EUROPEAN UNION

Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence

TARGETED ANALYSIS //

IMAGINE

Developing a metropolitan-regional imaginary in Milan-Bologna urban region

Scientific annex 3 // Exploring the state of the art in terms of integrated mobility offer

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Abbreviations

AV	*Alta Velocità*, the Italian acronym for High Speed.
COVID-19	Coronavirus disease 2019
DASTU	Department of Architecture and Urban Studies, Politecnico di Milano
EC	European Commission
ESPON	ESPON European Grouping of Territorial Cooperation
EU	European Union
EU 15	European Union countries that were member states prior to 2004 (incl. UK)
EU 13	European Union countries that joined after 2004
Eurostat	European Statistic Office
FUA	Functional Urban Area
G&L	Globus & Locus
HS / HSR	High Speed / High Speed Rail
ISTAT	Istituto Nazionale di Statistica (Italian National Institute of Statistics)
ITI	Integrated Territorial Initiative
LAU	Local Administrative Units
MEF	Italian National Ministry of Economy and Finance
MIT	Italian National Ministry for Infrastructures
NUTS	Nomenclature of Territorial Units for Statistics
OD	Origin-Destination matrix
POLIMI	Politecnico di Milano
PRMT	*Piano Regionale Mobilità e Trasporti* (Regional transport and mobility plan)
PSO	Public Service Obligation
RP	Regional Portrait
SLL	*Sistema Locale del Lavoro* (Local commuting area)
SUMP	Sustainable Urban Mobility Plan (PUMS in Italian)
VP	Visual Platform
WP	Work Package

Introduction: Milan-Bologna High-Speed Corridor – Reconstructing the state of the art of the mobility practices

This Annex to the Final Report includes all the elaborations and the analysis related to the mobility in the corridor Milan-Bologna, integrating the preliminary investigations already included in the Regional Portrait.

Studying the mobility is crucial for a corridor that exists because of a transport infrastructure built more than 2000 years ago, during Roman times, and that evolved in centuries practically in the same place, serving the same cities with continuity. The HSR line and stations are just the last step of the history of mobility along the Via Emilia and further, and it would be unwise to limit the focus to that line only. For this reason, we will analyse the mobility of the area as a whole, both in terms of *quantity of mobility* (already developed in the Regional Portrait report) and structure of it (mainly in this Annex): where are the flows and how flows move, in particular in terms of transport technology. As it will be clear, it is difficult – if not impossible – to separate the local from the longer-distance mobility in this territory, which is deeply interlinked internally and externally but still well recognisable as a territorial unity.

The Annex takes advantage of existing census data on mobility, integrated with recent simulations and big data from mobile phones movements. These data should provide a clear picture of mobility in the area, in the absence of official data from transport companies, primarily rail sold tickets and OD matrices. Demand data are integrated with an in-deep analysis of rail supply, with a particular focus on the evolution of it between 2008, the year before the revolution of HS, and 2020, the last timetable before the crisis of Covid19.

The analysis of demand, supply, and accessibility will provide a solid background to the last sections on suggested policies for the corridor and the transferability of Milano – Bologna experience to other European contexts.

Structure of the Annex

The Annex is structured in six chapters.

- *Chapter 1 Transport policies* along the corridor includes an introduction to the transport and mobility policies on the corridor, starting from the larger scale of the HSR line construction and successive rise of competition to the regional and urban scale.
- *Chapter 2 The mobility in and along the corridor* collects all analyses done on the mobility data. First of all, general mobility trends since 1991 are discussed. Then the mobility along the corridor is presented, showing the degree of internal connections of cities and their territories. After, we will broaden the sight to the connections of the corridor with the rest of the country and of Europe. A particular focus is given to the public transport data, showing how bus and rail transport are used and for where.
- *Chapter 3 The supply of transport services* is about collecting rail services and their evolution in time. It starts with a 2-layers perspective: the supply of cities from 2008 to 2020 and its development on some relevant city pairs, particularly Rome. The chapter then contains three zooms-in: one about the accessibility *to* rail transport, one about the case of Reggio Emilia AV station, and one about the evolution of rail and coach market prices in the area.
- *Chapter 4 The evolution of accessibility* presents a synthetic measure of how the interaction of supply and territory through a classical potential accessibility indicator at the national scale. The interesting elements of the analysis are the level of detail of the description of transport costs and in the fact that it adopts a diachronic perspective, showing the changes in national accessibility before and after the opening of the HS line.
- *Chapter 5 Comparing high-speed corridors in Europe* passes to a European perspective: a literature review shows previous studies on HSR models and corridors. The review is integrated by some new analyses on comparable corridors in terms of distance and flows in most of Europe. These

corridors are then analysed and compared in terms of population and other socio-economic indicators.

- Finally, *Chapter 6 Policy recommendations* summarises the main findings and bridge the presentation of three possible policy actions for the area, with particular interest for those involving different administrations. Finally, some comments about the transferability of these findings to the rest of Europe are presented.

Transport policies along the corridor Milan-Bologna

The history of the HSR line

The existing infrastructural corridor running between Milano and Bologna is nearly 2200 years old, since it strictly follows the roman Via Æmilia, completed in 187 B.C. The modern corridor is made of:

i. the National Road 9 linking Milano to Rimini aligned to the roman road except for the numerous bypasses around the main cities served;

ii. the conventional rail line, connecting Milano with Bologna and following southwards splitting into the *Adriatica* line (ending in Lecce) and the so-called *Linea Lenta* to Rome, afterward *Tirrenica* to Reggio Calabria;

iii. the A1 highway opened in 1964 and connecting Milano with Napoli;

iv. the High-Speed rail line, next to the highway and opened in 2008, connecting Firenze, Roma, Napoli and Salerno.

The four infrastructures connect a line of cities and towns, most of them built on the original roman cities, localized within by a highly productive agricultural plain, the Po Valley.

The Milan-Bologna high-speed line is just one section of the Italian HSR network, as seen in **Error! Reference source not found.**, currently connecting Torino with Salerno, Venezia with Bologna and Padova, and Milano with Brescia. Except for the last one, these sections were all completed by 2009. Other fast lines, not necessarily at 300km/h standard, are under construction: the Brescia-Padova which completes the east-west main corridor from Torino to Venezia, the Napoli-Bari, and some Alpine basis tunnels at different stages of construction: the Genova – Milano, the Brennero tunnel and the Frejus tunnel.

When it was first conceived in 1990, the Italian high-speed system was supposed to be a separate system, substantially independent from the rest of the network. Born as a project financing, however, it was returned entirely under State financial umbrella in 1998. The current network costed 32b Euro, but these figures refer to the lines only and exclude nodes and works completed after 2009. The bypass under Firenze (necessary to solve the bottleneck represented by the city's node and station) is still under construction.

This initial separate model, inspired by the French one, was revised already in 1996 and renamed as "Alta Velocità/Alta Capacità" (*High Speed/High Capacity* in Italian, or *AV/AC*). Lines maintained a different voltage[1] from the rest of the network and the same speed. Still, the introduction of many interconnections with the conventional network and the design with lower slopes allows lines to host heavy freight trains (Beria et al., 2018)[2]. The Torino-Salerno is designed to run at 300 km/h, except for the older Firenze-Roma and the Napoli-Salerno sections (both at 250 km/h) and the urban ones.

The properly said HSR line starts in Milano Rogoredo and separates from the conventional line near Melegnano, few kilometres south of Milan. Then it follows it aligned with the A1 highway until Modena, after which it joins the traditional line and enters Bologna's city. In 2013 a new high-speed station was opened under the Bologna station. The four tracks are used by HS trains only. The new infrastructure freed up capacity in the node that became available to regional services, which are now entirely separated from HSR flows.

In 2013 another new station was opened, the Reggio Emilia AV Mediopadana station, an extra-urban 4-tracks facility located north of Reggio Emilia and next to the highway. It is the first HSR station in Italy out of

[1] High-speed lines operate at 25kV AC, while the traditional network, including the urban terminals of high-speed lines into cities, operate at 3kV CC.

[2] 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.

a city and it soon became an important stop, serving an extended area ranging from Modena to Parma and Mantova. We will discuss the case of that station in-depth in section 0.

The HSR line also includes numerous interconnections with the conventional line, other branched lines and intermediate cities. For example, it would be possible to leave the fast line, call at Parma, and re-enter the line (Figure 1). However, these interconnections have been seldom used and intermediate cities are not served by HSR trains (see section 0). The same happened to cargo traffic: it remained on the conventional line, perfectly suitable for it, and enjoys a significantly lower access charge.

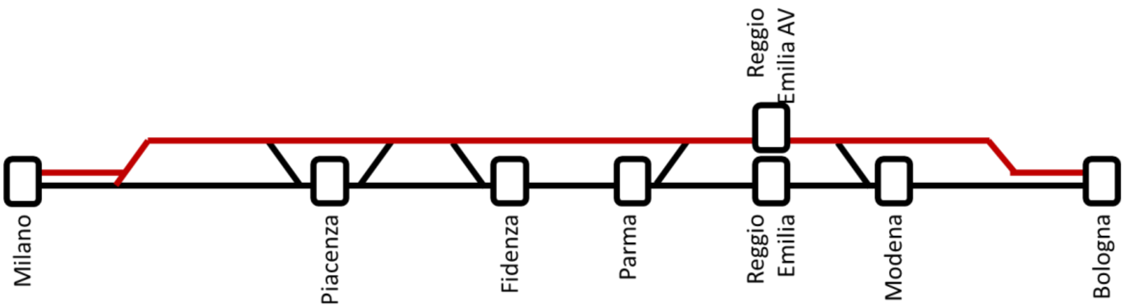


Figure 1 – HSR line Milan-Bologna scheme and interconnections

The battlefield of rail competition

After the line's opening, the service has been provided by the national railways, Trenitalia, which took the chance of the new line to rebrand its market services, now called “leFrecce” (tr. *TheArrows*).

But since 2012, Italy saw a world-unique[3] case of competition in the market between two high-speed rail companies. A newly founded private company, NTV, entered the market under the brand name of “.Italo”. In April 2012, a handful of trains served Milano, Napoli and the intermediate cities. In December, with the new timetable, Torino, Salerno, Padova and Venezia were also included. Since December 2015, Verona and the Brennero axes were also added. .Italo trains operated for the first time out of the HS lines between Torino/Milano and Venezia in 2018. Bergamo was also added in 2019 when seasonal services south of Napoli were also added.

In terms of market share, Italo is one of the few European newcomers that provide niche services and an extensive and nationwide network. Already in 2016, Italo transported 21% of total *long-distance non-PSO passengers* in Italy (17% including Trenitalia’s PSOs) (Beria & Bertolin, 2019), but this share increased later thanks to a significant market repositioning. Even more impressive was the share in *HS passengers/km*: in 2017 Italo served 35% of them (Beria et al., 2019).

The competitiveness and success of .Italo concerning other European newcomers can be linked to two elements: it operates mostly on fast tracks allowing high trainset usage and it started a wide offer (and with new trains) already in early stages, rather than increasing slowly train by train like what happened for example in the Czech Republic. The path of .Italo was not free of threats and its future is far from sure due to COVID-19 crisis and its consequences. The main turning point was in 2015 when the company left the idea of being a “luxury” train to become a sort of low-cost HS operator. Load factors increased thanks to a change in pricing that went on in the following years. Overall, Italo is 10% to 20% cheaper than Trenitalia according to advanced purchase and route, for comparable service in everything except slightly lower frequencies. For a detailed price analysis of the Milano – Bologna route, refer to section 0.

“Italia Veloce” and the concept of “AV Rete”

The Italian HS model of the ‘90es adopted the French concept of building a separate network of new fast lines serving the main cities. Italian decision-makers changed the concept into something different and more expensive, called “AV/AC”, where AC stands for high- capacity in addition to high-speed. Lines were

[3] Until 2021, when HS competition is starting also in Spain, even if according to a different model.

pervasively interconnected with the conventional network, not for passenger trains (which basically never used them) but for letting heavy freight trains enter the new lines. These were heavier in terms of the superstructure, but also slopes were minimal. This made the lines much more expensive than any other contemporary continental line (Beria et al., 2019).

Since 2017, the leading national transport programming document (not a plan, however), the *Allegato Infrastrutture al DEF* ("Infrastructure Annex to the Department of Economy and Finance"; MEF, 2017) introduced a new concept for the future development of the fast rail services in Italy. The concept has been called AVR - Alta Velocità di Rete (sounding like "Network-centered High-Speed"): infrastructure investments are targeted to make possible the operation of *services* connecting the main urban areas of Italy with Rome in less than 4h30, which is the current travel time between the capital and Turin, the farthest city connected with the HS network. In other words, the network investments are not finalised to build a 300km/h network but to allow services that are comparable to the currently fastest ones.

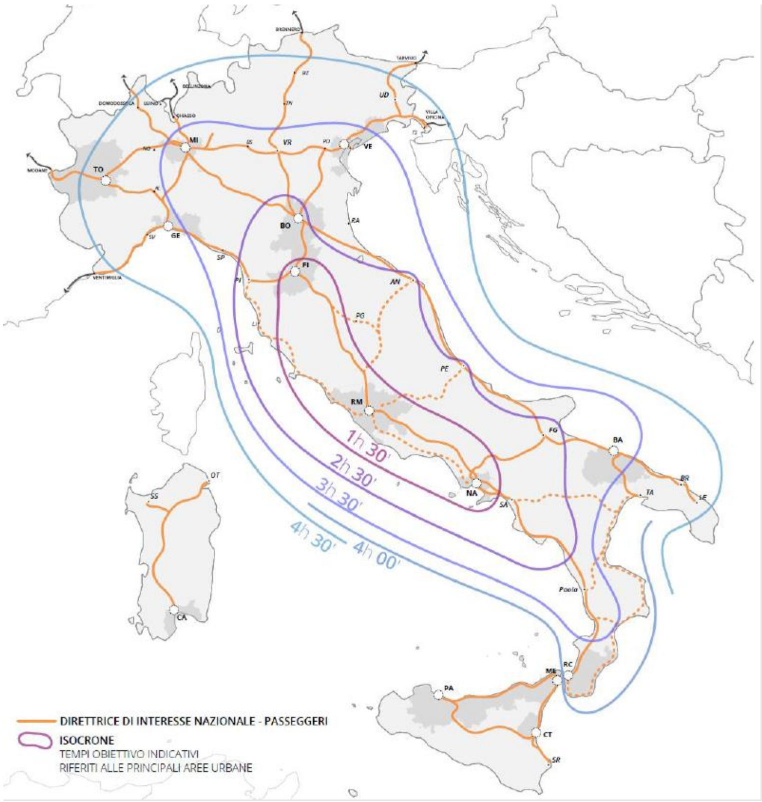


Figure 2 – Target isochrones of the AVR programme. Source: MEF, 2017.

It is worth noticing that the AVR is not a plan of services since long-distance connections are – according to Italian normative – generally offered *in the market* and not planned, but "just" a logic for designing new lines and prioritizing them. Railway undertakings can decide connections, frequency, prices, etc., and the network is developed by the planner, guaranteeing a certain standard of timetable performance.

Unfortunately, the concept of AVR is blending every year, under the political pressure from local authorities and lobbies reclaiming 300km/h new tracks everywhere, even where demand figures cannot justify anything more than just a few trains/day. In this sense, the recent PNRR (National Recovery Plan) added confusion, reaffirming the AVR model and financing the first part of a new 300km/h line with 18‰ slopes adapt for freight trains[4] from Salerno to Reggio Calabria.

[4] Passenger HS trains normally run on 35‰ lines.

Regional transport in Lombardy

Lombardia is the most populated Italian Region and has invested more than any other region in Italy in rail transport. The current system was conceived in 1982 when the idea of restructuring the entire Regional Rail System according to principles already extensively used in other European countries:

a. Specialization of services (*RegioExpress* to connect quickly main towns and cities, *Suburban* to serve the metropolitan area of Milano and, later, other cities with a metro-like system, *Regional* for the remaining local connections).

b. Regular timetables based on the 30' frequency.

c. Symmetric timetables at nodes to boost the network effect.

d. The lines' specialization, which includes extensive infrastructure works to upgrade to 4-tracks the lines entering Milano and constructing a rail tunnel under Milano (the so-called "Passante Ferroviario").

e. The use of adequate rolling stock.

The most recent plan, the PRMT (Regione Lombardia, 2016), fully confirmed the original plan, and 30 years later, the regional system is nearly completed. The principles listed have been *really* followed with continuity of decisions and investments by the regional government. Excluding some lines whose infrastructural upgrade is not yet realized, the primary failure of that plan lays in the rolling stock of suburban services, which continues to be traditional (heavy, low acceleration, low density of seats, reduced door sizes, frills) instead of lighter solutions more adapt to serve short distances[5].

[5] For example in analogy with German and French suburban rolling stock: no frills, but high capacity.

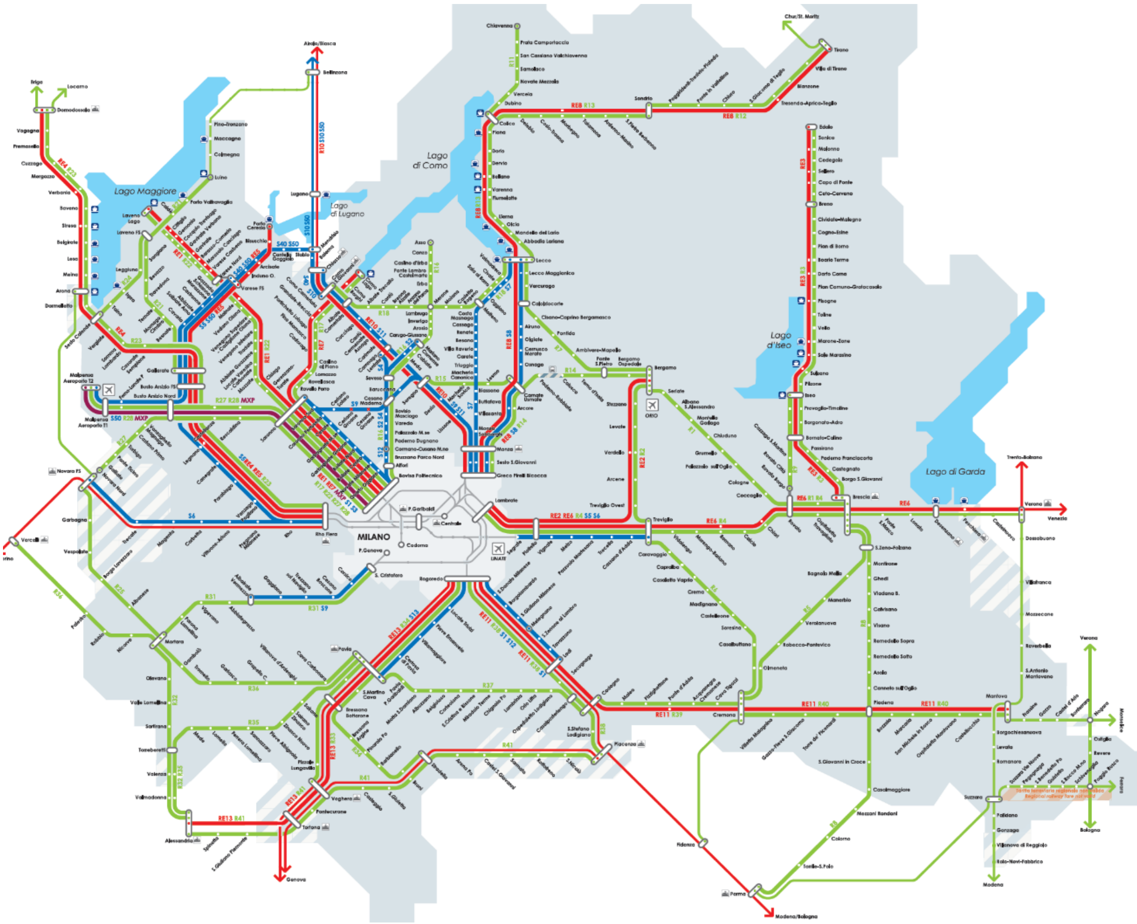


Figure 3 – Map of the Lombard Regional Rail System, January 2020. Source: Regione Lombardia.

