649	31	23.1395441
Bielefeld	Münster	57	36.047164	57	36.047164
Bilbao	Burgos	151	103.700409	151	103.700409
Bilbao	San Sebastián	211	91.3912915	55	30.8124988
Bilbao	Santander	192	76.1083495	192	76.1083495
Bilbao	Vitoria-Gasteiz	153	83.0945538	43	23.1263722
Bilbao	Zaragoza	269	177.182457	269	177.182457
Birmingham	Bristol	71	59.7970996	71	59.7970996
Birmingham	Carlisle	173	115.37179	166	120.213758
Birmingham	Leicester	57	33.1631604	57	33.1631604
Birmingham	Liverpool	100	59.5729623	93	66.221597

Birmingham	London	76	63.7249536	49	33.6783769
Birmingham	Manchester	90	55.8828527	90	55.8828527
Birmingham	Nottingham	77	37.2536308	77	37.2536308
Birmingham	Sheffield	60	47.979485	60	47.979485
Birmingham	Southampton	159	98.898354	159	98.898354
Bitola	Veles	150	108.042826	150	108.042826
Boden	Kiruna	185	145.660069	185	145.660069
Boden	Luleå	27	16.0352628	27	16.0352628
Boden	Tornio	X	68.5720804	96.4925964	68.5720804
Boden	Umeå	195	153.131877	195	153.131877
Bodø	Trondheim	586	442.248382	586	442.248382
Bologna	Florence	37	23.5268982	37	23.5268982
Bologna	Genoa	166	92.0888843	166	92.0888843
Bologna	Milan	64	48.9779341	64	48.9779341
Bologna	Venice	82	53.8490394	82	53.8490394
Bologna	Verona	52	37.7601561	52	37.7601561
Bolzano	Innsbruck	123	80.456779	55	39.7165934
Bolzano	Verona	90	63.2675882	30	22.3543654
Bordeaux	La Rochelle	140	99.3396343	140	99.3396343
Bordeaux	Limoges	143	89.8465962	143	89.8465962
Bordeaux	Toulouse	136	97.0201881	60	43.250523
Bordeaux	Tours	105	65.9554316	105	65.9554316
Bourges	Clermont-Ferrand	148	80.8027124	148	80.8027124
Bourges	Dijon	202	129.522402	202	129.522402
Bourges	Limoges	135	87.0268545	135	87.0268545
Bourges	Lyon	201	126.942469	201	126.942469
Bourges	Paris	120	81.2241522	120	81.2241522
Bourges	Tours	82	60.9681244	82	60.9681244
Braga	Ourense	408	99.0545406	408	99.0545406
Braga	Porto	36	23.945453	36	23.945453
Braga	Vigo	150	76.7213331	30	18.2457979
Brașov	Bucharest	148	105.059846	148	105.059846
Brașov	Cluj-Napoca	381	213.225277	271.757662	167.6
Brașov	Deva	330	172.263446	254.380261	156.89
Brașov	Galați	309	212.499635	309	212.499635
Bratislava	Brno	100	67.1421911	100	67.1421911
Bratislava	Győr	82	54.5157982	82	54.5157982
Bratislava	Vienna	46	36.0326098	40	26.4889328
Bratislava	Žilina	123	82.4978077	123	82.4978077
Bregenz	Feldkirch	31	15.8149416	31	15.8149416
Bregenz	Munich	122	99.2606639	122	99.2606639
Bregenz	Ulm	96	61.8116483	96	61.8116483
Bregenz	Zurich	87	60.4387689	79	55.8424385
Bremen	Groningen	-	-	131	100.149593
Bremen	Hamburg	57	42.2582723	57	42.2582723
Bremen	Hanover	59	47.4983901	59	47.4983901
Bremen	Münster	75	59.9344994	75	59.9344994
Bremen	Zwolle	205	118.264202	205	118.264202
Brest	Rennes	120	93.6226208	120	93.6226208

Brig	Lausanne	102	62.2817988	102	62.2817988
Brig	Milan	119	73.6849717	119	73.6849717
Brig	Turin	185	89.0136605	185	89.0136605
Bristol	Exeter	57	47.3595645	57	47.3595645
Bristol	London	76	60.652289	76	60.652289
Bristol	Southampton	100	64.6466226	100	64.6466226
Bristol	Swansea	85	62.2894125	85	62.2894125
Brno	Hradec Králové	133	86.164137	133	86.164137
Brno	Ostrava	165	89.2820073	36	6.36681975
Brno	Prague	148	116.968484	148	116.968484
Brno	Vienna	87	64.2580608	60	37.780678
Bruges	Ghent	22	17.9515227	12.9660596	13.3
Bruges	Lille	100	43.4634186	100	43.4634186
Brussels	Ghent	28	22.4104937	28	22.4104937
Brussels	Liège	44	33.3638844	44	33.3638844
Brussels	Lille	33	27.0285181	33	27.0285181
Brussels	Luxembourg	196	109.692745	120	73.7554751
Bucharest	Constanța	150	99.3768807	150	99.3768807
Bucharest	Craiova	243	120.645891	243	120.645891
Bucharest	Galați	217	159.399133	217	159.399133
Bucharest	Pitești	111	63.8947396	111	63.8947396
Bucharest	Ruse	210	101.371948	80	47.3876114
Budapest	Győr	65	59.9155371	65	59.9155371
Budapest	Miskolc	134	97.3939626	134	97.3939626
Budapest	Pécs	147	119.956308	147	119.956308
Budapest	Subotica	-	-	72	53.9683326
Budapest	Szeged	127	102.819387	127	102.819387
Budapest	Szolnok	80	48.8234789	80	48.8234789
Budapest	Varaždin	346	166.642801	346	166.642801
Budapest	Zagreb	377	199.537151	377	199.537151
Burgas	Edirne	345	165.581197	345	165.581197
Burgas	Shumen	320	132.285816	320	132.285816
Burgas	Stara Zagora	123	84.0481648	88	51.0707593
Burgas	Varna	213	135.874771	213	135.874771
Burgos	León	76	52.4665606	76	52.4665606
Burgos	Santander	238	141.567368	178	109.595297
Burgos	Valladolid	39	28.8534473	39	28.8534473
Burgos	Vitoria-Gasteiz	80	51.9600575	30	14.799735
Bydgoszcz	Gdańsk	80	67.7364023	80	67.7364023
Bydgoszcz	Kraków	351	219.70298	351	219.70298
Bydgoszcz	Łódź	165	117.761828	165	117.761828
Bydgoszcz	Olsztyn	181	108.549688	181	108.549688
Bydgoszcz	Poznań	81	66.0742674	81	66.0742674
Bydgoszcz	Warsaw	178	127.24663	178	127.24663
Cádiz	Córdoba	154	82.3126374	154	82.3126374
Cádiz	Seville	83	57.7276071	83	57.7276071
Caen	Cherbourg-Octe-ville	70	47.9282247	70	47.9282247
Caen	Le Havre	159	98.3853082	159	98.3853082

Caen	Le Mans	106	67.4729296	106	67.4729296
Caen	Paris	115	89.3966891	115	89.3966891
Cagliari	Olbia	254	140.321095	254	140.321095
Cagliari	Sassari	183	126.662572	183	126.662572
Carlisle	Edinburgh	76	60.0059368	76	60.0059368
Carlisle	Glasgow	73	61.2402634	73	61.2402634
Carlisle	Leeds	161	95.5931111	161	95.5931111
Carlisle	Liverpool	129	77.976765	129	77.976765
Carlisle	Manchester	108	73.5992407	108	73.5992407
Carlisle	Newcastle upon Tyne	80	67.2621712	80	67.2621712
Carlisle	Perth	150	99.1300328	150	99.1300328
Cartagena	Murcia	50	26.4778137	50	26.4778137
Cherbourg-Octe-ville	Rennes	223	126.036728	223	126.036728
Chișinău	Ungheni	180	166.113131	180	166.113131
Clermont-Ferrand	Dijon	260	141.023001	260	141.023001
Clermont-Ferrand	Limoges	225	146.225722	225	146.225722
Clermont-Ferrand	Lyon	145	110.143341	145	110.143341
Clermont-Ferrand	Reims	343	175.308512	343	175.308512
Cluj-Napoca	Deva	222	106.826197	147.860528	91.24
Cluj-Napoca	Oradea	229	109.960114	130.223521	80.37
Cluj-Napoca	Pitești	638	334.841698	638	334.841698
Cluj-Napoca	Suceava	399	263.190877	399	263.190877
Coimbra	Entroncamento	60	41.7249054	60	41.7249054
Coimbra	Guarda	150	91.7295929	127	77.7084604
Coimbra	Lisbon	-	-	51	33.5674724
Coimbra	Porto	69	40.7761295	30	21.3706204
Cologne	Düsseldorf	28	17.1143977	28	17.1143977
Cologne	Eindhoven	131	64.0033481	131	64.0033481
Cologne	Frankfurt	63	46.3847386	63	46.3847386
Cologne	Liège	62	41.6467166	62	41.6467166
Cologne	Mannheim	88	64.4057549	88	64.4057549
Cologne	Wuppertal	29	22.5952161	29	22.5952161
Constanța	Galați	237	143.078451	237	143.078451
Constanța	Iași	477	269.708674	477	269.708674
Copenhagen	Lübeck	-	-	110	76.7914742
Copenhagen	Malmö	38	17.2434838	38	17.2434838
Copenhagen	Odense	69	54.1686804	60	47.1261724
Córdoba	Madrid	118	85.0470815	118	85.0470815
Córdoba	Murcia	404	185.098771	404	185.098771
Córdoba	Seville	42	33.5601606	42	33.5601606
Córdoba	Valencia	218	152.399162	218	152.399162
Cork	Dublin	152	133.512161	152	133.512161
Cork	Limerick	99	63.1530757	99	63.1530757
Cork	Waterford	184	108.790956	184	108.790956
Cosenza	Naples	177	106.270245	105	67.7814168
Cosenza	Taranto	178	86.4086523	178	86.4086523
Cosenza	Villa San Giovanni	127	67.8681966	127	67.8681966
Craiova	Deva	337	187.93005	337	187.93005

Craiova	Pitești	167	101.115611	167	101.115611
Craiova	Ruse	347	153.628467	347	153.628467
Craiova	Sofia	525	334.488788	180	116.332407
Craiova	Timișoara	390	236.195736	233.368372	143.94
Daugavpils	Riga	205	114.048134	205	114.048134
Daugavpils	Šiauliai	X	136.104473	190.240685	136.104473
Daugavpils	Vilnius	X	94.8776129	136.265917	94.8776129
Debrecen	Košice	248	105.949491	248	105.949491
Debrecen	Miskolc	94	63.245297	94	63.245297
Debrecen	Oradea	162	61.1359482	69.5252853	47.23
Debrecen	Satu Mare	157	74.5938076	157	74.5938076
Debrecen	Szolnok	75	46.1859297	75	46.1859297
Dijon	Lausanne	121	92.3912721	121	92.3912721
Dijon	Lyon	95	67.0318069	95	67.0318069
Dijon	Paris	96	78.6928416	96	78.6928416
Dijon	Reims	196	93.0643021	196	93.0643021
Dijon	Strasbourg	126	83.523746	126	83.523746
Divača	Koper	45	38.8420357	22.5355602	20.2620357
Divača	Ljubljana	96	72.9607645	96	72.9607645
Divača	Rijeka	165	80.4484499	165	80.4484499
Divača	Trieste	60	36.6548444	60	36.6548444
Divača	Villach	209	103.992789	209	103.992789
Doncaster	Kingston upon Hull	48	35.2437065	48	35.2437065
Doncaster	Leeds	30	21.5542707	30	21.5542707
Doncaster	Nottingham	82	37.1305702	82	37.1305702
Doncaster	Peterborough	48	39.1388861	48	39.1388861
Doncaster	Sheffield	24	16.0271322	24	16.0271322
Doncaster	York	20	16.1979785	20	16.1979785
Dortmund	Essen	21	14.0503591	21	14.0503591
Dortmund	Kassel	132	91.0494287	132	91.0494287
Dortmund	Münster	29	24.3391676	29	24.3391676
Dortmund	Wuppertal	36	27.0662377	36	27.0662377
Drammen	Kristiansand	236	187.372405	193	140.999689
Drammen	Oslo	32	20.4512384	32	20.4512384
Dresden	Leipzig	68	47.2262255	47	34.6174765
Dresden	Liberec	123	82.1973211	123	82.1973211
Dresden	Prague	133	96.0890955	60	36.6926084
Dresden	Wrocław	213	125.475149	213	125.475149
Dublin	Galway	136	115.759142	136	115.759142
Dublin	Limerick	124	112.286163	124	112.286163
Dublin	Sligo	189	138.873574	189	138.873574
Dublin	Waterford	117	89.9082779	117	89.9082779
Duisburg	Düsseldorf	14	8.48201857	14	8.48201857
Duisburg	Eindhoven	101	54.0766459	101	54.0766459
Duisburg	Essen	11	8.45217303	11	8.45217303
Durrës	Tirana	-	-	20	13.5227064
Düsseldorf	Eindhoven	113	55.0626303	113	55.0626303
Düsseldorf	Wuppertal	20	13.4904704	20	13.4904704
Edinburgh	Glasgow	45	38.6550023	45	38.6550023

Edinburgh	Newcastle upon Tyne	87	73.7750469	87	73.7750469
Edinburgh	Perth	79	52.2871366	79	52.2871366
Edirne	Çorlu	123	78.0143741	123	78.0143741
Edirne	Istanbul	-	-	120	82.5882487
Edirne	Plovdiv	288	75.2683337	288	75.2683337
Edirne	Stara Zagora	158	100.854107	158	100.854107
Eindhoven	Liège	113	67.7427964	113	67.7427964
Eindhoven	Rotterdam	62	41.78456	48.336286	35.88
Eindhoven	Utrecht	48	37.4736836	48	37.4736836
Entroncamento	Lisbon	52	35.3852689	52	35.3852689
Erfurt	Frankfurt	125	105.78316	62	45.3780381
Erfurt	Hanover	143	93.7586053	143	93.7586053
Erfurt	Kassel	90	65.5291424	90	65.5291424
Erfurt	Leipzig	40	28.4084866	40	28.4084866
Erfurt	Nuremberg	80	57.9841016	60	43.9432966
Erfurt	Plzeň	293	155.225279	293	155.225279
Esbjerg	Odense	79	53.5531983	74	54.7873376
Esbjerg	Padborg	86	52.0844287	86	52.0844287
Exeter	Penzance	174	126.559814	174	126.559814
Exeter	Southampton	147	87.5054749	147	87.5054749
Faro	Lisbon	180	107.816881	150	91.0669173
Feldkirch	Innsbruck	115	91.6531079	115	91.6531079
Feldkirch	Vaduz/Schaan	18	9.9080569	18	9.9080569
Florence	Perugia	89	52.4758246	89	52.4758246
Florence	Pisa	52	31.7398073	52	31.7398073
Florence	Rome	95	68.6821721	95	68.6821721
Foggia	Naples	163	81.7461478	65	43.5536561
Foggia	Pescara	91	69.1037911	91	69.1037911
Frankfurt	Kassel	82	67.3088297	39	28.8785103
Frankfurt	Mannheim	38	28.8059172	29	21.7048025
Frankfurt	Nuremberg	123	92.4432634	123	92.4432634
Freiburg	Karlsruhe	60	46.565375	42	31.0306226
Freiburg	Strasbourg	64	37.6525191	56	40.8667996
Galați	Iași	253	180.2077	253	180.2077
Galway	Limerick	117	71.1804107	117	71.1804107
Gdańsk	Koszalin	157	101.782689	157	101.782689
Gdańsk	Olsztyn	137	80.5383222	137	80.5383222
Gdańsk	Warsaw	148	126.321397	148	126.321397
Geneva	Grenoble	123	83.9177549	123	83.9177549
Geneva	Lausanne	35	24.3761678	35	24.3761678
Geneva	Lyon	113	80.7058854	113	80.7058854
Geneva	Turin	320	154.256887	238	145.384565
Genoa	Milan	94	59.5118159	50	34.4682458
Genoa	Nice	192	89.7266192	122.986714	81.1166192
Genoa	Pisa	128	73.4711518	128	73.4711518
Genoa	Turin	105	64.1876079	60	40.525186
Ghent	Lille	72	33.7657067	72	33.7657067
Gijón	León	91	52.477109	91	52.477109

Gijón	Santander	354	152.124465	354	152.124465
Girona	Perpignan	38	23.1617394	38	23.1617394
Glasgow	Perth	57	51.7132853	57	51.7132853
Gothenburg	Hallsberg	130	84.5304586	130	84.5304586
Gothenburg	Malmö	153	100.111337	133	94.2557279
Gothenburg	Oslo	206	155.262796	183	132.138954
Graz	Klagenfurt	-	-	45	35.1165182
Graz	Linz	190	141.32142	190	141.32142
Graz	Maribor	60	31.5842598	45	36.3064436
Graz	Salzburg	238	173.33958	238	173.33958
Graz	Szombathely	136	81.4579683	136	81.4579683
Graz	Vienna	156	118.190456	110	82.3155059
Grenoble	Lyon	83	59.1351301	29	23.340276
Grenoble	Turin	191	119.696448	109	72.3966841
Groningen	Zwolle	56	49.2190433	47.9495808	35.55
Guarda	Porto	223	119.829538	223	119.829538
Guarda	Salamanca	X	78.4367468	128.803752	78.4367468
Győr	Szombathely	69	56.8941505	69	56.8941505
Győr	Vienna	78	50.6266968	78	50.6266968
Hallsberg	Linköping	88	50.5849462	88	50.5849462
Hallsberg	Oslo	225	157.505964	225	157.505964
Hallsberg	Stockholm	88	62.9870729	88	62.9870729
Hallsberg	Västerås	81	46.951228	81	46.951228
Hamburg	Hanover	76	60.1438892	76	60.1438892
Hamburg	Kiel	88	46.3320094	88	46.3320094
Hamburg	Lübeck	46	26.3369287	46	26.3369287
Hamburg	Padborg	122	82.2342053	122	82.2342053
Hamburg	Rostock	109	79.482495	109	79.482495
Hanover	Kassel	54	38.9314403	54	38.9314403
Hanover	Rostock	213	119.836662	213	119.836662
Helsinki	Joensuu	269	187.282317	269	187.282317
Helsinki	Kuopio	260	166.249273	260	166.249273
Helsinki	Tampere	95	62.2671096	95	62.2671096
Helsinki	Turku	112	107.670221	78	56.9135563
Hradec Králové	Liberec	147	96.2221417	147	96.2221417
Hradec Králové	Ostrava	160	115.934556	160	115.934556
Hradec Králové	Prague	95	54.2588284	95	54.2588284
Hradec Králové	Wrocław	256	132.529418	256	132.529418
Iași	Suceava	155	86.3572245	155	86.3572245
Iași	Ungheni	34	18.4239315	34	18.4239315
Innsbruck	Munich	104	70.1951393	55	41.3610329
Innsbruck	Salzburg	108	85.6489605	108	85.6489605
Innsbruck	Villach	263	174.422357	263	174.422357
Inverness	Perth	122	98.3160208	122	98.3160208
Inverness	Thurso	222	193.561037	222	193.561037
Istanbul	Çorlu	137	56.6696256	137	56.6696256
Jelgava	Liepāja	151	121.824147	151	121.824147
Jelgava	Riga	46	22.6455916	46	22.6455916
Jelgava	Šiauliai	78	60.8340842	78	60.8340842

Joensuu	Kuopio	252	101.613438	252	101.613438
Joensuu	Oulu	585	229.797393	585	229.797393
Joensuu	Tampere	289	203.266154	289	203.266154
Karlsruhe	Mannheim	24	17.1646569	24	17.1646569
Karlsruhe	Strasbourg	45	30.2869526	35	26.6341744
Karlsruhe	Stuttgart	40	28.291853	35	26.0090272
Kassel	Münster	142	97.4397041	142	97.4397041
Kassel	Nuremberg	120	89.0392	120	89.0392
Katowice	Kraków	47	35.6115403	47	35.6115403
Katowice	Łódź	155	121.776913	155	121.776913
Katowice	Lublin	269	161.571058	269	161.571058
Katowice	Ostrava	103	52.7198178	103	52.7198178
Katowice	Warsaw	142	110.690053	142	110.690053
Katowice	Wrocław	113	84.6142781	113	84.6142781
Katowice	Žilina	453	91.6961059	453	91.6961059
Kaunas	Riga	-	-	92	61.0665416
Kaunas	Šiauliai	124	82.4547772	124	82.4547772
Kaunas	Suwałki	158	102.781484	38	30.4892885
Kaunas	Vilnius	65	51.1628583	38	25.1814124
Kiel	Lübeck	70	45.7381817	70	45.7381817
Kiel	Padborg	111	55.3296672	111	55.3296672
Kingston upon Hull	Leeds	58	42.1435248	48	32.9387582
Kingston upon Hull	York	58	36.1556022	58	36.1556022
Kiruna	Narvik	186	107.814477	186	107.814477
Klagenfurt	Maribor	153	89.7343155	153	89.7343155
Klagenfurt	Vienna	237	186.657681	237	186.657681
Klagenfurt	Villach	23	18.6610086	23	18.6610086
Klaipėda	Šiauliai	116	86.1485117	82	59.7024663
Kolari	Tornio	157	110.687672	157	110.687672
Košice	Miskolc	79	53.7691495	79	53.7691495
Košice	Prešov	37	22.3255647	38.5001451	19.4255647
Košice	Žilina	184	143.247348	142.984615	107.48
Koszalin	Poznań	209	145.603413	209	145.603413
Koszalin	Szczecin	121	89.5945269	121	89.5945269
Kraków	Łódź	154	129.866136	154	129.866136
Kraków	Ostrava	143	72.4420297	143	72.4420297
Kraków	Prešov	517	200.457987	517	200.457987
Kraków	Rzeszów	86	62.3267416	86	62.3267416
Kraków	Warsaw	137	115.426762	137	115.426762
Kraków	Žilina	232	111.40157	232	111.40157
Kristiansand	Stavanger	176	127.414183	176	127.414183
Kuopio	Oulu	237	157.955311	237	157.955311
Kuopio	Tampere	191	140.63836	191	140.63836
La Rochelle	Limoges	227	141.539415	227	141.539415
La Rochelle	Nantes	106	84.9408929	106	84.9408929
La Rochelle	Tours	109	79.899824	109	79.899824
Larissa	Thessaloniki	89	64.5563537	89	64.5563537
Le Havre	Lille	242	123.831881	242	123.831881
Le Havre	Paris	129	92.6631361	129	92.6631361

Le Mans	Nantes	78	58.3887861	78	58.3887861
Le Mans	Paris	59	45.7260801	59	45.7260801
Le Mans	Rennes	45	35.6198954	45	35.6198954
Le Mans	Tours	58	36.187657	58	36.187657
Lecce	Taranto	71	49.7602308	71	49.7602308
Leeds	Manchester	54	37.4555547	43	29.240665
Leeds	Sheffield	40	29.4342409	40	27.0218091
Leeds	York	23	18.5546999	23	18.5546999
Leicester	Liverpool	166	70.6774258	166	70.6774258
Leicester	London	67	57.7999749	67	57.7999749
Leicester	Manchester	125	65.1605408	125	65.1605408
Leicester	Nottingham	29	19.203283	29	19.203283
Leicester	Peterborough	55	39.446018	55	39.446018
Leicester	Sheffield	65	41.656817	65	41.656817
Leipzig	Wrocław	319	156.799518	319	156.799518
León	Santander	202	154.535045	142	86.5369169
León	Valladolid	59	44.4755882	59	44.4755882
Liberec	Prague	147	91.6760878	147	91.6760878
Liège	Luxembourg	159	95.132349	159	95.132349
Lille	London	81	69.8643344	81	69.8643344
Lille	Paris	64	50.5894997	64	50.5894997
Lille	Reims	89	65.2177505	89	65.2177505
Limerick	Waterford	153	87.57361	153	87.57361
Limoges	Toulouse	218	156.468636	218	156.468636
Limoges	Tours	197	108.155034	197	108.155034
Linköping	Stockholm	79	77.2236292	65	44.753906
Linköping	Västerås	135	88.3722013	135	88.3722013
Linz	České Budějovice	118	97.7843792	118	97.7843792
Linz	Munich	166	117.447682	166	117.447682
Linz	Regensburg	117	97.494732	117	97.494732
Linz	Salzburg	68	56.3021111	56	43.1040392
Linz	Vienna	75	58.3181327	75	58.3181327
Lisbon	Porto	-	-	75	47.5067318
Liverpool	London	134	109.487089	105	75.0970207
Liverpool	Manchester	36	25.8410173	36	25.8410173
Liverpool	Nottingham	161	74.1383181	161	74.1383181
Liverpool	Swansea	268	161.074365	268	161.074365
Ljubljana	Maribor	109	89.5014026	109	89.5014026
Ljubljana	Rijeka	162	117.163408	162	117.163408
Ljubljana	Varaždin	205	125.370943	205	125.370943
Ljubljana	Villach	99	63.9632542	99	63.9632542
Ljubljana	Zagreb	129	87.050228	129	87.050228
London	Manchester	156	103.970204	100	71.3989275
London	Norwich	108	77.5759868	108	77.5759868
London	Peterborough	46	40.5462011	46	40.5462011
London	Southampton	75	53.1368019	75	53.1368019
Lübeck	Padborg	164	85.6637127	164	85.6637127
Lübeck	Rostock	108	64.8764364	108	64.8764364
Lublin	Rzeszów	144	111.900345	144	111.900345

Lublin	Warsaw	112	76.9871699	112	76.9871699
Lugano	Milan	75	37.4496099	75	37.4496099
Luleå	Umeå	-	-	90	62.9531052
Luxembourg	Metz	46	28.1971462	46	28.1971462
Lyon	Paris	116	99.347665	116	99.347665
Lyon	Reims	202	113.753726	202	113.753726
Lyon	Turin	211	155.769826	107	71.1497958
Madrid	Murcia	165	120.299882	165	120.299882
Madrid	Ourense	135	109.012894	135	109.012894
Madrid	Pamplona	179	125.59979	179	125.59979
Madrid	Salamanca	101	69.6143498	101	69.6143498
Madrid	Valencia	113	87.585222	113	87.585222
Madrid	Valladolid	64	47.5923645	64	47.5923645
Madrid	Zaragoza	75	65.6927847	75	65.6927847
Manchester	Nottingham	108	60.2302408	108	60.2302408
Manchester	Sheffield	53	34.5561385	42	28.5010464
Manchester	Swansea	260	157.436767	260	157.436767
Mannheim	Saarbrücken	77	63.642383	77	63.642383
Mannheim	Stuttgart	38	29.0052748	33	24.5742856
Maribor	Varaždin	119	50.6112292	119	50.6112292
Maribor	Zagreb	158	97.2401132	158	97.2401132
Marseille	Nice	148	102.928279	148	102.928279
Messina	Palermo	169	107.256559	169	107.256559
Messina	Syracuse	148	94.1538733	118	75.655439
Messina	Villa San Giovanni	85	85	85	85
Metz	Reims	47	40.6992088	47	40.6992088
Metz	Saarbrücken	62	39.9823125	62	39.9823125
Metz	Strasbourg	47	37.7828942	47	37.7828942
Milan	Turin	50	37.9055884	50	37.9055884
Milan	Verona	73	47.9248489	68	45.3707381
Montpellier	Perpignan	92	63.6209863	53	38.7546608
Montpellier	Toulouse	132	96.358325	105	72.1524945
Mostar	Sarajevo	115	104.454919	115	104.454919
Munich	Nuremberg	64	49.2473149	64	49.2473149
Munich	Regensburg	83	64.9170777	83	64.9170777
Munich	Salzburg	88	73.88773	88	73.88773
Munich	Ulm	73	54.2367111	73	54.2367111
Münster	Zwolle	136	73.4325182	136	73.4325182
Murcia	Valencia	240	91.0464792	172	105.752233
Nantes	Rennes	76	62.6861386	76	62.6861386
Nantes	Tours	94	70.666211	94	70.666211
Naples	Rome	63	48.2068289	63	48.2068289
Naples	Taranto	-	-	210	131.379289
Naples	Villa San Giovanni	245	151.845974	170	107.151528
Narva	Tallinn	192	112.438422	104.93808	91.41
Narva	Tartu	236	128.083655	166.047464	106.17
Newcastle upon Tyne	York	55	43.8005495	55	43.8005495
Niš	Podgorica	1079	532.124334	1079	532.124334

Niš	Skopje	X	187.090623	261.24728	187.090623
Niš	Sofia	X	194.879425	191.826204	133.97
Norwich	Peterborough	89	66.2152892	89	66.2152892
Nottingham	Peterborough	68	37.7275057	68	37.7275057
Nottingham	Sheffield	56	32.9049107	56	32.9049107
Novi Sad	Osijek	X	118.516743	180.822403	118.516743
Novi Sad	Subotica	216	143.740204	42	34.081077
Novi Sad	Zagreb	X	273.319425	389.912846	273.319425
Nuremberg	Plzeň	184	129.246729	148	106.570597
Nuremberg	Regensburg	52	48.4404724	52	48.4404724
Nuremberg	Stuttgart	129	89.6387231	129	89.6387231
Nuremberg	Ulm	121	73.3910592	121	73.3910592
Odense	Padborg	81	62.3342616	76	55.8817898
Olbia	Sassari	105	72.9478972	105	72.9478972
Olsztyn	Poznań	205	146.546969	205	146.546969
Olsztyn	Suwałki	391	158.44636	391	158.44636
Olsztyn	Warsaw	142	97.6600257	142	97.6600257
Oradea	Satu Mare	152	80.8001013	152	80.8001013
Oradea	Szolnok	164	74.8660869	164	74.8660869
Osijek	Pécs	153	61.813706	153	61.813706
Osijek	Sarajevo	X	254.637691	361.279755	254.637691
Osijek	Subotica	X	119.982559	182.802266	119.982559
Oslo	Trondheim	480	316.062191	450	330.141556
Ostrava	Prague	192	146.738903	192	146.738903
Ostrava	Žilina	92	61.5352954	92	61.5352954
Oulu	Rovaniemi	138	102.112083	138	102.112083
Oulu	Seinäjoki	155	105.38394	155	105.38394
Oulu	Tornio	111	63.0915344	111	63.0915344
Ourense	Porto	335	108.224489	335	108.224489
Ourense	Salamanca	223	95.8583916	223	95.8583916
Ourense	Santiago de Compostela	38	21.217592	38	21.217592
Ourense	Valladolid	208	84.7294702	208	84.7294702
Palermo	Syracuse	279	175.675593	219	136.830535
Pamplona	San Sebastián	306	76.0740377	306	76.0740377
Pamplona	Vitoria-Gasteiz	56	40.1408776	56	40.1408776
Pamplona	Zaragoza	110	72.8130452	60	34.0150516
Paris	Reims	46	32.5839019	46	32.5839019
Paris	Tours	61	48.8504163	61	48.8504163
Pärnu	Riga	-	-	60	68.4385821
Pärnu	Tallinn	X	138.98649	40	75.7252394
Pécs	Szombathely	262	165.958818	262	165.958818
Pécs	Varaždin	309	121.937397	309	121.937397
Pécs	Zagreb	340	145.161313	340	145.161313
Peja	Pristina	116	107.488912	116	107.488912
Perpignan	Toulouse	128	83.2849377	112	76.6483568
Perugia	Rome	135	71.9824692	120	76.8668271
Pescara	Rome	210	147.625108	120	76.8668271
Plovdiv	Sofia	152	112.993023	80	44.8126035

Plovdiv	Stara Zagora	130	66.2954185	95	56.5466456
Plzeň	České Budějovice	110	84.3623783	110	84.3623783
Plzeň	Prague	83	55.4685122	51	19.7037508
Plzeň	Regensburg	150	113.506806	114	79.5722833
Porto	Vigo	142	85.8912818	142	85.8912818
Poznań	Łódź	181	111.072556	65	51.9195627
Poznań	Szczecin	157	97.9785653	120	86.8271101
Poznań	Warsaw	153	120.566855	153	120.566855
Poznań	Wrocław	107	66.3431983	80	61.4398029
Prague	České Budějovice	98	74.4798537	80	45.4884841
Prešov	Rzeszów	X	199.453147	274.78575	199.453147
Prešov	Žilina	186	146.505582	150.56168	113.865582
Pristina	Skopje	160	91.0417473	160	91.0417473
Regensburg	Salzburg	187	104.914083	187	104.914083
Regensburg	Ulm	174	97.4272691	174	97.4272691
Reims	Strasbourg	77	59.9537748	77	59.9537748
Riga	Tartu	470	140.023317	470	140.023317
Riga	Vilnius	-	-	114	77.8705214
Rijeka	Split	473	321.718593	374.720983	265.628593
Rijeka	Zagreb	272	185.336609	90	32.8120246
Rostock	Szczecin	235	115.298771	235	115.298771
Rotterdam	The Hague	18	11.3013536	18	11.3013536
Rotterdam	Utrecht	37	27.0755198	37	27.0755198
Rovaniemi	Tornio	X	60.052629	82.6490223	60.052629
Ruse	Shumen	200	126.718038	200	126.718038
Ruse	Sofia	366	273.102027	366	273.102027
Ruse	Varna	220	176.757189	220	176.757189
Ruse	Veliko Tarnovo	155	111.197477	155	111.197477
Saarbrücken	Strasbourg	106	54.9394005	106	54.9394005
Salamanca	Valladolid	64	45.3428565	64	45.3428565
Salzburg	Villach	152	111.438774	152	111.438774
San Sebastián	Vitoria-Gasteiz	112	69.6621603	55	30.8124988
Santander	Valladolid	179	133.576396	119	71.8051742
Santiago de Compostela	Vigo	54	33.865526	54	33.865526
Satu Mare	Suceava	673	372.404542	673	372.404542
Seinäjoki	Tampere	63	50.8668766	63	50.8668766
Shumen	Stara Zagora	284	158.714594	284	158.714594
Shumen	Varna	99	78.9443329	99	78.9443329
Shumen	Veliko Tarnovo	131	99.331967	131	99.331967
Skopje	Sofia	-	-	145	100.023958
Skopje	Veles	52	33.7549832	52	33.7549832
Sofia	Thessaloniki	X	250.987735	413.733418	250.987735
Sofia	Veliko Tarnovo	300	190.357035	300	190.357035
Split	Zagreb	406	289.379127	355.766047	250.129127
Stara Zagora	Varna	221	162.303549	186	127.733168
Stara Zagora	Veliko Tarnovo	178	111.990677	178	111.990677
Stockholm	Östersund	301	204.65715	301	204.65715
Stockholm	Sundsvall	212	144.688997	212	144.688997

Stockholm	Västerås	56	34.5445296	56	34.5445296
Stuttgart	Ulm	42	31.0076844	27	20.270061
Stuttgart	Zurich	-	-	171	113.048871
Subotica	Szeged	82	24.3801867	82	24.3801867
Subotica	Timișoara	X	137.937448	209.587144	137.937448
Sundsvall	Östersund	136	97.8467207	136	97.8467207
Sundsvall	Umeå	156	107.814445	156	107.814445
Szeged	Szolnok	115	76.3420566	115	76.3420566
Szombathely	Varaždin	258	107.773988	258	107.773988
Szombathely	Vienna	190	71.452708	190	71.452708
Szombathely	Zagreb	289	140.668338	289	140.668338
Tallinn	Tartu	137	99.1540469	50.1218031	78.17
Tampere	Turku	100	71.5592089	100	71.5592089
The Hague	Utrecht	38	29.6797231	38	29.6797231
Thessaloniki	Veles	X	118.763217	158.270726	103.803217
Trieste	Venice	113	65.6078088	103	66.5700288
Trieste	Villach	193	85.652677	193	85.652677
Trondheim	Östersund	224	152.639784	224	152.639784
Utrecht	Zwolle	50	40.4895962	50	40.4895962
Vaduz/Schaan	Zurich	101	56.7258991	101	56.7258991
Valencia	Zaragoza	247	133.43573	247	133.43573
Varaždin	Zagreb	155	84.0858748	155	84.0858748
Västerås	Östersund	364	211.914772	364	211.914772
Venice	Verona	60	39.1992239	55	37.4967159
Venice	Villach	184	99.0353939	184	99.0353939
Vilnius	Šiauliai	138	109.2692	98	72.2555768
Warsaw	Łódź	72	61.2772925	45	39.2259091
Wrocław	Łódź	184	133.048867	60	48.7461493

