

The Impacts of High-Speed Rail on Territorial Accessibility: A Comparison Among Some European Countries

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Abstract. Over the centuries, the means of transport have changed due to the technological development, and one of the most interesting sectors is that of rail, which has experienced a real revolution. Indeed, investments in High Speed Rail (HSR) have been significant and new projects are going to be built around the world. Fast trains represent comfortable, safe, flexible and eco-sustainable means of transport both for people and goods. There is a classification of the effects induced by HSR services, according to which they can be grouped into: impacts on the transport system (internal), socio-economic impacts (external) and environmental impacts (external). Much less studied, however, are the impacts on accessibility. Users living in a given area, characterized by low accessibility to transport, will consequently have low accessibility to job opportunities, health and educational facilities, services, etc. Based on the previous considerations, the purpose of this paper is to study and analyze the impacts on accessibility induced by the introduction of HSR services in four European countries, i.e. Spain, France, Germany and Italy. The main findings show that HSR has brought an increase of accessibility.

Keywords: High Speed Rail · Accessibility measures · European countries

1 Introduction

Over the centuries, the means of transport have changed due to the technological development, and one of the most revolutionized sectors is that of rail transport, which has experienced significant changes in recent years. The revolution in this sector has been represented by the High Speed Rail (HSR). Indeed, significant expansion and new projects have been built and new ones are in the pipeline around the world. Fast trains represent a comfortable, safe, flexible and eco-sustainable means of transport both for people and goods. Major investments in this sector have significantly expanded the length of the European rail network, which in 2016 was more than 8,100 km long and is expected to reach more than 22,000 km by 2025 [1]. In the world, however, at the beginning of 2008, 20,000 km of lines dedicated to the provision of HSR services were in operation

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for passengers willing to pay for shorter travel times and for an improvement in the quality of rail transport. In the USA, the only HS service is the one that connects Boston to Washington and has been operational since 2001. In the USA, as well as for all of North America, HS is currently underdeveloped, but a large number of projects are going to be promoted. Around 763 km are under construction and more than 2000 km are planned. In Canada and Mexico, where at the moment there is no operational line, about 500 km are planned. In Latin America, no HSR are currently in operation, but approximately 500 km are planned in Brazil. In Africa, only in Morocco there is an operational HSR line, about 200 km long. In the next few years there will be an increase in the extension of the HS lines in the African continent. Indeed, approximately 4,700 km of new lines are planned, 1100 in Morocco, 1,200 in Egypt and 2,400 in South Africa.

A similar case to Africa concerns the Oceanic continent. There is currently no HSR line in operation but approximately 1,750 km are planned in Australia. Significant investments are expected in several Middle Eastern countries in the coming years. Turkey, which currently has about 600 km of operational lines, has planned an extension to 7,400 km. In Iran, between lines under construction and planned, approximately new 3,000 km will be reached. In China, the national railway operating mileage is over 139,000 km, of which 35,000 km is of HSR. China has the largest HSR network in the world, alone accounting for two-thirds of the world's HSR network. The first fully HS line was inaugurated in 2008 between Beijing and Tianjin, coinciding with the Olympic Games. Japan developed the world's first HSR with the Shinkansen line opened in 1964. In this country there are more than 2,000 km of railway line and others are under construction.

A classification of the effects produced by HSR services can be identified, according to which they can be grouped into impacts on the transport system (internal), socio-economic impacts (external) and environmental impacts (external). Much less studied, however, are the impacts on accessibility. The user who lives in a given area characterized by low accessibility to transport will consequently have low accessibility to job opportunities, health and education facilities, services, etc. The purpose of this paper is to study and analyze the impacts on accessibility produced by the introduction of HSR services in four European countries, i.e. Spain, France, Germany and Italy. The manuscript is organized as follows. In Sect. 2 the case studies are described. In Sect. 3 a review of accessibility measures is reported; while Sect. 4 deals with the methodology. Finally, conclusions are described in Sect. 5.