The suburban lines are now concentrated around Milano (Figure 3), but recently the distinction reached the international services between Switzerland and Milano and Malpensa airport. In the future, Bergamo and Brescia are also expected to have services specialised for the short-range, regularly operating 2 times/hour and with frequent stops.

The line Milano – Bologna is also quite symbolic of the evolution of services. As soon as the new HS line has been opened, most of the long-distance traffic left the conventional line, freeing capacity for regional trains, including the new *suburban* trains to Lodi, calling at every station. Figure 4 illustrates the two timetables of 2008 and 2020, showing the dramatic increase in services.

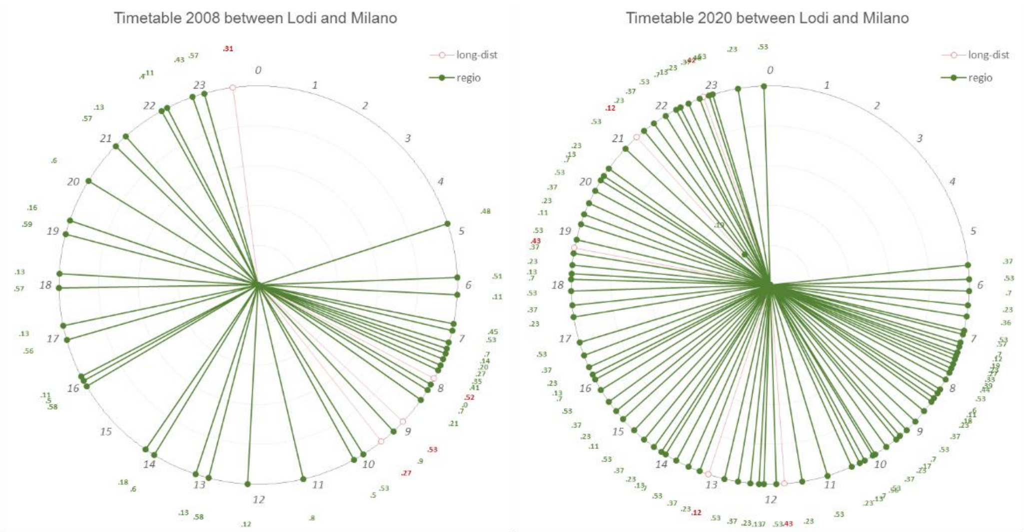


Figure 4 – Representation of 2008 and 2020 daily timetables of Lodi – Milano connection. Source: elaborations on official timetable.

Farther destinations are served by *regional* trains (to Piacenza, calling at all stations south of Lodi) or *Regi-oExpress* trains (Mantova and Bologna). In this case, we can see the difference between Mantova, belonging to the region, and Bologna and the cities of Via Emilia, belonging to the neighbouring region Emilia Roma-gna. Both services are every 2 hours, but those to Mantova are more regular and similarly fast (74,7 km/h vs. 76 km/h) despite the size of the market is smaller and the line is poor and single-tracked. Those traveling to Bologna also call at smaller stations in Emilia, significantly reducing the commercial speed.

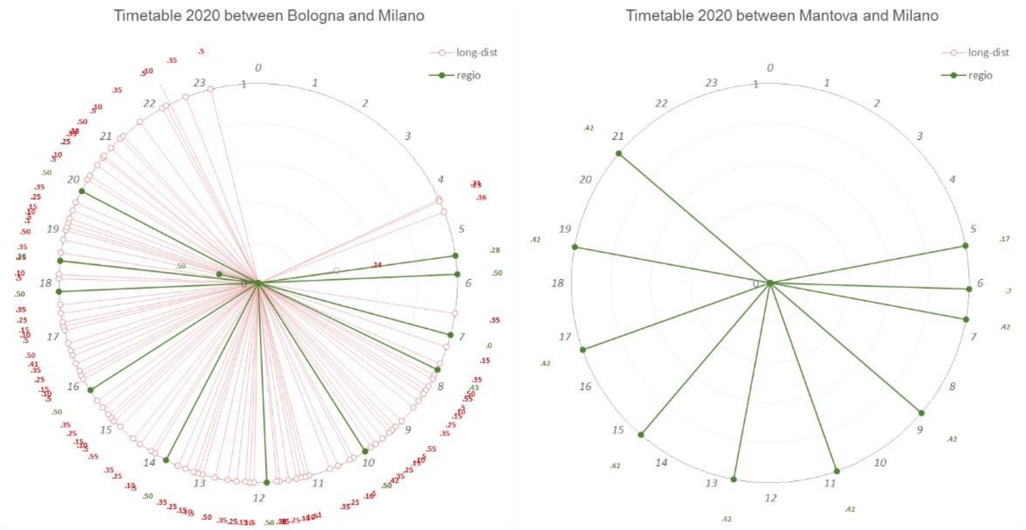


Figure 5 – Representation of 2020 daily timetable of Bologna – Milano and Mantova – Milano connections. Source: elaborations on official timetable.

Regional transport in Emilia-Romagna

Emilia-Romagna Region has recently completed the elaboration and approval of the new regional transport plan (PRIT 2025) (Regione Lombardia, 2016), finally overcoming the former regional plan of 1998.

The plan of 1998 was already foreseeing a restructuring of regional rail services centred on the increase of frequency, regular timetables, overlapping of two different types of services (fast regional calling at main stations and serving interregional relations, and regional services calling more frequently). Interestingly, the fast-regional trains (RV, "*regionale veloce*") were supposed to be relatively *infrequent* (hourly services all day long only between Padova and Bologna and Milano-Parma at peak hours, the remaining every 2-4 hours). Regional trains module was with few exceptions at 60' headway.

Th new PRIT for 2025 maintains the distinction between RV and regional trains (differently from the 3-levels of Regione Lombardia) but significantly increases the target of frequency to 30'-60' according to the lines, similarly to the targets of the neighbouring region. In this framework, the city of Bologna is now served by suburban lines, similar for the structure to the Milanese ones and overlapping in the centre reaching the 15' headway, but still not entirely passing-through and not yet wholly based on the 30' module.

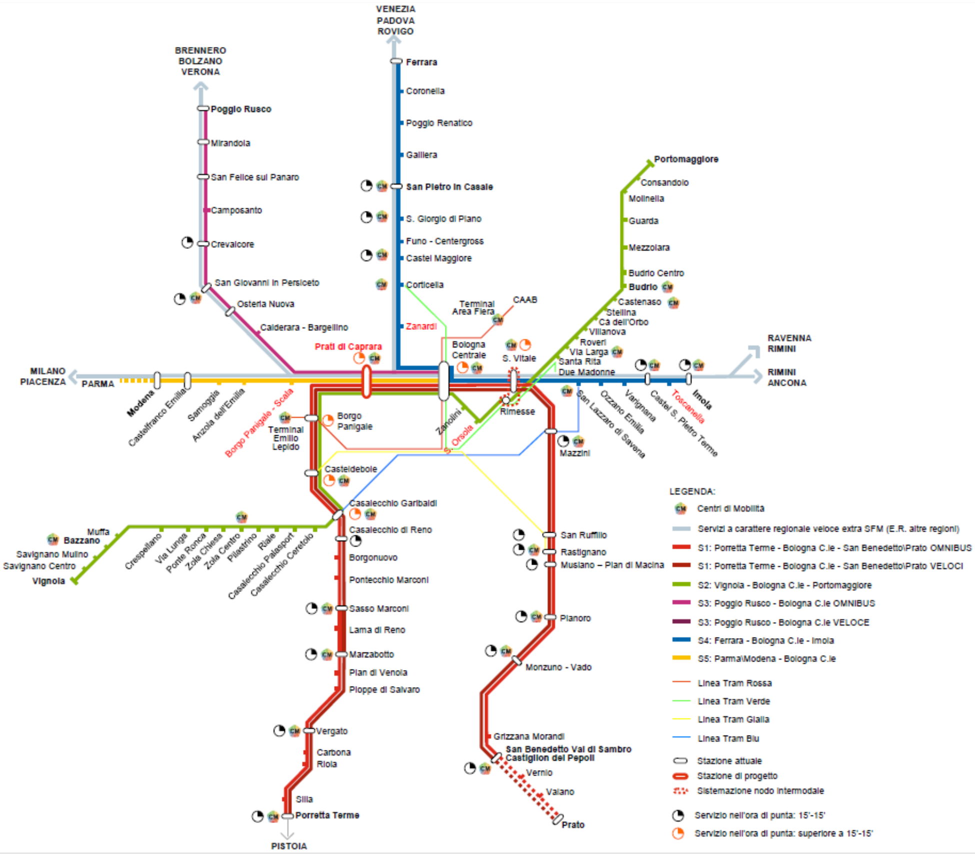


Figure 6 – Map of the Bologna metropolitan rail service (SFMBO). Source: Città Metropolitana di Bologna, 2019.

It is interesting to underline that in both regional plans (Lombardia and Emilia-Romagna), the fast interregional connection is present, but just at 120' headway and better integrating the corridors is announced. Lombard PRMT plan (Regione Lombardia, 2016) foresaw the introduction of new fast and regular interregional services between Genova and Brescia, but the line to Bologna remains at low frequency. This is a sign that the current, but especially the expected, integration along the corridor remains limited. We will go back on this later in the document, analysing the current demand.

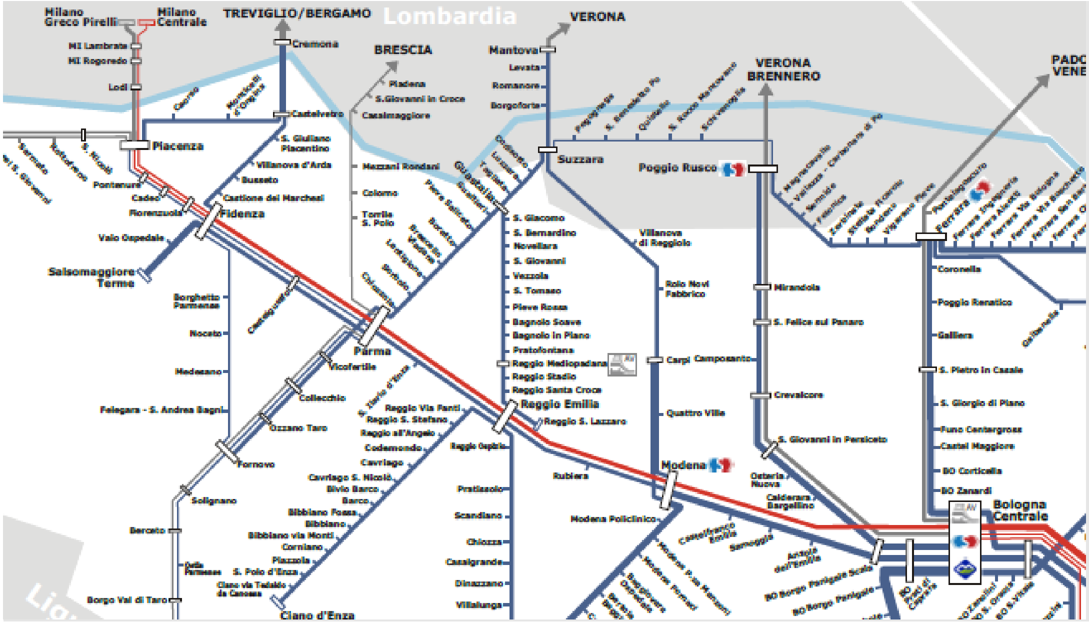


Figure 7 – Detail of the planned rail services in the corridor Milan-Bologna, according to Emilia-Romagna PRIT 2025.

Urban mass transport in the area

The scale of mass transit development in Milano is – for obvious dimensional reasons – incomparable with respect to Bologna or other corridor cities. However, some tramway projects came to maturity in the last years and should become reality in the next decade.

Bologna is planning through the SUMP (Città Metropolitana di Bologna, 2019), 4 tram lines crossing in the city centre and serving the peripheral districts. These tramways should substitute the main lines of the current bus system of Bologna, which is among the most frequent in Italy, with the lines often working with double buses at 4' headway. In 2020 a new fast connection between the station and the city airport has been opened, too.

Reggio Emilia is also ready to start constructing its first tramway line, financed in 2021, that will connect the southern part of the city with Reggio Emilia AV station, passing through the centre and the historical urban train station.

Milano is planning and realising numerous extensions of its mass transit network. None is related to the Milano – Bologna corridor, which M3 and suburban lines already serve through the gate-station of Rogoredo. A new tram line from Rogoredo will be built by 2026 to connect the station, the new hockey stadium for the Winter Olympic Games, and the M4 to Linate airport. Among the most significant ongoing projects, the new M4 line is due to open in the following years and M5 is planned to be doubled in extension to reach Monza.

The remaining cities mostly rely on bus systems. A metro line was planned for Parma, but the funding has been retired in 2010.

The mobility in and along the corridor

Data sources

The availability of updated, detailed and spatially defined data in the area presents some limits.

The most used source of mobility data is the national census origin-destination matrix by ISTAT (from now on "*OD ISTAT*"). It has been produced every ten years, it is based on many interviews and its spatial definition is the municipality, which makes it appropriate to almost any mobility analysis. Its limitations, which will suggest complementing the analysis with other sources, are that it is now old (the latest dates to 2011) and includes only commuting trips for study and work (no occasional trips are included). Moreover, it has only one trip per day (typically from home to work/study location, assuming an opposite return trip), and the modal split refers to the "prevalent mode".

Multipurpose ODs, including also non-commuting trips, are not available at the national scale, to our best knowledge. Regione Lombardia has produced a regional matrix in 2014, 2016 and 2020. These matrices are simulated and based on two survey campaigns. We will not refer to them for the general analysis simply because there is not a corresponding one for the Regione Emilia-Romagna.

To overcome the limits of OD ISTAT, we will refer for some of the elaborations below presented to another simulated matrix, called "i-TraM" and produced during the Italian national research programme Quaint (Beria et al. 2019a). The matrix is publicly available at http://www.quaint.polimi.it/dataset/. Its spatial definition is sub-provincial, including about 1700 zones. Main cities are generally split into sub-zones. The matrix is multipurpose (including overnight trips). For a description of the tool, refer to Section 0.

A third and even more recent matrix, less spatially detailed but not simulated, has been used to compare with the first two. The Movement between Administrative regions (provinces) for 2020, made available by the Facebook – Data for good programme (https://dataforgood.fb.com/) illustrates aggregate movement patterns of Facebook users with location history turned on over several hours throughout the day.

The numbers of rail passengers per station and train ride have been obtained from the two regional governments. Both come from a periodic 15-days survey conducted by the rail operators. For Trenord (the Regional railway company in Lombardia), surveys took place from November 2015 to 2019. Emilia Romagna data cover July and November 2010 to 2019, but not all periods are complete. The only entire year used for comparisons is 2016. In Emilia Romagna the temporal comparison is also between 2010 and 2019.

Overall mobility trends

To analyse the mobility trends of a specific study area diachronically, we can rely only on ISTAT database, which only maps commuting trips for work-study reasons in 1991, 2001, and 2011.

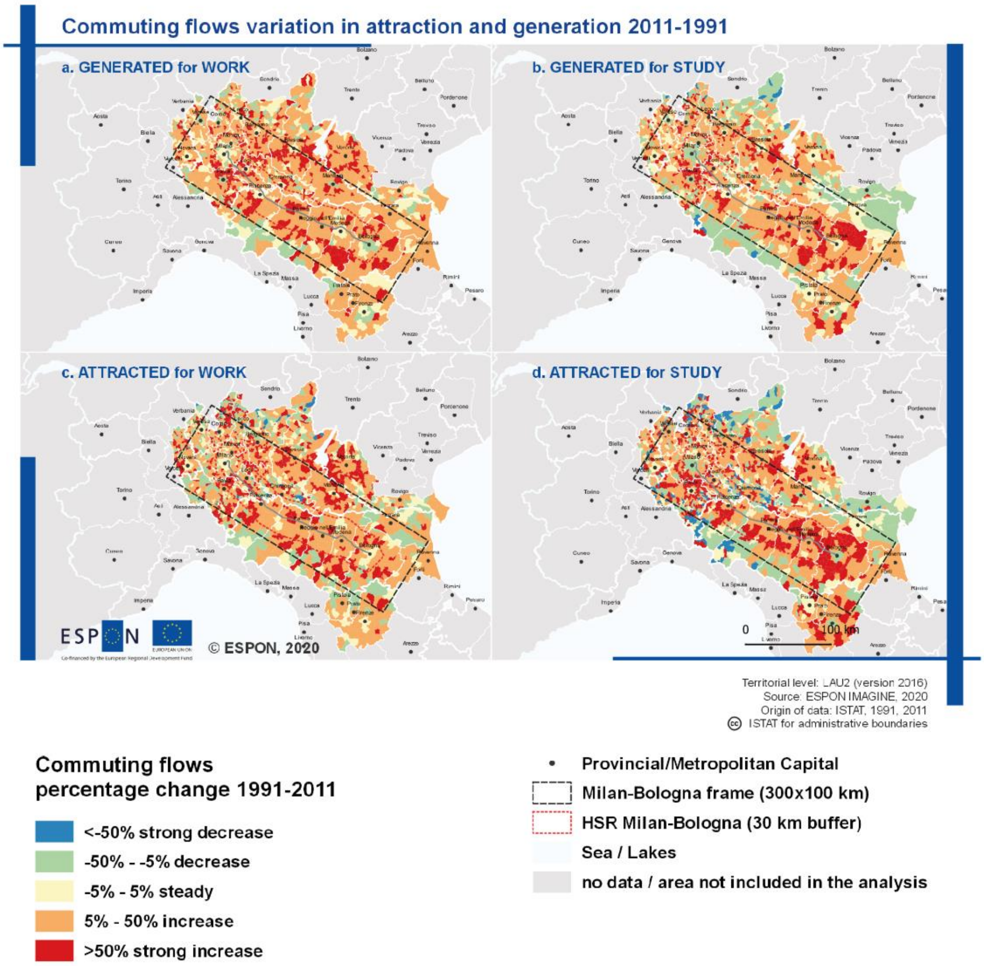
Considering the whole provinces and the capital cities only (Chart 1), we get a different picture. While generated working trips from Milano and its province are relatively steady in the period, the trend of the other provinces is increasing. This does not reflect only the demographic and employment trends of the metropolis, but probably also the fact that figures are based on officially residents only. Concerning the relative weight of the cities with respect to their provinces, the intermediate towns have a lower weight than Milano and Bologna. This indicates the existence of other relevant 2nd tier centres in the provinces, which sometimes are nearly comparable to the respective provincial capital (e.g. Carpi vs. Modena).