E – Edge Betweenness Centrality

***Table 13**: Current and future edge betweenness centrality values.*

city 1 / start	city 2 / end	edge betweenness centrality (realistic travel times) current [%]	future [%]
A Coruña	Santiago de Compostela	0.52551613	0.56841541
Aalborg	Aarhus	0.52551613	0.56841541
Aarhus	Esbjerg	0.00357494	0.00357494
Aarhus	Odense	0.08579855	0.12512289
Aarhus	Padborg	0.95808383	1.00455805
Aberdeen	Edinburgh	0.51836625	0.56126553
Aberdeen	Inverness	0.00357494	0.00357494
Aberdeen	Perth	0.00357494	0.00357494
Ajaccio	Bastia	0.00178747	0.00178747
Ajaccio	Calvi	0.00178747	0.00178747
Alexandroupolis	Çorlu	-	0.00893735
Alexandroupolis	Edirne	-	0.57020288
Alexandroupolis	Thessaloniki	0.00536241	0.03217446
Algeciras	Antequera	0.52551613	0.56841541
Alicante	Almería	-	0
Alicante	Cartagena	0	0
Alicante	Córdoba	0	0
Alicante	Madrid	0.29314505	0.04468675
Alicante	Murcia	0.00714988	1.48896237
Alicante	Valencia	0.23237108	1.97694164
Almería	Granada	0.52551613	0.05183663
Almería	Murcia	-	0.59522746
Alvesta	Gothenburg	0.02144964	0.02144964
Alvesta	Hallsberg	0.49334167	0.51836625
Alvesta	Kalmar	0.52551613	0.56841541
Alvesta	Linköping	5.9201001	11.4040576
Alvesta	Malmö	7.34650103	12.8697828
Amsterdam	Rotterdam	0.22164626	0.21628385
Amsterdam	The Hague	0.00178747	0.00178747
Amsterdam	Utrecht	0.29850746	0.26990795
Amsterdam	Zwolle	0.00357494	0.08043614
Ancona	Bologna	3.01367414	1.0903566
Ancona	Perugia	0.01072482	0.00357494
Ancona	Pescara	2.52926982	0.56662794
Ancona	Rome	0.01251229	0.00178747
Antequera	Cádiz	0	0
Antequera	Córdoba	2.59183126	2.24327464
Antequera	Granada	1.04745732	0.60237733
Antequera	Málaga	0.52551613	0.56841541
Antequera	Seville	0	0
Antwerp	Brussels	1.79372598	1.79461972
Antwerp	Eindhoven	0.17695951	0
Antwerp	Ghent	0.03217446	0.03217446

Antwerp	Liège	0.32889445	0.3735812
Antwerp	Rotterdam	1.70256502	1.92153007
Arad	Deva	8.67995353	2.92608812
Arad	Oradea	0.06971132	0.03217446
Arad	Szeged	0.25024578	0
Arad	Szolnok	9.25909375	4.75109483
Arad	Timișoara	0.49512914	1.56761105
Arnhem	Duisburg	1.8634373	1.86433104
Arnhem	Eindhoven	0.00178747	0.00178747
Arnhem	Münster	0	0
Arnhem	Utrecht	1.28429708	1.38528912
Arnhem	Zwolle	0.42184288	0.2842077
Arth-Goldau	Basel	0	0
Arth-Goldau	Bern	0	0
Arth-Goldau	Lugano	3.02082402	0.71856287
Arth-Goldau	Vaduz/Schaan	0	0
Arth-Goldau	Zurich	3.42121727	1.15113057
Athens	Larissa	0.00536241	1.13325588
Athens	Patras	-	0.56841541
Avignon	Dijon	0	0
Avignon	Grenoble	0.0768612	0
Avignon	Lyon	14.9378854	13.3774243
Avignon	Marseille	0.9419966	0.7703995
Avignon	Montpellier	14.1621235	12.5176513
Bacău	Brașov	0.01429976	0.01429976
Bacău	Bucharest	0.15193494	0.32710698
Bacău	Constanța	0.01072482	0.01072482
Bacău	Galați	0.00536241	0.00357494
Bacău	Iași	0.12154795	0.2430959
Bacău	Suceava	0.51479131	0.54160336
Badajoz	Entroncamento	1.56046117	0
Badajoz	Lisbon	-	1.92153007
Badajoz	Madrid	1.97157923	2.43274645
Badajoz	Seville	0.08579855	0.02144964
Bălți	Ungheni	0.52551613	0.56841541
Banja Luka	Novi Sad	-	0.09652337
Banja Luka	Osijek	-	0.00357494
Banja Luka	Sarajevo	-	0.27169542
Banja Luka	Zagreb	-	0.73286263
Banská Bystrica	Budapest	0.06971132	0.07864867
Banská Bystrica	Győr	0	0
Banská Bystrica	Miskolc	0	0
Banská Bystrica	Žilina	0.45580481	0.48976674
Bar	Podgorica	0.52551613	0.56841541
Barcelona	Girona	13.0485298	11.2467602
Barcelona	Valencia	0.68817589	2.47207078
Barcelona	Zaragoza	11.9635356	8.33497185
Bari	Foggia	1.54258647	1.68379659
Bari	Lecce	0.51479131	0.56484047

Bari	Taranto	0.5273036	0.55769059
Basel	Bern	0.82044865	0.94557154
Basel	Dijon	0.93842166	5.95763696
Basel	Freiburg	3.48556618	7.02475646
Basel	Lausanne	0	0
Basel	Strasbourg	0.80257396	0.45937975
Basel	Zurich	3.86272232	1.66413442
Bastia	Calvi	0.00178747	0.00178747
Bayonne	Bordeaux	4.38287604	7.79336849
Bayonne	San Sebastián	4.01465725	7.40370006
Bayonne	Toulouse	0.02859952	0.05004916
Belfast	Derry	0.01251229	0.01251229
Belfast	Dublin	0.02144964	0.02144964
Belgrade	Niš	0.52551613	10.5728841
Belgrade	Novi Sad	2.08061489	12.5301636
Belgrade	Osijek	-	0.06256144
Belgrade	Podgorica	1.04745732	1.13325588
Belgrade	Sarajevo	-	0.85441058
Belgrade	Timișoara	-	0.25382072
Bergen	Drammen	0.52551613	0.00536241
Bergen	Oslo	-	0.563053
Berlin	Dresden	0.89641612	6.28831888
Berlin	Erfurt	5.21047457	6.38573599
Berlin	Hamburg	2.27187416	7.76834391
Berlin	Hanover	2.30762356	1.10108142
Berlin	Leipzig	0.10367325	0.12691036
Berlin	Lübeck	0	0
Berlin	Poznań	7.56278488	8.25632317
Berlin	Rostock	0.22700867	0.25828939
Berlin	Szczecin	0.92680311	1.03315757
Bern	Brig	0.43793011	0.36643132
Bern	Lausanne	0.74358745	0.70426312
Bern	Zurich	0.6041648	0.414693
Białystok	Olsztyn	0.02323711	0
Białystok	Suwałki	6.07024756	7.11055501
Białystok	Warsaw	6.52962731	7.6324962
Bielefeld	Bremen	0	0
Bielefeld	Dortmund	2.29421754	4.10403074
Bielefeld	Hanover	2.46313343	4.53570471
Bielefeld	Münster	0.18321566	0.18857807
Bilbao	Burgos	0.0536241	0
Bilbao	San Sebastián	0.75788721	0.50227902
Bilbao	Santander	0.36106891	0.00178747
Bilbao	Vitoria-Gasteiz	0.00357494	0.06434891
Bilbao	Zaragoza	0.06792385	0
Birmingham	Bristol	0.12869783	0.12869783
Birmingham	Carlisle	0.28688891	0.06256144
Birmingham	Leicester	0.01072482	0.00893735
Birmingham	Liverpool	0.00893735	0.00893735

Birmingham	London	0.72839396	1.05818214
Birmingham	Manchester	0.00893735	0.00893735
Birmingham	Nottingham	0.00893735	0.00893735
Birmingham	Sheffield	0.07149879	0.5809277
Birmingham	Southampton	0	0
Bitola	Veles	0.00714988	0.56841541
Boden	Kiruna	1.04745732	1.13325588
Boden	Luleå	0.52551613	7.11055501
Boden	Tornio	-	5.52328179
Boden	Umeå	2.08061489	0
Bodø	Trondheim	0.52551613	0.56841541
Bologna	Florence	4.97095362	7.40370006
Bologna	Genoa	0	0
Bologna	Milan	5.09786397	3.16203414
Bologna	Venice	0.42541782	0.51657878
Bologna	Verona	2.88676379	5.31236035
Bolzano	Innsbruck	3.99678255	11.9680043
Bolzano	Verona	3.84306015	11.867906
Bordeaux	La Rochelle	0.0768612	0.0768612
Bordeaux	Limoges	0.02144964	0.08222361
Bordeaux	Toulouse	0.40396818	0.50585396
Bordeaux	Tours	5.05317723	8.54768076
Bourges	Clermont-Ferrand	0.02144964	0.03038699
Bourges	Dijon	0.03932434	0.0357494
Bourges	Limoges	0.4325677	0.47010457
Bourges	Lyon	0.1715971	0.13227277
Bourges	Paris	0.70783806	0.77933685
Bourges	Tours	0.0536241	0.11439807
Braga	Ourense	0	0
Braga	Porto	0.01251229	0.32174457
Braga	Vigo	0.51300384	0.86156046
Brașov	Bucharest	1.0134954	1.56582358
Brașov	Cluj-Napoca	0.02502458	0.12869783
Brașov	Deva	1.93404236	2.40057199
Brașov	Galați	0.48440433	0.49512914
Bratislava	Brno	0.0178747	0.06971132
Bratislava	Győr	1.98766646	0.17517204
Bratislava	Vienna	1.64089731	1.26910358
Bratislava	Žilina	3.22817052	0.9598713
Bregenz	Feldkirch	0.65600143	0.62025203
Bregenz	Munich	1.19402985	0.97863974
Bregenz	Ulm	0.37536867	0.49959782
Bregenz	Zurich	1.46036286	0.9187595
Bremen	Groningen	-	0.49155421
Bremen	Hamburg	4.17552954	0.37536867
Bremen	Hanover	0.27348288	0.66315131
Bremen	Münster	4.19519171	0.14657253
Bremen	Zwolle	0.11797301	0
Brest	Rennes	0.52551613	0.56841541

Brig	Lausanne	0.20198409	0.19662168
Brig	Milan	0.2430959	0.38073108
Brig	Turin	0	0
Bristol	Exeter	1.04388238	1.12968094
Bristol	London	1.94476718	2.11636429
Bristol	Southampton	0.00357494	0.00357494
Bristol	Swansea	0.52551613	0.56841541
Brno	Hradec Králové	0.24667084	0.25560819
Brno	Ostrava	0.83742962	4.84583073
Brno	Prague	0.25828939	6.87818393
Brno	Vienna	1.59621056	9.86147109
Bruges	Ghent	0.52551613	0.56841541
Bruges	Lille	0	0
Brussels	Ghent	1.01528287	1.10108142
Brussels	Liège	10.1295916	6.71194924
Brussels	Lille	11.7445706	8.22414872
Brussels	Luxembourg	0.0178747	0.10009831
Bucharest	Constanța	0.51300384	0.55590312
Bucharest	Craiova	0.02502458	0.35213156
Bucharest	Galați	0.02681205	0.06077397
Bucharest	Pitești	0.03753687	0.02681205
Bucharest	Ruse	0.23415855	0.73286263
Budapest	Győr	18.3859147	24.2738404
Budapest	Miskolc	0.47904192	0.60237733
Budapest	Pécs	1.00813299	0.53624095
Budapest	Subotica	-	13.5204218
Budapest	Szeged	3.21565824	0.47725445
Budapest	Szolnok	13.9744392	10.0241308
Budapest	Varaždin	0.07507373	0.09116096
Budapest	Zagreb	0.15014747	0.1126106
Burgas	Edirne	0	0
Burgas	Shumen	0	0
Burgas	Stara Zagora	0.01251229	0.56484047
Burgas	Varna	0.51300384	0.00357494
Burgos	León	0.73643757	0.85798552
Burgos	Santander	0	0
Burgos	Valladolid	1.21011708	4.49369917
Burgos	Vitoria-Gasteiz	2.15747609	5.81285191
Bydgoszcz	Gdańsk	0.38609348	0.38966842
Bydgoszcz	Kraków	0	0
Bydgoszcz	Łódź	0.00178747	0
Bydgoszcz	Olsztyn	0.00178747	0.00178747
Bydgoszcz	Poznań	0.87049781	0.92054697
Bydgoszcz	Warsaw	0.03038699	0.02859952
Cádiz	Córdoba	0	0
Cádiz	Seville	0.52551613	0.56841541
Caen	Cherbourg-Octeville	0.52551613	0.56841541
Caen	Le Havre	0.00357494	0.00357494
Caen	Le Mans	0.07149879	0.14299759

Caen	Paris	0.97238359	0.98668335
Cagliari	Olbia	0.00178747	0.00178747
Cagliari	Sassari	0.00178747	0.00178747
Carlisle	Edinburgh	0.01072482	0.02859952
Carlisle	Glasgow	0.05719903	0.58986505
Carlisle	Leeds	0	0
Carlisle	Liverpool	0.01251229	0.01251229
Carlisle	Manchester	0.0178747	1.07963178
Carlisle	Newcastle upon Tyne	0.25471445	0.01072482
Carlisle	Perth	0	0
Cartagena	Murcia	0.52551613	0.56841541
Cherbourg-Octeville	Rennes	0	0
Chișinău	Ungheni	0.52551613	0.56841541
Clermont-Ferrand	Dijon	0	0
Clermont-Ferrand	Limoges	0.00178747	0.00178747
Clermont-Ferrand	Lyon	0.50227902	0.53624095
Clermont-Ferrand	Reims	0	0
Cluj-Napoca	Deva	0.0357494	0.06613638
Cluj-Napoca	Oradea	3.34256859	3.53919028
Cluj-Napoca	Pitești	0.00178747	0
Cluj-Napoca	Suceava	2.90106354	2.98328716
Coimbra	Entroncamento	0.08043614	0.01608723
Coimbra	Guarda	0.52551613	0.60237733
Coimbra	Lisbon	-	0.27348288
Coimbra	Porto	1.04209491	0.3199571
Cologne	Düsseldorf	2.27634284	2.31298597
Cologne	Eindhoven	0.20913397	0.23058361
Cologne	Frankfurt	5.7690589	4.91554205
Cologne	Liège	10.6247207	7.28215211
Cologne	Mannheim	1.51488069	1.48538743
Cologne	Wuppertal	6.09974082	3.73223702
Constanța	Galați	0.00178747	0.00178747
Constanța	Iași	0	0
Copenhagen	Lübeck	-	16.5841451
Copenhagen	Malmö	10.7355438	16.416123
Copenhagen	Odense	11.1824113	0.30386987
Córdoba	Madrid	4.00393243	3.81982304
Córdoba	Murcia	0	0
Córdoba	Seville	1.0903566	1.11180624
Córdoba	Valencia	0.01429976	0.01072482
Cork	Dublin	0.00714988	0.00714988
Cork	Limerick	0.00357494	0.00357494
Cork	Waterford	0.00178747	0.00178747
Cosenza	Naples	0.5094289	0.55769059
Cosenza	Taranto	0.03038699	0.01072482
Cosenza	Villa San Giovanni	0.02859952	0.01429976
Craiova	Deva	6.27759407	0.05541156
Craiova	Pitești	0.4861918	0.54160336
Craiova	Ruse	4.37572616	0

Craiova	Sofia	0.97417106	0.3735812
Craiova	Timișoara	0.03038699	1.17258021
Daugavpils	Riga	0.52551613	0.01251229
Daugavpils	Šiauliai	-	0.00357494
Daugavpils	Vilnius	-	0.55232818
Debrecen	Košice	0	0
Debrecen	Miskolc	0.26633301	0.21628385
Debrecen	Oradea	0.05719903	4.01286978
Debrecen	Satu Mare	0.47546698	0.53087854
Debrecen	Szolnok	0.98489588	4.89945482
Dijon	Lausanne	0.10546072	0.10724819
Dijon	Lyon	9.02672267	5.40888373
Dijon	Paris	0.45401734	0.55411565
Dijon	Reims	0	0
Dijon	Strasbourg	8.62990437	0.03753687
Divača	Koper	0.52551613	0.56841541
Divača	Ljubljana	1.16364286	1.00455805
Divača	Rijeka	0.14836	0.41111806
Divača	Trieste	1.22262937	1.81964429
Divača	Villach	0	0
Doncaster	Kingston upon Hull	0.50406649	0.54696577
Doncaster	Leeds	0.48976674	0.53266601
Doncaster	Nottingham	0	0
Doncaster	Peterborough	6.1068907	5.32487264
Doncaster	Sheffield	0.6041648	0.09652337
Doncaster	York	4.24434713	3.79479846
Dortmund	Essen	1.16364286	1.27446599
Dortmund	Kassel	0.02144964	0
Dortmund	Münster	4.40432568	0.36464385
Dortmund	Wuppertal	5.82625793	3.45160425
Drammen	Kristiansand	1.04745732	1.13325588
Drammen	Oslo	2.08061489	1.689159
Dresden	Leipzig	2.12887658	2.75091608
Dresden	Liberec	0.39503083	0.41826794
Dresden	Prague	1.42908213	7.8398427
Dresden	Wrocław	0.92948431	0.83117347
Dublin	Galway	0.00893735	0.00893735
Dublin	Limerick	0.00714988	0.00714988
Dublin	Sligo	0.01251229	0.01251229
Dublin	Waterford	0.00893735	0.00893735
Duisburg	Düsseldorf	2.03145947	2.06095272
Duisburg	Eindhoven	0.11976048	0.13763518
Duisburg	Essen	1.43891322	1.52828671
Durrës	Tirana	-	0.00178747
Düsseldorf	Eindhoven	0.00357494	0.00357494
Düsseldorf	Wuppertal	0.01966217	0.01966217
Edinburgh	Glasgow	0.50406649	0.01429976
Edinburgh	Newcastle upon Tyne	3.03154884	2.73840379
Edinburgh	Perth	1.51219948	1.64089731

Edirne	Çorlu	1.04745732	0.55769059
Edirne	Istanbul	-	0.56662794
Edirne	Plovdiv	0.00536241	0
Edirne	Stara Zagora	1.56046117	2.22003754
Eindhoven	Liège	0.00357494	0.00178747
Eindhoven	Rotterdam	0.00357494	0.18589686
Eindhoven	Utrecht	0.00714988	0.00714988
Entroncamento	Lisbon	1.04745732	0.55232818
Erfurt	Frankfurt	5.73956564	9.81142193
Erfurt	Hanover	0.00536241	0.00714988
Erfurt	Kassel	0.02681205	0.02323711
Erfurt	Leipzig	2.49352042	2.90642595
Erfurt	Nuremberg	2.21825007	4.07275002
Erfurt	Plzeň	0	0
Esbjerg	Odense	0.04289928	0.06256144
Esbjerg	Padborg	0.47904192	0.50227902
Exeter	Penzance	0.52551613	0.56841541
Exeter	Southampton	0.00357494	0.00357494
Faro	Lisbon	0.52551613	0.56841541
Feldkirch	Innsbruck	0.3557065	0.4325677
Feldkirch	Vaduz/Schaan	0.30744481	0.38073108
Florence	Perugia	0.50227902	0.5451783
Florence	Pisa	0.55232818	0.38251854
Florence	Rome	3.51595317	5.9969613
Foggia	Naples	0.03038699	2.24863705
Foggia	Pescara	2.04129055	0.0357494
Frankfurt	Kassel	4.94414157	6.97917598
Frankfurt	Mannheim	9.92582	11.9108053
Frankfurt	Nuremberg	4.98972205	0
Freiburg	Karlsruhe	3.6267763	7.24104031
Freiburg	Strasbourg	0.09831084	0.10903566
Galați	Iași	0.00714988	0.00714988
Galway	Limerick	0.00357494	0.00357494
Gdańsk	Koszalin	0.03932434	0.0357494
Gdańsk	Olsztyn	0.00357494	0.00357494
Gdańsk	Warsaw	0.16802216	0.20377156
Geneva	Grenoble	0.11618554	0.00714988
Geneva	Lausanne	0.68638842	0.60058987
Geneva	Lyon	0.40933059	0.3968183
Geneva	Turin	0	0
Genoa	Milan	0.47725445	0.73107516
Genoa	Nice	0.25203325	0.36285638
Genoa	Pisa	0.03753687	0.18589686
Genoa	Turin	0.10903566	0.37536867
Ghent	Lille	0	0
Gijón	León	0.52551613	0.56841541
Gijón	Santander	0	0
Girona	Perpignan	13.4417732	11.6829029
Glasgow	Perth	0.05004916	0.05004916

Gothenburg	Hallsberg	0.01966217	0.03753687
Gothenburg	Malmö	2.93860041	3.08874788
Gothenburg	Oslo	2.47922066	2.60434355
Graz	Klagenfurt	-	1.55509876
Graz	Linz	0.52909107	0
Graz	Maribor	1.49253731	1.87684333
Graz	Salzburg	0.29850746	0
Graz	Szombathely	0.57556529	0.12869783
Graz	Vienna	0.4861918	2.12708911
Grenoble	Lyon	0.26812048	0.36106891
Grenoble	Turin	0.06434891	0.20019662
Groningen	Zwolle	0.52551613	0.39860577
Guarda	Porto	0	0
Guarda	Salamanca	-	1.13146841
Győr	Szombathely	0.99740817	0.44329252
Győr	Vienna	16.5519707	24.6921083
Hallsberg	Linköping	0.01251229	0.01251229
Hallsberg	Oslo	0.09831084	0.18768433
Hallsberg	Stockholm	0.10367325	0.22879614
Hallsberg	Västerås	0.01251229	0.01251229
Hamburg	Hanover	8.36535883	12.3934221
Hamburg	Kiel	0.47189204	0.49691661
Hamburg	Lübeck	0.47189204	16.8951649
Hamburg	Padborg	13.2630262	2.49173295
Hamburg	Rostock	0.29135758	0.2457771
Hanover	Kassel	8.89981232	10.2136026
Hanover	Rostock	0	0
Helsinki	Joensuu	0.00357494	0.00357494
Helsinki	Kuopio	0.00178747	0.00178747
Helsinki	Tampere	0.01072482	0.563053
Helsinki	Turku	0.00357494	0.00357494
Hradec Králové	Liberec	0.11082313	0.13942265
Hradec Králové	Ostrava	0.0589865	0.02859952
Hradec Králové	Prague	0.31638216	0.38073108
Hradec Králové	Wrocław	0.01072482	0.03932434
Iași	Suceava	1.95191706	2.00196622
Iași	Ungheni	1.56582358	1.6945214
Innsbruck	Munich	1.75708285	4.97363482
Innsbruck	Salzburg	2.79202788	7.43408705
Innsbruck	Villach	0	0
Inverness	Perth	1.04388238	1.12968094
Inverness	Thurso	0.52551613	0.56841541
Istanbul	Çorlu	0.52551613	0.00178747
Jelgava	Liepāja	0.52551613	0.56841541
Jelgava	Riga	2.59183126	1.1439807
Jelgava	Šiauliai	3.60353919	0.02502458
Joensuu	Kuopio	0.00893735	0.56126553
Joensuu	Oulu	0	0
Joensuu	Tampere	0.00357494	0.00357494

Karlsruhe	Mannheim	10.2770578	11.5399053
Karlsruhe	Strasbourg	14.9655912	12.8671016
Karlsruhe	Stuttgart	8.39395835	8.7612834
Kassel	Münster	0.13674144	0.05809277
Kassel	Nuremberg	4.3587452	3.56242738
Katowice	Kraków	0.62561444	0.27884529
Katowice	Łódź	0.12869783	0.14299759
Katowice	Lublin	0	0
Katowice	Ostrava	2.71784789	3.34614353
Katowice	Warsaw	2.14675127	2.53999464
Katowice	Wrocław	1.28965949	0.94914648
Katowice	Žilina	0	0
Kaunas	Riga	-	3.85378497
Kaunas	Šiauliai	4.58486013	1.10108142
Kaunas	Suwałki	5.58405577	6.58503888
Kaunas	Vilnius	0.5094289	1.10108142
Kiel	Lübeck	0.00357494	0.06256144
Kiel	Padborg	0.05004916	0.00893735
Kingston upon Hull	Leeds	0.00536241	0.00536241
Kingston upon Hull	York	0.01608723	0.01608723
Kiruna	Narvik	0.52551613	0.56841541
Klagenfurt	Maribor	0.20913397	0
Klagenfurt	Vienna	0.40754312	0
Klagenfurt	Villach	0.86692287	1.75887032
Klaipėda	Šiauliai	0.52551613	0.56841541
Kolari	Tornio	0.01608723	0.56841541
Košice	Miskolc	0.33068192	0.36106891
Košice	Prešov	0.08579855	0.16444722
Košice	Žilina	0.5809277	0.54696577
Koszalin	Poznań	0.02413084	0.02144964
Koszalin	Szczecin	0.46563589	0.51479131
Kraków	Łódź	0.00357494	0.23594602
Kraków	Ostrava	0.17517204	0.5094289
Kraków	Prešov	0	0
Kraków	Rzeszów	0.52551613	0.53802842
Kraków	Warsaw	0.06434891	0.06077397
Kraków	Žilina	0.17517204	0.01072482
Kristiansand	Stavanger	0.52551613	0.56841541
Kuopio	Oulu	0.01429976	1.11895612
Kuopio	Tampere	0.00536241	0.00536241
La Rochelle	Limoges	0.00178747	0.00178747
La Rochelle	Nantes	0.00536241	0.00536241
La Rochelle	Tours	0.44150505	0.48440433
Larissa	Thessaloniki	0.00714988	1.6945214
Le Havre	Lille	0	0
Le Havre	Paris	0.52194119	0.56484047
Le Mans	Nantes	0.43793011	0.47904192
Le Mans	Paris	1.88578068	1.90008044
Le Mans	Rennes	1.04030744	1.126106

Le Mans	Tours	0.15014747	0.37715614
Lecce	Taranto	0.01072482	0.00357494
Leeds	Manchester	0.01429976	0.01608723
Leeds	Sheffield	0.01429976	0.01429976
Leeds	York	0.02323711	0.02144964
Leicester	Liverpool	0	0
Leicester	London	0.96880865	1.0546072
Leicester	Manchester	0	0
Leicester	Nottingham	0.4861918	0.52909107
Leicester	Peterborough	0.00536241	0.00357494
Leicester	Sheffield	0.02681205	0.02681205
Leipzig	Wrocław	0	0
León	Santander	0.00357494	0.00357494
León	Valladolid	0.30744481	0.27169542
Liberec	Prague	0.01966217	0.01072482
Liège	Luxembourg	0.02323711	0.01608723
Lille	London	12.501564	13.6169452
Lille	Paris	8.59772991	7.11234248
Lille	Reims	1.50594334	4.39360086
Limerick	Waterford	0.00178747	0.00178747
Limoges	Toulouse	0.05541156	0
Limoges	Tours	0.01251229	0.01251229
Linköping	Stockholm	5.19885602	10.9232282
Linköping	Västerås	0.24756457	0
Linz	České Budějovice	0.57735276	0.20913397
Linz	Munich	0	0
Linz	Regensburg	8.71749039	3.12092233
Linz	Salzburg	10.5907588	15.4258647
Linz	Vienna	18.3519528	18.3734024
Lisbon	Porto	-	0.03396193
Liverpool	London	0.4861918	0.52909107
Liverpool	Manchester	0.0178747	0.0178747
Liverpool	Nottingham	0	0
Liverpool	Swansea	0	0
Ljubljana	Maribor	0.60058987	0.34319421
Ljubljana	Rijeka	0.37000626	0.15372241
Ljubljana	Varaždin	0.13227277	0.00714988
Ljubljana	Villach	1.24050407	0.85798552
Ljubljana	Zagreb	0.75788721	1.11538118
London	Manchester	0.48440433	1.58191081
London	Norwich	0.49512914	0.53802842
London	Peterborough	6.54660828	5.80927697
London	Southampton	0.51836625	0.56126553
Lübeck	Padborg	0.05004916	0.00178747
Lübeck	Rostock	0.00357494	0.06434891
Lublin	Rzeszów	0.00357494	0.0357494
Lublin	Warsaw	0.52194119	0.53266601
Lugano	Milan	2.77772813	0.71856287
Luleå	Umeå	-	7.6324962

Luxembourg	Metz	0.48797927	0.51657878
Lyon	Paris	6.16855841	4.19072303
Lyon	Reims	0	0
Lyon	Turin	4.89766735	9.71757977
Madrid	Murcia	1.04030744	0.18232192
Madrid	Ourense	4.00929484	2.99579945
Madrid	Pamplona	0.04468675	0
Madrid	Salamanca	0.13763518	0.24488337
Madrid	Valencia	0.04468675	0.04468675
Madrid	Valladolid	1.07605684	2.76521584
Madrid	Zaragoza	11.3236214	7.67182054
Manchester	Nottingham	0.00536241	0
Manchester	Sheffield	0.01966217	0.03038699
Manchester	Swansea	0	0
Mannheim	Saarbrücken	0.29493252	0.38788095
Mannheim	Stuttgart	1.23335419	2.03682188
Maribor	Varaždin	0.31101975	0.45401734
Maribor	Zagreb	0.13227277	0.55411565
Marseille	Nice	0.42720529	0.20555903
Messina	Palermo	0.52372866	0.56662794
Messina	Syracuse	0.52372866	0.56662794
Messina	Villa San Giovanni	1.56582358	1.6945214
Metz	Reims	0.50853517	0.43971758
Metz	Saarbrücken	0.17338457	0.17695951
Metz	Strasbourg	0.66404504	0.74716239
Milan	Turin	5.01385289	9.69970507
Milan	Verona	2.39520958	7.82107427
Montpellier	Perpignan	13.6759317	11.9814103
Montpellier	Toulouse	0.11797301	0.13227277
Mostar	Sarajevo	0.00178747	0.56841541
Munich	Nuremberg	2.55786934	4.40521941
Munich	Regensburg	0.18053445	0.30923228
Munich	Salzburg	10.0205559	9.91867012
Munich	Ulm	8.53516847	9.66931808
Münster	Zwolle	0.12869783	0.05719903
Murcia	Valencia	0	0
Nantes	Rennes	0.00714988	0.00714988
Nantes	Tours	0.08222361	0.08401108
Naples	Rome	3.05299848	5.4875324
Naples	Taranto	-	0
Naples	Villa San Giovanni	2.05201537	2.23791224
Narva	Tallinn	0.00178747	0.56841541
Narva	Tartu	0.52372866	0
Newcastle upon Tyne	York	3.78675485	3.29251944
Niš	Podgorica	0	0
Niš	Skopje	-	4.5687729
Niš	Sofia	-	5.55009384
Norwich	Peterborough	0.03038699	0.03038699
Nottingham	Peterborough	0.00357494	0.00357494

Nottingham	Sheffield	0.02144964	0.02681205
Novi Sad	Osijek	-	0.00178747
Novi Sad	Subotica	2.59183126	12.6481366
Novi Sad	Zagreb	-	0.29493252
Nuremberg	Plzeň	0.24130843	0.13942265
Nuremberg	Regensburg	8.94449906	3.27643221
Nuremberg	Stuttgart	0.38788095	0.32174457
Nuremberg	Ulm	0.06434891	0.00357494
Odense	Padborg	11.497006	0.55947806
Olbia	Sassari	0.00178747	0.00178747
Olsztyn	Poznań	0.37536867	0.38251854
Olsztyn	Suwałki	0	0
Olsztyn	Warsaw	0.12154795	0.18053445
Oradea	Satu Mare	0.03753687	0.02681205
Oradea	Szolnok	3.74653678	0
Osijek	Pécs	0.52551613	0.01966217
Osijek	Sarajevo	-	0.00714988
Osijek	Subotica	-	0.48440433
Oslo	Trondheim	0.02144964	0.02144964
Ostrava	Prague	0.67030119	0
Ostrava	Žilina	2.31656091	0.97953347
Oulu	Rovaniemi	0.01608723	0.01251229
Oulu	Seinäjoki	0.02859952	2.23791224
Oulu	Tornio	0.02859952	3.89132183
Ourense	Porto	0	0
Ourense	Salamanca	0.01429976	0.00714988
Ourense	Santiago de Compostela	3.53382787	2.47028331
Ourense	Valladolid	0	0
Palermo	Syracuse	0.00178747	0.00178747
Pamplona	San Sebastián	0	0
Pamplona	Vitoria-Gasteiz	0.45580481	0.59522746
Pamplona	Zaragoza	0.17517204	0.34140674
Paris	Reims	5.24264903	8.38055233
Paris	Tours	5.6180177	8.90517473
Pärnu	Riga	-	2.25221199
Pärnu	Tallinn	-	1.6945214
Pécs	Szombathely	0.00714988	0.00893735
Pécs	Varaždin	0.00714988	0.00536241
Pécs	Zagreb	0.02502458	0.02323711
Peja	Pristina	0.00714988	0.56841541
Perpignan	Toulouse	0.15908482	0.13763518
Perugia	Rome	0.01251229	0.01966217
Pescara	Rome	0.00178747	0.00178747
Plovdiv	Sofia	0.49870408	4.22379122
Plovdiv	Stara Zagora	0.04289928	3.69112521
Plzeň	České Budějovice	0.10724819	0.01072482
Plzeň	Prague	0.19125927	0.47546698
Plzeň	Regensburg	0.11439807	0.17874698
Porto	Vigo	1.53364912	0

Poznań	Łódź	0.35391903	6.58682635
Poznań	Szczecin	0.0536241	0.04289928
Poznań	Warsaw	5.38922156	0
Poznań	Wrocław	0.60505854	0.51657878
Prague	České Budějovice	0.20198409	0.37715614
Prešov	Rzeszów	-	0.06613638
Prešov	Žilina	0.43971758	0.45937975
Pristina	Skopje	0.01072482	1.13325588
Regensburg	Salzburg	0	0
Regensburg	Ulm	0	0
Reims	Strasbourg	6.35803021	12.4506211
Riga	Tartu	1.56582358	0
Riga	Vilnius	-	0.01251229
Rijeka	Split	0.00178747	0.17695951
Rijeka	Zagreb	0.00536241	0.17695951
Rostock	Szczecin	0.00357494	0
Rotterdam	The Hague	0.23594602	0.22879614
Rotterdam	Utrecht	0.99115202	1.03315757
Rovaniemi	Tornio	-	0.55590312
Ruse	Shumen	0.5094289	0.04289928
Ruse	Sofia	0.02144964	0.04111181
Ruse	Varna	1.01885781	0.03217446
Ruse	Veliko Tarnovo	2.57038162	0.16623469
Saarbrücken	Strasbourg	0.05719903	0.00357494
Salamanca	Valladolid	0.3735812	1.42282599
Salzburg	Villach	1.85181875	1.7838949
San Sebastián	Vitoria-Gasteiz	2.86352668	6.4652784
Santander	Valladolid	0.16087229	0.563053
Santiago de Compostela	Vigo	2.54356958	1.40137635
Satu Mare	Suceava	0.01251229	0.01072482
Seinäjoki	Tampere	0.03038699	1.68737153
Shumen	Stara Zagora	0.00893735	0.01072482
Shumen	Varna	0.00536241	0.00536241
Shumen	Veliko Tarnovo	0.00536241	0.51300384
Skopje	Sofia	-	0.38609348
Skopje	Veles	0.01072482	3.3246939
Sofia	Thessaloniki	-	0
Sofia	Veliko Tarnovo	0.00357494	1.02600769
Split	Zagreb	0.52372866	0.39145589
Stara Zagora	Varna	0.01072482	0.53087854
Stara Zagora	Veliko Tarnovo	2.07167754	0.14299759
Stockholm	Östersund	1.51219948	1.58727321
Stockholm	Sundsvall	3.06729824	8.57985521
Stockholm	Västerås	0.26543927	0.55590312
Stuttgart	Ulm	9.00348557	10.3190634
Stuttgart	Zurich	-	0
Subotica	Szeged	3.0994727	0.0536241
Subotica	Timișoara	-	0.00893735
Sundsvall	Östersund	0.03217446	0.08579855