2 The Case Studies

2.1 France

France was the first European nation to enter the high speed era and has the second largest HSR network in Europe after Spain (2814 km compared to almost 2852 km in Spain) but with higher traffic (54 billion of passenger-km compared to 12 billion passenger-km in Spain) (Crozet, 2014). The acronym LGV indicates high-speed lines (Lignes à Grande Vitesse), with TGV instead refers to high-speed trains (Train à Grande Vitesse). In 1975 the first Lyon-Paris high-speed line (TGV South-East) was approved, the opening took place in two stages, the southern section Lyon Sathonay-Saint Florentin, 275 km long,

was opened in September 1981 and the 142 km long northern section Combs la Ville (Paris)-Saint Florentin was opened in September 1983 [2, 3]. The success of this line provided the basis for extending the network. In 1989 the Bagneux (Paris)–Connerré Junction (Le Mans) section of the TGV Atlantique line was inaugurated, which was then extended by 101 km in 1990 with the Courtalain Junction - Monts Junction (Tours) section.

In 1992 he opened the Rhône-Alpes TGV line that connects Montanay Junction station to Satolas airport, which was extended in 1994 by 84 km, connecting Satolas airport to St Marcel les Valence. The TGV North Europe line was inaugurated in 1993, is 333 km long and connects Paris to Lille and Lille to Calais. In 1994 the TGV Paris interconnection was opened which allows high-speed trains to serve all French regions without passing through Paris, which ended in 1996 with a 17 km extension link connecting the Northern Europe, South East and Atlantique lines. In 2001 the TGV Méditerranée line (also called LN5 or New Line 5) was inaugurated, connecting Valence to Marseille, 251 km long, the project had started in 1989 but following a series of disputes on the route and anti-TGV protests the works have been delayed [4]. In 2007 the TGV Est line was opened that connects Paris to Strasbourg, passing through Luxembourg, Switzerland and Germany, with a length of 406 km, the first 300 km (connecting Vaires-sur-Marne near Paris to Baudrecourt in the Moselle) can be traveled with a speed of 350 km/h, the remaining 106 instead can support a speed of 320 km. This line forms a commercial network connecting 26 French cities and 11 European cities.

In 2011 the first section of the Rhine-Rhone line was opened which is not directly connected to Paris. In 2017, several LGV lines were inaugurated, one of which, Contournement Nîmes - Montpellier, is the first high-speed line in France built for mixed traffic (goods and passengers), in December 2017 the first freight train crossed the route and, in the July 2018, the first passenger services began. In July 2017, the 340 km long LGV Sud Europe Atlantique line (extension of the Atlantique line) connecting Tours to Bordeaux, the Bretagne-Pays de la Loire line, an extension of the TGV Atlantique, entered into service on the same day. 182 km plus 32 km of connections with the existing network which led to an improvement in the rail service in the countries served.

All French TGV lines are interconnected, today it is possible to go from Calais in the far north to Marseille in the far south of France in just over 3 h with a train traveling at 300 km/h. The LGV network has a star structure (Fig. 1), radiates from Paris and aims to connect the capital with the main cities in order to allow users to move and re-enter during the day. The TGV in France and neighboring countries (including Eurostar and Thalys services) is managed by the SNCF (Société Nationale des Chemins de fer Français) and offers a service dedicated exclusively to passengers. The trains are able to use both dedicated high-speed lines and conventional lines as long as they are electrified, thus serving around 200 French cities, some of which are distant from the LGV lines [3]; Performance in France: From appraisal methodologies to ex-post evaluation]. In addition, TGV trains can serve the UK, Belgium, the Netherlands, Germany, Switzerland and Italy directly [3]. The frequency of services is very high, just think that between Paris and Lyon or Paris and Nantes there are 23 round trips per day. The TGV service is aimed at users who can afford to pay only about 10–15% of the French population use high speed on a regular basis (Crozet, 2013).

Roissy Charles de Gaulle (CDG) airports near Paris and Lyon Saint Exupéry (LYS) are served by TGV stations inside the airport itself, both stations were inaugurated in 1994. The TGV Air service combines international flights, operated by many airlines, with high-speed travel in a single ticket thus allowing you to reach several French cities [3]. A characteristic of the French TGV are the relatively low construction costs, just think that the first South-East TGV cost 4 million per km, the lowest value in the world. In 2013, annual TGV traffic amounted to 90 million passengers.