As generator, Milano in 2011 was lower than twenty years before, while as an attractor is just slightly higher. A similar trend is also visible in Bologna. So, their relative weight decreased somewhat, thanks to the dynamism of the others.

Chart 1– Trend of daily flows in the study area (1991-2001-2021) for work and study reasons.

From a spatial point of view, the dynamics of generation and attraction of the area are not particularly lively (

Map 1). Work attractors decreased in remote areas and increased locally. Among the most increasing areas, the provinces of Pavia and Piacenza (probably linked to the impressive development of the logistic sector). But also the rest of the corridor sees lively local areas, e.g., Parma. Cities, instead, are less dynamic as shown before. Generation levitated especially south of Milano, only partially matching with the areas mentioned above. Cities declined, as already underlined. Study reason movements reduction is more linked to demographic dynamics. At the same time, the impoverishment of remote areas, especially in the Apennines and in some areas of the Po Valley, is well visible and related to a general trend from several decades.



Map 1 – A4 2.2 Commuting flows attraction and generation dynamics in the study area

Mobility along the corridor

The territory of the Po Valley is characterised by a *continuum* of relations, which makes quite meaningless the scheme of pole-periphery mobility. Poles, of course, exist and are poles primarily for their catchment area, but at the same time a significant share of trips occur out of the single areas, between poles, and especially between the peripheries of the poles. This is particularly relevant in Emilia-Romagna, where poles are at the same time mid-sized and very next to each other and are immersed in a complex and economically lively context. On the contrary, Milano has an attraction effect on a different scale, both in size and quantity, capable of hiding the attraction of the near cities of Pavia and Lodi (but also Monza, much larger).

Self-containment indicator measures how much a place is self-sufficient in terms of workplaces and schools. The pop-up sites are either the main centres (Milano, Bologna, etc.) or the second-tier isolated cities (Cremona, Mantova, etc.). Instead, a stronger dependency characterises places like Lodi, Pavia, Piacenza (and limitedly Modena) from external attractors, Milan and Bologna, respectively (Chart 2 and Chart 3). But, if we consider the self-containment of larger zones and take into consideration also the non-systematic mobility, the picture changes significantly. Map 2 expresses the difference between the main corridors (Milan-Bologna and Milano-Venezia), where the minority of trips remain internal, and the rest of land, where mobility is more contained and thus local.

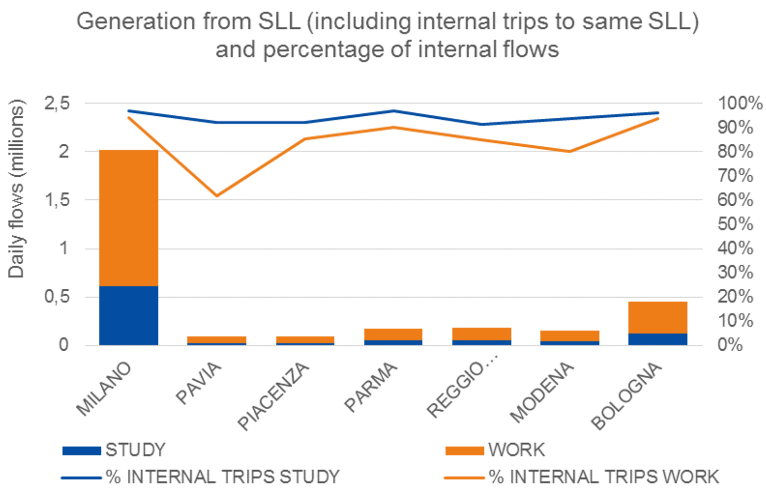


Chart 2 – Generation from local commuting areas (SLL) and self-containment. Source: elaborations on ISTAT, 2011.

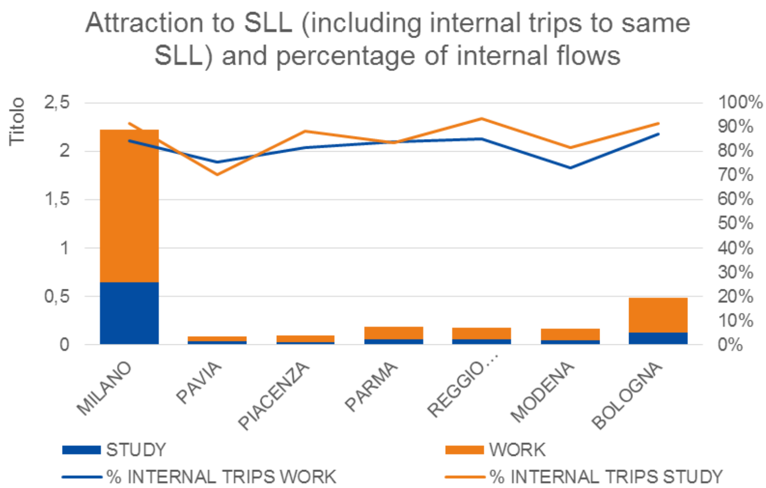
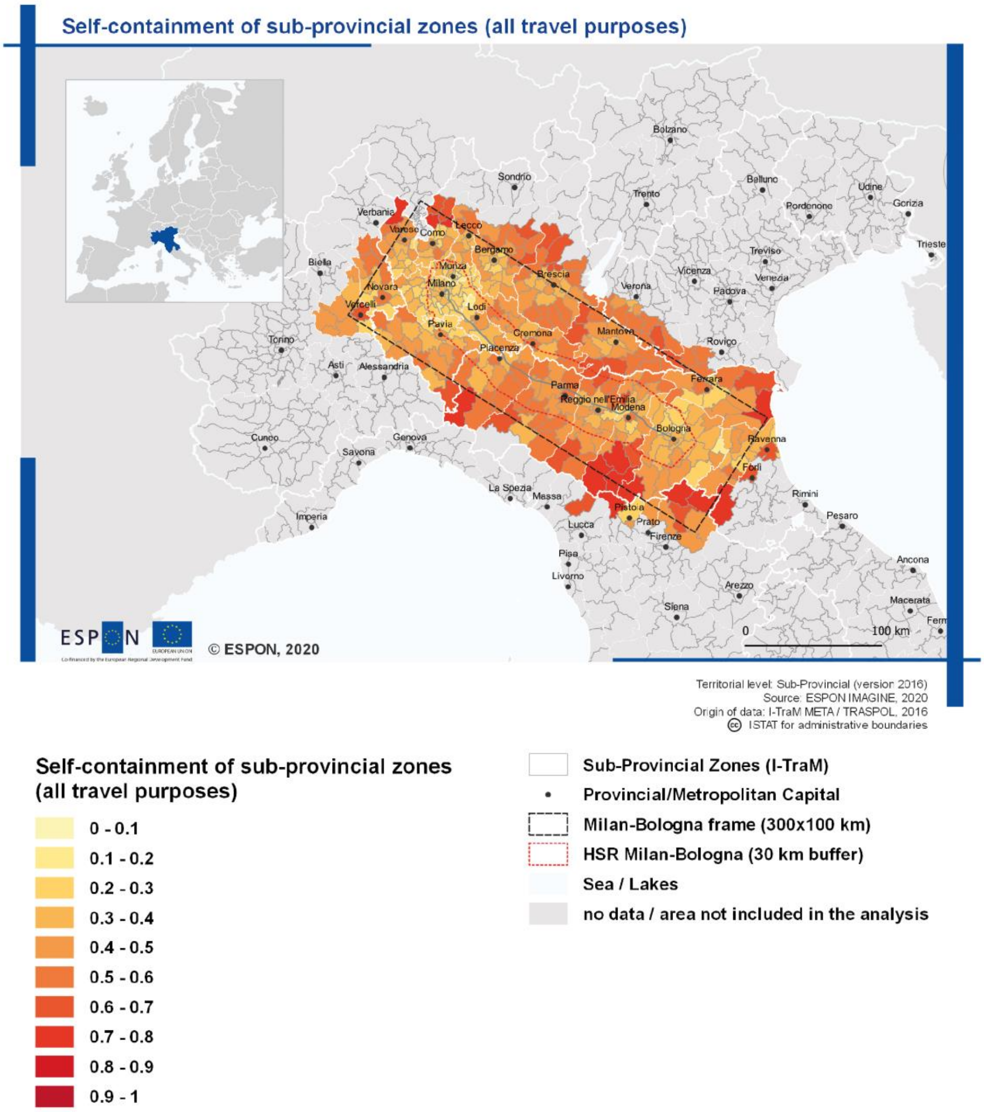


Chart 3 – Attraction to local commuting areas (SLL) and self-containment. Source: elaborations on ISTAT, 2011.



Map 2 – Self-containment of sub-provincial zones (all travel purposes). Source: based on i-TraM matrix 2016

Since mobility is not simply directed to the respective provincial capitals, but it is made of a *continuum* of OD relations, we can map the main attractors and the generators. Map 3 shows both the size of attractors and generators and their signs. Also, in this map, differences among territories appear:

a. Milano (and few of its near satellites) act as a “hoover” of trips;

b. Pavia, Lodi and Piacenza provinces fall into Milano catchment area and are almost always net generators;

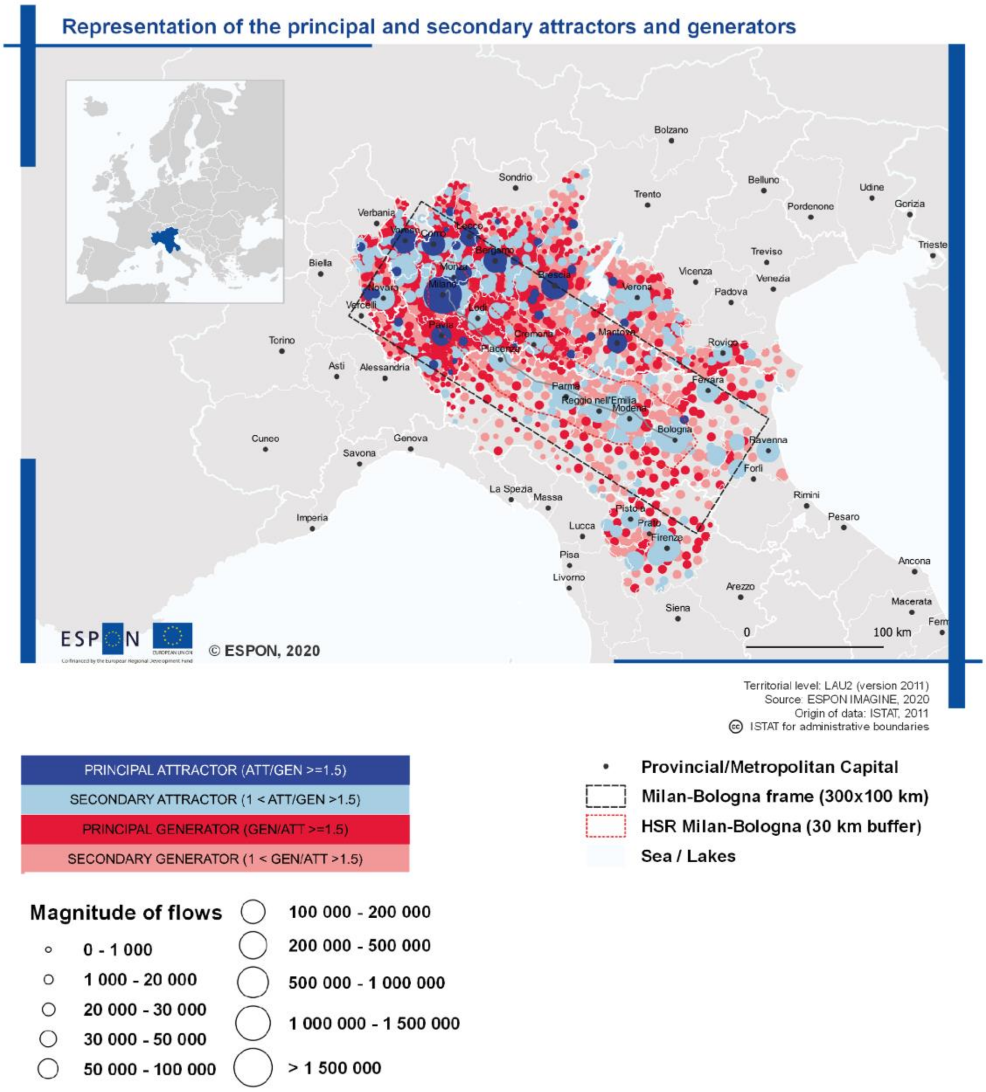
c. South of Piacenza everything is more blurred and mixed: attractors are milder and generators, too. All attractors belong to the Via Emilia or its buffer, which confirms to be the structuring axis of workplaces in the region;

d. Veneto corridor is characterised by a more significant role of provincial capitals (only Verona and Vicenza are part of a more complex system and consequently more similar to the Via Emilia cities). Attractors are more spread and typically belong to small industrial towns.

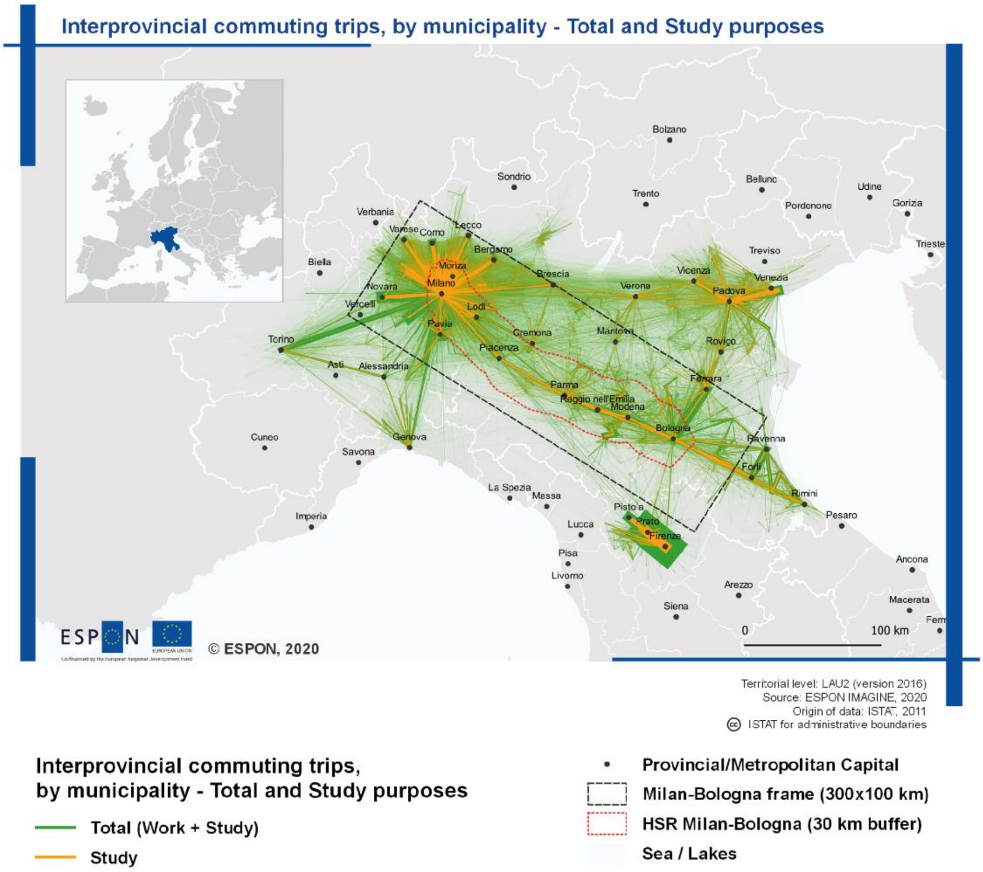
The poles of the corridor are not only the main cities: some significant attractors can also be found in the provinces. Almost all workplaces and relations belong to the corridor's alignment, which is a continuous strip of cities and “countryside”. From the mobility point of view, Lombardia and Veneto – despite the differences – are more adherent to the idea of a city structuring the surroundings and quite limitedly exchanging with other peer cities. In the following sections, we will go more in-depth in the mobility between poles.

Map 4, is also showing an interesting feature. While typically study trips are a fraction of work trips, in Via Emilia, the pattern is different. Study trips are more interprovincial than elsewhere, especially between the main cities of the same order of magnitude of work trips. We have no indication of the type of activity associated with working trips (manufacturing, tertiary, etc.). Still, this evidence on study trips may suggest that the ties between the cities in higher-level activities are relatively stronger than elsewhere.