Sundsvall	Umeå	2.59183126	8.15086245
Szeged	Szolnok	0.13763518	0.03753687
Szombathely	Varaždin	0.00357494	0.00357494
Szombathely	Vienna	0	0
Szombathely	Zagreb	0.00714988	0.01251229
Tallinn	Tartu	0.52372866	0.56841541
Tampere	Turku	0.01251229	0.56484047
The Hague	Utrecht	0.28778264	0.3378318
Thessaloniki	Veles	-	2.22718742
Trieste	Venice	1.37277683	2.18428814
Trieste	Villach	0.18589686	0.16087229
Trondheim	Östersund	1.02600769	1.11180624
Utrecht	Zwolle	0.37536867	0.38788095
Vaduz/Schaan	Zurich	0.21807132	0.18768433
Valencia	Zaragoza	0	0
Varaždin	Zagreb	0.00357494	0.01072482
Västerås	Östersund	0	0
Venice	Verona	1.77138261	2.81526499
Venice	Villach	0.55947806	0.8651354
Vilnius	Šiauliai	0.01608723	0.00357494
Warsaw	Łódź	0.03217446	6.21324515
Wrocław	Łódź	0.00536241	0.21628385

F – Node Betweenness/Closeness Centrality

***Table 14**: Node betweenness and closeness centrality values, including differences, for all cities.*

node	node betweenness centrality			node closeness centrality		
	current [%]	future [%]	difference [% points]	current	future	difference (of ASPL) [min]
A Coruña	0	0	0	0.0006728	0.0007875	-216.49307
Aalborg	0	0	0	0.00081971	0.0009807	-200.27038
Aarhus	0.52687418	0.57003111	0.04315693	0.00088368	0.00104509	-174.78023
Aberdeen	0	0	0	0.00074603	0.00083952	-149.28141
Ajaccio	0	0	0	2.24E-05	2.24E-05	0
Alexandroupolis	0	0.02157846	0.02157846	1.43E-05	0.00059477	change, but initially not connected
Algeciras	0	0	0	0.00061466	0.00071515	-228.6242
Alicante	0.00359641	1.47992304	1.47632663	0.00069958	0.0008653	-273.76876
Almería	0	0.03956052	0.03956052	0.00059335	0.00078689	-414.51773
Alvesta	6.93208178	12.4813436	5.54926184	0.00079082	0.00103969	-302.68527
Amsterdam	0	0	0	0.00111097	0.00129071	-125.35375
Ancona	2.5354696	0.55025085	-1.9852188	0.00091284	0.00116236	-235.1587
Antequera	2.09490928	1.71728615	-0.3776231	0.00069823	0.00082087	-213.97346
Antwerp	1.76493859	1.78741616	0.02247757	0.00115044	0.00132724	-115.78875
Arad	9.16904929	4.38042833	-4.788621	0.00080013	0.00101139	-261.0661
Arnhem	1.53207099	1.49251047	-0.0395605	0.00114609	0.00133215	-121.86882
Arth-Goldau	2.97602992	0.65454676	-2.3214832	0.0011308	0.00133381	-134.60018
Athens	0	0.57003111	0.57003111	2.10E-05	0.00055733	change, but initially not connected
Avignon	14.8855442	13.1268994	-1.7586449	0.00106693	0.00126822	-148.76303
Bacău	0.14745284	0.28771286	0.14026002	0.00050899	0.00062116	-354.80024
Badajoz	1.55544766	1.91508874	0.35964108	0.00064239	0.00081996	-337.11762
Bălți	0	0	0	0.00046007	0.00055355	-367.07769
Banja Luka	0	0.26973081	0.26973081	0	0.00085181	change, but initially not connected
Banská Bystrica	0	0	0	0.00086397	0.00104474	-200.28099
Bar	0	0	0	0.00044648	0.00061358	-609.95003
Barcelona	12.6629624	10.8072144	-1.855748	0.00088227	0.00105977	-189.84078
Bari	1.03576631	1.12567657	0.08991027	0.00075279	0.00093518	-259.07641
Basel	4.72028915	7.78802755	3.0677384	0.0012062	0.0014417	-135.42903
Bastia	0	0	0	2.47E-05	2.47E-05	0
Bayonne	3.97403391	7.38343134	3.40939742	0.00094018	0.00112077	-171.38867
Belfast	0.01078923	0.01078923	0	9.23E-05	9.23E-05	0
Belgrade	1.57342972	12.4939311	10.9205013	0.00066099	0.00104461	-555.5835
Bergen	0	0	0	0.0004969	0.00063937	-448.44568
Berlin	9.54757152	15.4169139	5.8693424	0.001139	0.00142773	-177.55492
Bern	1.04655554	0.93686501	-0.1096905	0.00115736	0.00135553	-126.32163
Białystok	6.08512704	7.12988438	1.04475733	0.00080055	0.00104472	-291.93867
Bielefeld	2.22078366	4.15475356	1.9339699	0.00117217	0.00140198	-139.83669
Bilbao	0.36143928	0	-0.3614393	0.00075078	0.0009923	-324.1848
Birmingham	0.3659348	0.65274856	0.28681376	0.00100763	0.00118797	-150.65213
Bitola	0	0	0	4.02E-05	0.00067189	change, but initially not connected

Boden	1.57342972	6.6389743	5.06554459	0.00048877	0.00064413	-493.49392
Bodø	0	0	0	0.00037509	0.00044948	-441.26184
Bologna	7.98223373	8.50910791	0.52687418	0.00101993	0.00132507	-225.78532
Bolzano	3.67912823	11.7036198	8.02449156	0.00104488	0.00138374	-234.36908
Bordeaux	4.73467479	8.26814839	3.53347359	0.00102776	0.00120469	-142.90514
Bourges	0.45314776	0.4999011	0.04675334	0.00105	0.00123286	-141.25954
Braga	0	0.30929133	0.30929133	0.00059683	0.0007552	-351.37735
Brașov	1.48172124	2.03017389	0.54845264	0.00058971	0.00077038	-397.68917
Bratislava	3.19361277	0.95844347	-2.2351693	0.00105583	0.00129125	-172.67601
Bregenz	1.58961357	1.23177069	-0.3578429	0.001166	0.00137067	-128.06681
Bremen	4.14306522	0.55744367	-3.5856215	0.00113919	0.00135415	-139.34775
Brest	0	0	0	0.0009252	0.0010756	-151.13667
Brig	0.17982054	0.18881157	0.00899103	0.00109217	0.00128408	-136.84405
Bristol	1.56983331	1.69930409	0.12947079	0.00100391	0.00114761	-124.73427
Brno	1.22277967	10.7352862	9.51250652	0.00102319	0.00131737	-218.24415
Bruges	0	0	0	0.00112255	0.00130951	-127.18127
Brussels	12.160364	8.73388358	-3.4264804	0.00119812	0.00138674	-113.52543
Bucharest	0.74265883	1.5356674	0.79300858	0.00054337	0.00070399	-419.87372
Budapest	18.5269101	24.7217277	6.19481757	0.00098069	0.00119738	-184.53087
Burgas	0	0	0	0.00039539	0.00068331	-1065.6843
Burgos	1.82697668	5.32988078	3.5029041	0.00077861	0.00097661	-260.40235
Bydgoszcz	0.38481595	0.38841236	0.00359641	0.00090484	0.00111313	-206.80083
Cádiz	0	0	0	0.00065096	0.0007599	-220.23896
Caen	0.52687418	0.57003111	0.04315693	0.0010405	0.00121507	-138.0833
Cagliari	0	0	0	2.74E-05	2.74E-05	0
Calvi	0	0	0	2.11E-05	2.11E-05	0
Carlisle	0.05754257	0.61138983	0.55384726	0.00085081	0.00100173	-177.08322
Cartagena	0	0	0	0.00066142	0.00079483	-253.77579
České Budějovice	0.18161874	0.01438564	-0.1672331	0.00102523	0.00129738	-204.60631
Cherbourg-Octeville	0	0	0	0.00096123	0.00111571	-144.0458
Chișinău	0	0	0	0.00044034	0.00052727	-374.40306
Clermont-Ferrand	0	0	0	0.00095564	0.00112548	-157.90922
Cluj-Napoca	2.90769812	3.09291327	0.18521516	0.00068096	0.00086351	-310.4589
Coimbra	0.56463649	0.32367697	-0.2409595	0.00057473	0.00074879	-404.45947
Cologne	13.062164	9.75346604	-3.3086979	0.0012395	0.00145183	-117.98898
Constanța	0	0	0	0.00049787	0.00063446	-432.41592
Copenhagen	10.7604611	16.4661668	5.70570571	0.00087067	0.00116176	-287.78353
Córdoba	3.60899822	3.32847818	-0.28052	0.00071585	0.00084304	-210.75727
Cork	0	0	0	8.80E-05	8.80E-05	0
Çorlu	0.52687418	0	-0.5268742	0.00036619	0.00060232	-1070.5782
Cosenza	0.02157846	0.00719282	-0.0143856	0.00072494	0.00095072	-327.58993
Craiova	5.85675496	0.96923271	-4.8875223	0.00058628	0.00080786	-467.83207
Daugavpils	0	0	0	0.00049263	0.00079952	-779.18226
Debrecen	0.6329683	4.57283631	3.93986801	0.00086074	0.00102322	-184.48698
Derry	0	0	0	6.34E-05	6.34E-05	0
Deva	8.25016633	2.45455036	-5.795616	0.0007274	0.00093301	-302.96343
Dijon	9.39022855	5.80101059	-3.589218	0.00117569	0.00138819	-130.20142
Divača	1.27492762	1.62737588	0.35244826	0.00091357	0.00112929	-209.09631
Doncaster	5.74616533	4.89291687	-0.8532485	0.00099078	0.001131	-125.1322

Dortmund	6.63178148	4.33906961	-2.2927119	0.00118462	0.00138588	-122.59228
Drammen	1.57342972	1.13646581	-0.4369639	0.00062618	0.00081525	-370.36683
Dresden	2.64246282	8.83278488	6.19032206	0.00110853	0.00144205	-208.6351
Dublin	0.02697308	0.02697308	0	0.00013472	0.00013472	0
Duisburg	2.47882613	2.52647857	0.04765244	0.00120079	0.00140401	-120.53756
Durrës	0	0	0	0	0.0001497	change, but initially not connected
Düsseldorf	1.91418964	1.92587797	0.01168834	0.00121215	0.00141762	-119.57283
Edinburgh	2.54086422	2.22078366	-0.3200806	0.00084447	0.00095558	-137.68248
Edirne	1.05015195	1.68312025	0.6329683	0.00038572	0.00065211	-1059.0535
Eindhoven	0	0	0	0.00112138	0.00130578	-125.92945
Entroncamento	1.08791426	0	-1.0879143	0.00057749	0.00074001	-380.2947
Erfurt	7.62978547	11.3871356	3.75735016	0.00121228	0.0015072	-161.4144
Esbjerg	0	0	0	0.00091347	0.00108303	-171.39424
Essen	1.04475733	1.12387837	0.07912104	0.00119146	0.00139233	-121.082
Exeter	0.52687418	0.57003111	0.04315693	0.00094325	0.00107453	-129.51986
Faro	0	0	0	0.00050153	0.00068724	-538.79453
Feldkirch	0.3992016	0.4351657	0.03596411	0.00112785	0.00133025	-134.90222
Florence	4.535074	6.92129255	2.38621855	0.00098072	0.00126544	-229.42487
Foggia	1.55364946	1.71009333	0.15644387	0.00078963	0.00098972	-256.02622
Frankfurt	15.514017	16.6235097	1.10949273	0.00126834	0.00151941	-130.28347
Freiburg	3.36264408	6.94466922	3.58202514	0.00122544	0.0014687	-135.15987
Galați	0	0	0	0.00049514	0.00062878	-429.26408
Galway	0	0	0	8.68E-05	8.68E-05	0
Gdańsk	0.03596411	0.0323677	-0.0035964	0.00085638	0.00104368	-209.55531
Geneva	0.34525544	0.21938106	-0.1258744	0.00109136	0.00126379	-125.02028
Genoa	0.17622413	0.54665444	0.37043031	0.00096073	0.00127903	-259.03335
Ghent	0.52687418	0.57003111	0.04315693	0.00115485	0.00133321	-115.8487
Gijón	0	0	0	0.00068714	0.0008408	-265.9545
Girona	13.0603658	11.2477747	-1.812591	0.00090827	0.00109547	-188.13958
Glasgow	0.04315693	0.04315693	0	0.00081118	0.00093285	-160.79118
Gothenburg	2.48152344	2.60739782	0.12587438	0.00074486	0.00098488	-327.18283
Granada	0.52687418	0.04315693	-0.4837173	0.00066782	0.00079758	-243.60708
Graz	1.43676611	2.57503012	1.13826401	0.00097932	0.001232	-209.43076
Grenoble	0	0	0	0.00104502	0.00131332	-195.48581
Groningen	0	0.16183849	0.16183849	0.00102253	0.00124133	-172.37854
Guarda	0	0.58621496	0.58621496	0.00052362	0.00080885	-673.45506
Győr	18.8110266	24.6551941	5.84416752	0.00103267	0.00126284	-176.49497
Hallsberg	0.10789232	0.21578465	0.10789232	0.00070165	0.00090472	-319.89218
Hamburg	14.4791498	20.1695708	5.69042096	0.00111886	0.00136065	-158.82512
Hanover	10.9600619	14.2579705	3.29790869	0.00119012	0.00144248	-147.00164
Helsinki	0.00179821	0.00179821	0	9.11E-05	0.00048074	change, but initially not connected
Hradec Králové	0.10969053	0.13846182	0.02877129	0.00097212	0.00127711	-245.66655
Iași	1.56983331	1.69930409	0.12947079	0.00049281	0.00059775	-356.25115
Innsbruck	4.21319523	12.1927317	7.97953642	0.00114149	0.00143458	-178.97581
Inverness	0.52687418	0.57003111	0.04315693	0.00071033	0.00079776	-154.2799
Istanbul	0	0	0	0.00034651	0.00060286	-1227.1811
Jelgava	3.11628994	0.58801316	-2.5282768	0.00057235	0.00082662	-537.43514

Joensuu	0	0	0	6.04E-05	0.00044166	change, but initially not connected
Kalmar	0	0	0	0.00073796	0.0009564	-309.49956
Karlsruhe	18.4792577	20.0401	1.56084228	0.00126803	0.00152203	-131.6057
Kassel	8.98473324	10.1949255	1.21019223	0.0012267	0.0014908	-144.41221
Katowice	3.21069573	3.36444229	0.15374656	0.00090542	0.0011607	-242.91946
Kaunas	5.10690331	6.07253961	0.96563629	0.00065362	0.00093399	-459.27974
Kiel	0	0	0	0.00101795	0.00122221	-164.17349
Kingston upon Hull	0	0	0	0.00094062	0.0010708	-129.24353
Kiruna	0.52687418	0.57003111	0.04315693	0.00044366	0.00057308	-509.04431
Klagenfurt	0.48191904	1.38102174	0.8991027	0.0010185	0.00124255	-177.04111
Klaipėda	0	0	0	0.00055747	0.00077989	-511.57959
Kolari	0	0	0	5.82E-05	0.00055183	change, but initially not connected
Koper	0	0	0	0.00087294	0.00109998	-236.44988
Košice	0.23736311	0.25354696	0.01618385	0.00082874	0.0010375	-242.79632
Koszalin	0.00179821	0.00179821	0	0.00084168	0.00110573	-283.72101
Kraków	0.52507597	0.53586521	0.01078923	0.00086944	0.00111245	-251.24389
Kristiansand	0.52687418	0.57003111	0.04315693	0.00053695	0.00070057	-434.94154
Kuopio	0.00719282	0.56283829	0.55564547	8.94E-05	0.00049929	change, but initially not connected
La Rochelle	0	0	0	0.00100062	0.00117099	-145.39972
Larissa	0.00359641	1.13646581	1.1328694	3.06E-05	0.00063127	change, but initially not connected
Lausanne	0.60959163	0.52327777	-0.0863139	0.00111847	0.00129927	-124.41281
Le Havre	0	0	0	0.00102117	0.00118984	-138.82323
Le Mans	1.53926381	1.73886461	0.1996008	0.00111771	0.00132012	-137.17592
Lecce	0	0	0	0.00070577	0.00086761	-264.31278
Leeds	0.01078923	0.01078923	0	0.00096023	0.00109416	-127.47374
Leicester	0.48911187	0.53047059	0.04135872	0.00101574	0.00116175	-123.73252
Leipzig	2.11289133	2.62358167	0.51069033	0.00117335	0.00146859	-171.33052
León	0.52687418	0.57003111	0.04315693	0.00073949	0.00091402	-258.20324
Liberec	0	0	0	0.00099019	0.00123734	-201.72283
Liège	10.3540666	6.95006384	-3.4040028	0.00120705	0.00140451	-116.4742
Liepāja	0	0	0	0.00052134	0.00073108	-550.29713
Lille	17.0137203	16.4877452	-0.5259751	0.00119257	0.0013816	-114.72751
Limerick	0.00179821	0.00179821	0	0.00010295	0.00010295	0
Limoges	0	0	0	0.00093424	0.00107992	-144.39495
Linköping	5.45935157	10.9510708	5.49171926	0.00074115	0.00096548	-313.50399
Linz	19.2354031	18.3902465	-0.8451565	0.00114295	0.00139078	-155.90471
Lisbon	0.52687418	1.39900379	0.87212961	0.00055863	0.00077038	-492.05202
Liverpool	0	0	0	0.00094814	0.00111434	-157.30547
Ljubljana	1.88092284	1.46553739	-0.4153854	0.00094767	0.00113381	-173.23268
Łódź	0	6.45196094	6.45196094	0.00087371	0.00118017	-297.20133
London	12.1468774	13.2275989	1.08072144	0.00109339	0.0012575	-119.3539
Lübeck	0.00179821	16.6190142	16.617216	0.00105822	0.00129499	-172.77783
Lublin	0	0	0	0.00080569	0.00101582	-256.75032
Lugano	2.65235295	0.43696391	-2.215389	0.00106117	0.00128707	-165.39824
Luleå	0	7.12988438	7.12988438	0.00048157	0.00065516	-550.1921
Luxembourg	0.00179821	0.0323677	0.03056949	0.001146	0.00135885	-136.68316
Lyon	18.0360001	16.8770567	-1.1589434	0.0011275	0.00134908	-145.66709

Madrid	11.7800435	9.87574401	-1.9042995	0.00078671	0.00093574	-202.43817
Málaga	0	0	0	0.00068844	0.00080837	-215.50668
Malmö	10.3091115	15.9986334	5.68952186	0.00084359	0.00112011	-292.63475
Manchester	0.02157846	1.08971247	1.068134	0.0009297	0.00112249	-184.73198
Mannheim	11.4284944	13.4766503	2.04815594	0.00126565	0.00152403	-133.95544
Maribor	1.11668555	1.33786481	0.22117926	0.00093912	0.00116871	-209.18383
Marseille	0.42437647	0.20499541	-0.2193811	0.00102557	0.00121377	-151.19202
Messina	1.05015195	1.13646581	0.08631386	0.00064518	0.00082901	-343.69523
Metz	0.65814317	0.65994138	0.00179821	0.0012152	0.00143945	-128.20042
Milan	7.78622934	11.0382838	3.25205445	0.00105029	0.00134408	-208.11588
Miskolc	0.27692363	0.30749312	0.03056949	0.00087322	0.0010442	-187.51426
Montpellier	13.79763	12.1037205	-1.6939095	0.00100675	0.00118859	-151.96673
Mostar	0	0	0	2.60E-05	0.00065218	change, but initially not connected
Munich	11.9310928	14.9322976	3.0012048	0.00122948	0.00148472	-139.82038
Münster	4.28692165	0.12407617	-4.1628455	0.00115996	0.00135428	-123.69538
Murcia	0.52687418	1.14006222	0.61318804	0.00068714	0.00082934	-249.51685
Nantes	0.00359641	0.00359641	0	0.00102421	0.00120199	-144.40467
Naples	2.57503012	5.01159842	2.4365683	0.00084292	0.00105879	-241.88191
Narva	0	0	0	0.00038622	0.00072709	-1213.8522
Narvik	0	0	0	0.00040575	0.00051554	-524.88755
Newcastle upon Tyne	3.29341317	2.75305245	-0.5403607	0.00091767	0.00104292	-130.86561
Nice	0.07732283	0	-0.0773228	0.00091373	0.00114223	-218.93331
Niš	0	10.1220981	10.1220981	0.00052945	0.00095848	-845.44337
Norwich	0	0	0	0.00096819	0.00110465	-127.59079
Nottingham	0	0	0	0.00098539	0.00112486	-125.82798
Novi Sad	2.08591825	12.5766485	10.4907303	0.00067891	0.00107653	-544.04586
Nuremberg	11.688335	7.65226304	-4.036072	0.00124197	0.0014755	-127.43666
Odense	11.2082142	0.24275773	-10.965456	0.00092408	0.00110461	-176.86123
Olbia	0	0	0	3.34E-05	3.34E-05	0
Olsztyn	0	0	0	0.00083244	0.00101197	-213.1076
Oradea	3.38422255	3.54246462	0.15824207	0.00080084	0.00096131	-208.44891
Osijek	0	0.00539462	0.00539462	0.00073888	0.00093293	-281.51688
Oslo	2.08951466	2.26214238	0.17262772	0.00064041	0.0008378	-367.8975
Östersund	1.02857348	1.11488734	0.08631386	0.00056888	0.00072204	-372.88469
Ostrava	3.14416213	4.59801118	1.45384906	0.00092451	0.00126658	-292.12154
Oulu	0.03596411	3.36624049	3.33027638	0.00010793	0.00056837	change, but initially not connected
Ourense	3.53707	2.4671378	-1.0699322	0.00070709	0.00083115	-211.09333
Padborg	12.9632627	2.01219183	-10.951071	0.000994	0.00118535	-162.40311
Palermo	0	0	0	0.00057433	0.00072308	-358.16819
Pamplona	0.07552463	0.18521516	0.10969053	0.00079268	0.000968	-228.49322
Paris	14.9107191	16.5012318	1.59051267	0.00119922	0.00141654	-127.93059
Pärnu	0	1.69930409	1.69930409	0	0.00081691	change, but initially not connected
Patras	0	0	0	0	0.00052372	change, but initially not connected
Pécs	0.52687418	0.01258744	-0.5142867	0.00084733	0.00101785	-197.71445
Peja	0	0	0	4.00E-05	0.00063835	change, but initially not connected
Penzance	0	0	0	0.00079544	0.00089862	-144.34096

Perpignan	13.4559709	11.6865368	-1.7694341	0.00093568	0.00113338	-186.42464
Perth	1.04835374	1.1346676	0.08631386	0.00078683	0.00088742	-144.07107
Perugia	0	0	0	0.00089491	0.00113565	-236.87797
Pescara	2.0355685	0.01798205	-2.0175864	0.0008547	0.00107696	-241.46142
Peterborough	6.12019205	5.33347719	-0.7867149	0.00104072	0.00119202	-121.95849
Pisa	0.0323677	0	-0.0323677	0.00092802	0.00119154	-238.31969
Pitești	0	0	0	0.00053308	0.00071506	-477.41917
Plovdiv	0.01078923	3.69531208	3.68452285	0.0004128	0.0007788	-1138.4406
Plzeň	0.06473539	0.11868156	0.05394616	0.00104479	0.00131303	-195.52973
Podgorica	0.52687418	0.57003111	0.04315693	0.00046021	0.00063775	-604.92449
Porto	1.03756451	0.05394616	-0.9836183	0.0006003	0.00073705	-309.07195
Poznań	7.39871608	8.12788837	0.72917229	0.00098176	0.00122653	-203.26968
Prague	1.28841416	7.74307241	6.45465825	0.00103916	0.00138725	-241.46353
Prešov	0	0.06113898	0.06113898	0.00082245	0.00102292	-238.28482
Pristina	0.00539462	0.57003111	0.56463649	5.64E-05	0.000692	change, but initially not connected
Regensburg	8.76804949	3.17742893	-5.5906206	0.00119941	0.0014296	-134.24805
Reims	6.58412904	12.6234018	6.03927281	0.00121059	0.00143596	-129.64702
Rennes	0.52687418	0.57003111	0.04315693	0.00105821	0.00124367	-140.91523
Riga	2.09131287	3.37343331	1.28212044	0.00055623	0.00086022	-635.34484
Rijeka	0	0.17622413	0.17622413	0.0008267	0.00101595	-225.32712
Rome	3.05335275	5.5025085	2.44915574	0.00089327	0.00113325	-237.0637
Rostock	0	0	0	0.00101899	0.00124837	-180.31405
Rotterdam	1.32258007	1.51768535	0.19510528	0.00112709	0.00129995	-117.97812
Rovaniemi	0	0	0	7.24E-05	0.00057703	change, but initially not connected
Ruse	4.12688137	0.22477567	-3.9021057	0.00048617	0.00067053	-565.53076
Rzeszów	0.00179821	0.03596411	0.0341659	0.00080201	0.00101851	-265.04299
Saarbrücken	0	0	0	0.00119435	0.00141712	-131.61691
Salamanca	0	1.12567657	1.12567657	0.00073169	0.00090206	-258.13475
Salzburg	12.5892359	17.0991351	4.50989912	0.00116822	0.00141939	-151.47838
San Sebastián	3.57663052	6.94287101	3.36624049	0.00088215	0.00104334	-175.13657
Santander	0	0	0	0.00066677	0.0008515	-325.3789
Santiago de Compostela	3.05694916	1.94745644	-1.1094927	0.00068746	0.00080611	-214.10806
Sarajevo	0	0.57003111	0.57003111	2.60E-05	0.00070776	change, but initially not connected
Sassari	0	0	0	4.16E-05	4.16E-05	0
Satu Mare	0	0	0	0.00075558	0.00087945	-186.41046
Seinäjoki	0.02157846	1.68851486	1.6669364	0.00011402	0.00052159	change, but initially not connected
Seville	0.59160957	0.57003111	-0.0215785	0.00069337	0.00081363	-213.16913
Sheffield	0.11688335	0.10429591	-0.0125874	0.00096648	0.00111242	-135.74795
Shumen	0.00179821	0.00179821	0	0.00043963	0.00061838	-657.52794
Šiauliai	4.12688137	0.57003111	-3.5568503	0.00060151	0.00083585	-466.10046
Skopje	0.00719282	4.44876014	4.44156732	6.94E-05	0.00078209	change, but initially not connected
Sligo	0	0	0	6.60E-05	6.60E-05	0
Sofia	0.48911187	5.54926184	5.06014997	0.00044222	0.00083	-1056.4999
Southampton	0	0	0	0.00100137	0.00114545	-125.61658
Split	0	0	0	0.00061959	0.00075652	-292.13872
Stara Zagora	1.6004028	3.31589074	1.71548794	0.00041389	0.00072901	-1044.3649

Stavanger	0	0	0	0.00048505	0.00062047	-449.93299
Stockholm	4.83986981	10.7173041	5.87743432	0.00069908	0.00091431	-336.73937
Strasbourg	15.6183129	13.1313949	-2.4869181	0.00125398	0.00149099	-126.76427
Stuttgart	9.30211649	10.4979231	1.19580659	0.00124934	0.001517	-141.22299
Subotica	2.59840679	13.1520742	10.5536674	0.00080967	0.00111791	-340.54754
Suceava	2.44196292	2.49950549	0.05754257	0.00053554	0.00065461	-339.67427
Sundsvall	2.59840679	8.1728435	5.57443671	0.00060317	0.00077463	-366.9768
Suwałki	5.59781338	6.6030102	1.00519681	0.00073353	0.00096745	-329.62956
Swansea	0	0	0	0.00091546	0.00104127	-131.97446
Syracuse	0	0	0	0.00058228	0.00075211	-387.78978
Szczecin	0.46483609	0.51428674	0.04945065	0.00093917	0.00127732	-281.87531
Szeged	3.10729892	0	-3.1072989	0.00087305	0.00105246	-195.25414
Szolnok	13.8713564	9.62938987	-4.2419665	0.00091852	0.00110215	-181.38387
Szombathely	0.53586521	0.01438564	-0.5214796	0.0009625	0.00117426	-187.35592
Tallinn	0	1.13826401	1.13826401	0.0004037	0.00079022	-1211.6367
Tampere	0.02337667	1.1346676	1.11129093	0.00011402	0.00050467	change, but initially not connected
Taranto	0.02157846	0.00179821	-0.0197803	0.00070645	0.00086846	-264.06069
Tartu	1.05015195	0	-1.0501519	0.00043053	0.00075875	-1004.7479
The Hague	0	0	0	0.00111388	0.00128471	-119.37431
Thessaloniki	0.00359641	1.70290051	1.69930409	3.06E-05	0.0006702	change, but initially not connected
Thurso	0	0	0	0.00060272	0.00067297	-173.18957
Timișoara	0	1.22457787	1.22457787	0.00074781	0.00095962	-295.15907
Tirana	0	0	0	0	0.0001497	change, but initially not connected
Tornio	0.01438564	5.01519484	5.00080919	8.33E-05	0.00060688	change, but initially not connected
Toulouse	0.12047976	0.12947079	0.00899103	0.00093552	0.00114867	-198.35128
Tours	5.47553542	9.03238568	3.55685026	0.00112495	0.00133131	-137.79017
Trieste	1.1346676	1.80899462	0.67432702	0.00092727	0.00117847	-229.877
Trondheim	0.52687418	0.57003111	0.04315693	0.00049935	0.00062064	-391.34712
Turin	4.80840122	9.77054899	4.96214778	0.00103122	0.00131537	-209.48448
Turku	0	0	0	8.55E-05	0.00047946	change, but initially not connected
Ulm	8.77883872	10.0213986	1.24255993	0.00123019	0.00149917	-145.85095
Umeå	2.08591825	7.65316214	5.56724389	0.00054653	0.00069452	-389.86921
Ungheni	1.05195015	1.13826401	0.08631386	0.00048375	0.00058545	-359.07089
Utrecht	1.3675352	1.4349679	0.0674327	0.00113287	0.00131281	-120.98964
Vaduz/Schaan	0	0	0	0.00112294	0.00131023	-127.29441
Valencia	0.22837208	1.97982414	1.75145205	0.00076986	0.00091061	-200.77184
Valladolid	1.30909352	4.50090809	3.19181457	0.00076716	0.00095223	-253.3436
Varaždin	0.00359641	0.00179821	-0.0017982	0.00084896	0.00103732	-213.89352
Varna	0.51428674	0.00179821	-0.5124885	0.00043559	0.00064513	-745.65611
Västerås	0	0	0	0.00067017	0.00086889	-341.26186
Veles	0.00539462	2.79261297	2.78721836	6.46E-05	0.00075115	change, but initially not connected
Veliko Tarnovo	2.07512902	0.64375753	-1.4313715	0.00044984	0.00067218	-735.30629
Venice	1.81259103	2.92388197	1.11129093	0.00099591	0.00129199	-230.11012
Verona	5.21659384	13.7059215	8.48932765	0.00103962	0.00137508	-234.66321
Vienna	19.3702685	28.0448113	8.67454281	0.00109595	0.00135084	-172.17197
Vigo	2.04455953	0.85234936	-1.1922102	0.0006611	0.00077267	-218.41986

Villa San Giovanni	1.56983331	1.69930409	0.12947079	0.00068727	0.00089414	-336.64587
Villach	2.1021021	2.44376113	0.34165902	0.00103175	0.00125754	-174.02344
Vilnius	0	0.55384726	0.55384726	0.00062431	0.00090138	-492.35574
Vitoria-Gasteiz	2.49231267	6.22179065	3.72947798	0.00081759	0.00100152	-224.62105
Warsaw	7.28273183	8.46235457	1.17962274	0.00089671	0.00114472	-241.60748
Waterford	0	0	0	9.07E-05	9.07E-05	0
Wrocław	1.16433799	0.99800399	-0.166334	0.00094341	0.00120659	-231.20141
Wuppertal	5.74436712	3.33746921	-2.4068979	0.00121344	0.00141973	-119.74599
York	3.79511248	3.29790869	-0.4972038	0.00097048	0.00110643	-126.61295
Zagreb	0.54305803	1.43676611	0.89370808	0.00086573	0.00104023	-193.77833
Zaragoza	11.5714517	7.9372786	-3.6341731	0.00082998	0.00098841	-193.11377
Žilina	3.35545126	1.44755534	-1.9078959	0.0009518	0.00116478	-192.10946
Zurich	4.54766143	1.89530848	-2.652353	0.00117824	0.00138553	-126.98079
Zwolle	0.52687418	0.32187876	-0.2049954	0.00109341	0.00127062	-127.54634

G – Relative Reductions and Individual Project Impacts

Table 15: Relative reductions between the two cities affected by a project edges; individual positive and negative (i.e., inverse) impacts on the average shortest path length of every project.

city 1 / start	city 2 / end	direct reduction along edge [%]	positive single impact on ASPL [‰]	negative single impact on ASPL [‰]
Durrës	Tirana	100	0	0
Graz	Vienna	29.49	-0.4075133	0.71830019
Graz	Maribor	25	-0.258982	0.29762828
Graz	Klagenfurt	78.87	-1.8718062	0.8414153
Brno	Vienna	31.03	-0.5343765	2.78317749
Bratislava	Vienna	13.04	-0.1123927	0.07826429
Linz	Salzburg	17.65	-1.4543004	2.02287817
Innsbruck	Munich	47.12	-1.5949176	2.25295859
Bolzano	Innsbruck	55.28	-4.1049447	7.72525466
Bregenz	Zurich	9.2	-0.1371682	0.06291885
Bruges	Ghent	25.91	-0.0202837	0.05618677
Brussels	Luxembourg	38.78	-0.0344416	0.03318375
Plovdiv	Sofia	47.37	-0.4149665	3.30221104
Craiova	Sofia	65.71	-10.057101	0.27045946
Niš	Sofia	31.25	-2.2255369	11.5150035
Skopje	Sofia	100	31.8464197	0.78598982
Plovdiv	Stara Zagora	26.92	-0.0192813	1.40750679
Bucharest	Ruse	61.9	-6.649437	0.6317211
Stara Zagora	Varna	15.84	-0.0042847	0.20144808
Burgas	Stara Zagora	28.46	-0.0747828	0.21050531
Rijeka	Zagreb	66.91	-0.145944	0.18543231
Split	Zagreb	13.56	-0.2219764	0.18916237
Rijeka	Split	17.43	-0.1596677	0.07090763
Plzeň	Prague	38.55	-0.2129105	0.13360232
Prague	České Budějovice	18.37	-0.0437665	0.06290313
Dresden	Prague	54.89	-1.3472727	4.00899621
Nuremberg	Plzeň	19.57	-0.3300469	0.00312932
Plzeň	Regensburg	24	-0.1691088	0.0303935
Brno	Ostrava	78.18	-4.2224801	4.3483987
Copenhagen	Odense	13.04	-1.1500956	0.02986543
Copenhagen	Lübeck	64.97	-14.799433	18.5667717
Aarhus	Odense	5.43	-0.0048968	0.00684538
Esbjerg	Odense	6.33	-0.0024484	0.00342269
Odense	Padborg	6.17	-0.6565935	0.03060864
Aalborg	Aarhus	23.08	-0.1079847	0.11195135
Narva	Tallinn	18.7	-0.0009755	0.53999543
Tallinn	Tartu	21.16	-0.3067252	0.53885635
Pärnu	Tallinn	100	6.43179078	7.17706127
Narva	Tartu	17.11	-0.1601332	0
Pärnu	Riga	100	3.02141327	10.2285032
Helsinki	Turku	30.36	0	0.00132996
Genoa	Nice	9.6	-0.0481161	0.22665449
Montpellier	Perpignan	42.39	-6.24424	3.91635699