Fig. 1. HSR in France. *Source:* www.evasion-online.com

2.2 Germany

Germany was one of the first European countries to invest in high speed but due to legal disputes the first high speed line was inaugurated after the French LGV lines. The German HSR network was built and extended in two main waves which are structurally very different [5]. During the first wave, which ran from 1991 to 1998, about all the major cities of Germany were connected by the HSR but, being the largest cities distributed unevenly across the territory, the 46 stations existing in 1998 were found only in 3 of the 16 German states (Baden-Württemberg, Hesse, North Rhine-Westphalia). The second wave led to the construction of HSR stations also in the smaller cities located along the ICE connections previously built between two metropolitan areas, during this period 34 medium and small cities were annexed to the network. The reason why even smaller cities have been added to the network is that these cities have been obliged to contribute to the costs of updating the network for the use of high-speed trains, in return stops have been scheduled on their territory. Construction of the first 327 km long high-speed line linking Hanover in Saxony to Wàrzburg in Bavaria began in August 1973 and the line, built section by section between 1988 and 1991, was fully opened in June. in 1991, although the Würzburg-Fulda section was used by InterCity trains as early as 1988 [6]. In 1988 the construction of the Mannheim-Stuttgart line which has a length of 99 km

was completed, the line was officially opened in May 1991 and the passenger service began in June of the same year at the same time as the one on the Hannover-Würzburg line.

In 1998 the Berlin-Hanover line was opened consisting of five sections consisting of new and upgraded lines and in 2002 the 182 km long link between the cities of Cologne and Frankfurt was opened and traveled at a speed of 300 km/h, which has alleviated the congestion on the two existing railway lines that bordered the Rhine, this line also allows access to the airports of the two cities. In 2006 the Nuremberg-Munich line was inaugurated, 90.1 km long on which both long-distance and regional services operate, the ICE trains reach speeds of 300 km/h. In 2015, the 123 km long Erfurt - Leipzig/Halle section was opened, a section of the route that connects Munich to Berlin of the trans-European networks, to the south it connects with the Nuremberg-Erfur high-speed line, opened in 2017. travel between Munich and Berlin were reduced by about 4 h.

The Cologne-Aachen high-speed line is the German part of the high-speed network project linking Paris, Brussels and Cologne. From 2002 onwards, speeds of 250 km/h can be reached on the line from Cologne to Düren and 160 km/h in the section between Düren and Aachen. The planned and not yet completed high-speed lines are: 1) Frankfurt-Mannheim which will connect the two existing high-speed lines Cologne-Frankfurt and Mannheim-Stuttgart; 2) Karlsruhe - Basel which is part of the Rotterdam-Genoa corridor, which is expected to reduce travel time between the two cities by 31 min; 3) Hanau-Gelnhausen an expansion of the railway line that will connect the cities of Hanau and Gelnhausen to the Hannover-Würzburg high-speed railway network; 4) Stuttgart-Wendlingen and Wendlingen-Ulm two high-speed lines that will be connected to each other, are part of the Paris-Budapest axis of the trans-European network, once opened the travel time between Stuttgart and Ulm will be only 28 min instead of 54.

To date, the German network extends for 1658 km (Fig. 2). German high-speed trains, InterCityExpress (ICE) do not travel on reserved tracks but use conventional



Fig. 2. HSR in Germany. *Source:* www.forsal.pl

railway lines serving other passenger and freight trains called Ausbaustrecken (ABS) (Barrón et al., 2009), reaching lower speeds, only on short sections the trains travel on dedicated and newly built tracks called Neubaustrecken (NBS). The idea was to use ICE high-speed trains for both passenger and freight transport, but since its introduction, ICE has been used only for passenger transport [7]. The opening and expansion of the HSR network has reduced travel times on average by 9.5% on relationships with a direct connection, leading to an increase in the number of commuters. Between 1996 and 2004 the number of passengers increased by 132.8% [8]. The trains currently in use by the German state railway Deutsche Bahn are 259, which can travel up to a speed of 320 km/h, have a very high level of comfort and the rates are not calculated based on the km but are at fixed prices for connections from station to station.