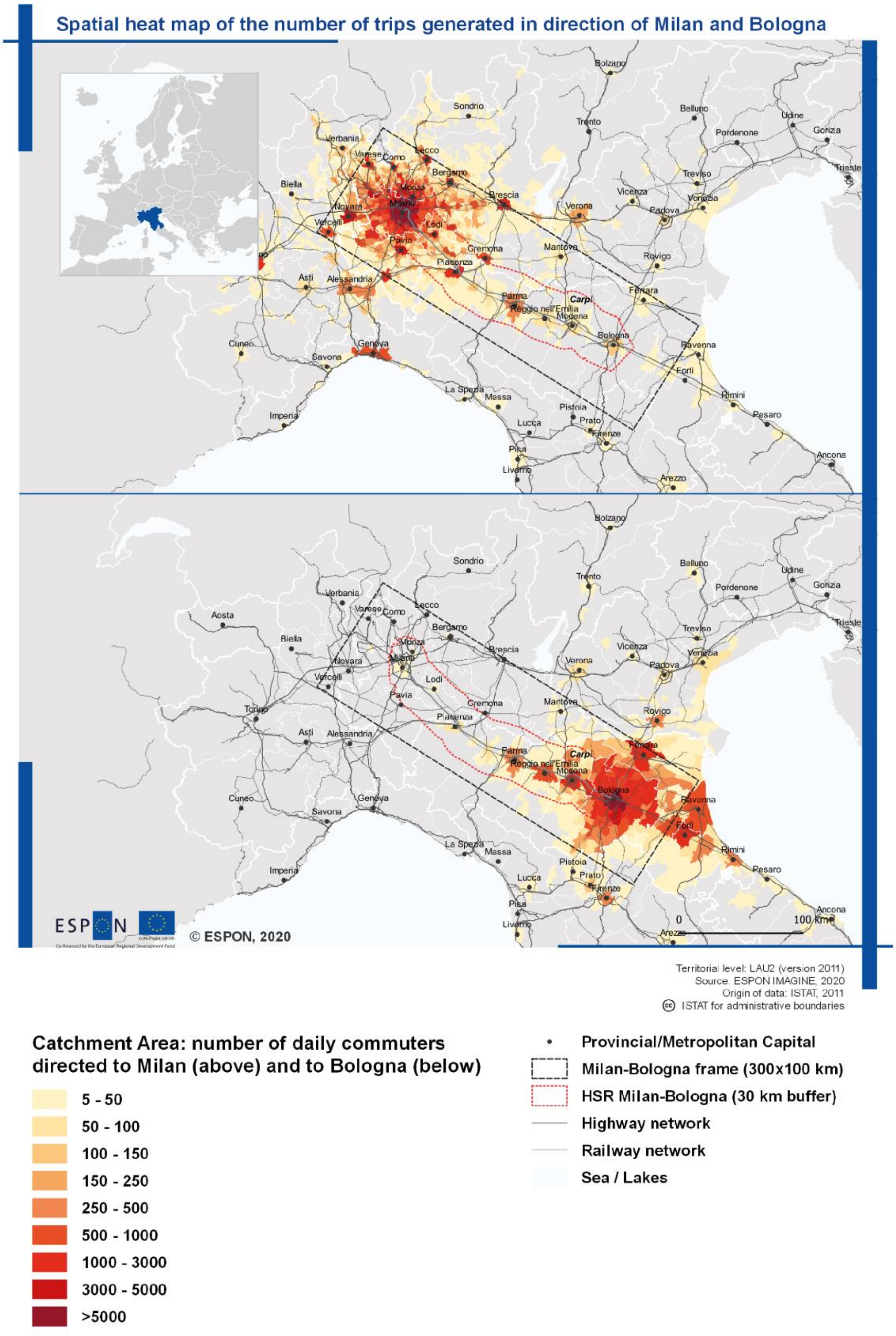
The attraction power of provincial capitals and other poles goes well beyond the provincial borders. Significantly, many of these trips are aligned along the corridor (Map 5).



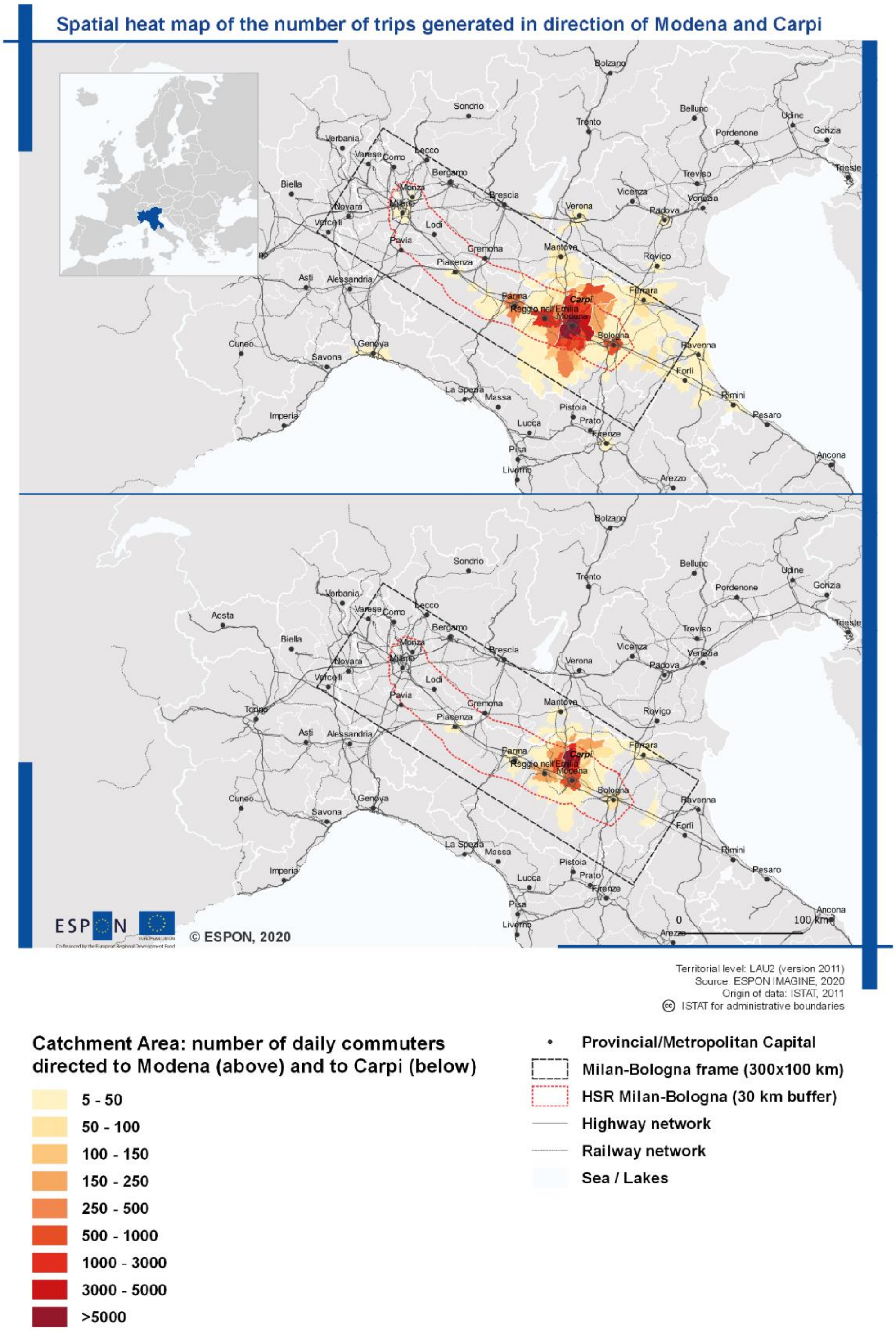
Map 3 – A4 2.4 Map of attractors and generators. Source: based on ISTAT, 2011



Map 4 – Total commuting mobility in the corridor, interprovincial trips between municipalities. Source: based on ISTAT, 2011



Map 5 – Examples of catchment areas of corridor poles: Milano and Bologna. Source: based on ISTAT, 2011.



Map 6 – Examples of catchment areas of corridor poles: Modena and Carpi.

Intercity mobility

As we have seen, the typical pattern made of many local trips directed to the nearest pole and fewer longer trips between poles is made more complex in the area due to the vicinity of poles and their alignment along a highly structured corridor. For this reason, in this section, we go more in-depth in the mobility between provincial capitals.

To do that, we leave the 2011 commuting Census matrix, estimate non-commuting trips (which are important at this scale), and rely on a more recent estimation, possibly embedding the effects of HSR rail investments and regional rail evolution. Figure 8 shows the overall correlation between the simulated interprovincial trips of i-TraM matrix (2016)[6] and the measured (but intrinsically partial) Facebook Movements matrix of January-February 2020 (pre-Covid). Despite the very different genesis of the two data, the fit is perfect except few low-traffic observations. Thanks to this check, we will rely on i-TraM matrix, which is complete, purpose-detailed and more spatially detailed.

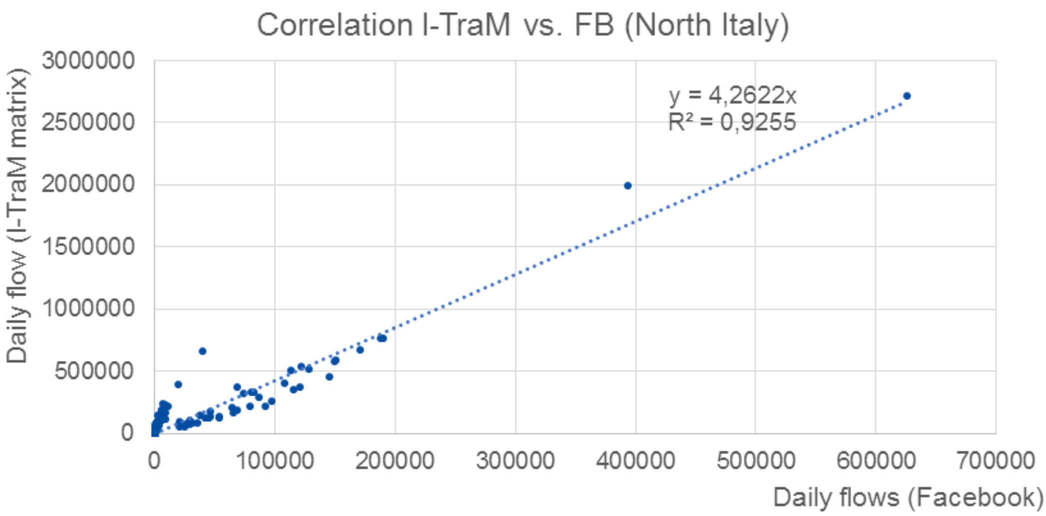


Figure 8 – Correlation between interprovincial trips of i-TraM multipurpose matrix and Facebook Data for Good total users' matrix. The coefficient of the interpolation function is >1 because Facebook matrix refers to FB users only.

A first analysis looks at the distance-decay relation of flows between cities in Northern Italy (Figure 9). To maintain readability, we limited to the 50-220 km range, which includes the Milan – Bologna relation but excludes the shortest pairs where most of the commuting occurs. The correlation shows a good fit with a power function: the trips per inhabitant of the OD pair falls rapidly after 50km – which is the typical range of commuting. If we compare the group of OD pairs of the corridor (Via Emilia provinces, excluding PV, CR) we can see that the mobility is slightly higher than in the remaining areas of Northern Italy, especially for longer pairs. This is again a sign of tighter relations with respect to average peers.

[6] For a general description of i-TraM model and its matrix, please refer to Section 0

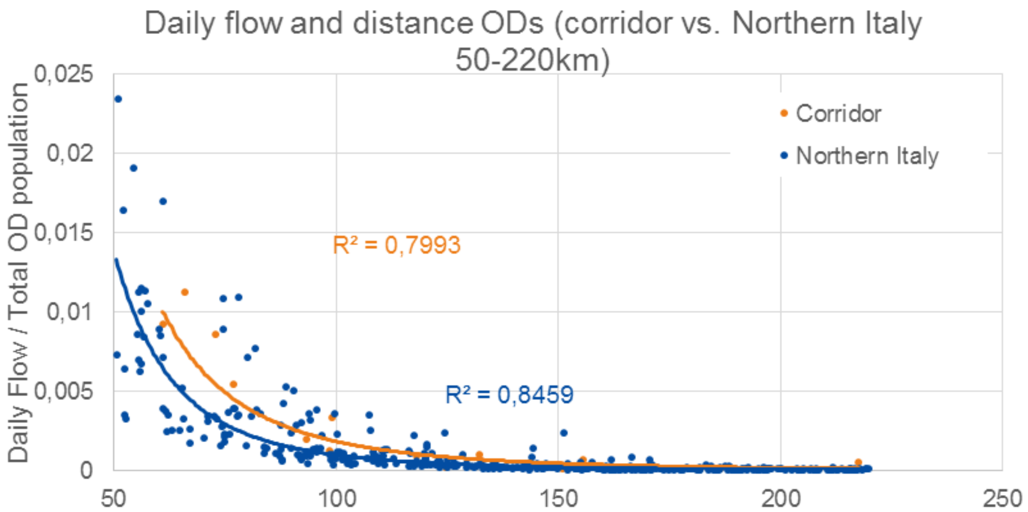


Figure 9 – Relation between distance and trips among cities, in the corridor and in the rest of Northern Italy. Source: elaborations based on i-TraM matrix 2016.

The positive effect of the presence of fast direct train connections can be seen in Figure 10. One series includes only cities served by at least some direct *Frecce* (including Frecciabianca, the conventional market services). Compared with all other city pairs with slow/regional trains only or no direct train connection, the difference is evident, especially in the visualised distance range. Almost all relevant connections belong to the selected group.

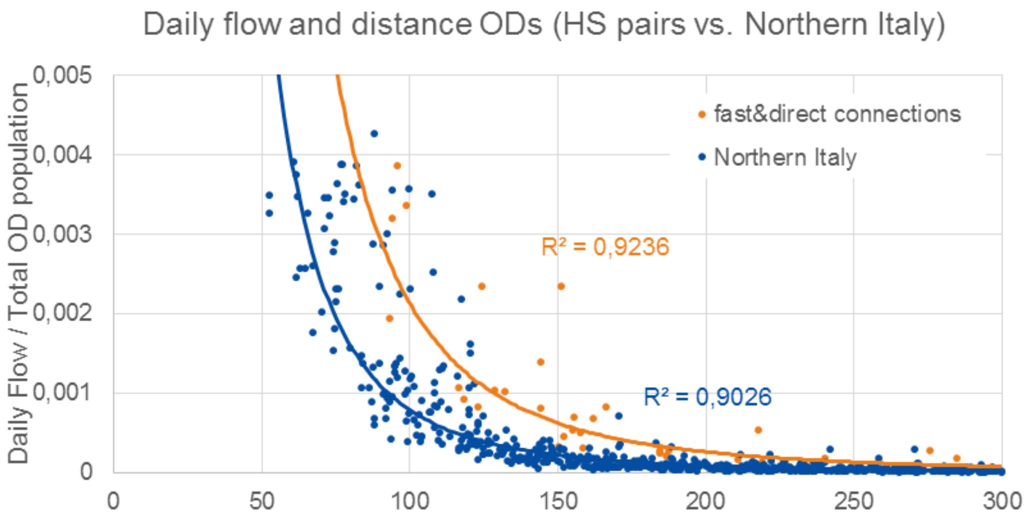


Figure 10 – Relation between distance and trips among cities in Northern Italy. Difference between pairs directly connected with fast trains and others. Source: elaborations based on i-TraM matrix 2016.

Limiting to the range of distance of the Milan-Bologna (180-220km), we can verify (Figure 11) that the pair is, by far, the most important of the group, with mobility 5 times higher than the average. The two other pairs in the range (Milano – Modena and Lodi – Bologna) stand above the average. On the contrary, we can see that all pairs connecting the Via Emilia cities with the area north of Milan are systematically below the average of peers. We can suppose that the scarce public transport connections and the "barrier effect" of Milano limit the creation of ties between the areas. A similar exercise for the distance range of Parma – Bologna (70-110 km, Figure 12) shows that the specificity of the corridor is more limited, while the "barrier effect" of Milano remains.

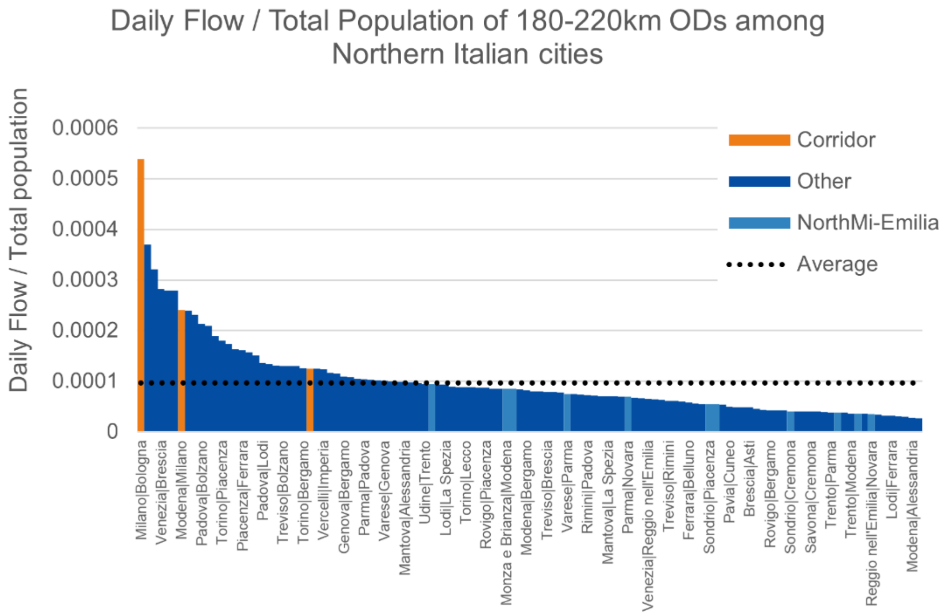


Figure 11 – Trips per capita, city pairs in Northern Italy, distance 180-220km. Source: elaborations based on i-TraM matrix 2016.

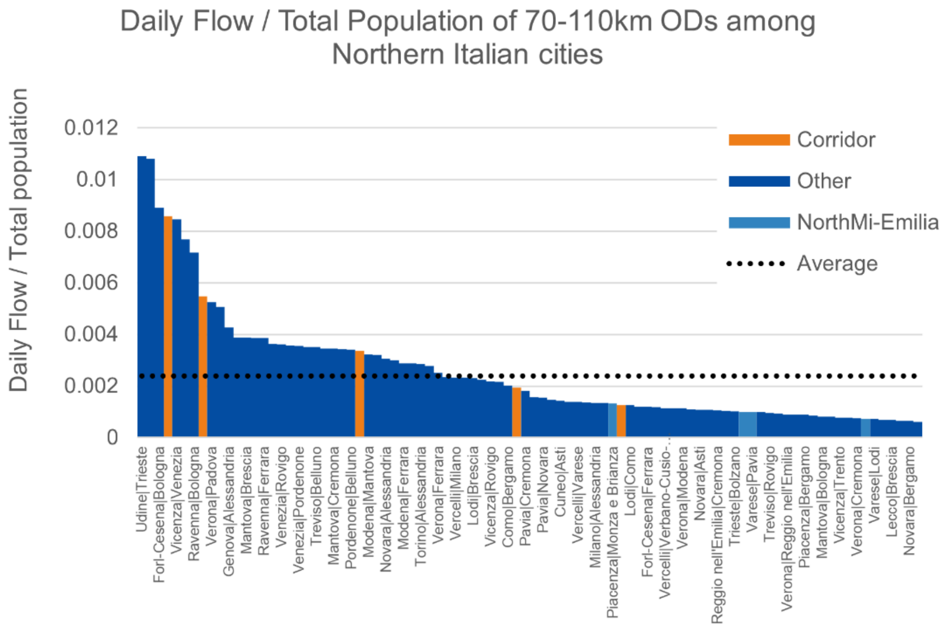


Figure 12 – Trips per capita, city pairs in Northern Italy, distance 70-110km. Source: elaborations based on i-TraM matrix 2016.