Montpellier	Toulouse	20.45	-0.0381144	0.03526276
Perpignan	Toulouse	12.5	-0.0329724	0.02276579
Bayonne	Toulouse	38.42	-0.0295445	0.00592615
Bordeaux	Toulouse	55.88	-0.6242337	0.33340927
Bayonne	Bordeaux	28.04	-1.5457759	2.26863488
Grenoble	Lyon	65.06	-0.2339555	0.18312352
Lyon	Turin	49.29	-6.4255939	3.22992987
Karlsruhe	Strasbourg	22.22	-1.7277125	1.38508818
Freiburg	Strasbourg	12.5	-0.0092019	0.00921193
Grenoble	Turin	42.93	-2.0717057	0.05879206
Bielefeld	Hanover	38	-1.0525176	0.51236846
Karlsruhe	Stuttgart	12.5	-0.4799676	0.47244454
Freiburg	Karlsruhe	30	-1.14666	0.62711532
Berlin	Dresden	27.27	-0.3304961	2.02087414
Berlin	Hanover	15.84	-0.4945496	0.18288908
Berlin	Szczecin	51.35	-1.0148165	0.96672426
Dresden	Leipzig	30.88	-0.5183024	0.57329489
Erfurt	Frankfurt	50.4	-4.9048439	2.23283474
Erfurt	Nuremberg	25	-0.5514316	0.40129592
Bremen	Groningen	49.81	-0.2401814	0.24604951
Frankfurt	Kassel	52.44	-4.1504702	3.04764279
Frankfurt	Mannheim	23.68	-1.0263678	1.14238093
Mannheim	Stuttgart	13.16	-0.0713546	0.11066051
Stuttgart	Ulm	35.71	-1.5816135	1.59016998
Stuttgart	Zurich	11.4	-0.0104873	0
Basel	Freiburg	32.5	-0.5221626	0.49376726
Thessaloniki	Veles	12.6	-0.321764	3.21916053
Athens	Patras	100	0	-5.0690419
Budapest	Subotica	65.55	-4.4641179	18.4452522
Debrecen	Oradea	22.75	-0.0969233	0.93212132
Arad	Szolnok	1.54	-0.1719478	3.27356769
Palermo	Syracuse	21.51	-0.0012242	0.00117349
Messina	Syracuse	20.27	-0.1793751	0.18599884
Naples	Villa San Giovanni	30.61	-1.7597957	1.51365111
Cosenza	Naples	40.68	-0.7263051	0.43855436
Naples	Taranto	30	-0.0090999	0
Foggia	Naples	60.12	-0.2246474	0.21353684
Ancona	Rome	13.95	-0.0042847	9.78E-05
Perugia	Rome	11.11	-0.0021423	0.00322711
Pescara	Rome	42.86	-0.0148128	0.00176024
Ancona	Perugia	6.25	-0.0012242	0.00039116
Genoa	Turin	42.86	-0.1192089	0.11174867
Genoa	Milan	46.81	-0.2622074	0.31883182
Geneva	Turin	25.62	-0.0015302	0
Milan	Verona	6.85	-0.1368825	0.41863949
Venice	Verona	8.33	-0.1012707	0.15369053
Bolzano	Verona	66.67	-3.4721708	7.02693328
Trieste	Venice	8.85	-0.1572304	0.23732007
Kaunas	Riga	62.9	-5.3192935	2.53005359

Riga	Vilnius	56.49	-2.0276181	0.00219052
Vilnius	Šiauliai	28.99	-0.0073452	0.00156466
Klaipėda	Šiauliai	29.31	-0.2039907	0.21146366
Kaunas	Vilnius	41.54	-0.1570263	0.3252926
Kaunas	Suwałki	75.95	-7.7076561	8.6463056
Eindhoven	Rotterdam	14.13	-0.0316948	0.02368554
Amsterdam	Zwolle	13.91	-0.0354313	0.01297466
Amsterdam	Utrecht	27.55	-0.0220216	0.00719507
Groningen	Zwolle	27.77	-0.1005142	0.0346424
Oslo	Trondheim	6.25	-0.0073452	0.00704097
Bergen	Oslo	11.28	-0.2672496	0.27723802
Gothenburg	Oslo	11.17	-0.6513022	0.65541609
Drammen	Kristiansand	18.22	-0.514381	0.53319667
Białystok	Warsaw	32.56	-3.1417927	3.49771695
Białystok	Suwałki	27.52	-2.0829945	2.33408005
Poznań	Szczecin	23.57	-0.0231376	0.01736771
Poznań	Łódź	64.09	-1.6112925	2.55620296
Poznań	Wrocław	25.23	-0.2032559	0.14926877
Warsaw	Łódź	37.5	-0.0178734	1.83088572
Wrocław	Łódź	67.39	-0.2928698	0.10669019
Braga	Vigo	80	-2.204504	0.53198812
Coimbra	Porto	56.52	-0.4685719	0.0337615
Coimbra	Guarda	15.33	-0.1379846	0.09850694
Coimbra	Lisbon	54.46	-0.0201994	0.10764563
Lisbon	Porto	58.56	-0.4647121	0.00222964
Faro	Lisbon	16.67	-0.1799875	0.18658559
Badajoz	Lisbon	63.13	-1.7963038	1.56313069
Arad	Deva	54.19	-5.2242714	1.31889119
Arad	Timișoara	11.9	-0.7807534	0.34461447
Cluj-Napoca	Deva	14.59	-0.0046997	0.02703802
Brașov	Deva	8.92	-0.3875482	1.55367961
Craiova	Timișoara	39.06	-9.0542321	1.46747911
Brașov	Cluj-Napoca	21.4	-0.289017	0.072881
Cluj-Napoca	Oradea	26.91	-1.4181196	2.10312374
Novi Sad	Subotica	80.56	-5.1743302	21.7323855
Belgrade	Niš	69.88	-1.3935919	24.1601162
Košice	Žilina	24.97	-0.513067	0.2406529
Prešov	Žilina	22.28	-0.2195522	0.14611394
Košice	Prešov	12.99	-0.0267268	-0.0026993
Divača	Koper	47.83	-0.1366315	0.13971802
Pamplona	Zaragoza	45.45	-0.1282293	0.14175352
Murcia	Valencia	28.33	-0.0004081	0
Alicante	Valencia	53.12	-0.7487816	0.86015172
Antequera	Seville	24.24	0	0
Badajoz	Madrid	43.23	-3.3248231	2.25173895
Santander	Valladolid	33.52	-0.3286178	0.10669019
Burgos	Santander	25.21	-0.1391275	0
León	Santander	29.7	-0.0024484	0.00140819
Bilbao	San Sebastián	73.93	-1.4777304	0.21087692

Bilbao	Vitoria-Gasteiz	71.9	-0.5593568	0.04695933
San Sebastián	Vitoria-Gasteiz	50.89	-2.2293013	2.28481009
Burgos	Vitoria-Gasteiz	62.5	-1.5032694	2.25108381
Antequera	Granada	39.66	-0.2750682	0.15077445
Almería	Murcia	87.94	-0.8675764	0.35905012
Almería	Granada	60.84	-0.606216	0.04731138
Luleå	Umeå	59.46	-2.1777817	6.83619073
Linköping	Stockholm	17.72	-0.8711123	1.6620199
Gothenburg	Malmö	13.07	-0.6713033	0.67593269
Arth-Goldau	Zurich	15	-0.2352211	0.06497246
Edirne	Istanbul	53.85	-0.8376349	0.85823476
Birmingham	Liverpool	7	-0.0007957	0.00068454
Birmingham	London	35.53	-0.4766387	0.20856904
Birmingham	Carlisle	4.05	-0.0431544	0.00420502
Manchester	Sheffield	20.75	-0.0036318	0.00273815
Leeds	Manchester	20.37	-0.0023464	0.00185803
London	Manchester	35.9	-0.6474615	0.30579304
Liverpool	London	21.64	-0.3271274	0.16782924
Leeds	Sheffield	0	0	0
Kingston upon Hull	Leeds	17.24	-0.0006121	0.00058675

H – Capital and Metropole Access

Table 16: Changes in capital and metropole (>500'000 inhabitants) access.

node	capi-tal	$t_{current}$ [min]	t_{future} [min]	differ-ence [%]	metropole (≥500'000 inh)	$t_{current}$ [min]	t_{future} [min]	differ-ence [%]
A Coruña	no	201	201	0	no	201	201	0
Aalborg	no	239	207	13.39	no	239	207	13.39
Aarhus	no	161	147	8.7	no	161	147	8.7
Aberdeen	no	396	396	0	no	149	149	0
Ajaccio	no	X	X	X	no	X	X	X
Alexandroupolis	no	793	793	0	no	793	265.29	66.55
Algeciras	no	322	322	0	no	190	190	0
Alicante	no	142	142	0	no	128	60	53.12
Almería	no	374	230	38.5	no	242	118	51.24
Alvesta	no	163	149	8.59	no	117	117	0
Amsterdam	yes	-	-	-	yes	-	-	-
Ancona	no	215	185	13.95	no	170	170	0
Antequera	no	150	150	0	no	18	18	0
Antwerp	no	35	35	0	yes	-	-	-
Arad	no	610	492.95	19.19	no	251	175.79	29.97
Arnhem	no	60	57.56	4.06	no	60	57.56	4.06
Arth-Goldau	no	96	90	6.25	no	144	144	0
Athens	yes	-	-	-	yes	-	-	-
Avignon	no	179	179	0	no	34	34	0
Bacău	no	247	247	0	no	247	247	0
Badajoz	no	266	151	43.23	no	217	80	63.13
Bălți	no	274	274	0	no	274	274	0
Banja Luka	no	X	334.98	100	no	X	248.91	100
Banská Bystrica	no	222	222	0	no	268	262	2.24
Bar	no	59	59	0	no	646	646	0
Barcelona	no	158	158	0	yes	-	-	-
Bari	no	283	185	34.63	no	220	122	44.55
Basel	no	58	58	0	no	140	104	25.71
Bastia	no	X	X	X	no	X	X	X
Bayonne	no	273	243	10.99	no	203	125	38.42
Belfast	no	X	X	X	no	125	125	0
Belgrade	yes	-	-	-	yes	-	-	-
Bergen	no	399	354	11.28	no	399	354	11.28
Berlin	yes	-	-	-	yes	-	-	-
Bern	yes	-	-	-	no	185	162	12.43
Białystok	no	129	87	32.56	no	129	87	32.56
Bielefeld	no	151	116	23.18	no	46	31	32.61
Bilbao	no	254	176	30.71	no	254	159	37.4
Birmingham	no	76	49	35.53	yes	-	-	-
Bitola	no	202	202	0	no	202	202	0
Boden	no	563	485	13.85	no	563	485	13.85
Bodø	no	1066	1036	2.81	no	1066	1036	2.81

Bologna	no	132	132	0	no	64	64	0
Bolzano	no	274	214	21.9	no	163	98	39.88
Bordeaux	no	166	166	0	no	136	60	55.88
Bourges	no	120	120	0	no	120	120	0
Braga	no	217	111	48.85	no	217	111	48.85
Brașov	no	148	148	0	no	148	148	0
Bratislava	yes	-	-	-	no	46	40	13.04
Bregenz	no	353	341	3.4	no	122	122	0
Bremen	no	160	144	10	yes	-	-	-
Brest	no	224	224	0	no	224	224	0
Brig	no	66	66	0	no	119	119	0
Bristol	no	76	76	0	no	71	71	0
Brno	no	148	148	0	no	87	60	31.03
Bruges	no	50	40.97	18.07	no	50	40.97	18.07
Brussels	yes	-	-	-	yes	-	-	-
Bucharest	yes	-	-	-	yes	-	-	-
Budapest	yes	-	-	-	yes	-	-	-
Burgas	no	405	263	35.06	no	405	263	35.06
Burgos	no	103	103	0	no	103	103	0
Bydgoszcz	no	178	178	0	no	81	81	0
Cádiz	no	243	243	0	no	83	83	0
Caen	no	115	115	0	no	115	115	0
Cagliari	no	X	X	X	no	X	X	X
Calvi	no	X	X	X	no	X	X	X
Carlisle	no	249	208	16.47	no	73	73	0
Cartagena	no	215	215	0	no	215	164	23.72
České Budějovice	no	98	80	18.37	no	98	80	18.37
Cherbourg-Octeville	no	185	185	0	no	185	185	0
Chișinău	yes	-	-	-	yes	-	-	-
Clermont-Ferrand	no	261	261	0	no	145	145	0
Cluj-Napoca	no	529	419.76	20.65	no	473	354.75	25
Coimbra	no	112	51	54.46	no	112	51	54.46
Cologne	no	262	222	15.27	yes	-	-	-
Constanța	no	150	150	0	no	150	150	0
Copenhagen	yes	-	-	-	yes	-	-	-
Córdoba	no	118	118	0	no	42	42	0
Cork	no	152	152	0	no	152	152	0
Çorlu	no	excetption: capital not in network			no	137	137	0
Cosenza	no	240	168	30	no	177	105	40.68
Craiova	no	243	243	0	no	243	180	25.93
Daugavpils	no	205	205	0	no	205	136.27	33.53
Debrecen	no	155	155	0	no	155	155	0
Derry	no	X	X	X	no	246	246	0
Deva	no	478	402.38	15.82	no	383	266.36	30.46
Dijon	no	96	96	0	no	95	95	0
Divača	no	96	96	0	no	225	225	0
Doncaster	no	94	94	0	no	24	24	0

Dortmund	no	197	162	17.77	yes	-	-	-
Drammen	no	32	32	0	no	32	32	0
Dresden	no	110	80	27.27	yes	-	-	-
Dublin	yes	-	-	-	yes	-	-	-
Duisburg	no	229	194	15.28	yes	-	-	-
Durrës	no	X	20	100	no	X	X	X
Düsseldorf	no	243	208	14.4	yes	-	-	-
Edinburgh	no	256	256	0	no	45	45	0
Edirne	no	excetption: capital not in network			no	260	120	53.85
Eindhoven	no	74	71.56	3.29	no	62	48.34	22.04
Entroncamento	no	52	52	0	no	52	52	0
Erfurt	no	97	97	0	no	40	40	0
Esbjerg	no	148	134	9.46	no	148	134	9.46
Essen	no	218	183	16.06	yes	-	-	-
Exeter	no	133	133	0	no	128	128	0
Faro	no	180	150	16.67	no	180	150	16.67
Feldkirch	no	366	354	3.28	no	153	153	0
Florence	no	95	95	0	no	95	95	0
Foggia	no	226	128	43.36	no	163	65	60.12
Frankfurt	no	222	159	28.38	yes	-	-	-
Freiburg	no	344	254	26.16	no	100	77	23
Galați	no	217	217	0	no	217	217	0
Galway	no	136	136	0	no	136	136	0
Gdańsk	no	148	148	0	no	148	148	0
Geneva	no	102	102	0	no	113	113	0
Genoa	no	275	246	10.55	yes	-	-	-
Ghent	no	28	28	0	no	28	28	0
Gijón	no	214	214	0	no	214	214	0
Girona	no	196	196	0	no	38	38	0
Glasgow	no	301	281	6.64	yes	-	-	-
Gothenburg	no	218	218	0	yes	-	-	-
Granada	no	208	185	11.06	no	76	53	30.26
Graz	no	156	110	29.49	no	156	110	29.49
Grenoble	no	199	145	27.14	no	83	29	65.06
Groningen	no	121	98.21	18.84	no	121	98.21	18.84
Guarda	no	262	178	32.06	no	262	178	32.06
Győr	no	65	65	0	no	65	65	0
Hallsberg	no	88	88	0	no	88	88	0
Hamburg	no	104	104	0	yes	-	-	-
Hanover	no	101	85	15.84	yes	-	-	-
Helsinki	yes	-	-	-	yes	-	-	-
Hradec Králové	no	95	95	0	no	95	95	0
Iași	no	364	364	0	no	214	214	0
Innsbruck	no	251	239	4.78	no	104	55	47.12
Inverness	no	457	457	0	no	179	179	0
Istanbul	no	excetption: capital not in network			yes	-	-	-
Jelgava	no	46	46	0	no	46	46	0
Joensuu	no	269	269	0	no	269	269	0
Kalmar	no	243	229	5.76	no	197	197	0

Karlsruhe	no	284	212	25.35	no	40	35	12.5
Kassel	no	155	139	10.32	no	54	39	27.78
Katowice	no	142	142	0	no	47	47	0
Kaunas	no	65	38	41.54	no	65	38	41.54
Kiel	no	192	192	0	no	88	88	0
Kingston upon Hull	no	142	142	0	no	58	48	17.24
Kiruna	no	748	670	10.43	no	748	670	10.43
Klagenfurt	no	237	155	34.6	no	237	155	34.6
Klaipėda	no	254	180	29.13	no	240	180	25
Kolari	no	581	581	0	no	581	581	0
Koper	no	141	118.54	15.93	no	270	247.54	8.32
Košice	no	307	265.98	13.36	no	213	213	0
Koszalin	no	305	305	0	no	209	209	0
Kraków	no	137	137	0	yes	-	-	-
Kristiansand	no	268	225	16.04	no	268	225	16.04
Kuopio	no	260	260	0	no	260	260	0
La Rochelle	no	170	170	0	no	170	170	0
Larissa	no	202	202	0	no	202	202	0
Lausanne	no	67	67	0	no	148	148	0
Le Havre	no	129	129	0	no	129	129	0
Le Mans	no	59	59	0	no	59	59	0
Lecce	no	363	265	27	no	300	202	32.67
Leeds	no	124	124	0	yes	-	-	-
Leicester	no	67	67	0	no	57	57	0
Leipzig	no	73	73	0	yes	-	-	-
León	no	123	123	0	no	123	123	0
Liberec	no	147	147	0	no	123	123	0
Liège	no	44	44	0	no	44	44	0
Liepāja	no	197	197	0	no	197	197	0
Lille	no	64	64	0	no	33	33	0
Limerick	no	124	124	0	no	124	124	0
Limoges	no	255	255	0	no	218	203	6.88
Linköping	no	79	65	17.72	no	79	65	17.72
Linz	no	75	75	0	no	75	75	0
Lisbon	yes	-	-	-	yes	-	-	-
Liverpool	no	134	105	21.64	yes	-	-	-
Ljubljana	yes	-	-	-	no	129	129	0
Łódź	no	72	45	37.5	yes	-	-	-
London	yes	-	-	-	yes	-	-	-
Lübeck	no	150	150	0	no	46	46	0
Lublin	no	112	112	0	no	112	112	0
Lugano	no	165	159	3.64	no	75	75	0
Luleå	no	590	458	22.37	no	590	458	22.37
Luxembourg	yes	-	-	-	no	139	120	13.67
Lyon	no	116	116	0	yes	-	-	-
Madrid	yes	-	-	-	yes	-	-	-
Málaga	no	168	168	0	yes	-	-	-
Malmö	no	242	228	5.79	no	38	38	0

Manchester	no	156	100	35.9	yes	-	-	-
Mannheim	no	260	188	27.69	no	38	29	23.68
Maribor	no	109	109	0	no	158	155	1.9
Marseille	no	213	213	0	yes	-	-	-
Messina	no	393	318	19.08	no	169	169	0
Metz	no	93	93	0	no	93	93	0
Milan	no	196	196	0	yes	-	-	-
Miskolc	no	134	134	0	no	134	134	0
Montpellier	no	249	249	0	no	104	104	0
Mostar	no	115	115	0	no	X	576.37	100
Munich	no	241	221	8.3	yes	-	-	-
Münster	no	208	173	16.83	no	29	29	0
Murcia	no	165	165	0	no	165	114	30.91
Nantes	no	137	137	0	no	137	137	0
Naples	no	63	63	0	yes	-	-	-
Narva	no	192	104.94	45.34	no	706	204.94	70.97
Narvik	no	1247	1169	6.26	no	934	856	8.35
Newcastle upon Tyne	no	169	169	0	no	78	78	0
Nice	no	361	361	0	no	148	122.99	16.9
Niš	no	332	100	69.88	no	332	100	69.88
Norwich	no	108	108	0	no	108	108	0
Nottingham	no	96	96	0	no	56	56	0
Novi Sad	no	36	36	0	no	36	36	0
Nuremberg	no	177	157	11.3	yes	-	-	-
Odense	no	69	60	13.04	no	69	60	13.04
Olbia	no	X	X	X	no	X	X	X
Olsztyn	no	142	142	0	no	142	142	0
Oradea	no	755	549.98	27.15	no	244	224.53	7.98
Osijek	no	493	493	0	no	300	178.13	40.62
Oslo	yes	-	-	-	yes	-	-	-
Östersund	no	301	301	0	no	301	301	0
Ostrava	no	192	184	4.17	no	143	96	32.87
Oulu	no	313	313	0	no	313	313	0
Ourense	no	135	135	0	no	135	135	0
Padborg	no	150	136	9.33	no	122	122	0
Palermo	no	562	487	13.35	yes	-	-	-
Pamplona	no	179	135	24.58	no	110	60	45.45
Paris	yes	-	-	-	yes	-	-	-
Pärnu	no	X	40	100	no	X	60	100
Patras	no	X	110	100	no	X	110	100
Pécs	no	147	147	0	no	147	147	0
Peja	no	116	116	0	no	276	276	0
Penzance	no	307	307	0	no	302	302	0
Perpignan	no	341	302	11.44	no	76	76	0
Perth	no	335	335	0	no	57	57	0
Perugia	no	135	120	11.11	no	135	120	11.11
Pescara	no	210	120	42.86	no	210	120	42.86

Peterborough	no	46	46	0	no	46	46	0
Pisa	no	147	147	0	no	128	128	0
Pitești	no	111	111	0	no	111	111	0
Plovdiv	no	152	80	47.37	no	152	80	47.37
Plzeň	no	83	51	38.55	no	83	51	38.55
Podgorica	yes	-	-	-	no	587	587	0
Porto	no	181	75	58.56	no	181	75	58.56
Poznań	no	153	110	28.1	yes	-	-	-
Prague	yes	-	-	-	yes	-	-	-
Prešov	no	309	273.56	11.47	no	250	251.5	0
Pristina	yes	-	-	-	no	160	160	0
Regensburg	no	229	209	8.73	no	52	52	0
Reims	no	46	46	0	no	46	46	0
Rennes	no	104	104	0	no	104	104	0
Riga	yes	-	-	-	yes	-	-	-
Rijeka	no	272	90	66.91	no	272	90	66.91
Rome	yes	-	-	-	yes	-	-	-
Rostock	no	120	120	0	no	109	109	0
Rotterdam	no	38	38	0	yes	-	-	-
Rovaniemi	no	451	451	0	no	451	451	0
Ruse	no	366	366	0	no	210	80	61.9
Rzeszów	no	223	223	0	no	86	86	0
Saarbrücken	no	337	265	21.36	no	115	106	7.83
Salamanca	no	101	101	0	no	101	101	0
Salzburg	no	143	131	8.39	no	88	88	0
San Sebastián	no	295	188	36.27	no	278	171	38.49
Santander	no	243	183	24.69	no	243	183	24.69
Santiago de Compostela	no	173	173	0	no	173	173	0
Sarajevo	yes	-	-	-	no	X	461.37	100
Sassari	no	X	X	X	no	X	X	X
Satu Mare	no	907	701.98	22.6	no	312	312	0
Seinäjoki	no	158	158	0	no	158	158	0
Seville	no	160	160	0	yes	-	-	-
Sheffield	no	118	109	7.63	yes	-	-	-
Shumen	no	431	431	0	no	410	280	31.71
Šiauliai	no	138	98	28.99	no	124	98	20.97
Skopje	yes	-	-	-	yes	-	-	-
Sligo	no	189	189	0	no	189	189	0
Sofia	yes	-	-	-	yes	-	-	-
Southampton	no	75	75	0	no	75	75	0
Split	no	406	355.77	12.37	no	406	355.77	12.37
Stara Zagora	no	282	175	37.94	no	282	175	37.94
Stavanger	no	444	401	9.68	no	444	401	9.68
Stockholm	yes	-	-	-	yes	-	-	-
Strasbourg	no	123	123	0	no	85	70	17.65
Stuttgart	no	298	221	25.84	yes	-	-	-
Subotica	no	252	78	69.05	no	209	72	65.55

Suceava	no	347	347	0	no	347	347	0
Sundsvall	no	212	212	0	no	212	212	0
Suwałki	no	238	166	30.25	no	223	76	65.92
Swansea	no	161	161	0	no	156	156	0
Syracuse	no	541	436	19.41	no	279	219	21.51
Szczecin	no	310	230	25.81	no	157	90	42.68
Szeged	no	127	127	0	no	127	127	0
Szolnok	no	80	80	0	no	80	80	0
Szombathely	no	134	134	0	no	134	134	0
Tallinn	yes	-	-	-	no	607	100	83.53
Tampere	no	95	95	0	no	95	95	0
Taranto	no	363	265	27	no	300	202	32.67
Tartu	no	137	50.12	63.41	no	470	150.12	68.06
The Hague	no	50	50	0	yes	-	-	-
Thessaloniki	no	291	291	0	no	291	210.27	27.74
Thurso	no	679	679	0	no	401	401	0
Timișoara	no	633	476.37	24.74	no	336	181.64	45.94
Tirana	yes	-	-	-	no	X	X	X
Tornio	no	424	424	0	no	424	424	0
Toulouse	no	302	226	25.17	yes	-	-	-
Tours	no	61	61	0	no	61	61	0
Trieste	no	327	317	3.06	no	246	226	8.13
Trondheim	no	480	450	6.25	no	480	450	6.25
Turin	no	246	246	0	yes	-	-	-
Turku	no	112	78	30.36	no	112	78	30.36
Ulm	no	298	248	16.78	no	42	27	35.71
Umeå	no	368	368	0	no	368	368	0
Ungheni	no	180	180	0	no	180	180	0
Utrecht	no	26	23.56	9.37	no	26	23.56	9.37
Vaduz/Schaan	yes	-	-	-	no	171	171	0
Valencia	no	113	113	0	yes	-	-	-
Valladolid	no	64	64	0	no	64	64	0
Varaždin	no	155	155	0	no	155	155	0
Varna	no	503	361	28.23	no	430	300	30.23
Västerås	no	56	56	0	no	56	56	0
Veles	no	52	52	0	no	52	52	0
Veliko Tarnovo	no	300	300	0	no	300	235	21.67
Venice	no	214	214	0	no	133	123	7.52
Verona	no	184	184	0	no	73	68	6.85
Vienna	yes	-	-	-	yes	-	-	-
Vigo	no	227	227	0	no	227	141	37.89
Villa San Giovanni	no	308	233	24.35	no	245	170	30.61
Villach	no	260	178	31.54	no	228	178	21.93
Vilnius	yes	-	-	-	yes	-	-	-
Vitoria-Gasteiz	no	183	133	27.32	no	166	116	30.12
Warsaw	yes	-	-	-	yes	-	-	-
Waterford	no	117	117	0	no	117	117	0

Wrocław	no	255	105	58.82	yes	-	-	-
Wuppertal	no	233	198	15.02	no	20	20	0
York	no	114	114	0	no	23	23	0
Zagreb	yes	-	-	-	yes	-	-	-
Zaragoza	no	75	75	0	yes	-	-	-
Žilina	no	123	123	0	no	169	163	3.55
Zurich	no	56	56	0	no	184	157	14.67
Zwolle	no	65	50.26	22.68	no	65	50.26	22.68

I – Reachability Changes

***Table 17**: Changes in reachability within the ranges of 4 h, 8 h, and 12 h.*

	number of newly reachable node within rail journeys below…		
node	**4 h**	**8 h**	**12 h**
A Coruña	3	4	6
Aalborg	0	5	21
Aarhus	0	7	15
Aberdeen	0	0	3
Ajaccio	0	0	0
Alexandroupolis	2	7	16
Algeciras	0	5	6
Alicante	5	12	24
Almería	8	21	19
Alvesta	1	17	44
Amsterdam	3	10	24
Ancona	3	19	46
Antequera	3	7	15
Antwerp	0	12	20
Arad	4	13	42
Arnhem	1	13	21
Arth-Goldau	2	12	26
Athens	1	2	6
Avignon	4	22	27
Bacău	0	0	5
Badajoz	7	9	18
Bălți	0	0	0
Banja Luka	0	17	44
Banská Bystrica	1	6	33
Bar	0	0	0
Barcelona	4	19	24
Bari	2	2	25
Basel	10	17	27
Bastia	0	0	0
Bayonne	9	29	25
Belfast	0	0	0
Belgrade	8	33	80
Bergen	0	0	3
Berlin	12	27	30
Bern	4	12	21
Białystok	9	19	51
Bielefeld	8	20	24
Bilbao	6	27	67
Birmingham	3	11	30
Bitola	0	5	19
Boden	3	8	14
Bodø	0	0	0
Bologna	5	41	49

Bolzano	14	49	56
Bordeaux	6	17	24
Bourges	1	16	29
Braga	3	18	9
Brașov	1	7	19
Bratislava	5	21	29
Bregenz	6	16	21
Bremen	8	18	23
Brest	0	5	18
Brig	3	11	20
Bristol	1	5	23
Brno	9	43	42
Bruges	5	15	24
Brussels	4	14	18
Bucharest	1	4	16
Budapest	5	13	37
Burgas	1	6	20
Burgos	3	16	50
Bydgoszcz	0	15	37
Cádiz	0	5	5
Caen	0	10	24
Cagliari	0	0	0
Calvi	0	0	0
Carlisle	2	13	18
Cartagena	4	8	11
České Budějovice	5	37	41
Cherbourg-Octeville	0	7	22
Chișinău	0	0	1
Clermont-Ferrand	0	10	24
Cluj-Napoca	2	8	25
Coimbra	4	21	11
Cologne	5	17	21
Constanța	1	3	7
Copenhagen	6	33	54
Córdoba	2	8	13
Cork	0	0	0
Çorlu	1	3	7
Cosenza	2	5	40
Craiova	2	15	30
Daugavpils	4	8	22
Debrecen	4	8	24
Derry	0	0	0
Deva	2	11	30
Dijon	3	15	25
Divača	0	15	45
Doncaster	0	4	18
Dortmund	1	13	18
Drammen	0	1	12
Dresden	13	35	41

Dublin	0	0	0
Duisburg	3	17	19
Durrës	1	1	1
Düsseldorf	3	18	21
Edinburgh	0	0	7
Edirne	2	2	13
Eindhoven	4	14	24
Entroncamento	3	18	9
Erfurt	16	38	28
Esbjerg	0	9	21
Essen	3	16	22
Exeter	0	3	15
Faro	3	8	26
Feldkirch	4	15	20
Florence	3	30	45
Foggia	3	4	34
Frankfurt	6	20	21
Freiburg	8	18	29
Galați	0	1	7
Galway	0	0	0
Gdańsk	1	8	34
Geneva	3	10	28
Genoa	9	47	46
Ghent	1	11	21
Gijón	3	7	19
Girona	3	25	21
Glasgow	1	2	8
Gothenburg	1	9	48
Granada	3	9	11
Graz	2	29	32
Grenoble	14	28	40
Groningen	7	19	32
Guarda	7	28	35
Győr	6	19	32
Hallsberg	0	4	28
Hamburg	8	17	25
Hanover	12	26	24
Helsinki	0	0	4
Hradec Králové	2	38	61
Iași	0	1	5
Innsbruck	17	33	22
Inverness	0	0	1
Istanbul	1	6	7
Jelgava	4	10	22
Joensuu	0	0	1
Kalmar	1	6	42
Karlsruhe	8	20	25
Kassel	13	26	21
Katowice	4	24	58

Kaunas	6	16	49
Kiel	2	19	23
Kingston upon Hull	0	2	14
Kiruna	0	5	10
Klagenfurt	6	21	23
Klaipėda	1	7	17
Kolari	1	4	7
Koper	1	15	51
Košice	1	17	32
Koszalin	1	28	56
Kraków	4	20	61
Kristiansand	1	1	5
Kuopio	0	2	5
La Rochelle	2	13	32
Larissa	0	6	14
Lausanne	3	10	22
Le Havre	0	11	23
Le Mans	4	16	33
Lecce	1	3	18
Leeds	0	3	16
Leicester	0	5	21
Leipzig	18	36	32
León	1	12	39
Liberec	1	24	49
Liège	2	17	21
Liepāja	0	6	14
Lille	3	17	21
Limerick	0	0	0
Limoges	1	9	25
Linköping	0	6	43
Linz	6	25	23
Lisbon	6	26	15
Liverpool	2	10	22
Ljubljana	0	12	25
Łódź	3	37	63
London	3	8	20
Lübeck	9	19	26
Lublin	3	14	43
Lugano	4	17	26
Luleå	3	9	14
Luxembourg	8	15	25
Lyon	7	17	34
Madrid	7	6	23
Málaga	4	8	13
Malmö	4	26	55
Manchester	1	16	26
Mannheim	9	20	26
Maribor	5	23	33
Marseille	2	18	28

Messina	0	6	16
Metz	7	15	21
Milan	7	42	47
Miskolc	3	9	28
Montpellier	4	20	21
Mostar	0	2	8
Munich	11	25	22
Münster	0	11	18
Murcia	6	11	18
Nantes	0	13	31
Naples	5	14	46
Narva	2	11	20
Narvik	0	1	5
Newcastle upon Tyne	0	1	13
Nice	3	17	37
Niš	4	29	78
Norwich	1	5	18
Nottingham	0	3	18
Novi Sad	7	41	89
Nuremberg	4	23	20
Odense	2	11	24
Olbia	0	0	0
Olsztyn	0	5	31
Oradea	3	9	27
Osijek	3	14	25
Oslo	1	1	19
Östersund	0	2	8
Ostrava	8	40	66
Oulu	2	4	8
Ourense	3	3	12
Padborg	1	16	22
Palermo	1	1	6
Pamplona	2	17	45
Paris	3	15	26
Pärnu	9	18	35
Patras	1	3	6
Pécs	1	10	27
Peja	0	1	11
Penzance	0	0	6
Perpignan	4	21	21
Perth	0	0	4
Perugia	2	19	49
Pescara	1	16	53
Peterborough	0	7	21
Pisa	1	25	48
Pitești	1	6	18
Plovdiv	2	13	31
Plzeň	4	34	36
Podgorica	0	0	2

Porto	2	15	7
Poznań	3	28	57
Prague	8	47	57
Prešov	0	13	31
Pristina	0	6	21
Regensburg	2	24	18
Reims	5	16	31
Rennes	0	18	31
Riga	8	14	31
Rijeka	1	11	30
Rome	3	19	47
Rostock	1	16	30
Rotterdam	2	10	21
Rovaniemi	4	5	8
Ruse	3	3	16
Rzeszów	0	17	49
Saarbrücken	5	20	27
Salamanca	4	8	30
Salzburg	4	24	22
San Sebastián	5	23	20
Santander	4	13	27
Santiago de Compostela	3	4	11
Sarajevo	0	3	16
Sassari	0	0	0
Satu Mare	0	3	8
Seinäjoki	0	3	5
Seville	2	7	12
Sheffield	0	7	19
Shumen	0	3	9
Šiauliai	4	13	21
Skopje	3	13	40
Sligo	0	0	0
Sofia	5	23	43
Southampton	0	6	23
Split	0	0	6
Stara Zagora	1	8	22
Stavanger	0	0	4
Stockholm	2	6	34
Strasbourg	8	17	23
Stuttgart	10	28	32
Subotica	11	28	74
Suceava	0	1	7
Sundsvall	0	4	15
Suwałki	7	12	43
Swansea	0	3	15
Syracuse	1	2	10
Szczecin	13	50	82
Szeged	3	10	30
Szolnok	4	6	30