2.3 Spain

Spain with 2852 km is the second nation in the world, after China, in terms of length of the HSR network (Fig. 3) [9, 10], but relative to the number of trips it ranks after France, Germany and Italy despite their more limited networks. The number of passengers of the HSR service in 2014 in France, Germany and Italy was respectively 5, 4.4 and 2.6 times greater than in Spain. The main purpose of the high-speed train is to build a rapid link between all the provincial capitals of the country and the political capital Madrid [11–13]. The structure of the network gives priority to the connections between Madrid and the provincial capitals over the development of the country's transversal corridors or those that connect tourist destinations along the Mediterranean and the Cantabrian Sea respectively to the east and north of Spain. Spain has made HSR networks a priority in its transport policy, one third of all investments in the country's Transport Infrastructure Strategic Plan (PEIT) are dedicated to HSR [14]. Spain is the only country that starts building high-speed corridors to connect its most populated cities rather than introducing high-speed corridors into the more congested corridors. The first Spanish high-speed connection is the one between Madrid and Seville, with intermediate stations in Ciudad



Fig. 3. HSR in Spain. *Source:* https://www.vozpopuli.com/upload/Pablo_Garcia/aveespana-2.jpg

Real, Puertollano and Cordova, which began in 1988 and inaugurated in 1992 on the occasion of the Universal Exhibition held in Seville [15]. The train travels 471.8 km in 2 h and 15 min (direct service train). Traditional rail services have lost a large part of the traffic in this section, but the absence of a complementary freight service has ensured that conventional rail networks remain operational [16].

The construction of the Madrid-Barcelona-France line began in 1998, in 2003 the first 300 km long section connecting Madrid to Zaragoza/Lleida was opened, the second Madrid-Tarragona section was opened three years later and only in February 2008 the line, 621 km long, reached Barcelona [13, 17]. Thus connecting the two largest cities of Spain in 2 h and 30 min by direct train or in 3 h and 10 min with the train that stops at all the stations. In 2013, the Spanish high-speed train was connected to France through direct services on the high-speed network. In January 2001, work began on the infrastructure that connects Madrid to Montilla de Palancar and then divides into two different routes, one that reaches Valencia (inaugurated in 2010) and one that arrives in Alicante (inaugurated in 2013) [17]. In 2002 construction began on the line connecting Madrid to Valladolid via Segovia, inaugurated in 2008 and extended in 2015 to the city of Leon in northern Spain. In 2003 the Zaragoza-Huesca line branch of the Madrid-Barcelona-France line was inaugurated and in 2004 the Madrid-Toledo line was opened, a branch of the Madrid-Seville line that allows to travel between the two cities with a travel time less than 30 min.

In 2008, the Madrid-Malaga line was opened, which in the first 345 km, that is, up to the city of Cordoba, is in common with the Madrid-Seville line, the Cordoba-Malaga connection is 155 km long. The Madrid-Seville and Madrid-Malaga corridors are also used to connect Barcelona to the two cities of Andalucia. In 2015, the extension of the Madrid-Seville section to Cadiz was completed and put into service, and in 2019 the line connecting Antequera to Granada was opened. Not all regions are still connected and some important provinces, in particular the industrial Atlantic coastal regions, the northern and western regions, remain unconnected. New investments are planned in connections with other peripheral regions on the north and west limits of Spain [18]. At the end of the construction of all the high-speed lines, Spain will have 7000 km of lines that will allow you to connect Madrid in 4 h and Barcelona in 6 h to all the provincial capitals. Most lines are designed to reach maximum speeds between 300 and 350 km/h. In addition, the modernization of some conventional lines has allowed high-speed trains to operate at 200–220 km/h [15].