The overall picture of the intercity mobility in the area and in the Corridor can be seen in Map 7. Having removed the local trips from the province to the cities, visible in Map 4, the effect is a clear definition of the main corridors: Milan-Bologna, Milano-Venezia, Venezia-Bologna, Milano-Torino, and its southern version Milano-Alessandria-Torino. The corridors are very similar in population size (all cities count for about 1M plus Milano except Venezia-Bologna, counting 1M in total), but not in the urban structure. To give a weight of each corridor in terms of estimated trips/day, we summed up all internal OD pairs (i.e. excluding pairs originated or destinated beyond the corridor itself, such as Rimini-Milano).[7] Interestingly, the Milano – Bologna corridor is by far the most important, in absolute and relative terms. This is not due to the extremity trips (Milan-Bologna is as low as 1/5 of Milano-Torino), but to the number of cities and to the strength of ties among them. The opposite case is the Milano-Torino, where the intermediate cities (Novara and Vercelli) are smaller and less dynamic than their corresponding Emilian version, resulting in shallow figures (except Novara-Milano). Again, the Milano- Venezia corridor is the one that presents the most similarities, being made of mid-sized cities (almost perfectly matching with those of the Milan-Bologna). Still, the intercity flows involved are significantly smaller.

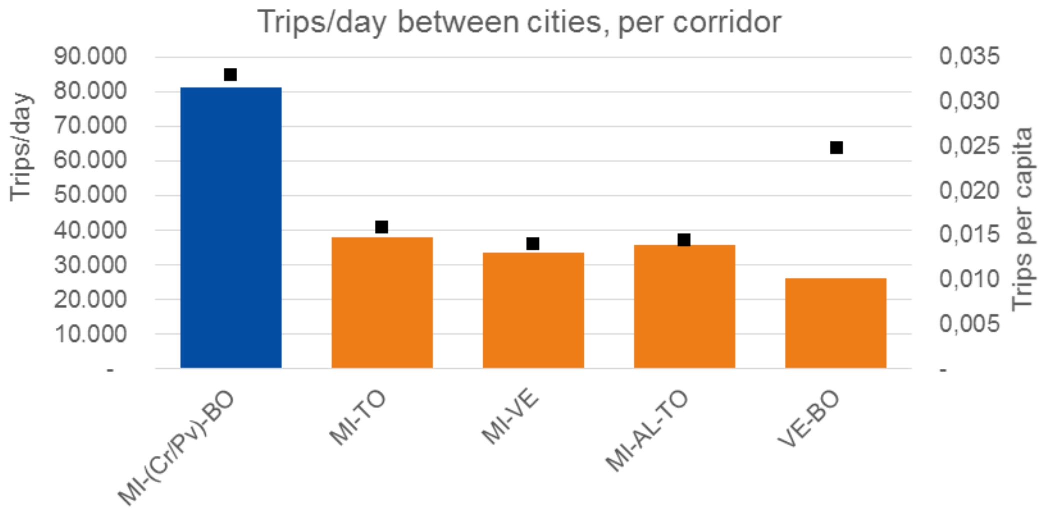


Chart 4 – Estimated trips per day in each corridor, year 2016. (MI: Milano, Cr: Cremona, Pv: Pavia, BO: Bologna, TO: Torino, VE: Venezia, AL: Alessandria). Source: elaborations based on i-TraM matrix 2016.

It is difficult to compare the different corridors in time, to point out an effect of the HS line. The sources used are entirely different (2011 OD refers to declared working trips, 2020 FB matrix refers to measured total trips). We tried to qualitatively compare the main Italian mid-distance OD pairs by normalising the 2011 and the 2020 data on one route, which we chose to be the Milano-Verona (the flows measured are in the middle of the list, and no significant changes occurred in the network). Then, in Chart 5, we compare routes according to their ratio with the Milano-Verona.

Some routes shrank significantly (which means that they were more crowded than the Milano-Verona in 2011 and now are less crowded). Except for the Bologna-Firenze, they all belong to the triangle Torino-Milano-Genova.[8] The relations between Milano and Veneto grew similarly to Milano-Verona. The other pairs served by the HS line grew, some very significantly (e.g., Firenze-Roma). The couple Bologna-Milano belongs to this group, even if the relative growth is not the largest. But, remarkably, it outstands the comparable Milano-Torino, suggesting that ties tightened.

In absolute terms, the size of the Milano-Torino OD is, in 2011, more significant than the Milan-Bologna (31% of it). It represents a well-established relation, with some historical commuting and economic ties. Instead, the Milan-Bologna OD is much smaller but grew, reaching in 2020 data the 37% of the Milano-Torino.

[7] Milano-Pavia is included in the Milano-Alessandria-Torino; Cremona and Pavia are included in the Milan-Bologna corridor only southwards (not towards Milano, since they use other infrastructure); Venezia-Padova is in the Milano-Venezia and not Venezia-Bologna. In all cases Monza was excluded by the calculations, despite it is few km far from Milano, but connected only via regional train.

[8] The Bologna-Firenze was one of the most benefited by the HS in terms of travel time. But cheap regional trains completely disappeared, which means that commuting now is entirely using the HS services, much more expensive).

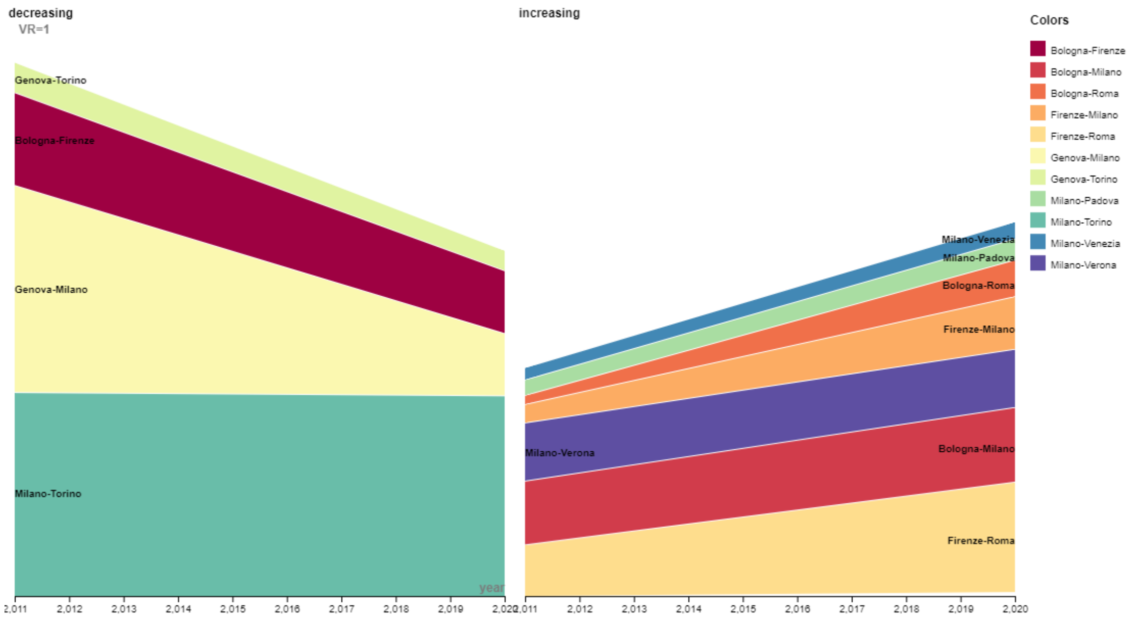
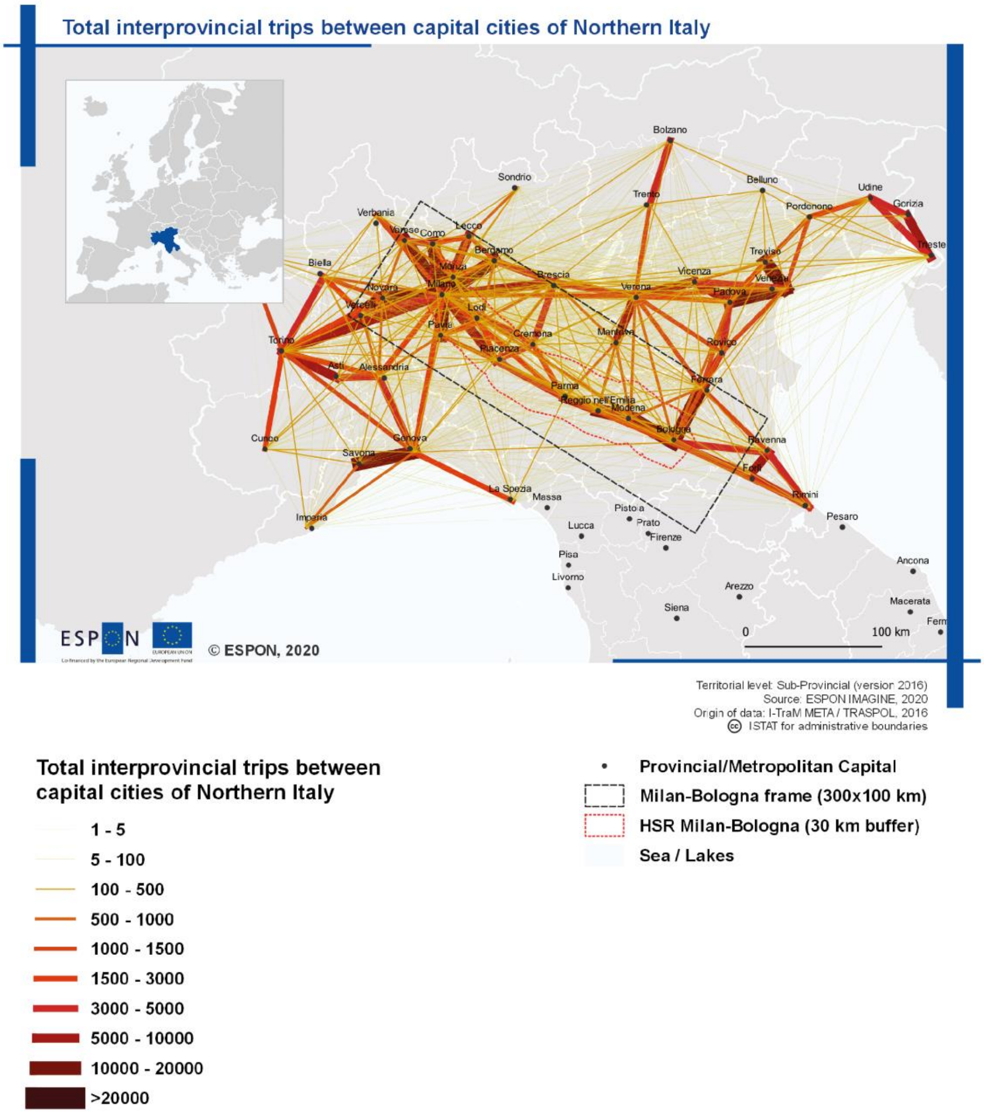


Chart 5 – Qualitative comparison between mid-distance OD routes in Central-Northern Italy. Source: ISTAT SLL 2011 and Facebook 2020 flows normalised on the Milano-Verona=1. Chart made with RAWGraphs.



Map 7 – A4 2.6 Interprovincial trips within Northern Italy, all purposes. Source: based on i-TraM matrix 2016.

The role of public transport

The picture above described refers to the totality of trips, whatever is the mode used. Private transport remains the dominant mode at the regional scale, but locally or for some types of trips, active, or public transportation may become relevant. In this section, we will discuss the role of public transport in the corridor.

Public vs. private transport

Overall modal shares for non-local trips[9] in Northern Italy are relatively similar, with public transport ranging from 5% to less than 20%. The only two exceptions are Monza and Milano, both above 20% and both clear outliers. Genova and Bolzano, for different reasons (orography and policies), occupy second place, with 16-17%. The remaining areas stay, on average, below 10%. In this sense, the provinces of the study areas are perfectly on average, the lowest being Modena (6.6%) and the highest Pavia (12%) due to the relation with Milano.

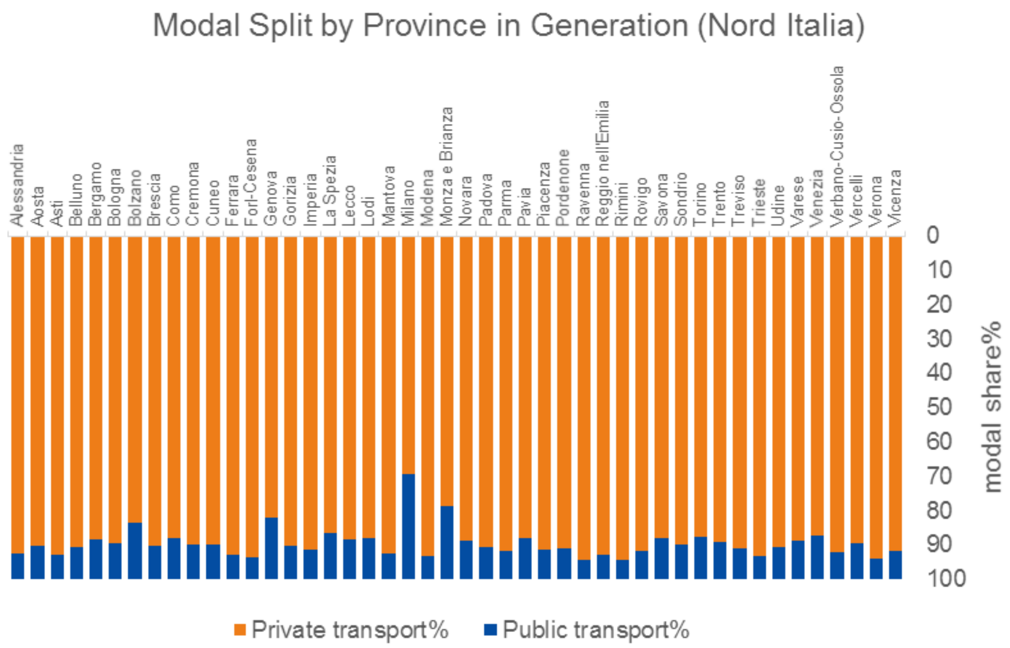


Chart 6 – Modal split by Northern Italian provinces, generated trips. Source: elaborations based on i-TraM matrix 2016.

We can have a picture of the changes over time using the 2011 ISTAT matrix, limiting the analysis to commuting trips. According to Chart 7, car dependency increases in the twenty years, while most of the growth occurred between 1991 and 2001. Interestingly, the Città Metropolitana di Milano is not an exception in this trend. Still, we can notice that in 2011 it is the only province slightly lower than in 2001, probably due to public transport and car restriction policies implemented here before than elsewhere.

Luckily, the picture changes if we refer to the cities instead of the entire provinces (Chart 8). After 2001 public transport regained role. The higher growth (again) in Milano, but this time also in Bologna. There, public transport in origin reaches shares of 25%, which is even more significant considering the absence of mass transit (just buses). As attractors, the percentage of public transport rises to nearly 50% of systematic trips to Milano with Pavia and Bologna at the second place around 30%.

[9] Here we account for trips going out of the zone of the matrix, corresponding to NUTS-5 size.

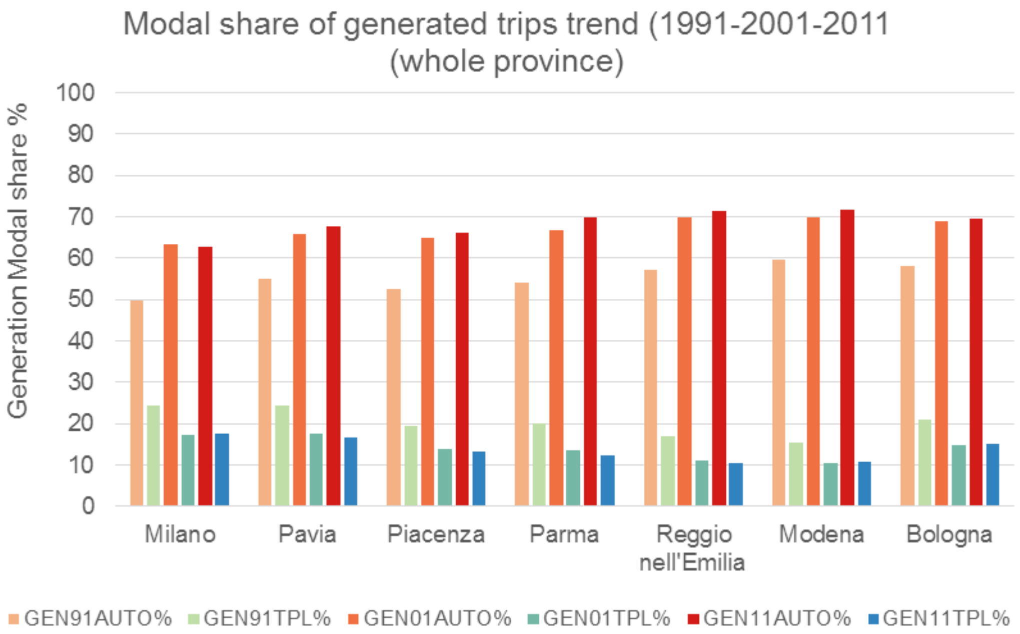


Chart 7 – Modal share of generated trips, by province. Source: based on ISTAT, 1991, 2001, 2011.