Szombathely	3	14	31
Tallinn	7	13	26
Tampere	0	2	5
Taranto	1	3	18
Tartu	3	11	17
The Hague	1	11	21
Thessaloniki	2	8	20
Thurso	0	0	0
Timișoara	6	15	32
Tirana	1	1	1
Tornio	4	6	11
Toulouse	6	39	30
Tours	3	18	38
Trieste	2	25	57
Trondheim	0	0	2
Turin	8	45	48
Turku	0	0	4
Ulm	8	32	27
Umeå	1	5	9
Ungheni	0	1	4
Utrecht	2	14	25
Vaduz/Schaan	3	12	24
Valencia	1	9	21
Valladolid	3	12	50
Varaždin	2	11	26
Varna	0	6	14
Västerås	0	5	21
Veles	2	11	37
Veliko Tarnovo	1	6	15
Venice	2	39	57
Verona	12	47	51
Vienna	6	25	34
Vigo	4	4	4
Villa San Giovanni	3	8	30
Villach	6	21	28
Vilnius	6	15	40
Vitoria-Gasteiz	5	19	34
Warsaw	3	26	45
Waterford	0	0	0
Wrocław	4	31	56
Wuppertal	3	18	22
York	0	3	17
Zagreb	1	7	23
Zaragoza	4	12	31
Žilina	2	13	39
Zurich	4	16	25
Zwolle	2	12	23

J – Rail Travel Times on Europe's Top 1000 Flight Routes

***Table 18**: Changes of realistic travel times along Europe's top 1000 most popular flight routes.*

rank	annual passen-gers	city 1	city 2	iso code 1	iso code 2	$t_{current}$ (realistic) [min]	t_{future} (realistic) [min]	$d_{relative}$ [reduction]	$d_{absolute}$ [min]
1	5'107'690	Dublin	London	IE	UK	-	-	-	-
2	4'925'746	Amsterdam	London	NL	UK	219	219	0	0
3	3'387'482	Barcelona	London	ES	UK	562	523	0.0694	-39
4	3'374'774	Edinburgh	London	UK	UK	256	256	0	0
5	3'216'294	Paris	Toulouse	FR	FR	302	226	0.2517	-76
6	3'178'806	Nice	Paris	FR	FR	361	361	0	0
7	3'147'547	London	Madrid	ES	UK	720	658	0.0861	-62
8	2'838'644	Berlin	London	DE	UK	482	442	0.083	-40
9	2'690'832	Barcelona	Paris	ES	FR	417	378	0.0935	-39
10	2'572'893	Barcelona	Madrid	ES	ES	158	158	0	0
11	2'561'787	Madrid	Paris	ES	FR	575	513	0.1078	-62
12	2'524'519	Geneva	London	CH	UK	374	374	0	0
13	2'503'822	London	Milan	IT	UK	522	418	0.1992	-104
14	2'392'594	London	Rome	IT	UK	718	614	0.1448	-104
15	2'375'583	Belfast	London	UK	UK	-	-	-	-
16	2'296'483	Glasgow	London	UK	UK	301	281	0.0664	-20
17	2'276'567	London	Malaga	ES	UK	888	826	0.0698	-62
18	2'248'716	Berlin	Frankfurt	DE	DE	222	159	0.2838	-63
19	2'247'612	Paris	Rome	FR	IT	573	469	0.1815	-104
20	2'227'971	Copenhagen	London	DK	UK	718	594	0.1727	-124
21	2'199'598	Lisbon	London	PT	UK	1203	889	0.261	-314
23	2'149'539	London	Paris	FR	UK	145	145	0	0
24	2'109'832	Lisbon	Paris	FR	PT	1058	744	0.2968	-314
25	2'103'647	Oslo	Trondheim	NO	NO	480	450	0.0625	-30
26	2'067'200	Frankfurt	London	DE	UK	283	283	0	0
27	2'036'432	Milan	Paris	FR	IT	377	273	0.2759	-104
28	2'003'549	Bergen	Oslo	NO	NO	399	354	0.1128	-45
30	1'946'968	London	Zurich	CH	UK	378	378	0	0
31	1'933'810	Berlin	Munich	DE	DE	241	221	0.083	-20
33	1'834'163	London	Munich	DE	UK	447	417	0.0671	-30
35	1'783'636	Alicante	London	ES	UK	862	755	0.1241	-107
37	1'740'129	Hamburg	Munich	DE	DE	314	314	0	0
38	1'685'154	Budapest	London	HU	UK	793	779	0.0177	-14
39	1'681'182	Oslo	Stavanger	NO	NO	444	401	0.0968	-43
41	1'660'456	Madrid	Rome	ES	IT	916	773	0.1561	-143
43	1'611'394	London	Stockholm	SE	UK	998	860	0.1383	-138
44	1'580'569	Palermo	Rome	IT	IT	562	487	0.1335	-75
45	1'563'209	Faro	London	PT	UK	1383	1039	0.2487	-344
46	1'558'924	Marseille	Paris	FR	FR	213	213	0	0
47	1'558'588	Lisbon	Madrid	ES	PT	483	231	0.5217	-252
49	1'552'302	Berlin	Cologne	DE	DE	262	222	0.1527	-40
50	1'545'970	Paris	Porto	FR	PT	944	798.8038	0.1538	-145.196
51	1'488'008	Düsseldorf	Munich	DE	DE	269	249	0.0743	-20

52	1'479'686	London	Nice	FR	UK	506	506	0	0
53	1'467'630	Copenhagen	Oslo	DK	NO	397	354	0.1083	-43
55	1'426'018	Frankfurt	Hamburg	DE	DE	212	169	0.2028	-43
56	1'410'148	Athens	London	EL	UK	-	1791.518	-	-
57	1'401'634	Berlin	Paris	DE	FR	452	370	0.1814	-82
58	1'399'202	Barcelona	Rome	ES	IT	758	615	0.1887	-143
59	1'391'764	London	Warsaw	PL	UK	800	717	0.1038	-83
60	1'387'160	Copenhagen	Stockholm	DK	SE	280	266	0.05	-14
61	1'386'340	Oslo	Stockholm	NO	SE	313	313	0	0
62	1'386'065	Amsterdam	Paris	FR	NL	202	202	0	0
63	1'382'718	Amsterdam	Barcelona	ES	NL	619	580	0.063	-39
64	1'381'565	Helsinki	Stockholm	FI	SE	-	1005.492	-	-
65	1'378'423	London	Oslo	NO	UK	1115	948	0.1498	-167
67	1'362'762	Bucharest	London	RO	UK	1654	1447.735	0.1247	-206.264
68	1'353'717	London	Vienna	AT	UK	650	636	0.0215	-14
69	1'333'907	London	Prague	CZ	UK	649	492	0.2419	-157
70	1'330'965	Athens	Thessaloniki	EL	EL	291	291	0	0
71	1'319'418	Amsterdam	Berlin	DE	NL	350	312.5637	0.107	-37.4363
72	1'239'196	London	Venice	IT	UK	655	541	0.174	-114
73	1'234'360	Berlin	Stuttgart	DE	DE	298	221	0.2584	-77
74	1'233'050	Berlin	Düsseldorf	DE	DE	243	208	0.144	-35
76	1'218'505	Bordeaux	Paris	FR	FR	166	166	0	0
77	1'215'609	Amsterdam	Dublin	IE	NL	-	-	-	-
79	1'207'604	Amsterdam	Milan	IT	NL	579	475	0.1796	-104
81	1'192'843	Milan	Rome	IT	IT	196	196	0	0
83	1'164'277	Berlin	Zurich	CH	DE	437	334	0.2357	-103
85	1'147'902	Milan	Palermo	IT	IT	758	683	0.0989	-75
86	1'144'665	Amsterdam	Madrid	ES	NL	777	715	0.0798	-62
87	1'136'524	Frankfurt	Munich	DE	DE	187	162	0.1337	-25
88	1'132'010	Barcelona	Berlin	DE	ES	851	723	0.1504	-128
90	1'129'207	Gothenburg	Stockholm	SE	SE	218	218	0	0
92	1'113'251	Madrid	Milan	ES	IT	720	577	0.1986	-143
93	1'109'819	Amsterdam	Copenhagen	DK	NL	586	442.2077	0.2454	-143.792
94	1'108'897	Frankfurt	Vienna	AT	DE	367	366	0.0027	-1
95	1'093'618	Paris	Venice	FR	IT	510	396	0.2235	-114
96	1'085'561	Brussels	Madrid	BE	ES	672	610	0.0923	-62
97	1'072'520	Cagliari	Rome	IT	IT	-	-	-	-
98	1'069'097	Frankfurt	Madrid	DE	ES	787	722	0.0826	-65
99	1'067'164	Amsterdam	Manchester	NL	UK	375	319	0.1493	-56
100	1'059'013	Geneva	Paris	CH	FR	229	229	0	0
101	1'048'073	Amsterdam	Rome	IT	NL	775	671	0.1342	-104
102	1'047'649	Dublin	Paris	FR	IE	-	-	-	-
103	1'047'343	Helsinki	London	FI	UK	-	1865.492	-	-
104	1'045'029	Barcelona	Seville	ES	ES	318	318	0	0
105	1'041'037	Frankfurt	Paris	DE	FR	230	211	0.0826	-19
106	1'034'545	Barcelona	Frankfurt	DE	ES	629	564	0.1033	-65
107	1'023'098	Malmö	Stockholm	SE	SE	242	228	0.0579	-14
108	1'017'011	Cologne	Munich	DE	DE	241	221	0.083	-20
109	1'014'022	Munich	Paris	DE	FR	323	293	0.0929	-30

112	1'008'951	Lisbon	Porto	PT	PT	181	75	0.5856	-106
113	1'008'288	Barcelona	Lisbon	ES	PT	641	389	0.3931	-252
114	1'008'254	Düsseldorf	London	DE	UK	248	248	0	0
115	1'002'034	Dublin	Manchester	IE	UK	-	-	-	-
116	989'305	Montpellier	Paris	FR	FR	249	249	0	0
117	977'778	Hamburg	London	DE	UK	446	438	0.0179	-8
118	976'448	Amsterdam	Zurich	CH	NL	428	394.5637	0.0781	-33.4363
119	972'444	Paris	Vienna	AT	FR	554	512	0.0758	-42
120	969'958	Madrid	Porto	ES	PT	369	293	0.206	-76
121	969'878	Amsterdam	Munich	DE	NL	404	381.5637	0.0555	-22.4363
122	965'728	Berlin	Vienna	AT	DE	421	348	0.1734	-73
123	956'926	Helsinki	Oulu	FI	FI	313	313	0	0
124	951'905	Barcelona	Brussels	BE	ES	514	475	0.0759	-39
125	948'616	Cork	London	IE	UK	-	-	-	-
126	944'882	Birmingham	Dublin	IE	UK	-	-	-	-
127	944'540	Amsterdam	Vienna	AT	NL	593	589.5637	0.0058	-3.4363
128	939'525	Vienna	Zurich	AT	CH	440	420	0.0455	-20
129	927'675	Amsterdam	Lisbon	NL	PT	1260	946	0.2492	-314
130	911'299	London	Sofia	BG	UK	2038	1220.826	0.401	-817.173
131	906'717	Berlin	Copenhagen	DE	DK	376	260	0.3085	-116
132	903'385	Athens	Paris	EL	FR	-	1667.518	-	-
133	902'309	Milan	Naples	IT	IT	259	259	0	0
134	900'794	Madrid	Munich	DE	ES	880	785	0.108	-95
135	891'190	Barcelona	Milan	ES	IT	562	419	0.2544	-143
136	889'281	Barcelona	Munich	DE	ES	722	627	0.1316	-95
137	888'423	Krakow	London	PL	UK	889	805	0.0945	-84
139	884'182	Copenhagen	Paris	DK	FR	701	536	0.2354	-165
141	881'458	London	Naples	IT	UK	781	677	0.1332	-104
142	881'423	Amsterdam	Frankfurt	DE	NL	226	223.5637	0.0108	-2.4363
143	876'959	Paris	Prague	CZ	FR	596	420	0.2953	-176
146	863'648	Amsterdam	Stockholm	NL	SE	866	708.2077	0.1822	-157.792
147	862'156	Cagliari	Milan	IT	IT	-	-	-	-
148	855'487	Frankfurt	Lisbon	DE	PT	1270	953	0.2496	-317
151	848'964	Barcelona	Malaga	ES	ES	326	326	0	0
152	848'433	Copenhagen	Helsinki	DK	FI	-	1271.492	-	-
154	837'447	Bodo	Oslo	NO	NO	1066	1036	0.0281	-30
156	835'758	Bilbao	Madrid	ES	ES	254	176	0.3071	-78
159	824'882	Athens	Rome	EL	IT	-	1663.518	-	-
160	822'908	London	Porto	PT	UK	1089	943.8038	0.1333	-145.196
161	821'579	Berlin	Madrid	DE	ES	1009	881	0.1269	-128
163	813'757	Frankfurt	Milan	DE	IT	399	353	0.1153	-46
164	804'578	Berlin	Rome	DE	IT	742	545	0.2655	-197
166	803'002	Malaga	Paris	ES	FR	743	681	0.0834	-62
167	793'826	Bologna	London	IT	UK	586	482	0.1775	-104
169	784'738	Aberdeen	London	UK	UK	396	396	0	0
170	783'420	London	Pisa	IT	UK	675	556	0.1763	-119
172	777'719	Aalborg	Copenhagen	DK	DK	239	207	0.1339	-32
173	772'869	Brussels	Lisbon	BE	PT	1155	841	0.2719	-314
174	770'693	Düsseldorf	Vienna	AT	DE	458	457	0.0022	-1

175	761'887	Bari	Rome	IT	IT	283	185	0.3463	-98
177	759'621	Dublin	Frankfurt	DE	IE	-	-	-	-
178	758'629	Amsterdam	Prague	CZ	NL	592	432.5637	0.2693	-159.436
180	747'857	Düsseldorf	Zurich	CH	DE	293	262	0.1058	-31
181	745'545	Belfast	Manchester	UK	UK	-	-	-	-
182	742'503	Alicante	Manchester	ES	UK	1018	855	0.1601	-163
183	739'393	Amsterdam	Helsinki	FI	NL	-	1713.700	-	-
184	736'612	Hamburg	Stuttgart	DE	DE	288	231	0.1979	-57
185	727'171	Berlin	Oslo	DE	NO	773	614	0.2057	-159
186	723'922	Budapest	Frankfurt	DE	HU	510	509	0.002	-1
187	723'610	Paris	Zurich	CH	FR	234	234	0	0
188	721'489	Amsterdam	Oslo	NL	NO	983	796.2077	0.19	-186.792
189	720'186	Brussels	Rome	BE	IT	670	566	0.1552	-104
190	719'748	Madrid	Santiago de Compostela	ES	ES	173	173	0	0
191	719'255	Hamburg	Vienna	AT	DE	494	452	0.085	-42
192	717'654	Lisbon	Rome	IT	PT	1399	1004	0.2823	-395
193	717'631	Munich	Rome	DE	IT	501	324	0.3533	-177
195	711'279	Paris	Stockholm	FR	SE	981	802	0.1825	-179
197	707'568	London	Toulouse	FR	UK	447	371	0.17	-76
198	706'238	Amsterdam	Geneva	CH	NL	431	431	0	0
199	703'024	Bari	Milan	IT	IT	388	381	0.018	-7
200	702'870	Amsterdam	Birmingham	NL	UK	295	268	0.0915	-27
201	696'482	Berlin	Budapest	DE	HU	564	491	0.1294	-73
202	696'260	Lyon	Paris	FR	FR	116	116	0	0
203	695'712	Frankfurt	Stockholm	DE	SE	764	591	0.2264	-173
204	692'936	Barcelona	Porto	ES	PT	527	451	0.1442	-76
205	692'724	Hamburg	Zurich	CH	DE	427	344	0.1944	-83
206	692'187	Frankfurt	Rome	DE	IT	595	486	0.1832	-109
207	691'185	Madrid	Zurich	CH	ES	692	653	0.0564	-39
208	687'568	Geneva	Porto	CH	PT	941	826	0.1222	-115
209	683'651	Manchester	Paris	FR	UK	301	245	0.186	-56
210	680'043	Amsterdam	Edinburgh	NL	UK	475	475	0	0
211	679'776	Berlin	Stockholm	DE	SE	656	526	0.1982	-130
212	675'947	Berlin	Brussels	BE	DE	368	328	0.1087	-40
213	675'583	Brussels	London	BE	UK	114	114	0	0
216	661'848	Copenhagen	Frankfurt	DE	DK	484	325	0.3285	-159
217	658'111	Dublin	Edinburgh	IE	UK	-	-	-	-
218	657'543	Barcelona	Zurich	CH	ES	534	495	0.073	-39
219	657'377	Dublin	Malaga	ES	IE	-	-	-	-
220	656'557	Amsterdam	Malaga	ES	NL	945	883	0.0656	-62
222	652'811	Brussels	Milan	BE	IT	474	370	0.2194	-104
223	652'094	Frankfurt	Zurich	CH	DE	215	175	0.186	-40
224	640'835	Barcelona	Geneva	CH	ES	414	375	0.0942	-39
225	640'597	Paris	Warsaw	FR	PL	770	645	0.1623	-125
226	639'550	Barcelona	Vienna	AT	ES	953	811	0.149	-142
228	633'829	Bucharest	Vienna	AT	RO	1004	811.7359	0.1915	-192.264
229	632'588	Milan	Olbia	IT	IT	-	-	-	-
231	628'620	Geneva	Zurich	CH	CH	158	158	0	0

232	625'362	Geneva	Lisbon	CH	PT	1055	764	0.2758	-291
233	623'617	London	Lyon	FR	UK	261	261	0	0
234	623'173	Bucharest	Paris	FR	RO	1558	1323.735	0.1504	-234.264
235	622'601	Barcelona	Bilbao	ES	ES	352	242	0.3125	-110
236	617'632	Athens	Frankfurt	DE	EL	-	1521.518	-	-
238	613'420	London	Marseille	FR	UK	358	358	0	0
239	612'419	Brussels	Geneva	BE	CH	326	326	0	0
240	610'082	Bucharest	Rome	IT	RO	1652	1319.735	0.2011	-332.264
241	606'530	Basel	Berlin	CH	DE	384	281	0.2682	-103
242	603'648	London	Riga	LV	UK	1444	1013	0.2985	-431
243	601'519	Barcelona	Dublin	ES	IE	-	-	-	-
244	598'917	Dublin	Munich	DE	IE	-	-	-	-
245	591'694	Gdansk	London	PL	UK	808	768	0.0495	-40
246	587'693	Helsinki	Munich	DE	FI	-	1741.492	-	-
247	587'280	Naples	Paris	FR	IT	636	532	0.1635	-104
249	585'513	Malaga	Manchester	ES	UK	1044	926	0.113	-118
250	584'708	Florence	Paris	FR	IT	478	374	0.2176	-104
251	581'927	Bordeaux	Lyon	FR	FR	282	282	0	0
252	581'008	Geneva	Madrid	CH	ES	572	533	0.0682	-39
253	579'172	Gothenburg	London	SE	UK	909	765	0.1584	-144
254	577'144	Brussels	Frankfurt	BE	DE	169	169	0	0
255	574'052	Paris	Valencia	ES	FR	589	550	0.0662	-39
256	573'442	London	Valencia	ES	UK	734	695	0.0531	-39
257	569'154	Cologne	London	DE	UK	220	220	0	0
258	568'148	Berlin	Helsinki	DE	FI	-	1531.492	-	-
259	564'025	Madrid	Vienna	AT	ES	1111	969	0.1278	-142
260	562'406	Berlin	Lisbon	DE	PT	1492	1112	0.2547	-380
261	561'918	Berlin	Dublin	DE	IE	-	-	-	-
262	560'930	Brest	Paris	FR	FR	224	224	0	0
263	560'854	Lyon	Nantes	FR	FR	253	253	0	0
264	558'916	Rome	Vienna	AT	IT	648	508	0.216	-140
265	558'219	Munich	Stockholm	DE	SE	866	736	0.1501	-130
267	555'609	Ajaccio	Paris	FR	FR	-	-	-	-
268	555'004	Madrid	Venice	ES	IT	853	700	0.1794	-153
269	553'989	Stuttgart	Vienna	AT	DE	346	319	0.078	-27
270	553'692	Dublin	Madrid	ES	IE	-	-	-	-
271	553'107	London	Manchester	UK	UK	156	100	0.359	-56
272	550'910	Nantes	Paris	FR	FR	137	137	0	0
274	547'930	Berlin	Milan	DE	IT	621	429	0.3092	-192
275	545'591	Bergen	Stavanger	NO	NO	779	736	0.0552	-43
276	543'670	Helsinki	Rovaniemi	FI	FI	451	451	0	0
277	542'260	Athens	Berlin	DE	EL	-	1503.518	-	-
278	541'007	Hanover	Munich	DE	DE	238	238	0	0
280	538'667	Dublin	Faro	IE	PT	-	-	-	-
281	538'045	Frankfurt	Oslo	DE	NO	881	679	0.2293	-202
284	532'354	Brussels	Malaga	BE	ES	840	778	0.0738	-62
285	530'248	Munich	Vienna	AT	DE	231	219	0.0519	-12
286	528'771	Helsinki	Oslo	FI	NO	-	1318.492	-	-
287	527'918	Belfast	Birmingham	UK	UK	-	-	-	-

289	526'606	Berlin	Manchester	DE	UK	638	542	0.1505	-96
290	526'454	Faro	Manchester	PT	UK	1539	1139	0.2599	-400
291	526'318	Frankfurt	Helsinki	DE	FI	-	1596.492	-	-
293	525'429	Frankfurt	Prague	CZ	DE	366	209	0.429	-157
294	523'585	Copenhagen	Malaga	DK	ES	1439	1215	0.1557	-224
295	523'020	Athens	Munich	DE	EL	-	1374.518	-	-
296	521'813	Düsseldorf	Hamburg	DE	DE	207	199	0.0386	-8
297	521'521	Frankfurt	Warsaw	DE	PL	540	434	0.1963	-106
298	517'200	Budapest	Paris	FR	HU	697	655	0.0603	-42
300	514'027	Barcelona	Venice	ES	IT	695	542	0.2201	-153
301	513'250	Copenhagen	Zurich	CH	DK	699	500	0.2847	-199
302	512'292	Copenhagen	Munich	DE	DK	586	470	0.198	-116
303	512'125	Amsterdam	Warsaw	NL	PL	668	587.5637	0.1204	-80.4363
304	512'008	Oslo	Paris	FR	NO	1098	890	0.1894	-208
305	511'000	Malaga	Stockholm	ES	SE	1719	1481	0.1385	-238
307	510'096	Frankfurt	Manchester	DE	UK	439	383	0.1276	-56
308	510'077	Kristiansand	Oslo	NO	NO	268	225	0.1604	-43
309	509'767	Bordeaux	London	FR	UK	311	311	0	0
310	505'218	Barcelona	Manchester	ES	UK	718	623	0.1323	-95
311	502'803	Milan	Munich	DE	IT	390	208	0.4667	-182
312	500'678	Lisbon	Munich	DE	PT	1363	1016	0.2546	-347
313	500'473	Dublin	Glasgow	IE	UK	-	-	-	-
314	500'092	Amsterdam	Athens	EL	NL	-	1745.081	-	-
315	497'204	Athens	Zurich	CH	EL	-	1575.518	-	-
316	495'204	London	Luxembourg	LU	UK	263	234	0.1103	-29
319	491'495	Helsinki	Paris	FI	FR	-	1807.492	-	-
320	490'225	Belfast	Liverpool	UK	UK	-	-	-	-
323	488'756	Rome	Turin	IT	IT	246	246	0	0
324	488'137	Lisbon	Zurich	CH	PT	1175	884	0.2477	-291
325	486'438	Madrid	Seville	ES	ES	160	160	0	0
326	486'219	Frankfurt	Venice	DE	IT	532	357	0.3289	-175
327	486'004	Dublin	Lisbon	IE	PT	-	-	-	-
328	485'990	Düsseldorf	Madrid	DE	ES	806	744	0.0769	-62
329	481'863	Belfast	Edinburgh	UK	UK	-	-	-	-
330	481'393	Amsterdam	Bucharest	NL	RO	1597	1401.299	0.1225	-195.700
333	478'816	Brussels	Copenhagen	BE	DK	604	480	0.2053	-124
334	478'701	Amsterdam	Nice	FR	NL	563	563	0	0
335	476'368	Amsterdam	Hamburg	DE	NL	314	286.2077	0.0885	-27.7923
339	470'116	Brussels	Vienna	AT	BE	536	535	0.0019	-1
340	470'061	Frankfurt	Krakow	DE	PL	606	522	0.1386	-84
341	465'994	London	Stuttgart	DE	UK	332	317	0.0452	-15
342	464'693	Hamburg	Paris	DE	FR	429	380	0.1142	-49
343	464'583	Düsseldorf	Paris	DE	FR	231	231	0	0
344	463'643	Cologne	Hamburg	DE	DE	226	218	0.0354	-8
345	463'618	Bastia	Paris	FR	FR	-	-	-	-
347	460'619	London	Newcastle upon Tyne	UK	UK	169	169	0	0
348	460'409	Berlin	Malaga	DE	ES	1177	1049	0.1088	-128
349	459'920	Dublin	Rome	IE	IT	-	-	-	-

350	457'789	Amsterdam	Bristol	NL	UK	295	295	0	0
351	456'935	Frankfurt	Sofia	BG	DE	1755	950.8262	0.4582	-804.1738
353	456'390	Copenhagen	Vienna	AT	DK	766	608	0.2063	-158
354	454'528	Amsterdam	Budapest	HU	NL	736	732.5637	0.0047	-3.4363
355	451'735	Frankfurt	Porto	DE	PT	1156	1009.803	0.1265	-146.196
356	451'506	Budapest	Rome	HU	IT	791	651	0.177	-140
357	450'137	Lisbon	Milan	IT	PT	1203	808	0.3283	-395
358	449'098	Alicante	Barcelona	ES	ES	300	232	0.2267	-68
359	447'740	Amsterdam	Basel	CH	NL	375	341.5637	0.0892	-33.4363
360	447'683	Milan	Vienna	AT	IT	537	392	0.27	-145
361	447'170	Munich	Oslo	DE	NO	983	824	0.1617	-159
362	447'001	Rome	Venice	IT	IT	214	214	0	0
363	445'782	Paris	Seville	ES	FR	735	673	0.0844	-62
364	444'837	Bucharest	Timisoara	RO	RO	633	476.3684	0.2474	-156.631
365	444'522	Barcelona	Copenhagen	DK	ES	1113	889	0.2013	-224
366	442'478	Katowice	London	PL	UK	842	758	0.0998	-84
367	440'413	Barcelona	Prague	CZ	ES	995	773	0.2231	-222
368	439'872	Amsterdam	Glasgow	NL	UK	520	500	0.0385	-20
369	438'121	Brussels	Munich	BE	DE	347	327	0.0576	-20
370	437'766	Brussels	Dublin	BE	IE	-	-	-	-
371	437'054	Alicante	Amsterdam	ES	NL	919	812	0.1164	-107
372	436'130	Belfast	Glasgow	UK	UK	-	-	-	-
373	433'455	Frankfurt	Geneva	CH	DE	322	282	0.1242	-40
374	432'682	Bergen	Copenhagen	DK	NO	796	708	0.1106	-88
375	431'599	Rome	Warsaw	IT	PL	1060	820	0.2264	-240
376	428'149	London	Vilnius	LT	UK	1261	959	0.2395	-302
377	428'130	Lyon	Toulouse	FR	FR	265	238	0.1019	-27
378	427'615	Bucharest	Madrid	ES	RO	2115	1780.735	0.158	-334.264
379	426'631	Bordeaux	Marseille	FR	FR	372	269	0.2769	-103
380	423'952	Barcelona	Santiago de Compostela	ES	ES	331	331	0	0
383	422'165	Bristol	Dublin	IE	UK	-	-	-	-
384	421'683	Belgrade	Zurich	CH	RS	1044	713	0.317	-331
385	421'275	Alicante	Stockholm	ES	SE	1693	1387	0.1807	-306
386	418'909	Helsinki	Malaga	ES	FI	-	2486.492	-	-
387	418'577	Prague	Rome	CZ	IT	789	572	0.275	-217
389	415'446	Berlin	Riga	DE	LV	962	571	0.4064	-391
390	414'206	Amsterdam	Venice	IT	NL	712	576.5637	0.1902	-135.436
391	413'036	Bremen	Munich	DE	DE	297	297	0	0
392	411'445	Alicante	Brussels	BE	ES	814	707	0.1314	-107
393	409'847	Bucharest	Cluj-Napoca	RO	RO	529	419.7577	0.2065	-109.242
396	407'960	Alicante	Birmingham	ES	UK	938	804	0.1429	-134
397	407'895	Barcelona	Naples	ES	IT	821	678	0.1742	-143
398	406'196	Rome	Zurich	CH	IT	380	374	0.0158	-6
399	404'979	Bologna	Paris	FR	IT	441	337	0.2358	-104
400	404'667	Copenhagen	Rome	DK	IT	1079	794	0.2641	-285
401	404'506	London	Seville	ES	UK	880	818	0.0705	-62
402	403'257	Birmingham	Paris	FR	UK	221	194	0.1222	-27

403	403'080	Frankfurt	Gothenburg	DE	SE	675	496	0.2652	-179
407	400'208	Stockholm	Zurich	CH	SE	979	766	0.2176	-213
408	398'464	Bristol	Edinburgh	UK	UK	317	313	0.0126	-4
414	390'314	Barcelona	Bologna	ES	IT	626	483	0.2284	-143
415	386'892	Krakow	Warsaw	PL	PL	137	137	0	0
416	386'357	Vienna	Warsaw	AT	PL	497	341	0.3139	-156
418	385'855	Geneva	Nice	CH	FR	358	358	0	0
419	384'362	Brussels	Nice	BE	FR	458	458	0	0
420	383'574	Bucharest	Frankfurt	DE	RO	1371	1177.735	0.141	-193.264
421	383'396	Frankfurt	Valencia	DE	ES	801	736	0.0811	-65
422	382'548	Berlin	Thessaloniki	DE	EL	-	1212.518	-	-
423	381'942	Athens	Madrid	EL	ES	-	2124.518	-	-
424	381'555	Frankfurt	Lyon	DE	FR	328	302	0.0793	-26
425	380'232	Barcelona	Budapest	ES	HU	1096	954	0.1296	-142
427	379'745	Dublin	Liverpool	IE	UK	-	-	-	-
428	379'674	Munich	Warsaw	DE	PL	559	496	0.1127	-63
429	379'198	Berlin	Geneva	CH	DE	544	441	0.1893	-103
430	379'103	Alicante	Oslo	ES	NO	1810	1475	0.1851	-335
431	378'728	Düsseldorf	Frankfurt	DE	DE	91	91	0	0
434	377'019	Alicante	Newcastle upon Tyne	ES	UK	1031	924	0.1038	-107
435	375'754	Cluj-Napoca	London	RO	UK	1266	1133.748	0.1045	-132.251
437	375'130	London	Wroclaw	PL	UK	729	645	0.1152	-84
438	374'599	Amsterdam	Valencia	ES	NL	791	752	0.0493	-39
439	373'754	Munich	Zurich	CH	DE	209	201	0.0383	-8
440	372'591	Cologne	Vienna	AT	DE	430	429	0.0023	-1
441	372'135	Bergen	Trondheim	NO	NO	879	804	0.0853	-75
442	370'496	Berlin	Naples	DE	IT	805	608	0.2447	-197
443	370'381	Birmingham	Malaga	ES	UK	964	875	0.0923	-89
444	367'446	Amsterdam	Bergen	NL	NO	1382	1150.207	0.1677	-231.792
445	367'212	Alicante	Bristol	ES	UK	938	831	0.1141	-107
447	365'740	Brussels	Stockholm	BE	SE	884	746	0.1561	-138
448	365'697	Rome	Valencia	ES	IT	930	787	0.1538	-143
450	365'547	Athens	Barcelona	EL	ES	-	1966.518	-	-
451	365'496	Alicante	Glasgow	ES	UK	1163	1036	0.1092	-127
452	365'262	Copenhagen	Milan	DK	IT	883	678	0.2322	-205
455	364'392	Amsterdam	Gothenburg	NL	SE	777	613.2077	0.2108	-163.792
456	363'605	Amsterdam	Newcastle upon Tyne	NL	UK	388	388	0	0
457	363'283	London	Verona	IT	UK	595	486	0.1832	-109
458	362'902	Edinburgh	Paris	FR	UK	401	401	0	0
459	362'446	Marseille	Nantes	FR	FR	350	350	0	0
461	357'341	Manchester	Munich	DE	UK	603	517	0.1426	-86
462	357'258	Madrid	Malaga	ES	ES	168	168	0	0
463	356'781	Bilbao	London	ES	UK	711	525	0.2616	-186
466	353'752	Frankfurt	Hanover	DE	DE	136	93	0.3162	-43
471	350'345	London	Turin	IT	UK	472	368	0.2203	-104
473	348'220	Brussels	Porto	BE	PT	1041	895.8038	0.1395	-145.196
474	347'550	Sofia	Vienna	AT	BG	1388	584.8262	0.5787	-803.173
475	346'664	Bristol	Malaga	ES	UK	964	902	0.0643	-62