Alta Velocidad Española (AVE), managed by Renfe or the national company of the Iberian railways, is a separate network, disconnected from the existing conventional infrastructure, even if compatible with conventional railway lines [13]. Spain has opted to purchase railway technology instead of developing its own [19]. The Spanish HSR is considered a symbol of modernity and enjoys user support, this also because the high-speed prices are low thanks to huge public subsidies, in fact in the first year of activity, on the Madrid-Seville route the price was reduced by 30% while on the Madrid-Ciudad Real route by 50% (de Rus and Román, 2006).

According to [20] on the Madrid-Seville and Madrid-Barcelona routes there are no significant differences between the emissions of high-speed services and conventional services, for the Madrid-Toledo connection instead the emissions of the HSR service are

50% higher. It should be considered that the first two routes are medium-distance connections while Madrid-Toledo is a short-distance connection and this seems to influence its performance.

2.4 Italy

In Italy the history of the high-speed rail network began in 1975 with the construction of the Rome-Florence line which ended in 1992, on which speeds exceeding 250 km/h were reached [21].The goal was to connect two main cities without intermediate stops. In 1996 the National General Transport Plan establishes high-speed lines as one of the main interventions capable of relaunching rail transport and hence the decision-making and implementation process of the Italian HSR network. In 2005 the second section of the network connecting Naples and Rome was completed and in 2009 the entire Turin-Salerno line was completed [21, 22]. On this line, the speed of 300 km/h is reached except on the Florence-Rome and Naples-Salerno routes where the speed does not exceed 250 km/h. In 2007 the Padua-Mestre high-speed line was completed, a 24 km route alongside the traditional railway, and entry into operation dates back to 2010. In 2016 the entire Milan-Brescia line, 39.6 km long in length, came into operation, which is made up of two lots, the first Milan-Treviglio lot which started operating in 2007 and the second Treviglio-Brescia lot completed in December 2016. The number of high-speed connections is small, only a few cities are served by the HSR. There are several high-speed lines currently under construction: Brescia-Padua, Milan-Genoa, Naples-Bari and Palermo-Catania-Messina. Today in Italy the entire high-speed network is 1,467 km



Fig. 4. HSR in Italy

long (Fig. 4) and only 34% of Italian citizens (20 million inhabitants) are directly served by an HSR station. The objective of the national general transport plan was to build a high-speed network for both passengers and freight trains, to date freight trains have not yet transited on the Italian high-speed network but their transit should start in 2020.

In 2012 a new railway transport operator, NTV-Nuovo Trasporto Viaggiatori, entered the Italian HSR market, bringing Italy to be the only country with competition in the market, this also led to a drop in ticket prices thus making the service accessible to several people.

From 2009 to 2017 the number of travellers using HSR increased by 169% in 8 years, limiting the reference period from 2013 to 2016, there was an increase in demand for AV services of around 40%, compared 8% and only 1.2% for auto and airplane modes. High speed now serves 43 million travellers, of which 7 million represent a demand diverted from the traditional railway network and 19 million are diverted from other modes of transport (for example, private cars). From 2010 to 2017, the demand induced by HSR services in Italy was about 17 million passengers/year, equal to 40% of the total annual demand [21] HSR services in Italy allow people to work in cities other than home, maintaining a "commuter" working model, in particular for the cities of Rome and Naples [23].

The internal impacts due to high-speed trains are: an increase in speed of about 32% compared to the traditional railway, considering also the stop time at the intermediate stops, an average effective speed of 164 km/h is reached, thus reducing the travel time between major cities; greater services offered to HSR travellers rather than traditional users (wi-fi network, waiting rooms, dedicated ticket offices, free newspapers, etc.); high frequency (34 trains travelled on the Naples-Rome route before the HSR on a weekday, but today about 94 trains travel with a train rush hour every 6 min).

The external impacts produced by the HSR are visible on the tourism market and on the environmental system. the external cost of the HSR is 70% lower than that of a car and 59% less than that of the airplane. The amount of CO2 saved for people who travel with the HSR service compared to cars and planes is about 700 thousand tons/year, an amount equivalent to the emissions produced by urban travel in a metropolis in a year.

The goal of the Italian government is to extend high speed to the whole peninsula, serving the main Italian cities. For the moment, the cities served by high speed are still few, it will take several years before the Italian subway is completed.