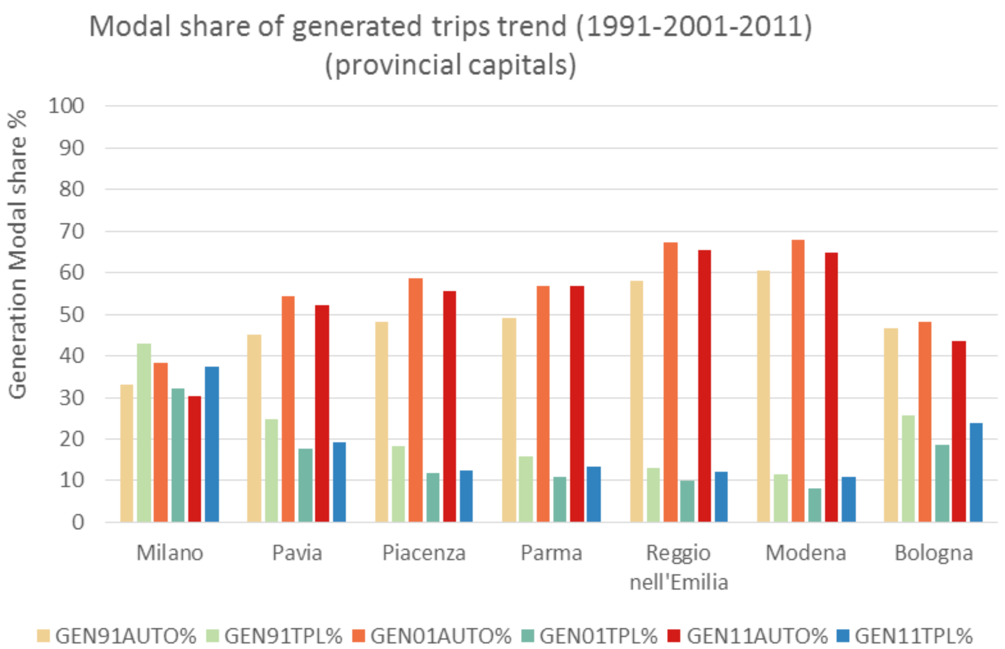


Chart 8 – Modal share of generated trips, by cities. Source: based on ISTAT, 1991, 2001, 2011.

Rail transport

The above figures refer to the entire public transport. Rail plays a much more limited role, for various reasons: reduced territorial coverage, land use regulation, a smaller share of non-urban trips, lack of proactive support of policies until the recent years, poor quality. So, the scope of rail shrinks to specific niches, the main one being the access to Milano.

This fact can be seen clearly in Map 8 (bus+rail) and Map 9 (rail only), interprovincial flows of public transport are almost invisible, and rail is concentrated around larger cities. Milano is leading, with Torino, Padova-Venezia and Genova and Bologna following.

In contrast with what we observed about total mobility, public transport and rail mobility in the corridor Milan-Bologna are limited, which means that people mostly move by car. Other similar corridors perform even worse (see Milano-Venice in Map 9), but this is not a merit. Overall, Northern Italy confirms that rail transport is used just to access larger cities from the periphery, not to move between cities.

Also the trend is not comfortable (Map 9): almost all rail commuting flows reduced since 1991, including along the corridor, and the areas of increase are just Milano and (out of our scope) Firenze, plus some directions around Torino, Trento and Pisa. Not surprisingly, Firenze is, together with Milano, one of the few areas where during the 2000s rail services were reorganised and improved: Milano with the suburban system, Firenze as the centre of “Memorario”, a regular interval timetable for fast regional trains (but not for suburban ones, which do not grow).

In conclusion, we focus on longer distance trips, including occasional mobility. To do that, we refer to i-TraM matrix 2016 and consider only the trips between provincial capitals aggregated by corridor (Chart 9). In terms of overall mobility per capita, the corridor is the largest in Northern Italy. However, the share of public transport (namely train, in this case) is the lowest. This is particularly problematic because we observe the worst result, despite the corridor hosts probably the best conditions for rail transport in the area;

i) a lot of intercity demand;

ii) mid-sized and compact cities aligned at some dozens of km each other.

iii) stations well located in the urban tissue.

iv) limited sprawl in a countryside highly productive for agriculture

v) a rail infrastructure with high performances, almost free of long-distance transport.

This fact suggests a mismatch between the demand and the supply in the corridor, particularly the scarcity and ineffectiveness of RegioExpress trains, which best suit occasional intercity mobility on such distances. Long-distance services, such as HS ones, are unadapted because they are more expensive and require to be booked in advance, which is unrealistic for 50-100 km trips. Existing RegioExpress are not particularly frequent and, moreover, relatively slow and irregular along the day. For a detailed analysis see section 0.

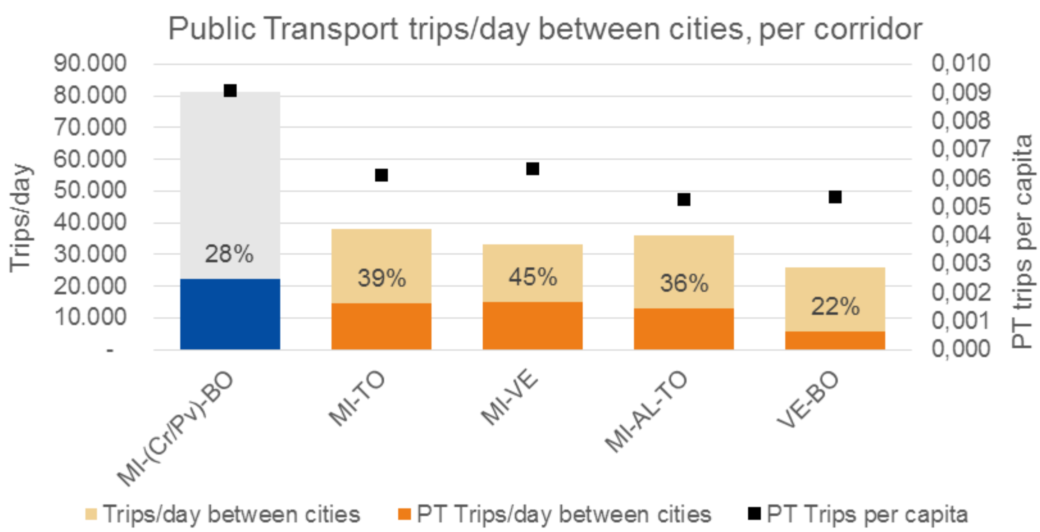
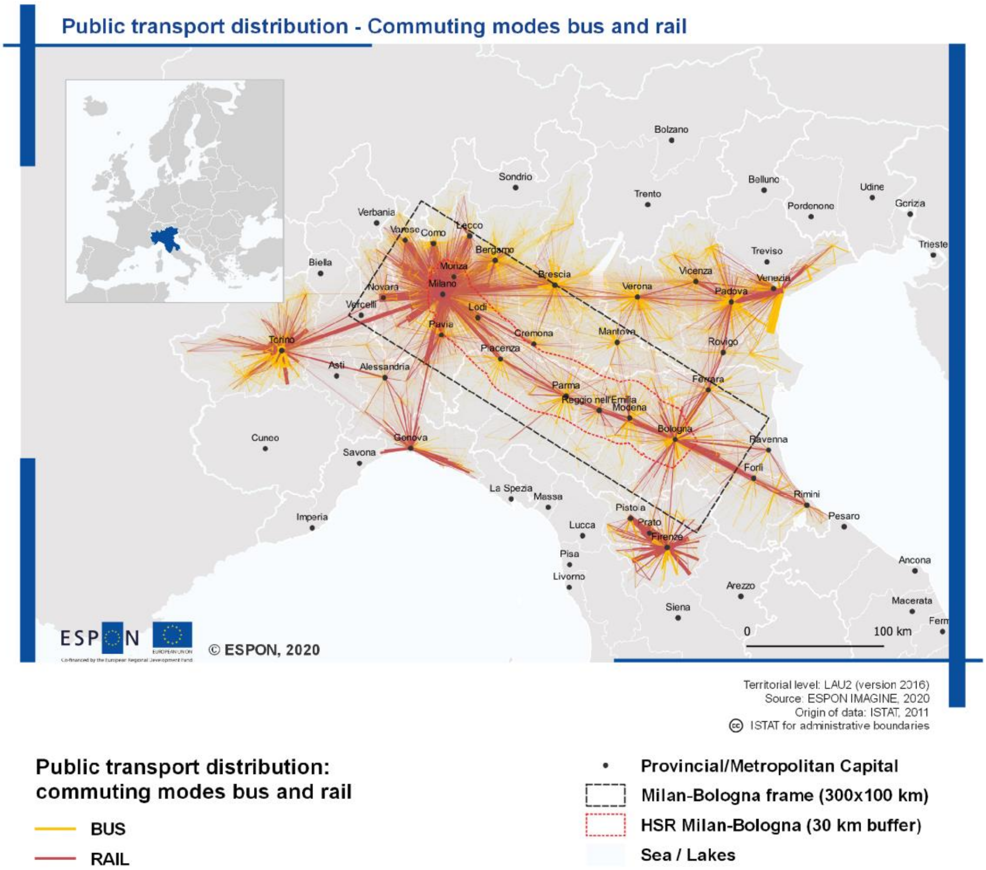
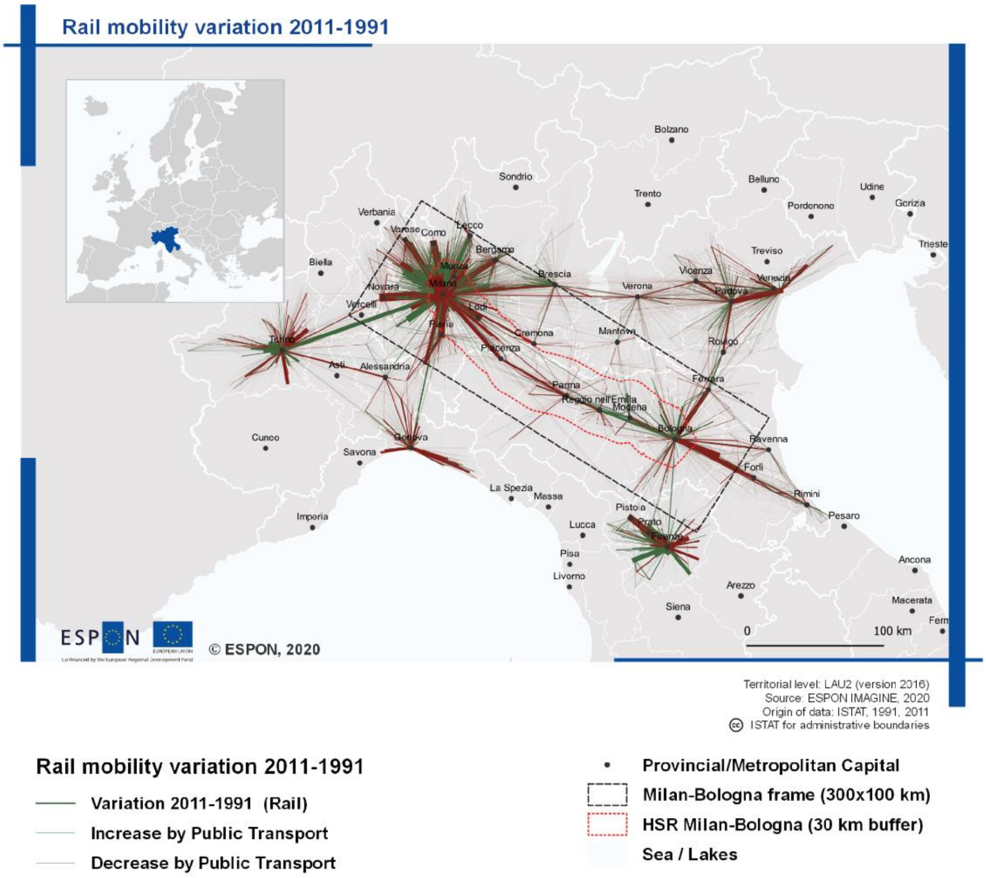


Chart 9 – Estimated trips per day in each corridor by public transport. Year 2016. (MI: Milano, Cr: Cremona, Pv: Pavia, BO: Bologna, TO: Torino, VE: Venezia, AL: Alessandria). Source: elaborations based on i-TraM matrix 2016.



Map 8 – Public transport distribution, commuting modes bus and rail, 2011. Source: based on ISTAT, 2011.



Map 9 – Rail mobility, commuting modes: number of trips (size) and variation 1991 – 2011 (color). Source: based on ISTAT, 2011.

Regional rail passengers at stations

To complete the picture, we mapped the average number of train users per station. The figures are measured through periodical surveys (see 0 for an introduction) and represent the measurable outcome of the mobility patterns described above. In Figure 14 we can appreciate the distribution of passengers on the line Milan-Bologna and secondary lines connected with it. In the picture, we recognize the different areas of influence and, indirectly, the types of services.

Around Milano, for 30-40 km, users are many and station coverage is dense. It is the area of *suburban services*, progressively introduced since 1998 (see 0 for a description) and nowadays almost complete. On the line of interest, such services end in Lodi. Despite the problems of reliability and quality of rolling stock, the Suburban system in Milano gained many passengers since its introduction. Today, it has a vital role in connecting the hinterland to the metropolis. A similar system is under development in Bologna (see Section 0): stations are similarly dense, even if traffic figures are not comparable.

In between, the Milan-Bologna line is served mainly by *RegioExpress* trains, calling at main stations. Here the figures on passengers tell a different story. Stations are less dense, and there is a considerable difference between primary and secondary stations, much more than anywhere else. In a significant number, we see passengers practically only at main cities and towns (the capitals, plus Codogno, Casalpusterlengo and Fidenza). Other stations exist, but they are almost empty. Again, the polarization of the territory comes up: few and large centers divided by agricultural countryside, where a train is just passing through.

It is interesting to see how the picture changes over the years. Unfortunately, older data are available only for Emilia Romagna (2010) and thus, the comparison is limited to that but still revealing (Figure 13). On the map, we see that many stations lost passengers, some significantly. Some were also closed to service, especially in Parma and Piacenza provinces. We see two areas of passengers' growth: the suburban service of Bologna (the same happened in Milan, out of the map) and some stations of the main line.

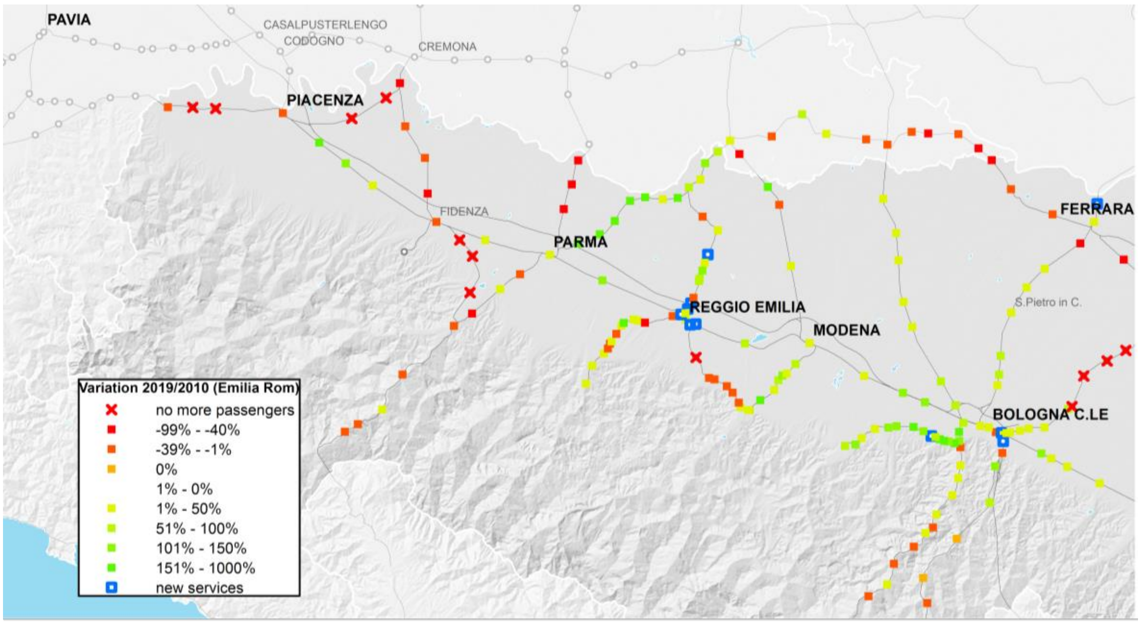


Figure 13 – Changes in regional rail passengers 2019-2010, per station. Source: elaborations on regional data.

We have the evidence of a progressive polarization of the demand again: more passengers and growth around and between the cores, fewer passengers far from the core-areas but also in intermediate areas, such as Piacenza, Cremona, Fidenza. This effect is a downward (and upward) spiral between decreasing demand and reducing supply (and the opposite in prosperous areas). The absolute decline cannot be attributed to a primary will of the planner to abandon areas, but to the natural contraction of unsuccessful services, often for territorial reasons (sprawl, unconstrained car use, low density). What can instead be said is that, in the decade and areas of analysis, the planner has invested (many) additional resources in core areas, and not everywhere, obtaining the described picture.

A final comment is related to the demand on the lines other than the main one. Numbers are lower on most lines connecting smaller localities with smaller cities, with the noticeable exception of lines to Bologna. One cannot expect that Piacenza has the same attraction capacity as Bologna, but in the entire area between Parma, Pavia, and Cremona, secondary lines are empty. Probably a different model, not focused on slow trains with frequent stops in all stations, but concentrating on major pairs, could perform better.

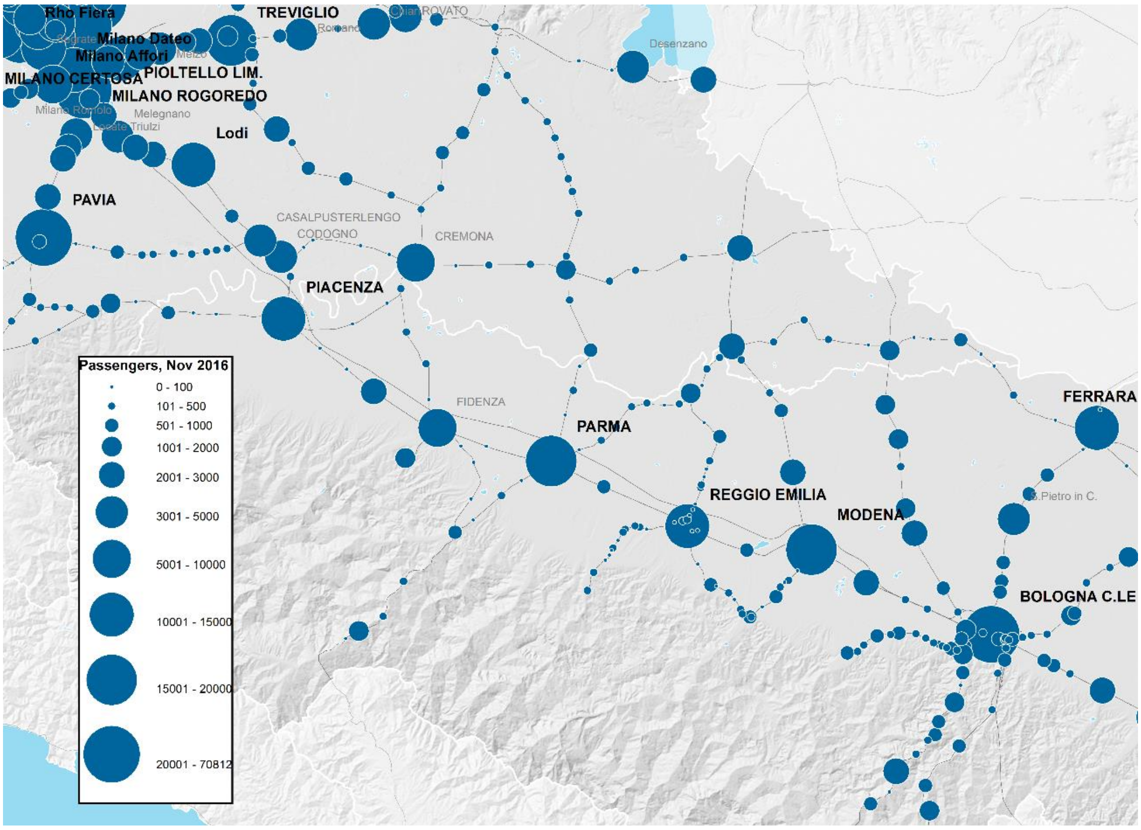


Figure 14 – Map of regional rail passengers, per station. Year 2016. Source: elaborations on regional data.