476	346'612	Bucharest	Munich	DE	RO	1235	1030.735	0.1654	-204.264
478	344'621	Amsterdam	Stuttgart	DE	NL	289	281.5637	0.0257	-7.4363
479	343'726	Amsterdam	Porto	NL	PT	1146	1000.803	0.1267	145.196
480	342'360	Copenhagen	Prague	CZ	DK	619	400	0.3538	-219
481	341'931	Luxembourg	Porto	LU	PT	1083	937.8038	0.1341	-145.196
482	341'210	Berlin	Bucharest	DE	RO	1425	1159.735	0.1862	-265.264
486	338'217	Madrid	Valencia	ES	ES	113	113	0	0
487	337'973	Lisbon	Lyon	FR	PT	942	651	0.3089	-291
488	337'752	Budapest	Munich	DE	HU	374	362	0.0321	-12
489	336'983	Rome	Tirana	AL	IT	-	-	-	-
490	336'254	Lisbon	Vienna	AT	PT	1594	1200	0.2472	-394
491	335'749	Barcelona	Düsseldorf	DE	ES	648	609	0.0602	-39
492	334'121	Helsinki	Riga	FI	LV	-	2102.492	-	-
493	333'833	Brussels	Prague	BE	CZ	535	378	0.2935	-157
494	333'828	Barcelona	Bucharest	ES	RO	1957	1622.735	0.1708	-334.264
496	333'389	Barcelona	Helsinki	ES	FI	-	2160.492	-	-
497	331'928	Dresden	Frankfurt	DE	DE	233	149	0.3605	-84
498	331'675	Stockholm	Warsaw	PL	SE	974	801	0.1776	-173
499	331'548	Lisbon	Manchester	PT	UK	1359	989	0.2723	-370
501	330'797	Athens	Bucharest	EL	RO	-	1069.270	-	-
503	329'783	Frankfurt	Zagreb	DE	HR	655	630	0.0382	-25
504	328'974	Basel	London	CH	UK	325	325	0	0
505	328'953	Copenhagen	Manchester	DK	UK	874	694	0.2059	-180
506	328'794	Genoa	Rome	IT	IT	275	246	0.1055	-29
507	328'716	Athens	Vienna	AT	EL	-	1155.518	-	-
508	328'608	Alicante	Leeds	ES	UK	986	879	0.1085	-107
512	326'964	Brussels	Warsaw	BE	PL	686	603	0.121	-83
513	326'474	Copenhagen	Düsseldorf	DE	DK	479	355	0.2589	-124
514	326'189	Geneva	Rome	CH	IT	452	452	0	0
515	325'380	Malaga	Oslo	ES	NO	1836	1569	0.1454	-267
517	324'821	Basel	London	FR	UK	325	325	0	0
518	324'698	Barcelona	Stockholm	ES	SE	1393	1155	0.1709	-238
519	323'942	Bilbao	Munich	DE	ES	889	673	0.243	-216
521	323'316	Amsterdam	Lyon	FR	NL	318	318	0	0
522	323'304	Bristol	Glasgow	UK	UK	317	310	0.0221	-7
523	322'993	Brussels	Zurich	BE	CH	330	330	0	0
526	321'813	Milan	Prague	CZ	IT	678	456	0.3274	-222
527	321'339	Frankfurt	Stuttgart	DE	DE	76	62	0.1842	-14
528	320'052	Aberdeen	Amsterdam	NL	UK	615	615	0	0
529	319'626	Düsseldorf	Manchester	DE	UK	404	348	0.1386	-56
531	317'539	London	Split	HR	UK	1321	1240.766	0.0607	-80.234
532	317'095	Birmingham	Frankfurt	DE	UK	359	332	0.0752	-27
533	316'697	Madrid	Prague	CZ	ES	1153	931	0.1925	-222
536	316'396	Eindhoven	London	NL	UK	241	229.3363	0.0484	-11.6637
537	316'322	Milan	Tirana	AL	IT	-	-	-	-
538	316'057	Nantes	Toulouse	FR	FR	335	259	0.2269	-76
539	315'930	Warsaw	Zurich	CH	PL	755	609	0.1934	-146
540	315'611	Copenhagen	Madrid	DK	ES	1271	1047	0.1762	-224
543	315'033	Lisbon	Luxembourg	LU	PT	1197	883	0.2623	-314

544	314'721	Kaunas	London	LT	UK	1196	921	0.2299	-275
545	314'469	London	Thessaloniki	EL	UK	-	1500.518	-	-
546	314'161	London	Poznan	PL	UK	647	607	0.0618	-40
547	313'533	Bologna	Madrid	ES	IT	784	641	0.1824	-143
548	313'512	Budapest	Warsaw	HU	PL	607	484	0.2026	-123
549	313'274	Frankfurt	Nice	DE	FR	573	525.9867	0.082	-47.0133
550	312'966	Bilbao	Paris	ES	FR	566	380	0.3286	-186
551	312'722	Lille	Nice	FR	FR	425	425	0	0
552	311'704	Helsinki	Prague	CZ	FI	-	1671.492	-	-
554	311'363	Bologna	Frankfurt	DE	IT	463	354	0.2354	-109
556	310'542	Berlin	Edinburgh	DE	UK	738	698	0.0542	-40
557	310'334	Belgrade	Podgorica	ME	RS	587	587	0	0
558	309'631	Olbia	Rome	IT	IT	-	-	-	-
559	309'376	Naples	Venice	IT	IT	277	277	0	0
561	309'081	Bratislava	London	SK	UK	696	676	0.0287	-20
562	308'684	Naples	Rome	IT	IT	63	63	0	0
563	308'070	Bristol	Faro	PT	UK	1459	1115	0.2358	-344
564	307'753	Barcelona	Nice	ES	FR	420	381	0.0929	-39
565	306'050	Munich	Naples	DE	IT	564	387	0.3138	-177
567	304'193	Barcelona	Warsaw	ES	PL	1169	998	0.1463	-171
568	304'162	Nice	Rome	FR	IT	467	368.9867	0.2099	-98.0133
569	303'335	Glasgow	Malaga	ES	UK	1189	1107	0.069	-82
570	303'113	Bremen	Frankfurt	DE	DE	195	152	0.2205	-43
571	302'512	Barcelona	Lyon	ES	FR	301	262	0.1296	-39
575	299'890	Copenhagen	Warsaw	DK	PL	694	535	0.2291	-159
576	299'866	Athens	Milan	EL	IT	-	1547.518	-	-
578	299'447	Alicante	Madrid	ES	ES	142	142	0	0
579	299'359	Budapest	Madrid	ES	HU	1254	1112	0.1132	-142
580	299'338	Amsterdam	Bordeaux	FR	NL	368	368	0	0
582	298'960	Bilbao	Seville	ES	ES	414	336	0.1884	-78
583	298'836	Dublin	Leeds	IE	UK	-	-	-	-
587	297'523	Helsinki	Tallinn	EE	FI	-	2202.492	-	-
588	297'300	Amsterdam	Marseille	FR	NL	415	415	0	0
589	297'271	Madrid	Toulouse	ES	FR	362	346	0.0442	-16
590	297'214	Stockholm	Vienna	AT	SE	1046	874	0.1644	-172
592	296'165	Budapest	Eindhoven	HU	NL	704	703	0.0014	-1
593	296'019	Amsterdam	Stavanger	NL	NO	1427	1197.207	0.161	-229.792
595	295'665	Eindhoven	Malaga	ES	NL	967	893.3363	0.0762	-73.6637
597	294'454	Copenhagen	Stavanger	DK	NO	841	755	0.1023	-86
598	294'171	Warsaw	Wroclaw	PL	PL	255	105	0.5882	-150
599	294'139	Malaga	Rome	ES	IT	1084	941	0.1319	-143
600	293'786	Brussels	Oslo	BE	NO	1001	834	0.1668	-167
603	291'734	Frankfurt	Malaga	DE	ES	955	890	0.0681	-65
604	291'333	Faro	Lisbon	PT	PT	180	150	0.1667	-30
607	290'000	Dortmund	Katowice	DE	PL	582	520	0.1065	-62
608	289'702	Riga	Tallinn	EE	LV	607	100	0.8353	-507
609	289'010	Barcelona	Hamburg	DE	ES	841	733	0.1284	-108
610	288'763	Stockholm	Tallinn	EE	SE	2225	1197	0.462	-1028
611	288'629	Geneva	Vienna	AT	CH	598	578	0.0334	-20

612	288'327	Copenhagen	Nice	DK	FR	1057	850.9867	0.1949	-206.013
613	288'024	Bologna	Rome	IT	IT	132	132	0	0
614	287'558	Nice	Zurich	CH	FR	470	350.9867	0.2532	-119.013
615	287'152	Birmingham	Faro	PT	UK	1459	1088	0.2543	-371
616	287'039	Alicante	Eindhoven	ES	NL	941	822.3363	0.1261	-118.663
617	284'321	Malaga	Zurich	CH	ES	860	821	0.0453	-39
620	283'067	Gdansk	Stockholm	PL	SE	982	852	0.1324	-130
621	281'578	Palermo	Pisa	IT	IT	709	634	0.1058	-75
622	281'450	Amsterdam	Brussels	BE	NL	105	105	0	0
624	281'109	Gdansk	Warsaw	PL	PL	148	148	0	0
625	280'995	Dublin	Zurich	CH	IE	-	-	-	-
626	280'602	Frankfurt	Tallinn	DE	EE	1791	830	0.5366	-961
627	279'608	Florence	Frankfurt	DE	IT	500	391	0.218	-109
629	278'961	Alicante	Paris	ES	FR	717	610	0.1492	-107
630	278'933	Leeds	Malaga	ES	UK	1012	950	0.0613	-62
631	278'852	Porto	Zurich	CH	PT	1061	946	0.1084	-115
632	278'471	Birmingham	Düsseldorf	DE	UK	324	297	0.0833	-27
633	278'423	Belfast	Bristol	UK	UK	-	-	-	-
635	277'751	Düsseldorf	Malaga	DE	ES	974	912	0.0637	-62
636	277'577	Nantes	Nice	FR	FR	498	498	0	0
637	277'509	Bologna	Palermo	IT	IT	694	619	0.1081	-75
638	277'342	Palermo	Turin	IT	IT	808	733	0.0928	-75
639	277'310	Oslo	Riga	LV	NO	1735	1185	0.317	-550
640	276'368	Barcelona	Stuttgart	DE	ES	607	546	0.1005	-61
641	276'020	Geneva	Manchester	CH	UK	530	474	0.1057	-56
643	275'980	Copenhagen	Gothenburg	DK	SE	191	171	0.1047	-20
645	274'326	Barcelona	Cologne	DE	ES	620	581	0.0629	-39
647	273'250	Athens	Brussels	BE	EL	-	1690.518	-	-
648	272'316	Frankfurt	Toulouse	DE	FR	532	437	0.1786	-95
649	272'203	Helsinki	Rome	FI	IT	-	2065.492	-	-
650	272'148	Lyon	Madrid	ES	FR	459	420	0.085	-39
652	271'707	Madrid	Santander	ES	ES	243	183	0.2469	-60
653	271'092	Munich	Thessaloniki	DE	EL	-	1083.518	-	-
655	270'622	Bordeaux	Nice	FR	FR	520	417	0.1981	-103
656	270'616	Amsterdam	Florence	IT	NL	680	576	0.1529	-104
658	269'689	Naples	Turin	IT	IT	309	309	0	0
660	269'360	Manchester	Rome	IT	UK	874	714	0.1831	-160
661	269'062	Alicante	Dublin	ES	IE	-	-	-	-
662	268'778	Liverpool	Malaga	ES	UK	1022	931	0.089	-91
664	268'575	Belfast	Newcastle upon Tyne	UK	UK	-	-	-	-
666	267'097	Alicante	Liverpool	ES	UK	996	860	0.1365	-136
668	266'176	Amsterdam	Leeds	NL	UK	343	343	0	0
669	265'980	Birmingham	Edinburgh	UK	UK	246	242	0.0163	-4
670	264'916	Copenhagen	Dublin	DK	IE	-	-	-	-
671	264'876	Bucharest	Iasi	RO	RO	364	364	0	0
672	264'872	Florence	Rome	IT	IT	95	95	0	0
673	264'731	Malaga	Newcastle upon Tyne	ES	UK	1057	995	0.0587	-62
674	264'444	Frankfurt	Leipzig	DE	DE	165	102	0.3818	-63

675	263'821	Prague	Zurich	CH	CZ	525	384	0.2686	-141
676	263'542	Krakow	Munich	DE	PL	625	458	0.2672	-167
677	263'217	Amsterdam	Naples	IT	NL	838	734	0.1241	-104
678	262'307	Geneva	Munich	CH	DE	367	359	0.0218	-8
679	261'535	Belgrade	Frankfurt	DE	RS	971	659	0.3213	-312
681	260'554	Riga	Stockholm	LV	SE	1618	1097	0.322	-521
682	260'520	Brussels	Lyon	BE	FR	213	213	0	0
683	260'000	Bastia	Marseille	FR	FR	-	-	-	-
684	259'666	Sofia	Varna	BG	BG	503	361	0.2823	-142
685	259'374	Munich	Toulouse	DE	FR	625	519	0.1696	-106
688	258'896	Munich	Sofia	BG	DE	1619	803.8262	0.5035	-815.173
689	258'335	Düsseldorf	Prague	CZ	DE	457	300	0.3435	-157
690	257'882	Budapest	Dublin	HU	IE	-	-	-	-
691	257'856	Munich	Nice	DE	FR	666	380.9867	0.4279	-285.013
692	256'694	Cologne	Zurich	CH	DE	265	234	0.117	-31
693	256'550	Barcelona	Oslo	ES	NO	1510	1243	0.1768	-267
694	256'448	Amsterdam	Düsseldorf	DE	NL	135	132.5637	0.018	-2.4363
695	256'020	Amsterdam	Toulouse	FR	NL	504	428	0.1508	-76
696	255'973	Belgrade	Paris	FR	RS	1158	805	0.3048	-353
698	255'867	Prague	Stockholm	CZ	SE	899	666	0.2592	-233
699	255'675	Bilbao	Malaga	ES	ES	422	344	0.1848	-78
700	255'111	Lyon	Porto	FR	PT	828	713	0.1389	-115
701	254'125	Düsseldorf	Milan	DE	IT	477	440	0.0776	-37
703	253'382	Frankfurt	Riga	DE	LV	1184	730	0.3834	-454
704	253'302	Faro	Paris	FR	PT	1238	894	0.2779	-344
705	253'250	Ajaccio	Marseille	FR	FR	-	-	-	-
706	253'156	Berlin	Bologna	DE	IT	610	413	0.323	-197
707	251'085	Amsterdam	Faro	NL	PT	1440	1096	0.2389	-344
708	250'066	Basel	Hamburg	CH	DE	374	291	0.2219	-83
709	250'013	Basel	Budapest	CH	HU	629	566	0.1002	-63
711	249'734	Frankfurt	Marseille	DE	FR	425	399	0.0612	-26
712	249'465	Frankfurt	Nuremberg	DE	DE	123	122	0.0081	-1
713	249'304	Alicante	Copenhagen	DK	ES	1413	1121	0.2067	-292
717	246'398	Prague	Warsaw	CZ	PL	437	378	0.135	-59
718	246'375	Alicante	Belfast	ES	UK	-	-	-	-
720	245'683	Valencia	Zurich	CH	ES	706	667	0.0552	-39
721	245'459	Bordeaux	Lisbon	FR	PT	967	578	0.4023	-389
725	245'030	Brussels	Manchester	BE	UK	270	214	0.2074	-56
726	245'027	Madrid	Marseille	ES	FR	430	391	0.0907	-39
728	243'221	Budapest	Milan	HU	IT	680	535	0.2132	-145
729	242'653	Gothenburg	Munich	DE	SE	777	641	0.175	-136
730	242'170	Amsterdam	Bilbao	ES	NL	768	582	0.2422	-186
733	240'710	Barcelona	Birmingham	ES	UK	638	572	0.1034	-66
735	239'930	Lisbon	Nantes	FR	PT	1166	777	0.3336	-389
737	239'764	Amsterdam	Liverpool	NL	UK	353	324	0.0822	-29
738	239'723	Venice	Zurich	CH	IT	317	301	0.0505	-16
741	239'201	Munich	Venice	DE	IT	377	195	0.4828	-182
742	238'801	Munich	Zagreb	DE	HR	468	468	0	0
744	238'228	Lisbon	Toulouse	FR	PT	845	577	0.3172	-268

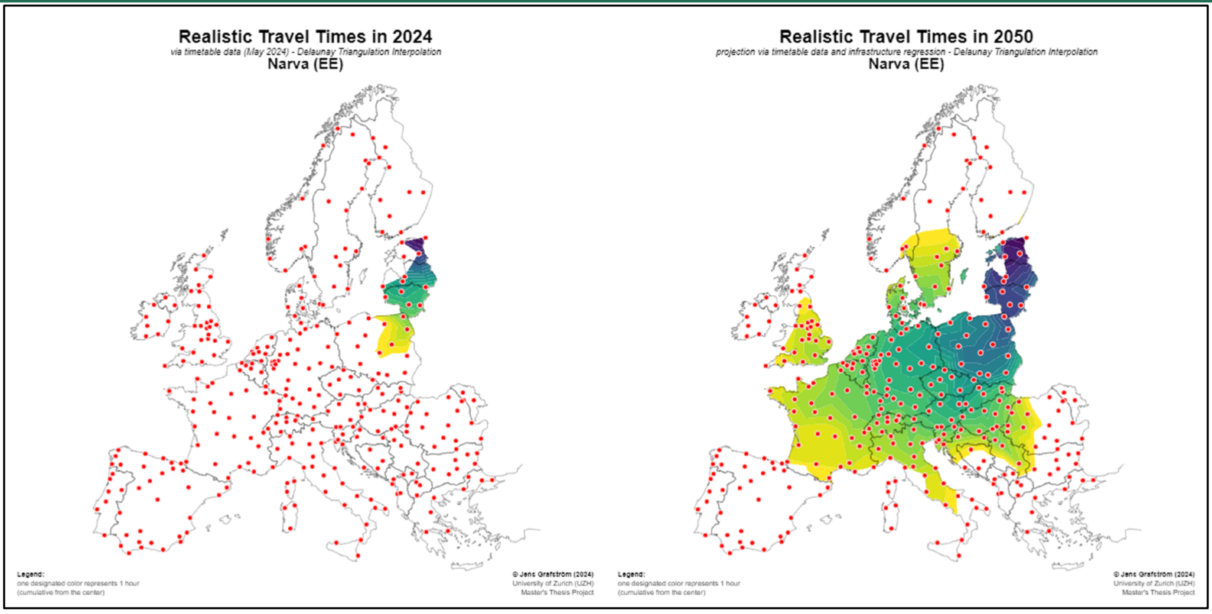
745	238'045	Düsseldorf	Stockholm	DE	SE	759	621	0.1818	-138
747	237'532	Frankfurt	Graz	AT	DE	482	470	0.0249	-12
748	237'421	Lisbon	Marseille	FR	PT	913	622	0.3187	-291
749	237'276	Naples	Palermo	IT	IT	499	424	0.1503	-75
750	236'844	Gothenburg	Helsinki	FI	SE	-	1223.492	-	-
751	236'773	Eindhoven	Faro	NL	PT	1462	1106.336	0.2433	-355.663
752	236'253	Athens	Sofia	BG	EL	-	646.2707	-	-
753	235'592	Lyon	Munich	DE	FR	421	365	0.133	-56
754	235'480	Hamburg	Lisbon	DE	PT	1482	1122	0.2429	-360
755	235'312	Paris	Pisa	FR	IT	530	411	0.2245	-119
756	235'222	Budapest	Zurich	CH	HU	583	563	0.0343	-20
757	235'159	Lyon	Rome	FR	IT	457	353	0.2276	-104
758	234'689	Belfast	Malaga	ES	UK	-	-	-	-
759	234'655	Bilbao	Frankfurt	DE	ES	796	591	0.2575	-205
762	234'307	Lille	Toulouse	FR	FR	366	290	0.2077	-76
763	234'103	Gdansk	Oslo	NO	PL	1099	940	0.1447	-159
764	234'019	Aalborg	Amsterdam	DK	NL	635	589.2077	0.0721	-45.7923
765	233'827	Düsseldorf	Dublin	DE	IE	-	-	-	-
766	233'718	Münster	Munich	DE	DE	326	315	0.0337	-11
767	233'666	Vilnius	Warsaw	LT	PL	461	242	0.4751	-219
768	233'652	Madrid	Naples	ES	IT	979	836	0.1461	-143
769	233'555	Bari	London	IT	UK	910	799	0.122	-111
772	232'957	Budapest	Prague	CZ	HU	378	351	0.0714	-27
773	232'915	Rome	Stockholm	IT	SE	1359	1060	0.22	-299
775	232'287	Barcelona	Liverpool	ES	UK	696	628	0.0977	-68
776	232'136	Manchester	Prague	CZ	UK	805	592	0.2646	-213
777	231'507	Brussels	Helsinki	BE	FI	-	1751.492	-	-
778	231'448	Budapest	Copenhagen	DK	HU	909	751	0.1738	-158
779	230'262	Birmingham	Glasgow	UK	UK	246	239	0.0285	-7
780	229'823	Faro	Frankfurt	DE	PT	1450	1103	0.2393	-347
781	229'729	Brussels	Venice	BE	IT	607	493	0.1878	-114
782	229'468	Riga	Vilnius	LT	LV	262	114	0.5649	-148
783	229'435	Brussels	Valencia	BE	ES	686	647	0.0569	-39
784	229'327	Budapest	Helsinki	FI	HU	-	2022.492	-	-
785	229'313	Palermo	Verona	IT	IT	746	671	0.1005	-75
786	228'428	Oslo	Warsaw	NO	PL	1091	889	0.1852	-202
789	228'167	Bucharest	Warsaw	PL	RO	1468	1152.735	0.2148	-315.264
790	227'821	Amsterdam	Bologna	IT	NL	643	539	0.1617	-104
791	227'815	Bordeaux	Lille	FR	FR	230	230	0	0
793	227'728	Eindhoven	Valencia	ES	NL	813	762.3363	0.0623	-50.6637
794	227'103	Frankfurt	Salzburg	AT	DE	275	250	0.0909	-25
795	227'095	Belfast	Faro	PT	UK	-	-	-	-
798	226'791	Frankfurt	Vilnius	DE	LT	1001	676	0.3247	-325
799	226'502	Copenhagen	Geneva	CH	DK	806	607	0.2469	-199
800	225'178	Graz	Munich	AT	DE	326	308	0.0552	-18
801	224'999	Rome	Sofia	BG	IT	2036	1092.826	0.4632	-943.173
802	224'321	Nice	Vienna	AT	FR	823	564.9867	0.3135	-258.013
803	224'161	Alicante	Edinburgh	ES	UK	1118	1011	0.0957	-107
804	224'115	Dortmund	London	DE	UK	285	285	0	0

805	223'520	Berlin	Sofia	BG	DE	1809	932.8262	0.4843	-876.173
806	223'335	Athens	Copenhagen	DK	EL	-	1763.518	-	-
807	223'215	Hanover	Vienna	AT	DE	418	418	0	0
808	222'658	London	Salzburg	AT	UK	535	505	0.0561	-30
809	222'354	Bologna	Bucharest	IT	RO	1520	1187.735	0.2186	-332.264
811	222'238	Dublin	Newcastle upon Tyne	IE	UK	-	-	-	-
813	221'932	Budapest	Stockholm	HU	SE	1189	1017	0.1447	-172
814	221'862	Copenhagen	Riga	DK	LV	1338	831	0.3789	-507
816	220'535	Lille	Marseille	FR	FR	277	277	0	0
817	220'227	Dublin	Vienna	AT	IE	-	-	-	-
818	220'084	Munich	Prague	CZ	DE	316	248	0.2152	-68
819	219'564	Copenhagen	Edinburgh	DK	UK	974	850	0.1273	-124
820	219'507	Marseille	Munich	DE	FR	518	462	0.1081	-56
821	219'327	Madrid	Nantes	ES	FR	683	546	0.2006	-137
822	218'293	Cologne	Rome	DE	IT	645	545	0.155	-100
823	218'268	Barcelona	Bordeaux	ES	FR	340	248	0.2706	-92
825	217'509	Düsseldorf	Rome	DE	IT	673	573	0.1486	-100
827	216'936	Frankfurt	Thessaloniki	DE	EL	-	1230.518	-	-
828	216'262	Luxembourg	Munich	DE	LU	293	263	0.1024	-30
829	215'905	Bristol	Geneva	CH	UK	450	450	0	0
830	215'319	Frankfurt	Naples	DE	IT	658	549	0.1657	-109
831	214'987	Hanover	Zurich	CH	DE	351	268	0.2365	-83
832	214'741	Copenhagen	Lisbon	DK	PT	1754	1278	0.2714	-476
833	214'552	Bordeaux	Geneva	CH	FR	395	395	0	0
835	214'215	Düsseldorf	Lisbon	DE	PT	1289	975	0.2436	-314
836	213'612	Berlin	Nice	DE	FR	795	601.9867	0.2428	-193.013
837	213'554	Athens	Geneva	CH	EL	-	1733.518	-	-
838	213'230	Aberdeen	Manchester	UK	UK	324	324	0	0
839	213'021	Belgrade	Vienna	AT	RS	604	293	0.5149	-311
840	213'013	Seville	Valencia	ES	ES	260	260	0	0
842	212'457	Helsinki	Milan	FI	IT	-	1949.492	-	-
843	212'418	Innsbruck	London	AT	UK	551	472	0.1434	-79
844	211'347	Dublin	Prague	CZ	IE	-	-	-	-
845	211'265	Amsterdam	Krakow	NL	PL	782	696.5637	0.1093	-85.4363
847	210'688	Almeria	Madrid	ES	ES	374	230	0.385	-144
849	210'380	Bodo	Trondheim	NO	NO	586	586	0	0
850	210'237	Birmingham	Munich	DE	UK	523	466	0.109	-57
851	209'873	Budapest	Oslo	HU	NO	1306	1105	0.1539	-201
852	209'867	Dresden	Munich	DE	DE	252	211	0.1627	-41
853	209'820	Krakow	Oslo	NO	PL	1205	998	0.1718	-207
856	209'195	Florence	Munich	DE	IT	406	229	0.436	-177
857	209'049	Lyon	Nice	FR	FR	245	245	0	0
858	208'781	Krakow	Manchester	PL	UK	1045	905	0.134	-140
861	208'346	Milan	Porto	IT	PT	1089	870	0.2011	-219
862	208'184	Athens	Budapest	EL	HU	-	1012.518	-	-
863	208'130	Alicante	Düsseldorf	DE	ES	948	841	0.1129	-107
864	208'035	Bergen	London	NO	UK	1514	1302	0.14	-212
865	207'861	Helsinki	Zurich	CH	FI	-	1771.492	-	-

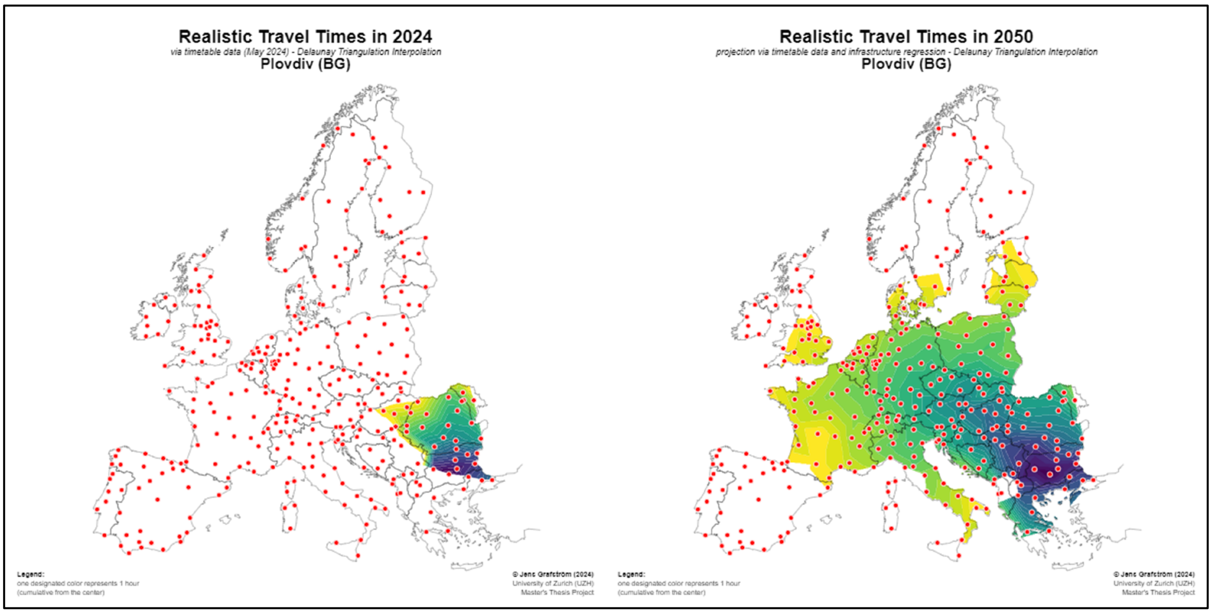
866	207'841	London	Tirana	AL	UK	-	-	-	-
868	207'548	Belgrade	Munich	DE	RS	835	512	0.3868	-323
869	207'279	Athens	Warsaw	EL	PL	-	1496.518	-	-
870	207'081	Geneva	Nantes	CH	FR	366	366	0	0
871	206'546	Helsinki	Lisbon	FI	PT	-	2549.492	-	-
872	206'335	Hamburg	Madrid	DE	ES	999	891	0.1081	-108
873	206'028	Bologna	Munich	DE	IT	369	192	0.4797	-177
874	205'853	Nice	Oslo	FR	NO	1454	1204.986	0.1713	-249.013
875	205'819	Barcelona	Turin	ES	IT	512	369	0.2793	-143
876	205'631	Paris	Sofia	BG	FR	1942	1096.826	0.4352	-845.173
878	204'766	Barcelona	Bristol	ES	UK	638	599	0.0611	-39
879	204'659	Innsbruck	Vienna	AT	AT	251	239	0.0478	-12
880	204'439	Madrid	Stockholm	ES	SE	1551	1313	0.1534	-238
882	203'985	Faro	Liverpool	PT	UK	1517	1144	0.2459	-373
885	203'433	Milan	Zurich	CH	IT	184	178	0.0326	-6
886	203'323	Brussels	Gothenburg	BE	SE	795	651	0.1811	-144
888	203'123	Iasi	London	RO	UK	1820	1687.748	0.0727	-132.251
889	202'602	Dublin	Hamburg	DE	IE	-	-	-	-
890	202'458	Frankfurt	Luxembourg	DE	LU	200	181	0.095	-19
891	202'443	Krakow	Stockholm	PL	SE	1088	910	0.1636	-178
892	202'401	Düsseldorf	Warsaw	DE	PL	561	483	0.139	-78
894	201'894	Brussels	Budapest	BE	HU	679	678	0.0015	-1
895	201'795	Amsterdam	Hanover	DE	NL	249	227.5637	0.0861	-21.4363
896	201'770	Faro	Leeds	PT	UK	1507	1163	0.2283	-344
897	201'768	Nice	Stockholm	FR	SE	1337	1116.9867	0.1646	-220.013
899	201'672	Berlin	Venice	DE	IT	618	416	0.3269	-202
900	201'194	Hamburg	Manchester	DE	UK	602	538	0.1063	-64
902	201'062	Lisbon	Stockholm	PT	SE	2034	1544	0.2409	-490
903	200'970	Rome	Verona	IT	IT	184	184	0	0
904	200'487	Poznan	Warsaw	PL	PL	153	110	0.281	-43
907	198'950	Budapest	Manchester	HU	UK	949	879	0.0738	-70
910	198'390	Manchester	Southampton	UK	UK	231	175	0.2424	-56
911	198'061	Amsterdam	Nuremberg	DE	NL	349	345.5637	0.0098	-3.4363
912	197'462	Berlin	Bristol	DE	UK	558	518	0.0717	-40
913	197'452	Barcelona	Santander	ES	ES	401	341	0.1496	-60
915	196'870	Copenhagen	Gdansk	DK	PL	702	586	0.1652	-116
917	196'795	Basel	Vienna	AT	CH	486	423	0.1296	-63
918	196'502	Edinburgh	Frankfurt	DE	UK	539	539	0	0
919	196'247	Brussels	Hamburg	BE	DE	332	324	0.0241	-8
920	195'860	Eindhoven	Lisbon	NL	PT	1282	956.3363	0.254	-325.663
923	195'502	Stuttgart	Thessaloniki	DE	EL	-	1183.518	-	-
924	194'569	Helsinki	Vienna	AT	FI	-	1879.4926	-	-
925	194'305	Brussels	Paris	BE	FR	97	97	0	0
927	193'357	Munich	Stuttgart	DE	DE	115	100	0.1304	-15
928	193'151	Madrid	Warsaw	ES	PL	1327	1156	0.1289	-171
929	193'085	Frankfurt	Turin	DE	IT	449	403	0.1024	-46
930	192'893	Edinburgh	Geneva	CH	UK	630	630	0	0
932	192'754	Madrid	Nice	ES	FR	578	539	0.0675	-39

933	192'683	Amsterdam	Nantes	FR	NL	339	339	0	0
934	192'642	Lisbon	Valencia	ES	PT	596	344	0.4228	-252
935	192'545	Munich	Turin	DE	IT	440	258	0.4136	-182
937	192'430	Frankfurt	Wroclaw	DE	PL	446	362	0.1883	-84
938	192'412	London	Nuremberg	DE	UK	406	405	0.0025	-1
939	191'898	Alicante	Helsinki	ES	FI	-	2392.492	-	-
940	191'772	Riga	Warsaw	LV	PL	644	296	0.5404	-348
941	191'306	Basel	Porto	CH	PT	1008	893	0.1141	-115
942	191'190	Bristol	Newcastle upon Tyne	UK	UK	230	230	0	0
943	191'102	Tallinn	Warsaw	EE	PL	1251	396	0.6835	-855
945	190'821	Hamburg	Stockholm	DE	SE	552	422	0.2355	-130
947	189'983	Düsseldorf	Thessaloniki	DE	EL	-	1321.518	-	-
948	189'596	Berlin	Pisa	DE	IT	699	502	0.2818	-197
951	189'037	Malaga	Milan	ES	IT	888	745	0.161	-143
952	188'065	Gothenburg	Malaga	ES	SE	1630	1386	0.1497	-244
954	187'997	Dortmund	Munich	DE	DE	306	286	0.0654	-20
955	187'410	Brussels	Toulouse	BE	FR	399	323	0.1905	-76
956	186'878	Tirana	Vienna	AL	AT	-	-	-	-
957	186'590	Bremen	London	DE	UK	389	389	0	0
958	186'336	Basel	Nice	CH	FR	425	403.9867	0.0494	-21.0133
960	185'458	Madrid	Manchester	ES	UK	876	758	0.1347	-118
961	185'289	Amsterdam	Luxembourg	LU	NL	301	225	0.2525	-76
963	185'048	Barcelona	Florence	ES	IT	663	520	0.2157	-143
964	185'001	Copenhagen	Hamburg	DE	DK	272	156	0.4265	-116
965	184'935	Edinburgh	Malaga	ES	UK	1144	1082	0.0542	-62
966	184'758	Faro	Newcastle upon Tyne	PT	UK	1552	1208	0.2216	-344
968	184'607	Budapest	Lisbon	HU	PT	1737	1343	0.2268	-394
971	182'796	Düsseldorf	Helsinki	DE	FI	-	1626.492	-	-
972	182'783	Madrid	Sofia	BG	ES	2499	1553.826	0.3782	-945.173
973	182'767	Edinburgh	Southampton	UK	UK	331	331	0	0
974	182'698	Berlin	Warsaw	DE	PL	318	275	0.1352	-43
975	182'455	Cagliari	Pisa	IT	IT	-	-	-	-
976	182'404	Bologna	Vienna	AT	IT	516	376	0.2713	-140
977	182'362	Manchester	Milan	IT	UK	678	518	0.236	-160
978	182'221	Marseille	Rome	FR	IT	554	450	0.1877	-104
982	181'702	Budapest	Stuttgart	DE	HU	489	462	0.0552	-27
983	181'620	Venice	Vienna	AT	IT	444	362	0.1847	-82
985	181'225	Split	Zagreb	HR	HR	406	355.766	0.1237	-50.234
986	181'029	Oslo	Zurich	CH	NO	1096	854	0.2208	-242
987	180'818	Geneva	Malaga	CH	ES	740	701	0.0527	-39
988	180'709	Basel	Lisbon	CH	PT	1122	831	0.2594	-291
989	180'676	Alicante	Bilbao	ES	ES	396	318	0.197	-78
991	180'510	Aarhus	Copenhagen	DK	DK	161	147	0.087	-14
994	179'728	Brussels	Bucharest	BE	RO	1540	1346.735	0.1255	-193.264
996	179'302	Stuttgart	Zurich	CH	DE	193	157	0.1865	-36
997	179'195	Basel	Frankfurt	CH	DE	162	122	0.2469	-40
999	178'955	Lyon	Rennes	FR	FR	220	220	0	0
1000	178'835	Barcelona	Basel	ES	FR	481	442	0.0811	-39