3 Transport Accessibility Measures

In the last century, transport has changed the space-time conception of the individual, guaranteeing accessibility to services, goods and opportunities never reached before. The concept of accessibility has long been discussed in the research on transportation planning as a measure of "*the extent and quality of the interaction between land development patterns of a given area and the transportation systems serving it*" [24] The very definition of accessibility can boast numerous and different interpretations, each representative of the approach followed and, therefore, poorly suited to having a general character. The evolution of interpretations is closely linked to the evolution over time of the purposes of accessibility studies.

The first ever who presented a first attempt to define accessibility is Reilly [25], who demonstrates an analogy with the universal gravitational law. For Shimble [26] accessibility is defined in a simplified form, in practice it is represented as the sum of the distances of zone j from all other zones of the study area. With Hansen [27] accessibility varies directly with the size of place j and inversely with an attribute of spatial separation between the two areas.

Ten years later, Wilson (1967), starting from Hansen's accessibility measure, proposed an impedance function in which the generalized cost appears as a linear combination by means of the homogenization coefficients of a cost attribute and a travel time attribute.

In 1971, Ingram [28] expressed the accessibility of an area simply as a function of spatial impedance. Starting from Shimble [26], an index was proposed based on an impedance function averaged over all the areas with respect to which the accessibility itself is calculated.

In 1971, however, Wickstram [29] highlighted that accessibility should be a function of the opportunities present in the territory and the time needed to reach them and expressed accessibility as a cumulative function of opportunities that could be achieved in a given time frame.

From 1975 to 1979 the indices based on gravitational analogy, although powerful tools, did not allow highlighting the direct relationship between accessibility and the choices made by users. As a consequence, users residing in the same area perceived the same accessibility, regardless the socio-economic class to which they belonged to, the modes of transport available and their travel choices. For this reason, the studies led to the development of the concept of accessibility in the light of the theory of random utility.

Burns et al. [30] introduced a behavioural approach, which provided a new and interesting definition of accessibility, associating it with the freedom of users to decide whether or not to participate in different activities in the area. Utility measures tried to best represent the choices of individuals with respect to possible paths to reach a given destination by identifying that path minimizes utility but actually maximizing accessibility.

Papaioannou and Martinez [31] introduced a new definition of accessibility, tackling the problem from an economic point of view by defining accessibility as the set of economic benefits deriving from the interaction between two activities for a specific purpose. The economic benefits are obtained from the difference between the benefits deriving from the contact between the two entities minus the cost of the interaction.

Monzón et al. [32] defined numerous accessibility indicators, based on the travel time of a network, i.e. the cost/time represented along the transport infrastructures.

The methodological contribution of this paper is twofold. Firstly, a general index is designed to assess the complete connectivity and accessibility levels of the HSR network. Secondly, this paper investigates how to quantify the impact of the future HSR network on the different levels of the cities over different time periods based on the change in the overall connectivity/accessibility index.

4 The Impact of HSR on Accessibility

HSR significantly reduces travel time between cities compared to the speed of a conventional line, the rapid development of HSR has raised questions about its implications for accessibility. In this paper the focus is on the main European countries above described. The variation in accessibility induced by the introduction of HSR over the years has been analysed, starting from the year 2000 till 2018. For Spain, 46 provinces have been considered; for Italy 102 provinces have been considered, for France 99 cities for the Germany 47 cities have been taken into account.

To evaluate the accessibility variations induced by the AV in the case studies considered, an accessibility measure has been proposed, based on the variation of the generalized cost expressed with the following equation:

$$\boldsymbol{A = \Delta CG = \Delta[(\sum_{o=1}^{N} CG_{od} * Addd)/(\sum_{o=1}^{N} Ad_o)]}$$

where:

CG_{od} is the generalised travel cost between two zones;

Add_d is the number of jobs (number of opportunities available in a given zone d).

The cost of the trip is calculated based on the Value Of Time. The reference VOT values (€/hour) considered for the estimates are those proposed by the European Commission in the "Mobility and Transport" section (2016) which results in a value of 19 €/h for extra-urban trips in Spain, 27 €/h in France, € 31/h in Germany and € 22/h in Italy.