Focus: international mobility

The estimation of international mobility to/from the corridor is more complex due to the limitedness of data. We refer to three existing sources:

1. The Regione Lombardia Origin-Destination matrix 2020 can provide a good multipurpose picture of land mobility to Switzerland, thanks to the fact that most of the trips must pass through the region.
2. The *Banca d'Italia* (Bank of Italy) survey at country borders (1997-2017) can give indications on the visited destinations of international tourists.
3. The *Facebook Social Connectedness Index* (2017), is not providing any information about mobility but of international social links from one region.

The first source is a complete simulated daily matrix consisting of various modes and travel purposes. The detail is provincial for the provinces neighbouring Regione Lombardia, regional for the rest of Italy. Switzerland is more detailed in Ticino and less for the other cantons. We considered all trips to Switzerland and divided the origins into three relevant groups: Milano alone, the provinces of the Via Emilia corridor including Pavia, and the provinces and regions south of Bologna that must transit from the corridor to Switzerland. Other areas of the country are excluded because not necessarily passing through the corridor (e.g. Sicily) or because not departing from the corridor and/or through Lombardia (e.g., Veneto and Piedmont, respectively).

Table 1 – Daily flows directed to Switzerland. Source: our elaborations on Regione Lombardia 2016 OD matrix

	1-way Trips/day	of which by train	of which business
Flows Milan - Switzerland	5 904	2 059 (35%)	947 (16%)
Flows from the cities of the corridor to Switzerland	736	163 (22%)	35 (5%)
Flows to Switzerland in transit through the corridor	2 500	797 (32%)	78 (3%)

The resulting picture is in Table 1. Among the considered areas, Milano is the primary generator of flows due to its proximity, role, and historical relation, especially with the Ticino canton. The cities of the corridor, including Bologna, generate 736 trips/day while the remaining provinces that geographically must pass through the Via Emilia 2500 trips/day (of these, the majority remains in the Emilia-Romagna region, see below). From the modal point of view, train has a relevant share of these trips, ranging from 35% of Milano to the 22% of the Corridor. The lack of direct connections south of Milano contributes to this fact, but the modal share remains significant. Milano sees 16% of business trips in terms of travel purpose, while for the rest of Italy, the percentage falls to a single-digit number. The Corridor has a 5% share, which is higher than the southern connections, but still limited.

Normalising the flows with the population (Figure 15), we better visualise the level of ties between areas and Switzerland.

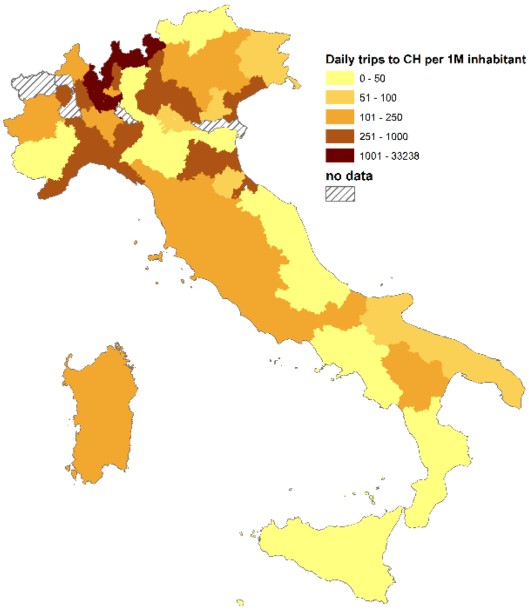


Figure 15 – Daily trips to Switzerland via Lombardy per 1M inhabitants. Source: our elaborations on Regione Lombardia 2016 OD matrix.

As expected, the relations between the border provinces of Como, Varese and Sondrio are out of scale due to the massive presence of commuting flows and the limited distance. Again, Milano is the only city with a relevant density of flows for the mentioned regions. The central provinces of the Corridor stand in the lowest range and just Bologna and Piacenza count for about 300 trips/day per million inhabitants. This is an indicator that ties to the neighbouring country are relatively low.

The Bank of Italy database provides continuous microdata since 1997 concerning the incoming and outgoing trips measured at national borders. Graphs of Chart 10 present the total numbers. Clearly, Milan is out of scale with respect to other provinces. Its size and role and its commuting relationships with Switzerland generate flows that are ten times those of Bologna. What is, however, interesting is that Bologna followed an even better trend (+127% Bologna vs. +59% Milano). Chart 11 clarifies how much the provincial capital is contributing to the total of the province. Again, Milano and Bologna have the highest values (decreasing in the very last years).

In general, all provinces grew in attractiveness (Parma and Lodi the most, Cremona and Pavia the least), obviously with numbers related to their size. There is no evidence that since the period 2008-2009, the trend changed (except Modena, with no evidence that there is a causality), which suggests that the HSR line did not change the incoming trips. This is not surprising due to the national focus of HSR network and services and the corresponding air transport growth until the COVID crisis.

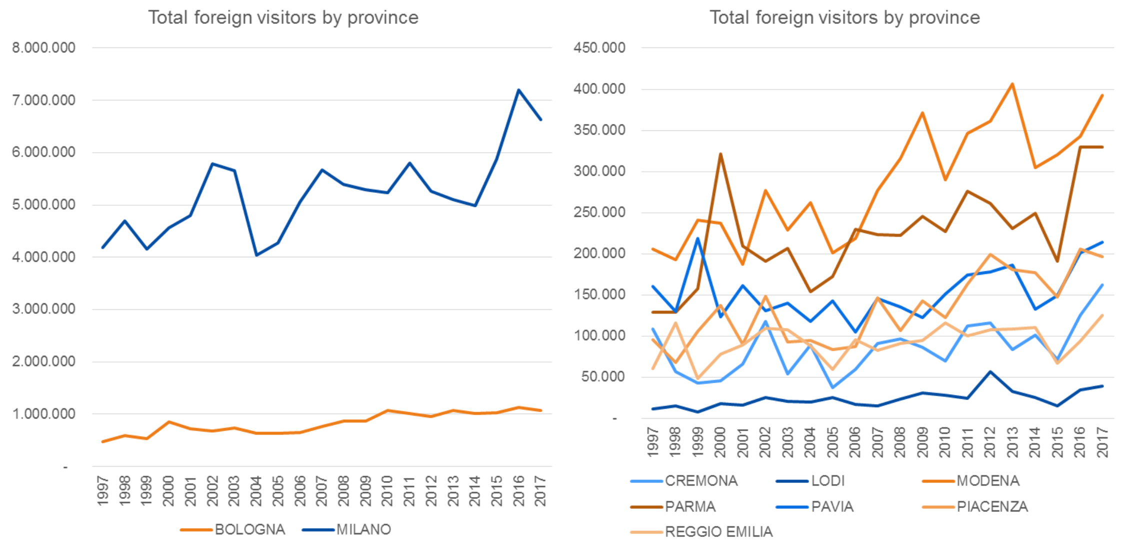


Chart 10 – Total yearly foreign visitors by province, 1997-2017.

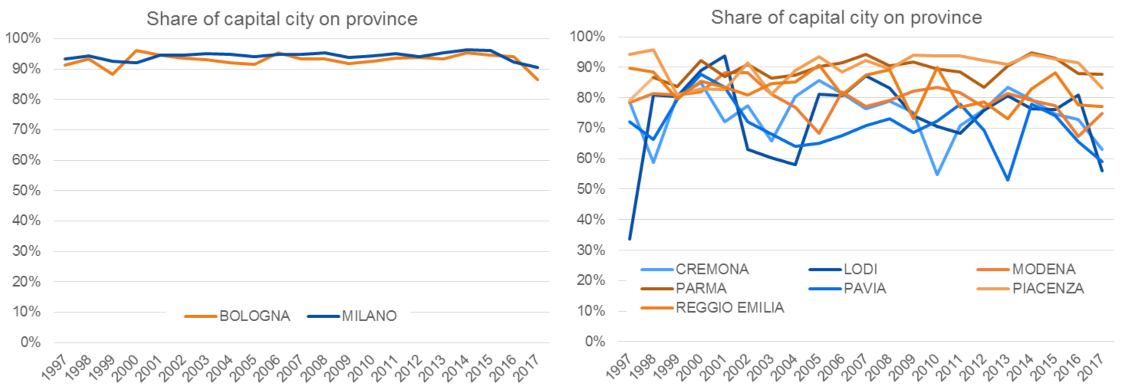


Chart 11 – Share of provincial capital foreign visitors over total provincial visitors, 1997-2017.

A further indication of the international relations between the Corridor and the rest of Europe can be obtained from the Facebook Social Connectedness Index (Bailey, Cao, Kuchler, Stroebel, and Wong, 2018). The Index is provided globally by the Facebook Data for Good programme and is computed as follows.

$$Social\ Connectedness_{i,j} = \frac{FB\_Connections_{i,j}}{FB\_Users_i * FB\_Users_j}$$

Basically, it is a relative measure of social media connections between two NUTS3 regions, weighted by the two populations. The denominator of the formula represents the total possible connections between the two populations of regions *i* and *j*. The numerator, instead, is the actual number of connections. The obtained ratio is then normalised.

The weighting and the normalisation make the measures incomparable if referred to different provinces, but only "internally". For example, we map the relations of Milano, Piacenza, and Reggio Emilia and the intensity in the three obtained maps of – say – London means how much London relates to each of the three cities, with respect to the other areas of the world.

The SCI is clearly neither a measure of trips nor of real connections, but only of "virtual" connections. Consequently, we can imagine the maps as the sum of different phenomena, not reciprocally separable:

- The "real" connections, for example, business connections (e.g., with Switzerland neighbouring cantons)
- The places of holiday (e.g., the Red Sea areas or European coasts)
- The places of emigration and immigration (e.g., Romania)

- The "ideal" places (e.g., fashion capitals are connected because of brands headquarters are located there).

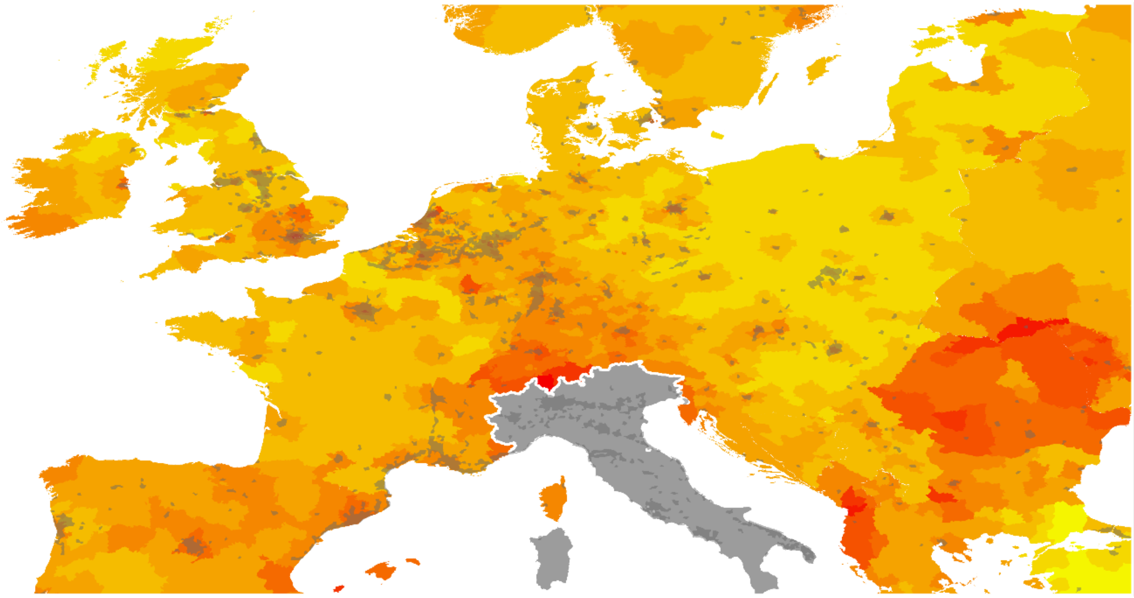


Figure 16 – Social Connected Index of Milano. Source: our elaborations on Facebook data

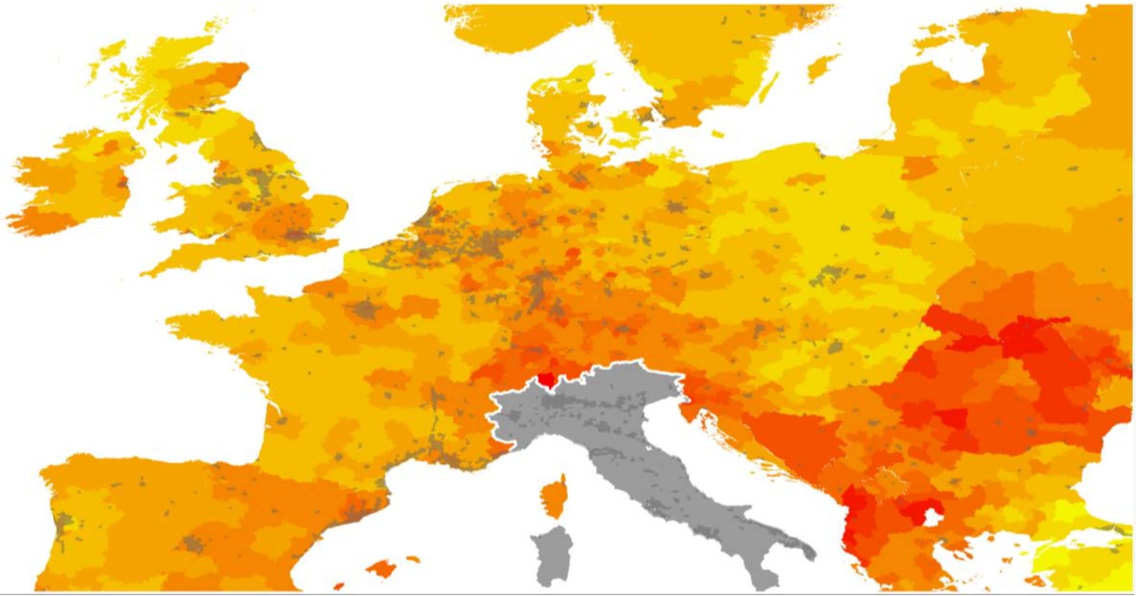


Figure 17 – Social Connected Index of Piacenza. Source: our elaborations on Facebook data

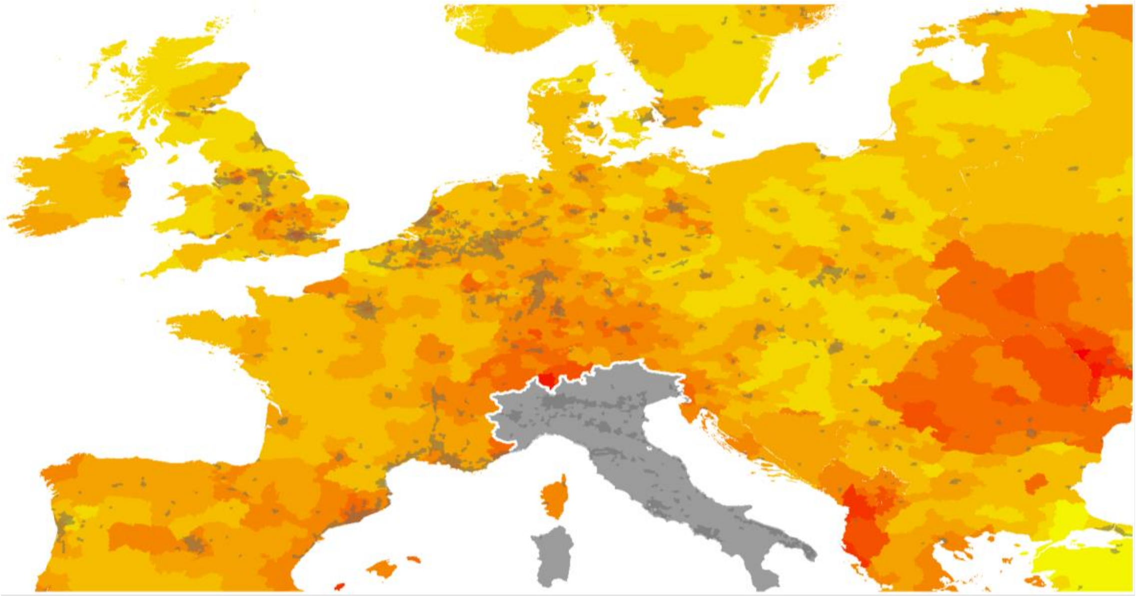


Figure 18 – Social Connected Index of Reggio Emilia. Source: our elaborations on Facebook data

Keeping in mind all of these biases, the previous maps show that proximity is not the first determinant of relations, for example, looking at differences between France and Germany. Urbanity is a driver, but not all urban areas show similar links, see, for example, central England, very populated but with few relations with Italy. Cities and capitals are instead strictly linked, also the far ones. Overall, the area with the continuous tight link with northern Italian cities is Germany and Benelux. Interestingly enough, the closer relations of Bologna and Milano with Cambridge, presumably due to the university relations. Also, it is visible the tighter ties of Italian cities with Spain than with French provinces, excluding the main cities.

On a broader scale, the places of emigration and those of holiday pop up. Places like Rumania, Albania or central Morocco (not visible) belong to the first group, while Sinai (not visible) or Greek Islands to the second.

The supply of transport services

Data sources

This chapter will use public and proprietary data related to all aspects of public transport supply in the study area.

Section 0 will primarily refer to official rail timetables up to 2020. Available years are 2008 (which is significant because representing the pre-HSR situation), 2011 (before the start of competition in HSR lines), and 2013-2020 excluding 2017 (not available). Timetables refer to the entire RFI network, including those also using the regional networks, international trains and of course also .Italo. Trenord is entirely included except for the Brescia-Edolo line, which is out of the study area. The timetable allows to compute the commercial speed of services, their frequency and map the connected stations. It is also possible to calculate an indicator of accessibility to rail services (as in Section 0).