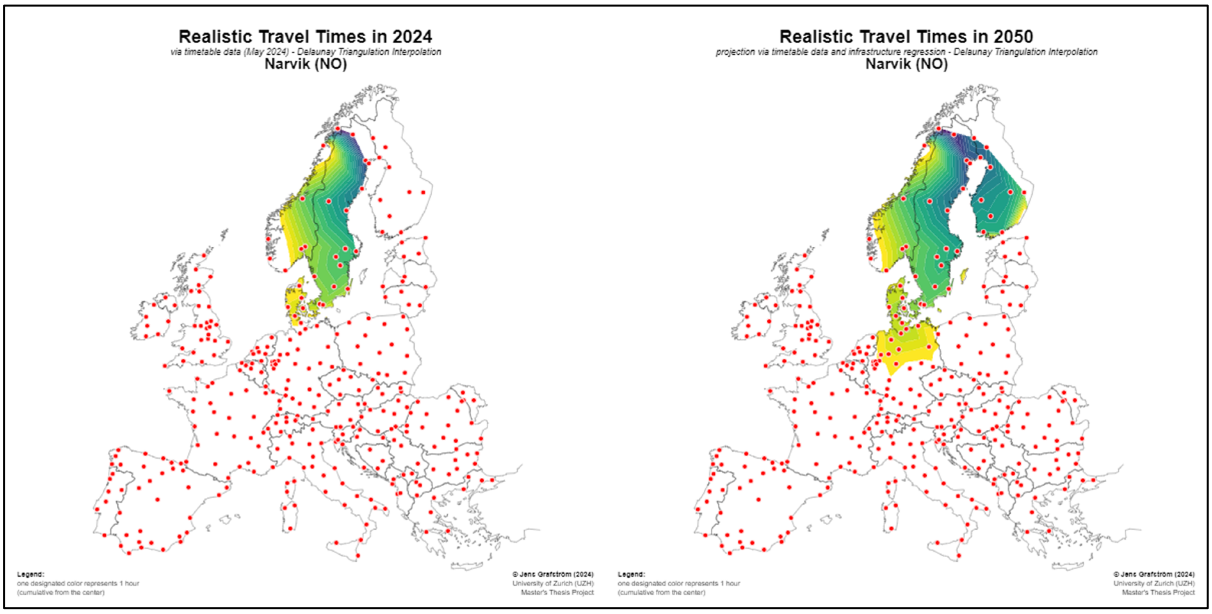
K – Isochrones



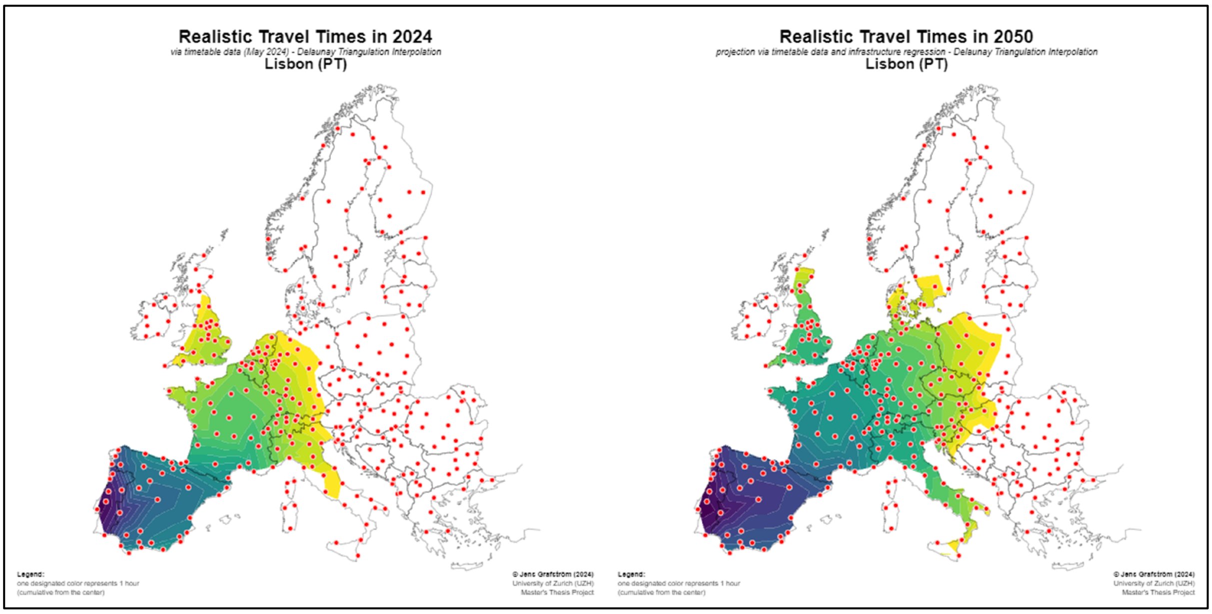
Figures 35 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Narva. Source: own illustration.*



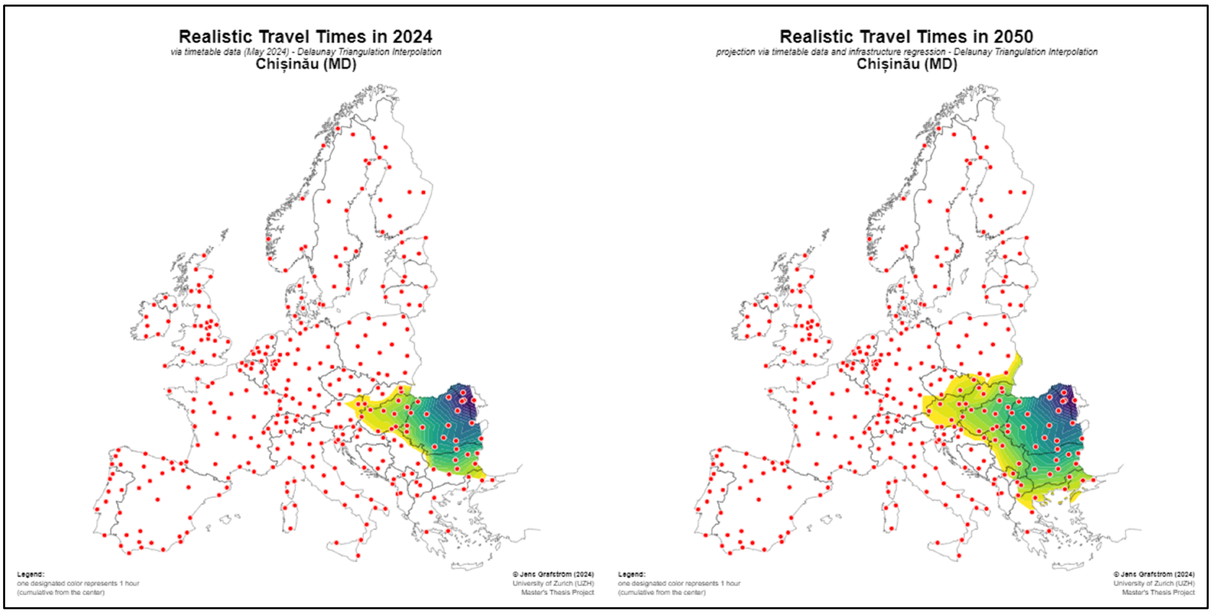
Figures 36 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Plovdiv. Source: own illustration.*



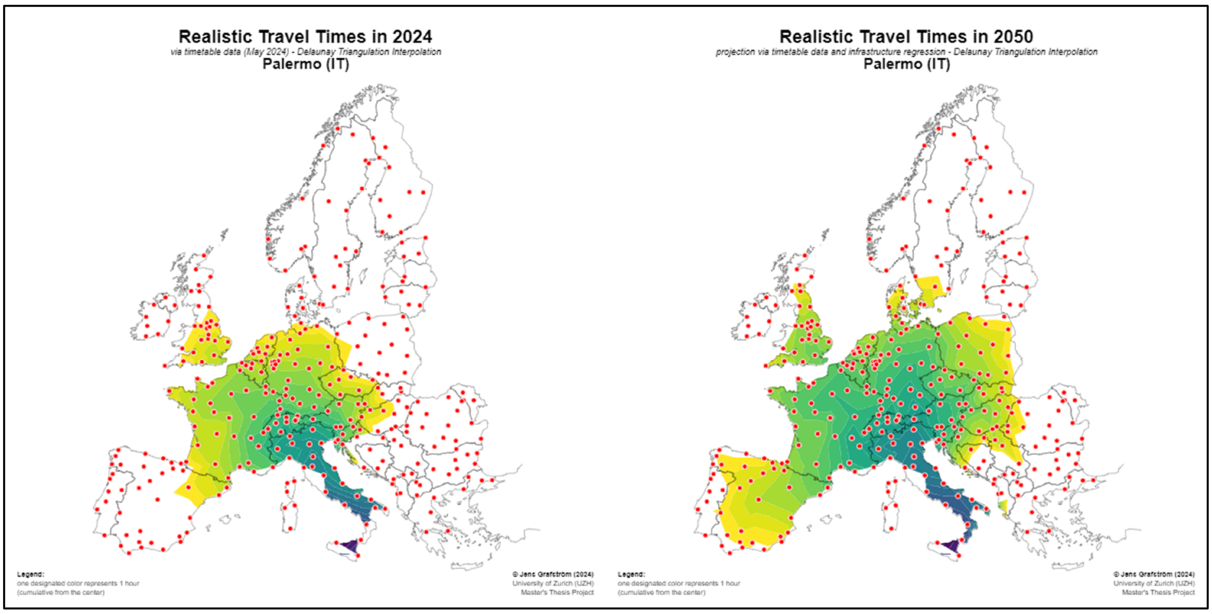
Figures 37 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Narvik. Source: own illustration.*



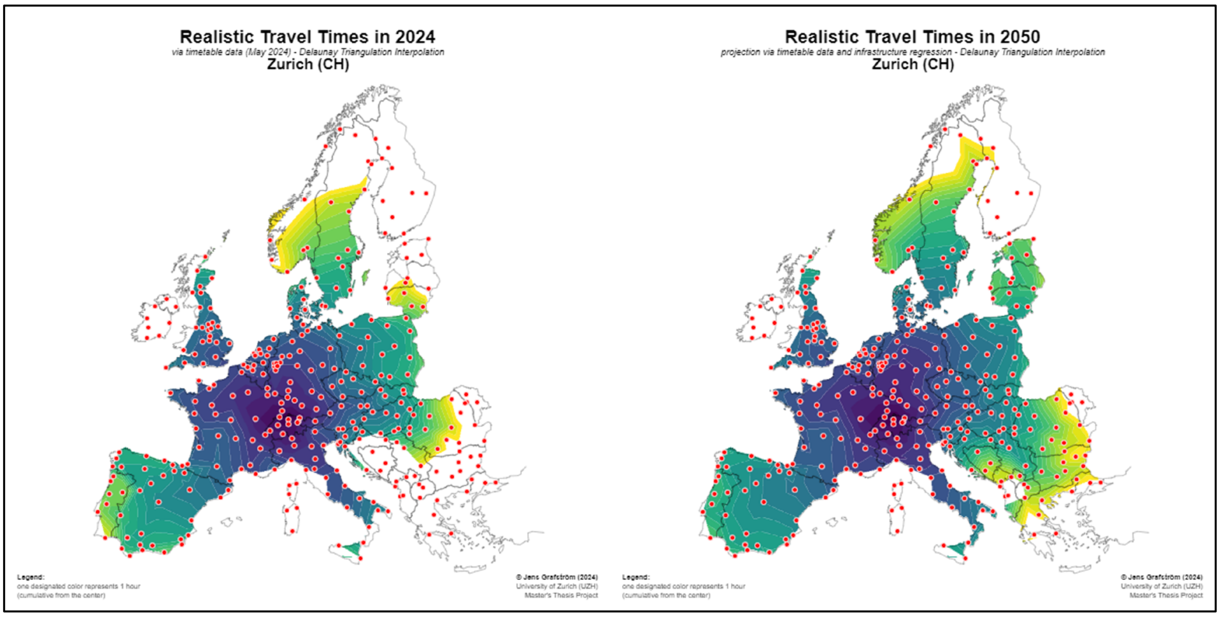
Figures 38 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Lisbon. Source: own illustration.*



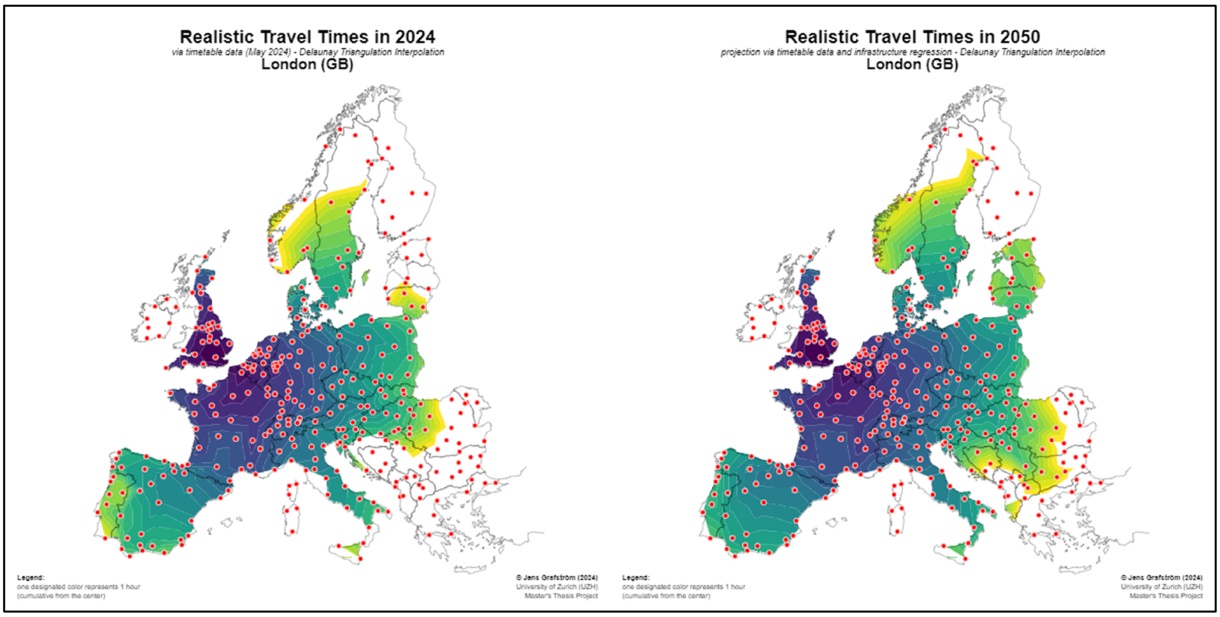
***Figures 39 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Chisinau.*
Source: own illustration.



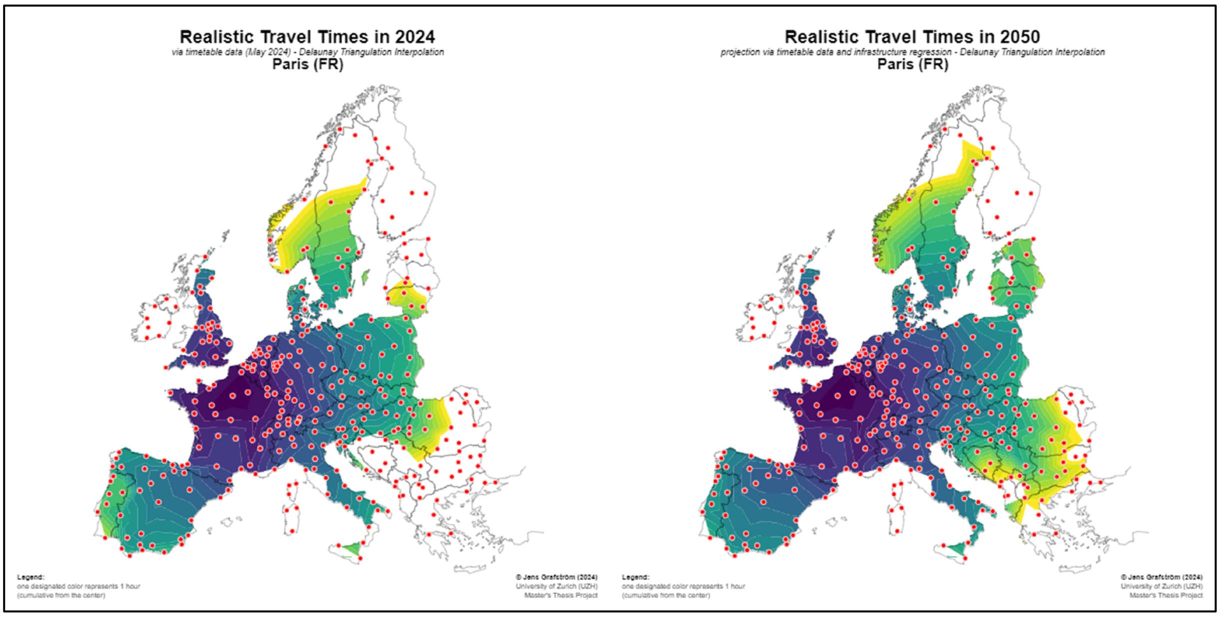
***Figures 40 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Palermo.*
Source: own illustration.



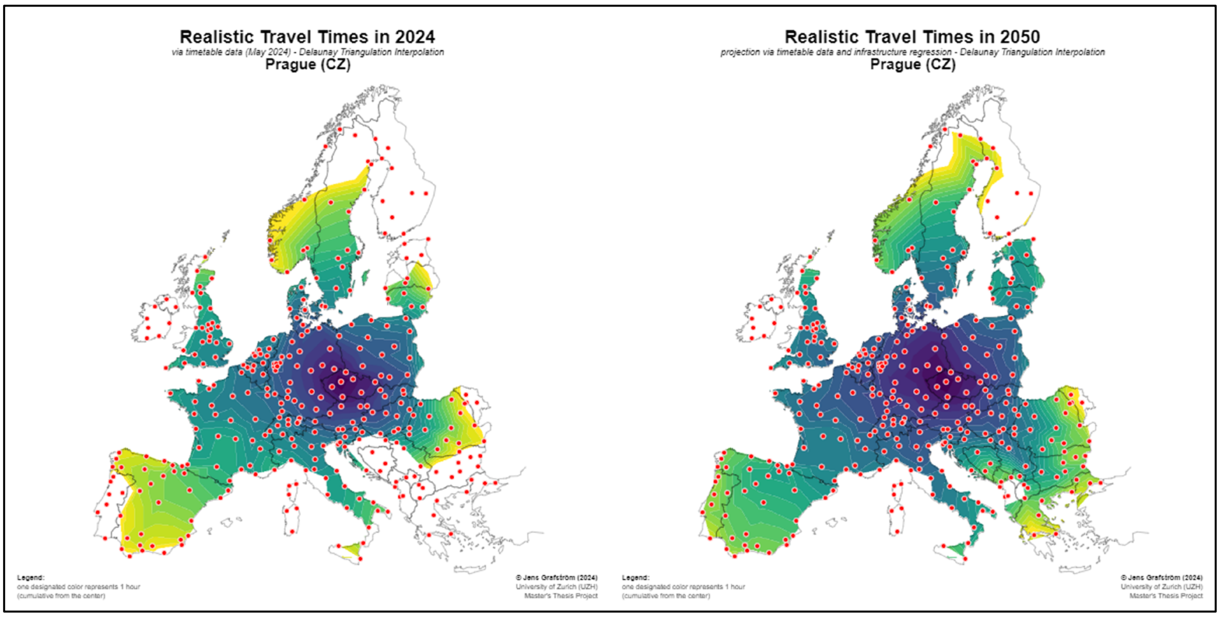
Figures 41 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Zurich. Source: own illustration.*



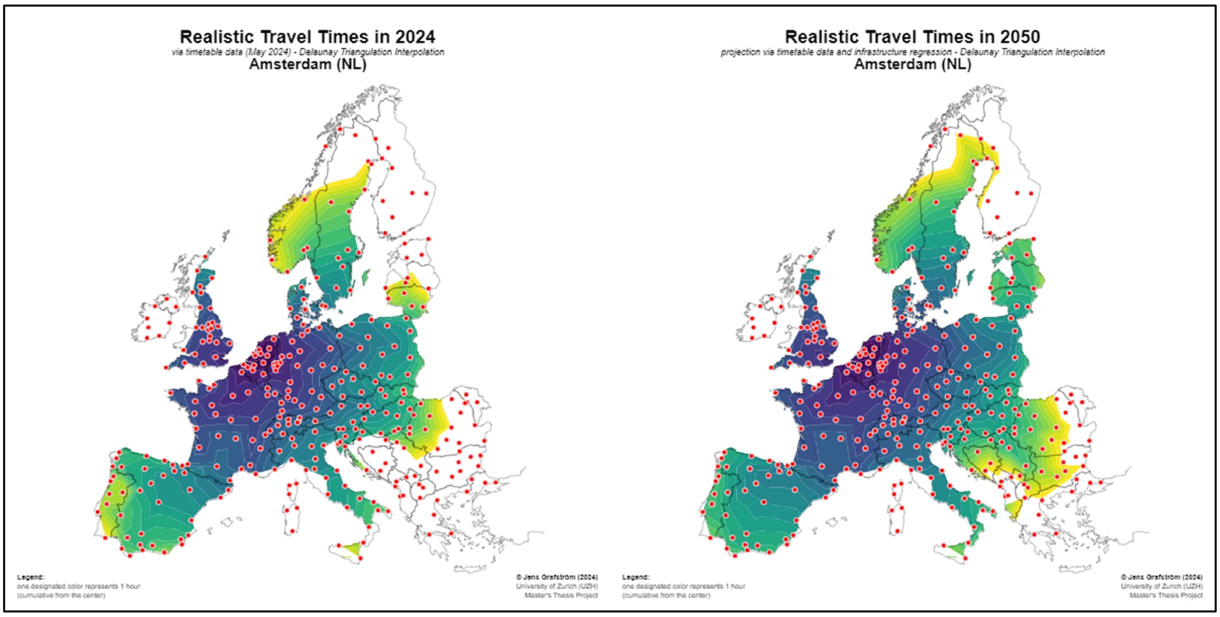
Figures 42 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from London. Source: own illustration.*



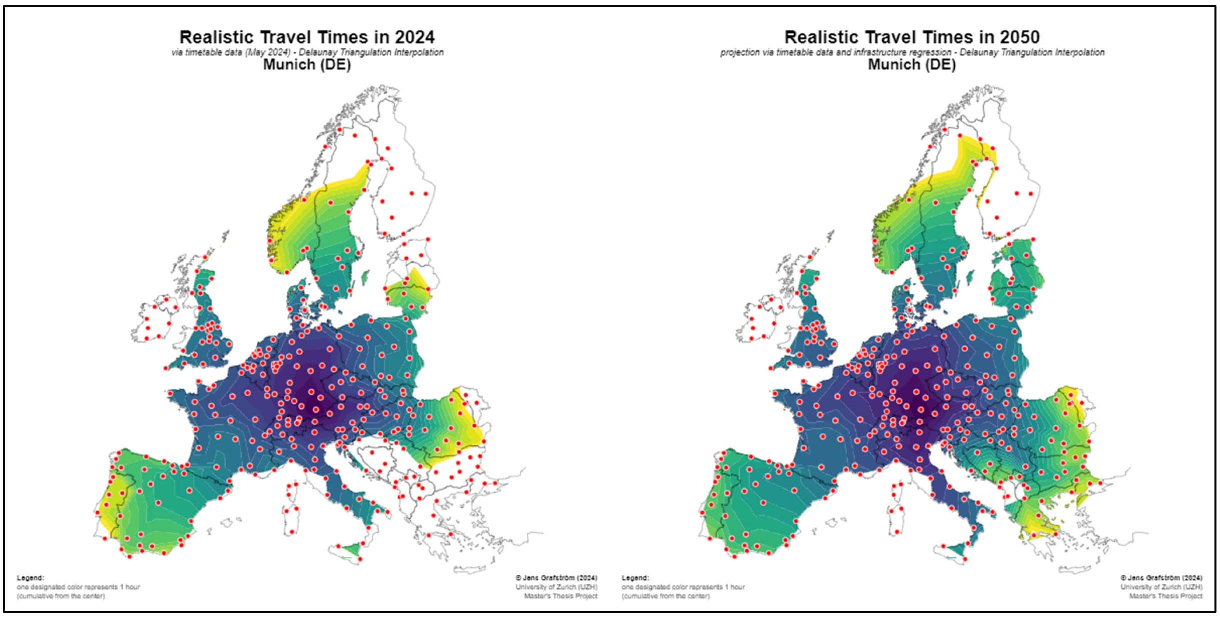
***Figures 43 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Paris. Source: own illustration.*



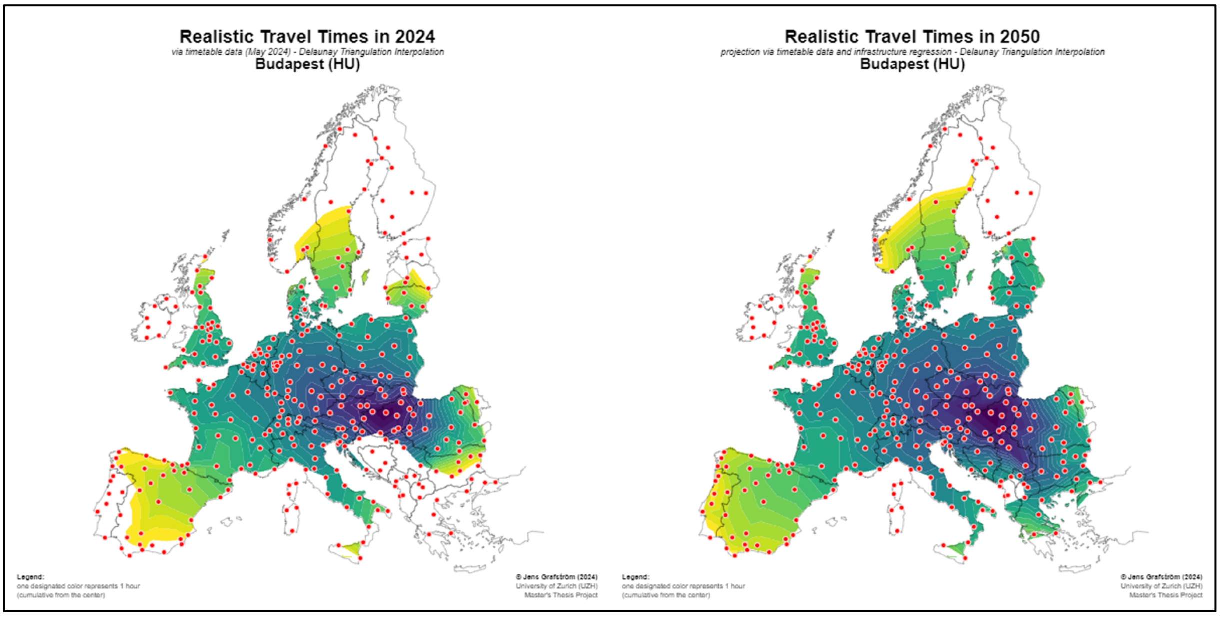
***Figures 44 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Prague. Source: own illustration.*



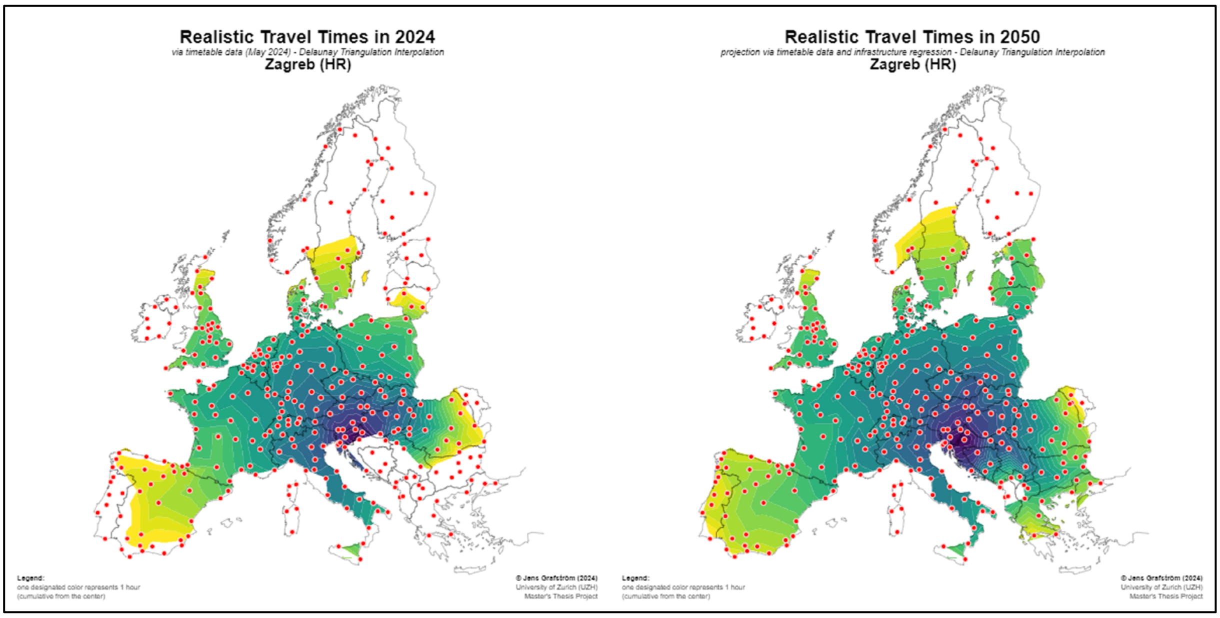
Figures 45 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Amsterdam.*
Source: own illustration.



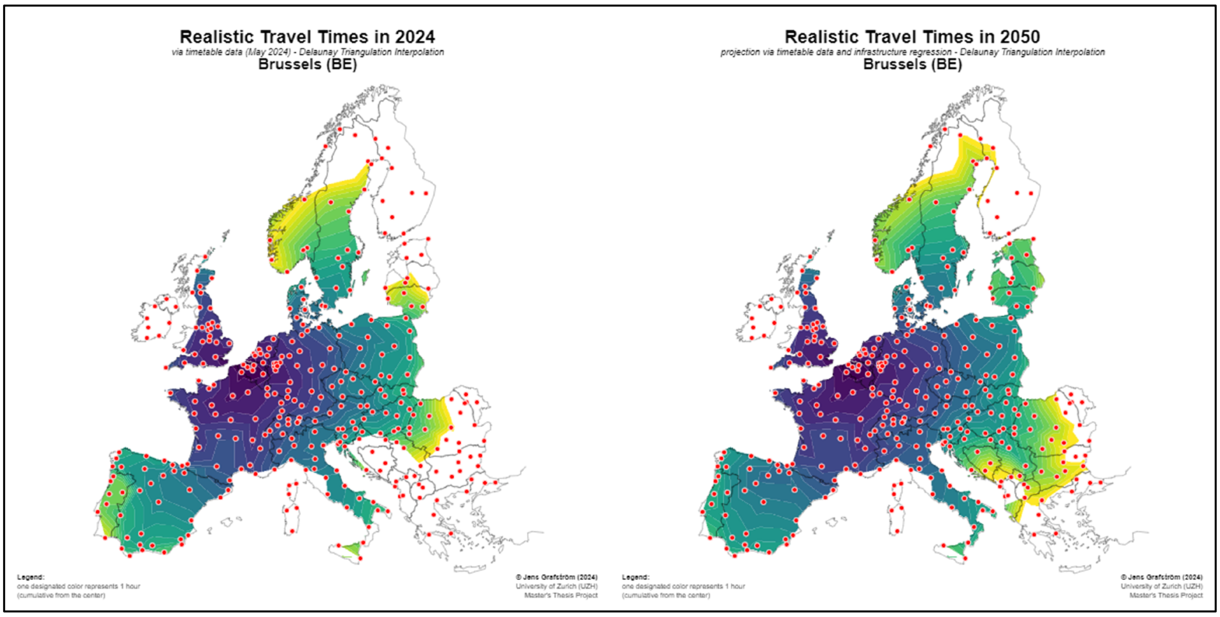
Figures 46 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Munich.*
Source: own illustration.



Figures 47 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Budapest.*
Source: own illustration.

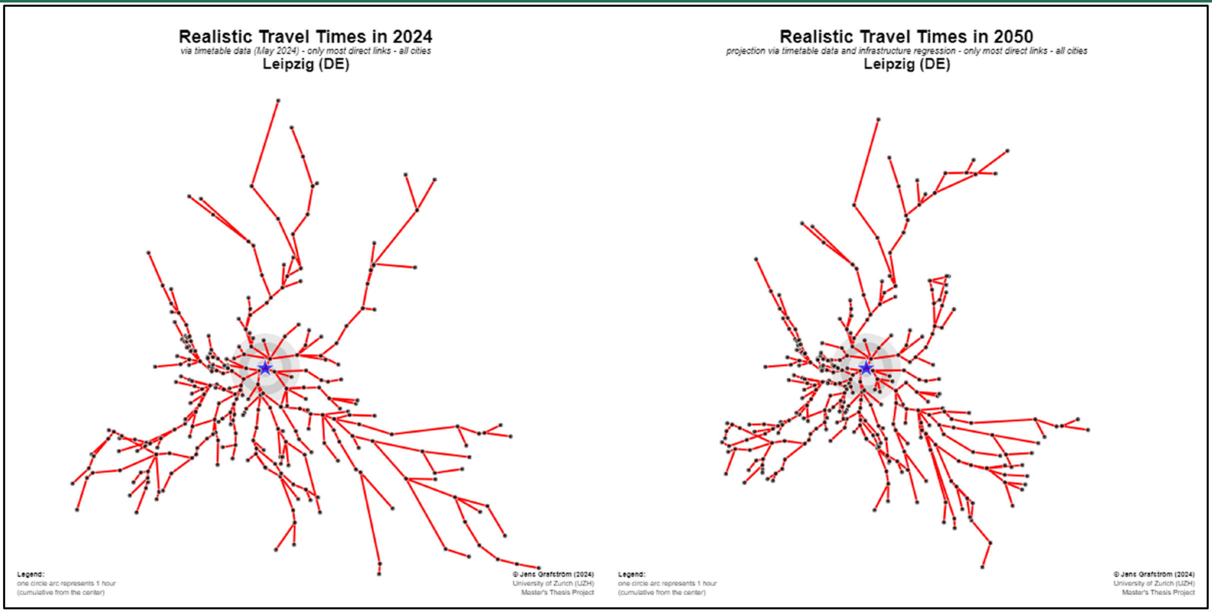


Figures 48 a-b*: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Zagreb.*
Source: own illustration.

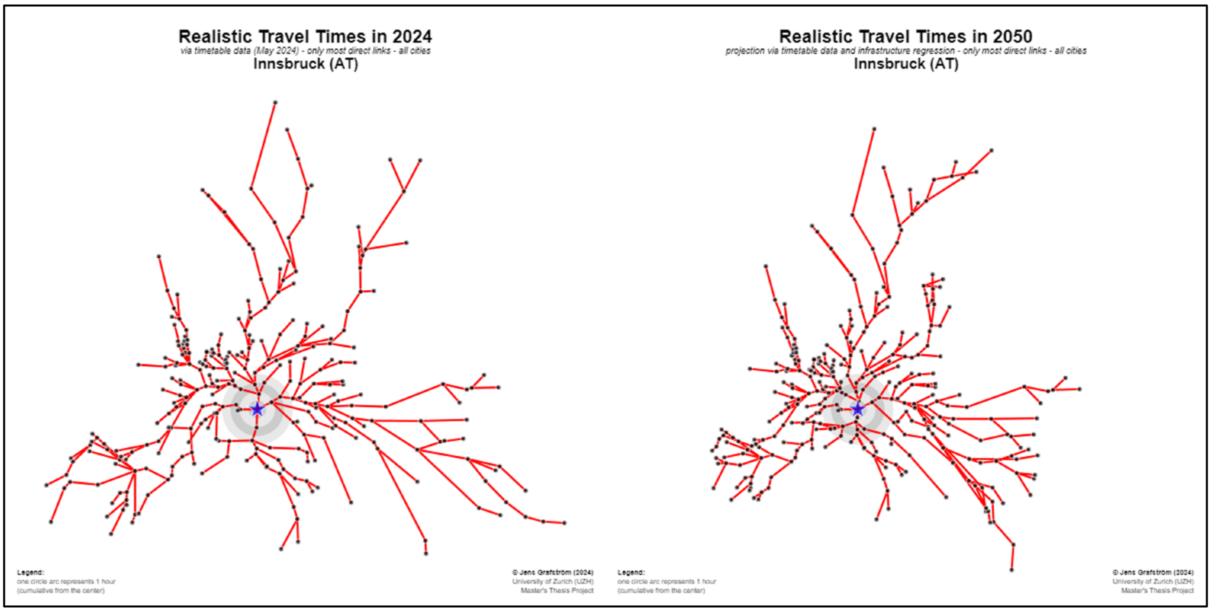


***Figures 49 a-b**: Isochrones covering a 24-hour range of (a) current and (b) future rail travel starting from Brussels.*
Source: own illustration.