To estimate the variation of the generalized cost for each country OD matrices related to travel times with the fastest railway service and the relative ticket cost to and from the cities considered have been estimated.

The results obtained show that in Spain, taking into account only OD pairs served by HSR (where the path is on a HSR section), the variation in 18 years (2018–2000) of the generalised cost is equal to −29% and for a traditional line is of −19%, therefore, on average on the network there has been an increase in accessibility with a reduction in the generalized cost on average of −24%. This happens because even the cities, the areas, not located on the HSR network have benefited from the service, in fact from the traditional service it is possible to switch to the fastest one. In Germany, on average on the network there has been an increase in accessibility with a reduction in the average generalized cost of −12%. This result is similar to the Spanish one but with a slighter decrease caused by the fact that the German network is not very extended in addition to the fact that the HS lines are already existing lines, renewed with a lower commercial speed.

Finally, similar conclusions also emerge from the studies carried out on all the French provinces. From Table 1 it can be seen that for France an overall reduction of −14% is reported, a result that would apparently be odd as the railway network is very capillary but it has been noted that the monetary cost over time increases a lot compared to the other countries considered. The accessibility measure in Italy as well has been calculated from the year 2000 to 2018. The results (consistent with the results of Cascetta et al. [33]) show that the introduction of the HSR service has produced a very significant increase in accessibility caused by the decrease of the generalised cost for long-distance areas.

Table 1. Results

	Δ (2018–2000) HSR network generalised cost	Δ (2018–2000) No HSR network generalised cost	Δ (2018–2000) Network generalised cost
Spagna	−29%	−19%	−24%
Germania	−14%	−10%	−12%
Francia	−18%	−9%	−14%
Italy	−26%	−3%	−9%

5 Conclusions and Further Perspectives

Similarly, to the construction of a new airport or the opening of a new motorway to traffic, the construction of a new HSR line falls within the typology of interventions on the transport system that generally introduces significant changes in the transport supply with inevitable social, economic and environmental impacts for the areas involved. For this reason, the impacts induced by the HSR infrastructures and the related services have been extensively studied in many countries in relation to the specific socio-economic and territorial characteristics, as well as at different levels of service variables (e.g. average speed, frequencies, etc.).

These results are relevant from an operational practical point of view, as they suggest significant insights in the context of transport planning. Transport policies and investments should aim at increasing accessibility, but often transport infrastructures and services are implemented precisely where there are more transport opportunities and demands to justify them. This is partly due to the fact that social justice considerations are much more difficult to measure than other factors relating to, for example, traffic speed or environmental pollution. In the future, more could potentially be done to make accessibility a less "intangible" aspect of transport planning.

Furthermore, it is important to emphasize that the accessibility measure used in this work could be enriched with many other variables in order to be able to carry out a broader and more complete analysis of this problem.

References

1. Cascetta, E.: Perché TAV. Risultati, prospettive e rischi di un Progetto Paese. Edited by Il sole 24 ore (2019)
2. Bonnafous, A.: The regional impact of the TGV. Transportation **14**, 127–137 (1987)
3. Arduin, J.-P., Ni, J.: French TGV network development. Japan Railway Transp. Rev. **40**, 22–28 (2005)
4. Leheis, S.: High-speed train planning in France: lessons from the Mediterranean TGV-line. Transp. Policy **21**, 37–44 (2012)
5. Heuermann, D.F., Schmieder, J.F.: The effect of infrastructure on worker mobility: evidence from high-speed rail expansion in Germany. J. Econ. Geogr. **19**, 335–372 (2019)
6. Ebeling, K.: High speed railway in Germany. Japan Railway Transp. Rev. **40**, 36–45 (2005)
7. Deutsche Bahn (2016). https://www.bahn.de/

8. Lee, Y.S.: A study of the development and issues concerning high speed rail (HSR). Transport Studies Unit, Oxford University Center for the Environment (2007)
9. Albalate, D., Bel, G.: Cuando la economía no importa: auge y esplendor de la alta velocidad en españa. Revista de Economía Aplicada **19**(55), 171–190 (2011)
10. Albalate, D., Fageda, X.: High speed rail and tourism: empirical evidence from Spain. Transp. Res. Part A **85**, 174–185 (2016)
11. Bel, G.: Infrastructure and nation building: the regulation and financing of network transport infrastructures in Spain (1720–2010). Bus. Hist. **53**(5), 688–705 (2011)
12. Bel, G.: Infrastructure and the Political Economy of Nation Building in Spain, 1720–2010. Sussex Academic Press, Eastbourne (2012)
13. Albalate, D., Bel, G.: High-speed rail: lessons for policy makers from experiences abroad. Public Adm. Rev. **72**(3), 336–349 (2012)
14. Bel, G.: Transport policy: more investment or better management? Economistas **111**, 279–284 (2007)
15. Beria, P., Grimaldi, R., Albalate, D., Bel, G.: Delusions of success: costs and demand of high-speed rail in Italy and Spain. Transp. Policy **68**, 63–79 (2018)
16. de Rus, G., Nash, C.: In what circumstances is investment in HSR worthwhile? ITS Working Paper, 590, University of Leeds (2007)
17. Betancor, O., Llobet, G.: Estudios sobre la economía española, Contabilidad Financiera y Social de la Alta Velocidad en España (2015)
18. Campa, J.L., Arce, R., López-Lambas, M.E., Guirao, B.: Can HSR improve the mobility of international tourists visiting Spain? Territorial evidence derived from the Spanish experience. J. Transp. Geogr. **73**, 94–107 (2018)
19. Vickerman, R.: High-speed rail in Europe: experience and issues for future development. Ann. Reg. Sci. **31**(1), 21–38 (1997)
20. García Alvarez, A.: Energy consumption and high-speed train emissions compared with other transportation modes. Anales de Mecánica y Electricidad **84**(5), 26–34 (2007)
21. Cascetta, E., Coppola, P.: Evidence from the Italian high-speed rail market: competition between modes and between HSR operators. In: High-Speed Rail and Sustainability (2017)
22. Cascetta, E., Coppola, P.: High Speed Rail (HSR) induced demand models. Procedia – Soc. Behav. Sci. **111**, 147–156 (2014)
23. Cascetta, E., Papola, A., Pagliara, F., Marzano, V.: Analysis of mobility impacts of the high speed Rome-Naples rail link using withinday dynamic mode service choice models. J. Transp. Geogr. **19**, 635–643 (2011)
24. Cascetta, E., Cartenì, A., Montanino, M.: A behavioral model of accessibility based on the number of available opportunities. J. Transp. Geogr. **51**, 45–58 (2016)
25. Reilly, W.J.: The Law of Retail Gravitation. Knickerbocker Press, New York (1931)
26. Shimble, A.: Structural parameters of communication networks. Bull. Math. Biophys. **15**, 501–507 (1953). https://doi.org/10.1007/BF02476438
27. Hansen, W.G.: How accessibility shapes land use. J. Am. Inst. Planners **25**(2), 73–76 (1959)
28. Ingram, D.R.: The concept of accessibility: a search for an operational form. Reg. Stud. **5**(2), 101–107 (1971)
29. Wickstram, C.E.: The Credibility Gap and the Ecology Reaction (1971)
30. Burns, R.B.: The Self Concept in Theory, Measurement, Development, and Behaviour. Addison-Wesley Longman Limited (1979)
31. Papaioannou, D., Martinez, L.M.: The role of accessibility and connectivity in mode choice. A structural equation modeling approach. Transp. Res. Procedia **10**, 831–839 (2015)
32. Monzón, A., Ortega, E., López, E.: Efficiency and spatial equity impacts of high-speed rail extensions in urban areas. Cities **30**, 18–30 (2013)
33. Cascetta, E., Cartenì, A., Henke, I., Pagliara, F.: Economic growth, transport accessibility and regional equity impacts of high-speed railways in Italy: ten years ex post evaluation and future perspectives. Transp. Res. Part A **139**, 412–428 (2020)