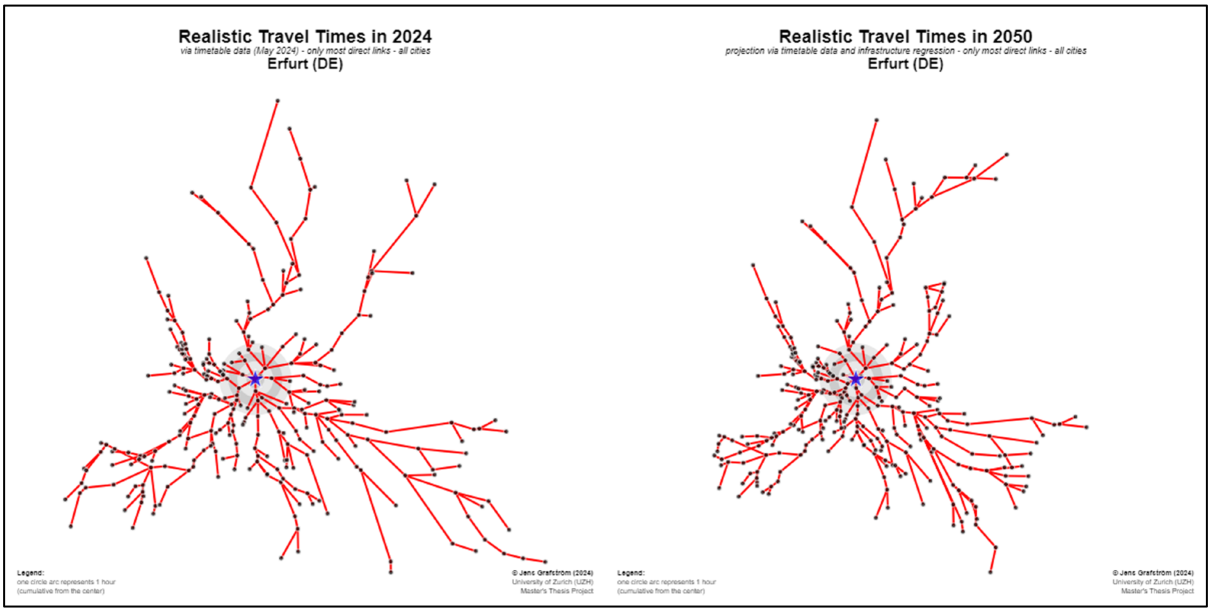
L – Linear Cartograms



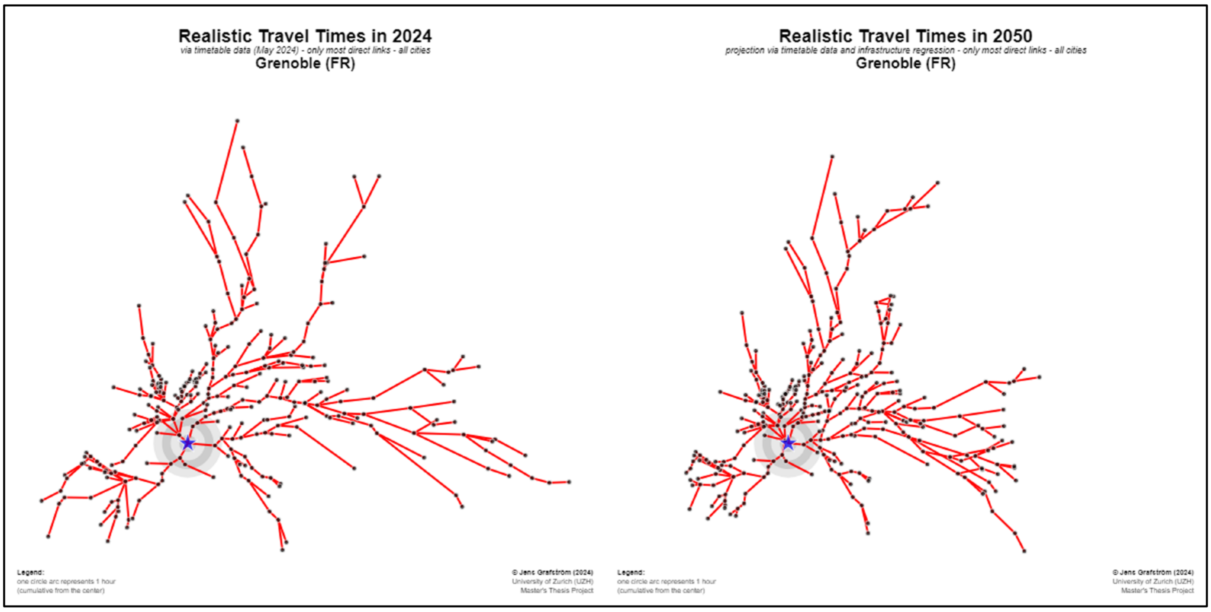
***Figures 50 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Leipzig.*
4-hour range highlighted for reachability context.
Source: own illustration.



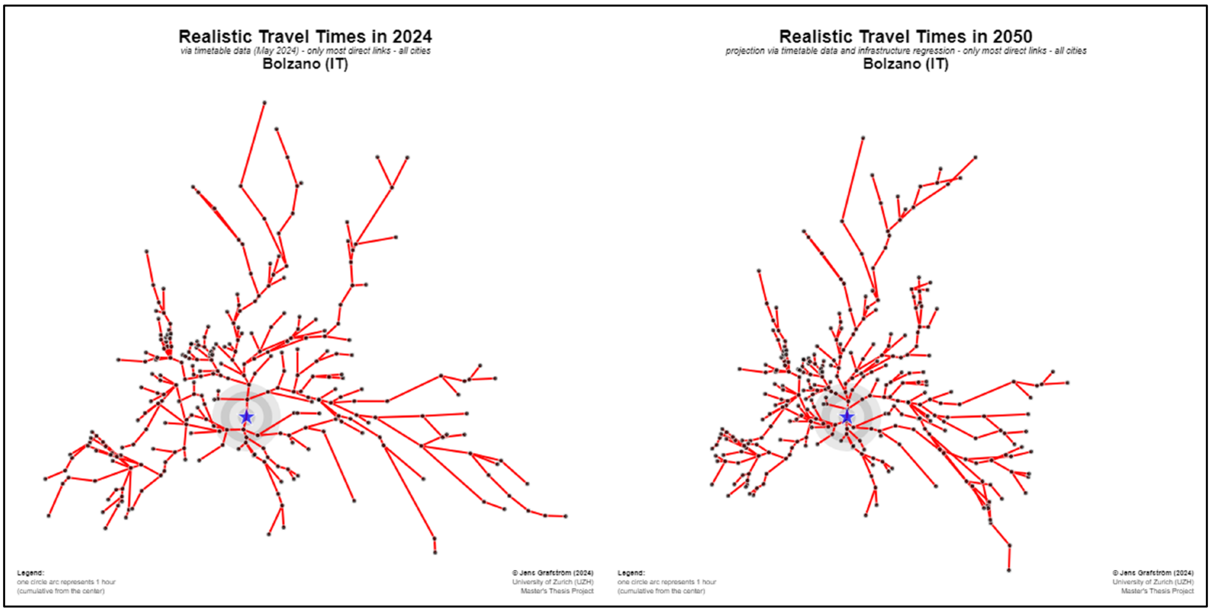
***Figures 51 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Innsbruck.*
4-hour range highlighted for reachability context.
Source: own illustration.



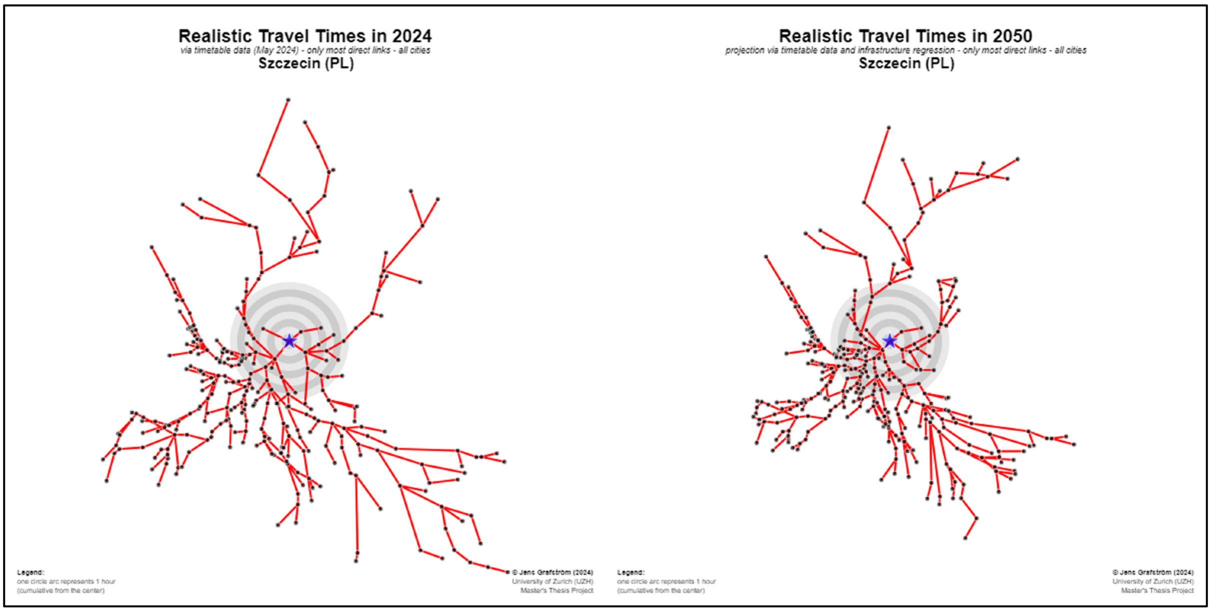
***Figures 52 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Erfurt.*
4-hour range highlighted for reachability context.
Source: own illustration.



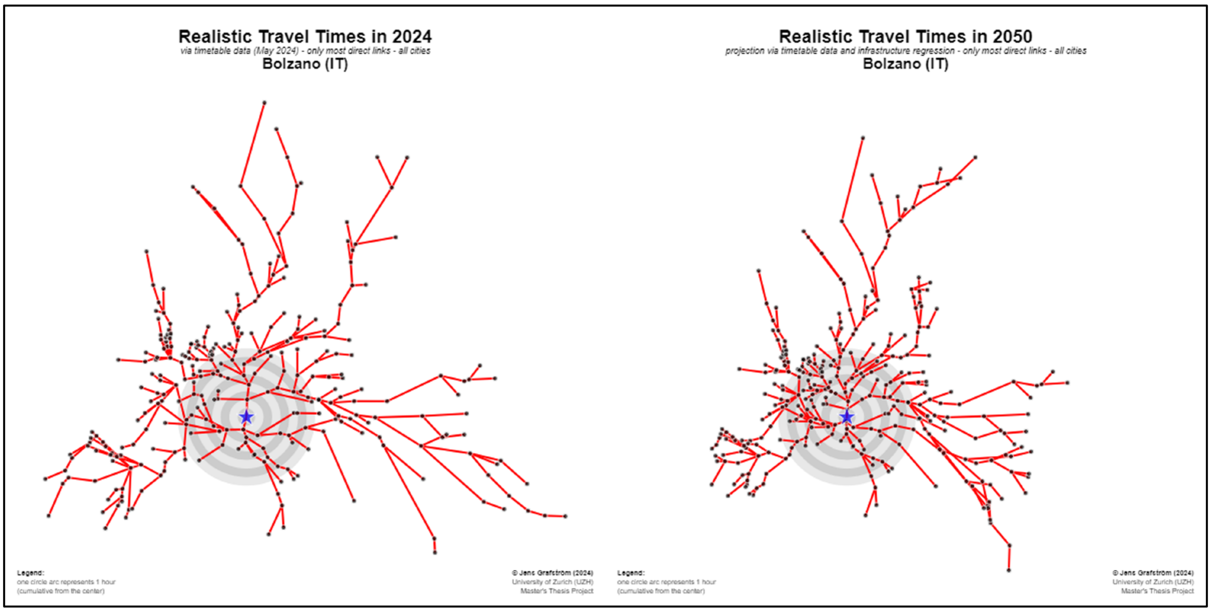
***Figures 53 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Grenoble.*
4-hour range highlighted for reachability context.
Source: own illustration.



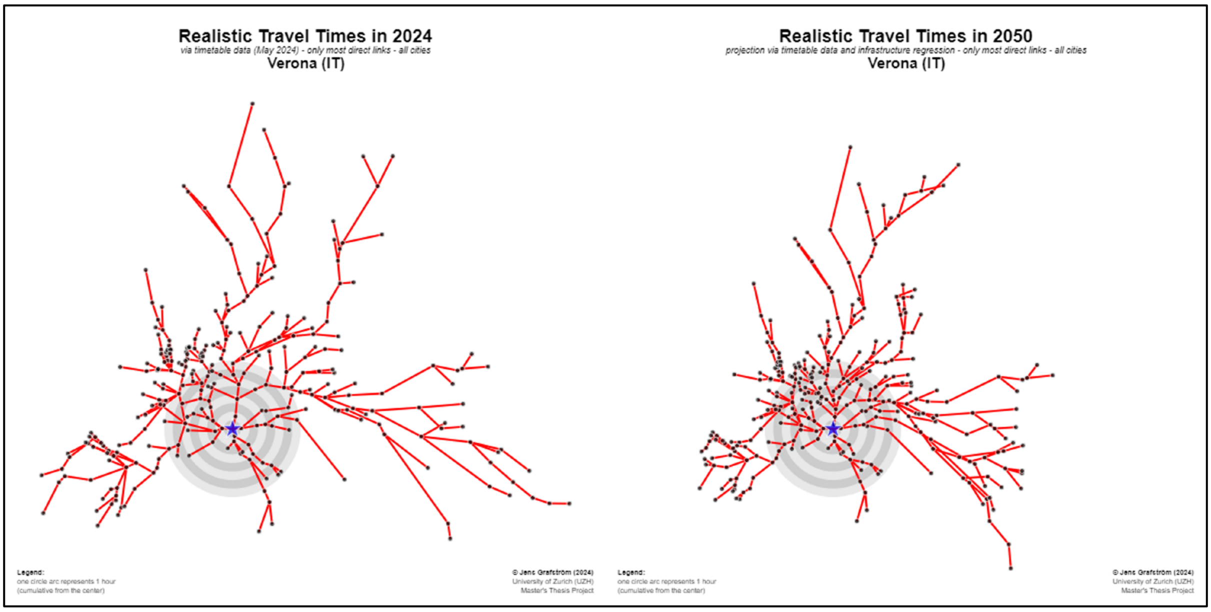
Figures 54 a-b*: Cartograms for (a) current and (b) future scenario, showing reachability from Bolzano.*
4-hour range highlighted for reachability context.
Source: own illustration.



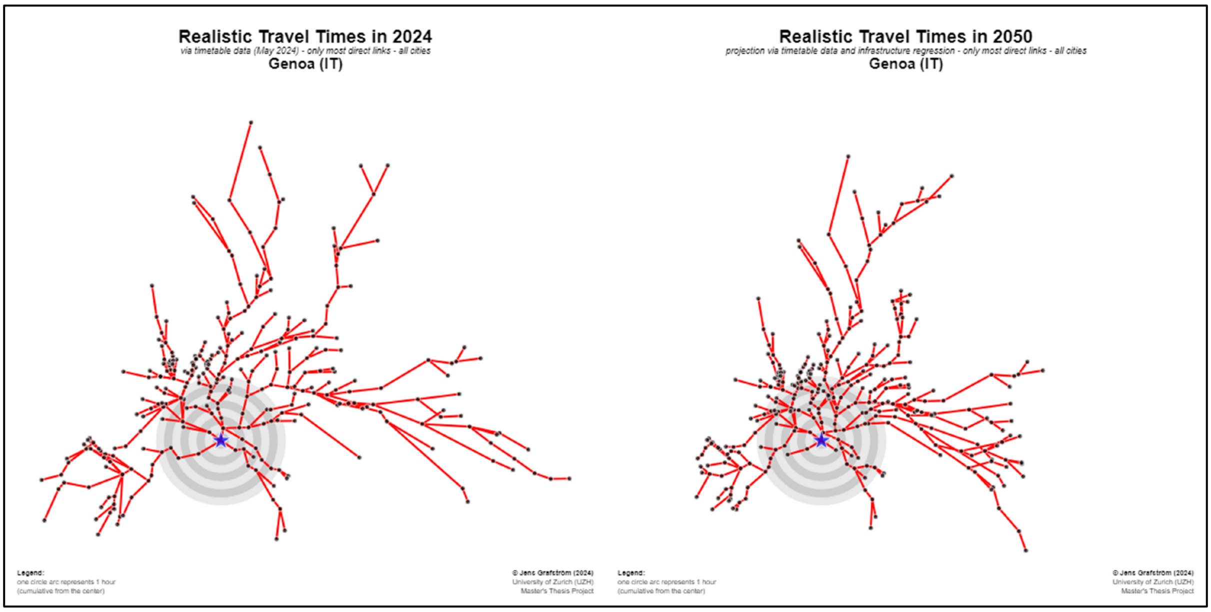
Figures 55 a-b*: Cartograms for (a) current and (b) future scenario, showing reachability from Szczecin.*
8-hour range highlighted for reachability context.
Source: own illustration.



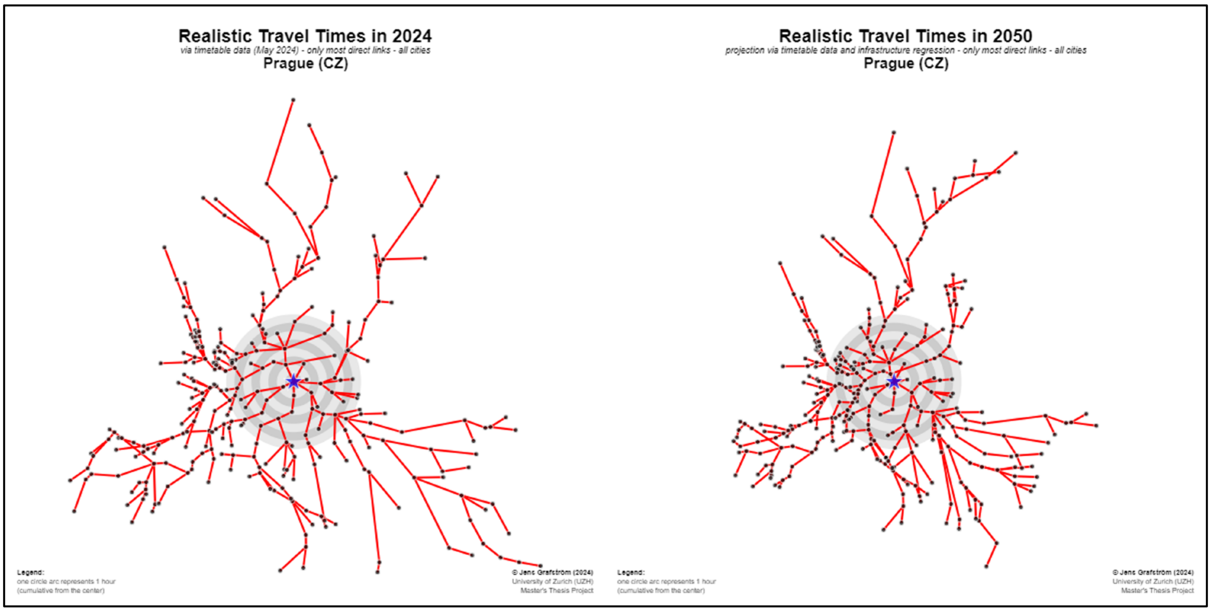
***Figures 56 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Bolzano.*
8-hour range highlighted for reachability context.
Source: own illustration.



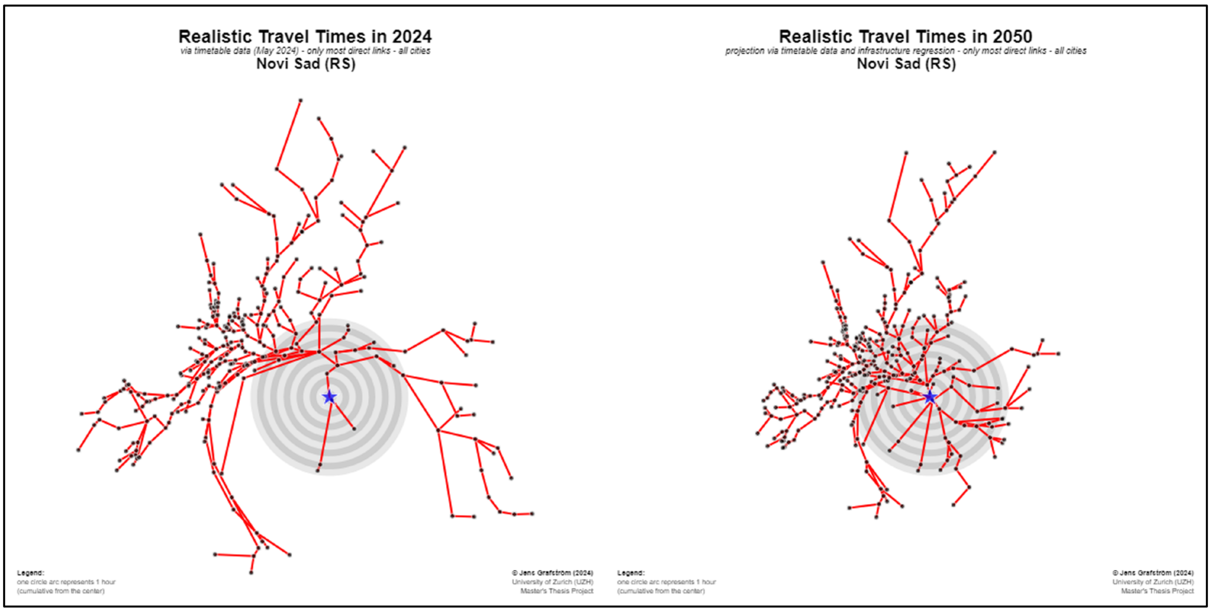
***Figures 57 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Verona.*
8-hour range highlighted for reachability context.
Source: own illustration.



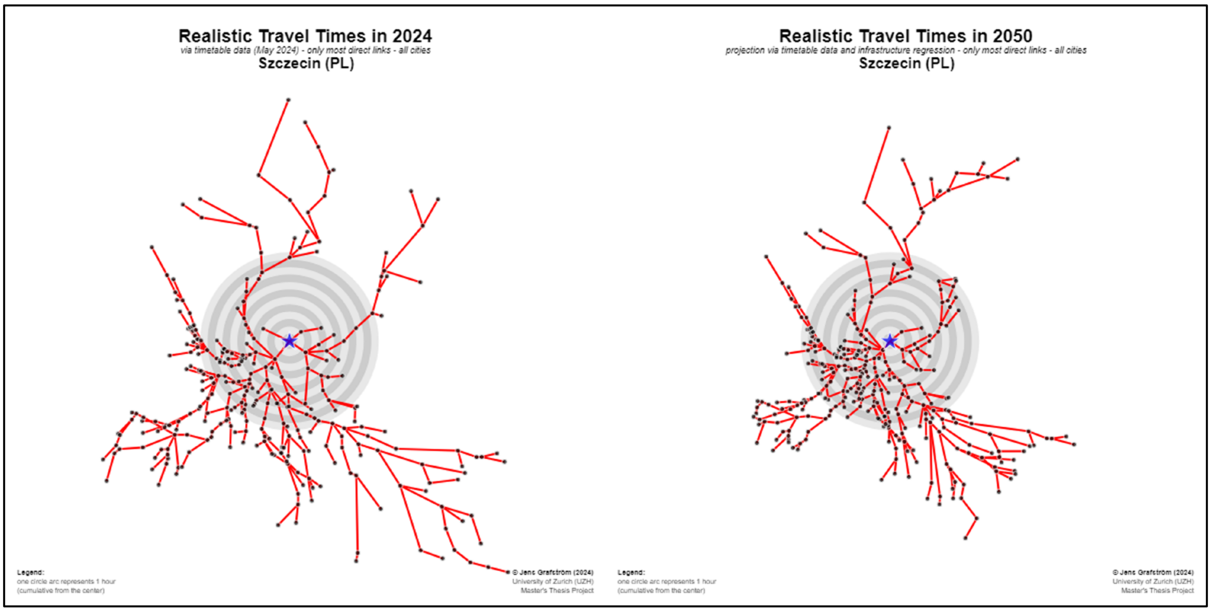
***Figures 58 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Genoa.*
8-hour range highlighted for reachability context.
Source: own illustration.



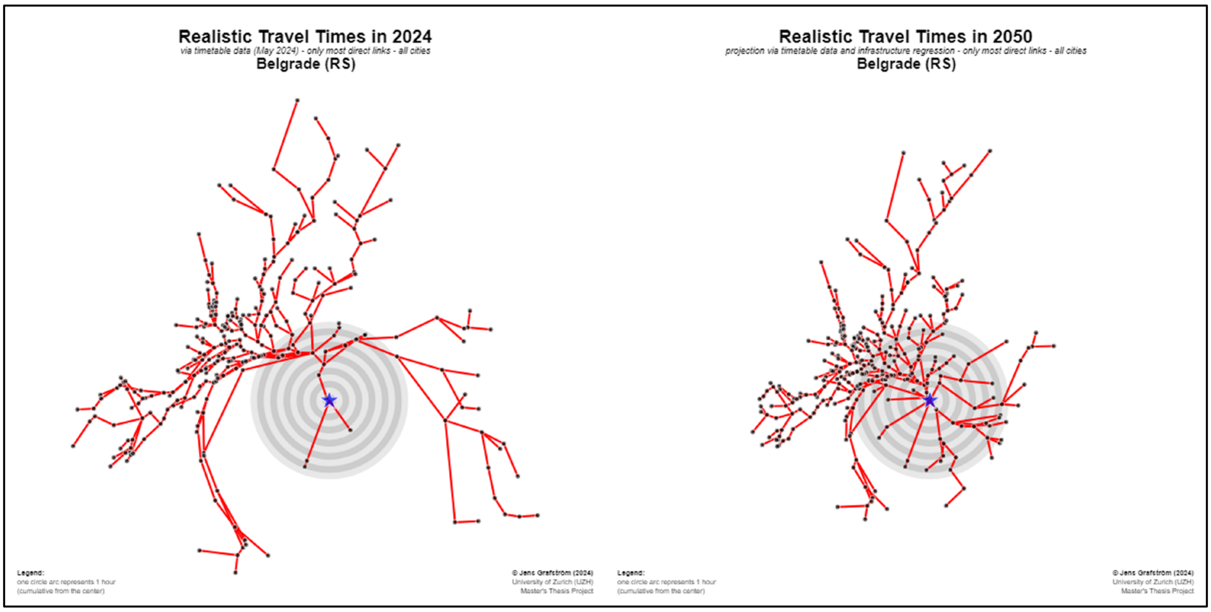
***Figures 59 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Prague.*
8-hour range highlighted for reachability context.
Source: own illustration.



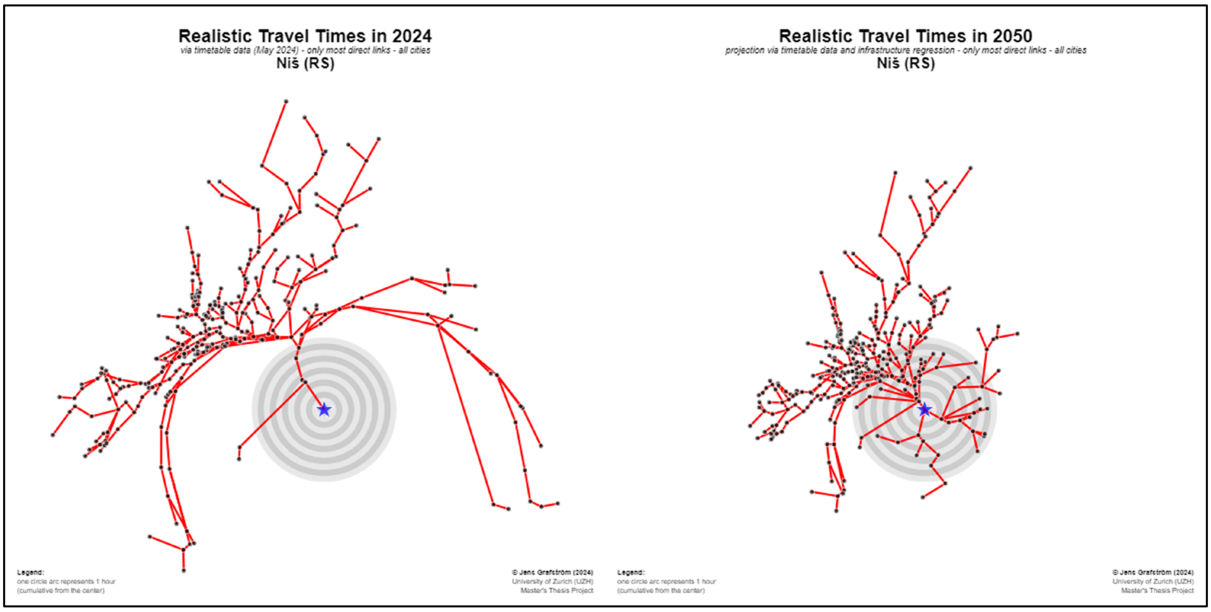
Figures 60 a-b: Cartograms for (a) current and (b) future scenario, showing reachability from Novi Sad.
12-hour range highlighted for reachability context.
Source: own illustration.



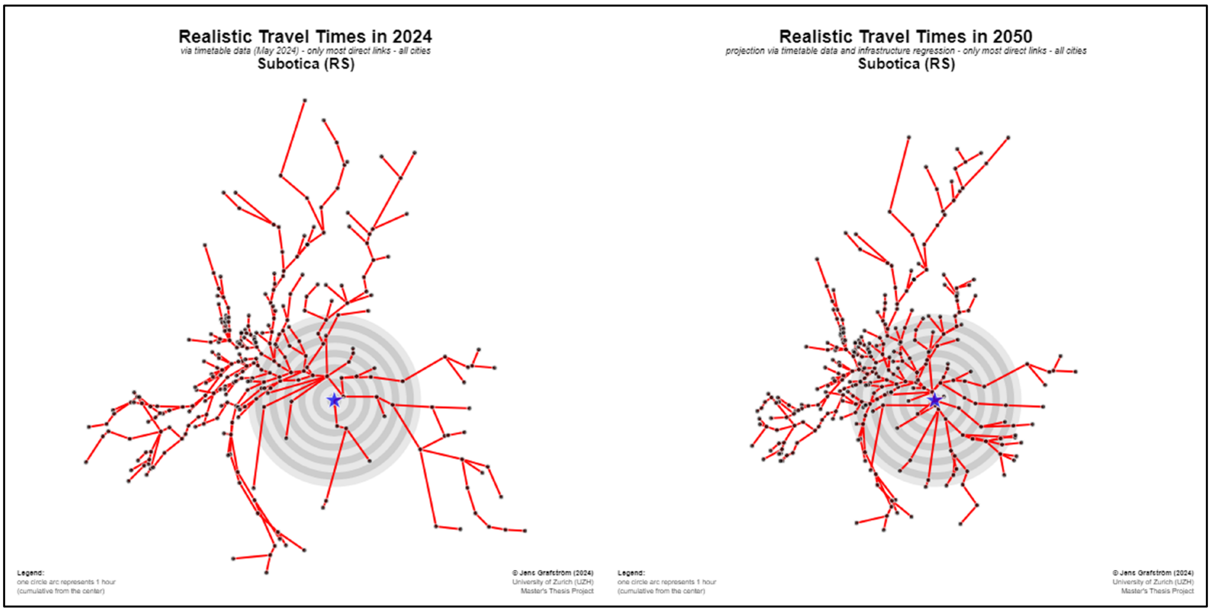
***Figures 61 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Szczecin.*
12-hour range highlighted for reachability context.
Source: own illustration.



***Figures 62 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Belgrade.*
12-hour range highlighted for reachability context.
Source: own illustration.



***Figures 63 a-b**: Cartograms for (a) current and (b) future scenario, showing reachability from Nis.*
12-hour range highlighted for reachability context.
Source: own illustration.



__Figures 64 a-b__: Cartograms for (a) current and (b) future scenario, showing reachability from Subotica.
12-hour range highlighted for reachability context.
Source: own illustration.

M – Distance Thresholds for International Network Computation

***Table 19**: Distance thresholds used during the computation of the international connections.*

country pair	conditional distance [km]	condition: required cities	alternative distance [km]
NO-SE	280	Kiruna, Hallsberg	425
FI-SE	120	Tornio, Boden	200
DK-SE	50	none	50
DE-DK	160	Padborg	250
DE-PL	300	none	300
LT-PL	120	Suwałki	400
LT-LV	220	Siauliai	270
EE-LV	150	Valga	250
DE-NL	200	Arnhem, Zwolle	300
BE-NL	110	Eindhoven, Antwerp	150
BE-DE	125	Liège, Duisburg	190
BE-LU	200	none	200
DE-LU	200	none	200
FR-LU	60	Metz	300
BE-FR	100	Lille (Europe)	270
FR-GB	260	Lille (Europe)	370
DE-FR	180	Strasbourg, Mannheim, Metz	460
CH-FR	200	Dijon	430
ES-FR	170	Perpignan, Bayonne, San Sebastián (interregional), San Sebastián (regional/narrow)	300
ES-PT	200	Badajoz	500
FR-IT	250	Nice	325
CH-IT	265	none	265
AT-IT	180	Villach, Bolzano	450
AT-CH	225	none	225
CH-DE	250	Mannheim	320
AT-DE	300	none	300
IT-SI	25	Divača	130
HR-IT	70	Rijeka, Trieste	150
HR-SI	150	none	150
AT-SI	150	Villach	285
AT-CZ	130	České Budějovice	270
CZ-DE	250	Plzeň	320
CZ-PL	140	Hradec Králové	230
DE-PL	330	none	330
PL-SK	160	Kraków, Prešov	320
CZ-SK	170	Žilina	350
AT-SK	65	none	65
AT-HU	120	Szombathely, Győr	300
SK-HU	180	none	180
HR-HU	320	none	320
BA-HR	370	none	370
HR-RS	175	Slavonski Brod	330

HU-RS	180	Subotica	280
BA-RS	230	none	230
BA-ME	190	none	190
ME-RS	300	none	300
ME-XK	170	none	170
RS-XK	300	none	300
AL-ME	140	none	140
MK-XK	100	none	100
AL-MK	180	none	180
MK-RS	170	none	170
BG-MK	190	none	190
BG-RS	150	none	150
AL-GR	300	none	300
GR-MK	220	none	220
GR-BG	250	none	250
GR-TR	510	none	510
BG-TR	180	Edirne	380
BG-RO	200	Ruse	300
RO-RS	150	none	150
HU-RO	280	Szolnok, Satu Mare	360
MD-RO	120	Iași	400
GB-IE	150	none	150
AT-LI	150	none	150
CH-LI	160	none	160
IT-MC	160	none	160
FR-MC	20	Nice	180