Data of Section 0 entirely comes from four detailed surveys conducted in 2014, 2015, 2016, 2018 for the municipality of Reggio Emilia (META, 2014, 2015, 2016, 2018). These studies are original and summarised here for the first time.

Finally, Section 0 takes advantage of three databases related to railway and coach prices. The first one is based on a large dataset of observations collected directly through booking simulations, including all categories of rail prices (classes, levels) on the Milan-Bologna route for three years, from November 2016 to the November 2019 (Beria et al. 2020b; Beria et al. 2019b). The second is provided by CheckMyBus and refers to the entire Italian coach market in 2017-2019 (Beria et al., 2020a). Differently from the previous one, this database does not include observed prices per ride. Still, it provides a monthly average price of «clicks» made on the search engine and redirected to the websites of the respective operators that offer that service. The third is more limited in time (15 days per year in winter and spring) but includes both obtained through direct observation of suggested lowest prices on price comparators.

Structure and evolution of rail supply in the cities of the corridor

The opening of the new HSR line has profoundly changed the supply structure of the rail transport, not only for the different speeds, but also because of the doubling of capacity on a corridor that was basically saturated. The line is the most important of the country, hosting not only many regional trains, but the majority of long-distance trains in Italy and many freight trains.

Put it simply, with the new HSR line:

- Faster trains to Rome, previously called “Eurostar Italia”, moved to the HS line, skipping all intermediate stations and becoming much faster.
- Other long-distance trains, mainly to the Adriatic coast, remained on the conventional line. Rolling stock was progressively changed, but speed and stations served remained relatively constant. Some faster trains to Ancona and southward were introduced, using the HS line between Milano and Bologna.
- Regional trains increased in number, but mainly in the suburban segment around Milan and Bologna.
- All cargo trains remained on the conventional line, relieved by faster trains.

This list, however, is not fully describing what happened to the cities of the corridor, whose stories are quite different. In the following, the evolution of train supply in main cities since 2008 will be described in more detail.

Milano

Milano has mainly benefited from the new HS line, both in commercial speed, frequency and improvement of regional transport thanks to the excess capacity available (Figure 19).

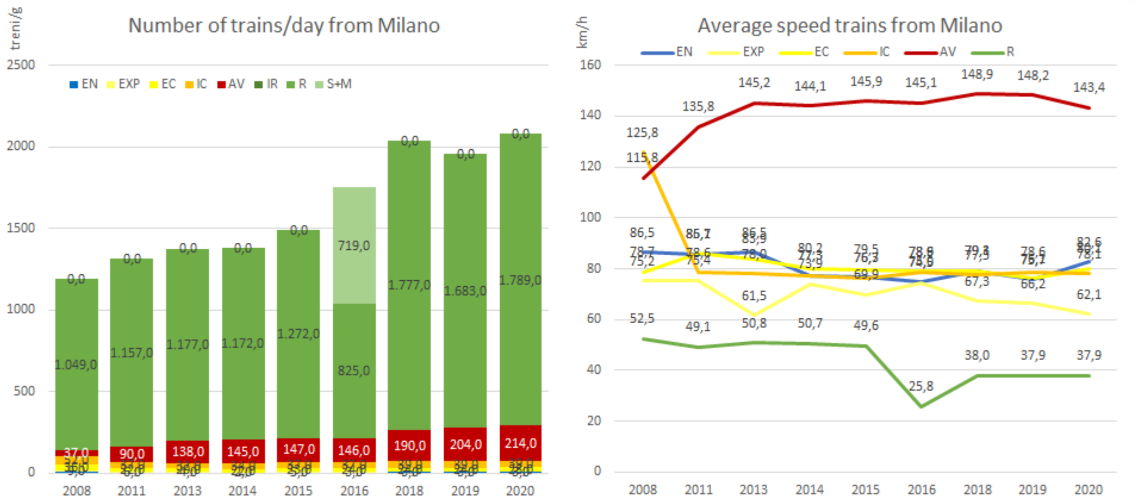


Figure 19 – Evolution of train supply in Milano, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

The speed increased significantly between 2008 and 2013. This is due to the progressive expansion of HS connections, passed from 90 of 2011 to 138 of 2013, which raised the average speed of the market segment. Afterward, the speed remained constant until 2020, when the new timetable (never applied due to COVID-19 crisis) modified the trains between Torino and Roma, moving many of them to the external stations of Rho-Fiera and Rogoredo instead of Milano Centrale. This is irrelevant for the city, as many faster services continue to exist from Central station. The addition of Rho-Fiera to the network significantly extended the possibilities of connections from the Simplon line.

Overall, the HS line and the concurrent rise of competition made HS connections boom from 90 of the beginning (2011) to 214 per day of 2020. Fast trains were just 37/day in 2008. At the same time, regional trains passed from about 1000 to about 1800/day. Of course, not all of them are linked to the HS line, but it was part of the picture that Regione Lombardia deployed to extend the accessibility to Milano (see section 0).

In terms of destinations reached from Milano, the following Figure 20 shows the evolution. In general, the spatial coverage did not shrink, but services are much more specialised. Trains to larger cities increased significantly, while connections with minor destinations decreased. It is a consequence of the profound change in the supply model associated with HS lines: no more “long” intercity trains calling every 50km from North to South but dedicated fast services. With few local exceptions, the range of destinations reachable directly from Milan did not decrease. The only exception is the Ionian coast of Calabria and Basilicata, now no more connected.

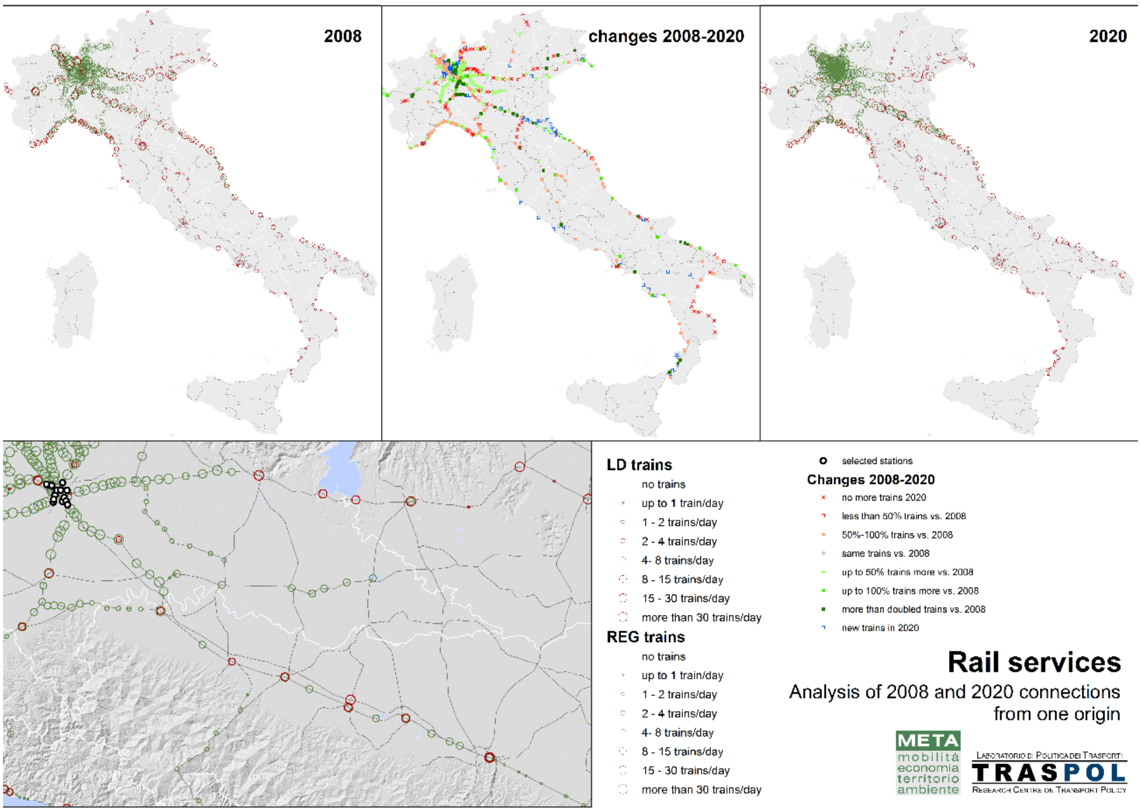


Figure 20 – Spatial evolution of train supply in Milano, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Pavia

Pavia is not on the HS line and actually, its supply did not change significantly in the last decade. Regional trains were increased, independently from the Milano – Bologna, and following the regional programme; a new RegioExpress connection from Stradella/Piacenza to Milano was added.

The long-distance segment is very similar: most trains connect Milano and Genova or southwards and their number slightly increased, but available destinations decreased. Interestingly, new HS rolling stock from Genova to Venice has been introduced in 2018, serving Pavia since 2020.[10]

[10] The line from Genova to Milan is currently under upgrade: in the mountain section a new line, mostly in tunnel, is under construction and due to open by 2023. The line, faster than the conventional one, is however not a properly said HSR (200-250km/h), being designed for heavy freight trains. The section in plain will be partially upgraded (4-tracks and 180km/h) between Pavia and Milano only; it is planned and financed in the recent PNRR.

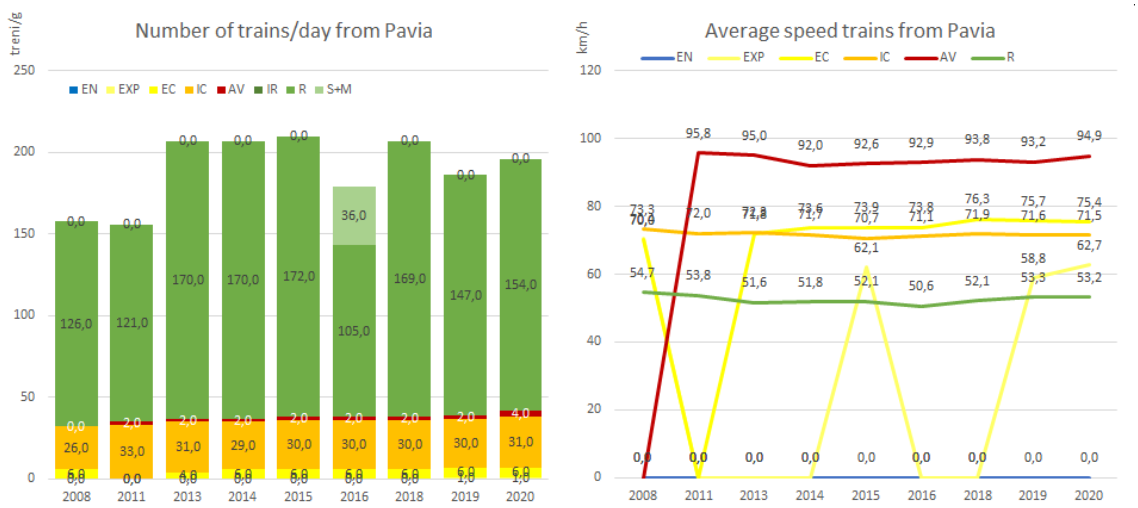


Figure 21 – Evolution of train supply in Pavia, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Lodi

Lodi was *apparently* not particularly touched by the change in fast trains supply that occurred after 2008: long-distance trains were and remained few, mostly night trains or PSOs and their number increased a bit. However, destinations have changed a lot. Initially limited to the Adriatic coast and few to Toscana, in 2020, Lodi is touched by long PSO trains to the South and therefore is directly connected with Puglia, Roma, Napoli and Reggio Calabria.

Regional transport instead remained similar for routes (limited to the Milan-Bologna and some seasonal connections with Pisa but increased significantly in number due to the introduction of the S1 line on the slots of the conventional line.

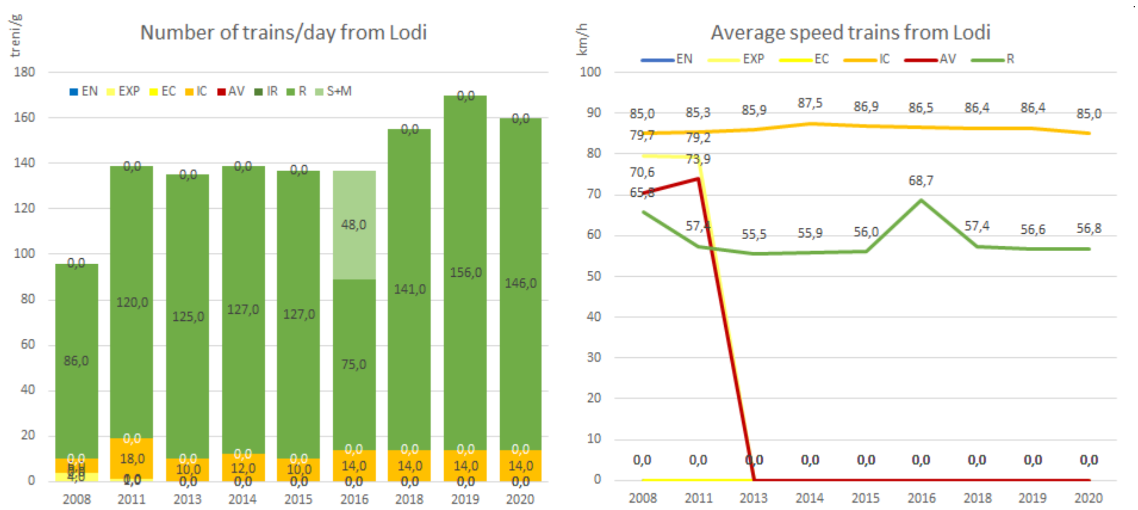


Figure 22 – Evolution of train supply in Lodi, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Piacenza

Piacenza is a net loser from the HS line opening. Regional transport is slightly reduced of about 10% due to the loss of connections with Cremona, Torino and the reduction towards Genova and Pisa. Trains to the main attractor, Milano, remained constant in number, despite the capacity increase. Probably the fact that the two cities are in different regions played a role.

Concerning long-distance traffic, conventional trains halved, and HS ones did not fill the gap. The picture did not change substantially in terms of destinations reached, but in all of them, frequencies reduced.

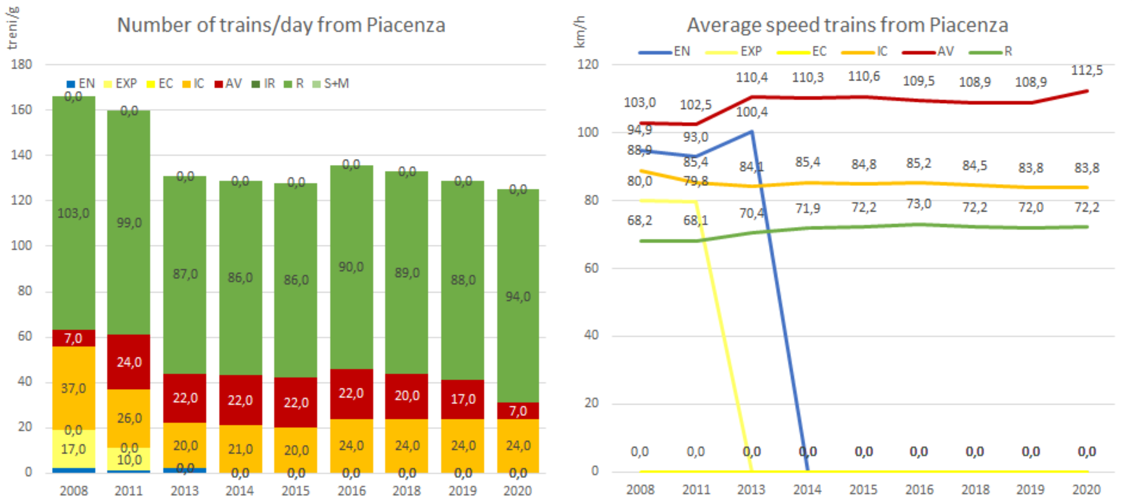


Figure 23 – Evolution of train supply in Piacenza, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Parma

The situation of Parma is somewhat similar to Piacenza, with a couple of differences. Regional trains increased not because of a generalised strengthening but for the reopening of the lines to Brescia (2011) and to Suzzara (2020). Long-distance services, instead, were 55 in 2008 and felt to 40 since 2013, despite the size of the city (the second of the region and the 16th in Italy). In 2020 faster trains increased speed thanks to a new timetable (see Section 0 for details)

In terms of destinations, the picture of 2020 is poorer than 2008 (Figure 25): the few connections with southern Piemonte disappeared and trains to Liguria and south Italy. Significant areas of the country are totally disconnected from this vital city: the entire Veneto, Trentino and Friuli, plus the southern part of Piemonte are unreachable despite the relatively short distance.

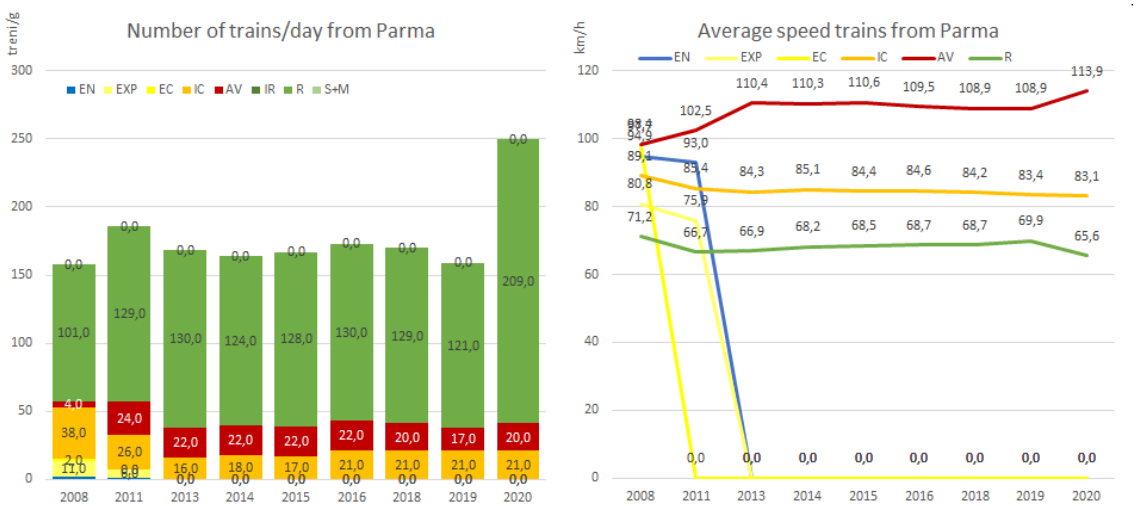


Figure 24 – Evolution of train supply in Parma, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

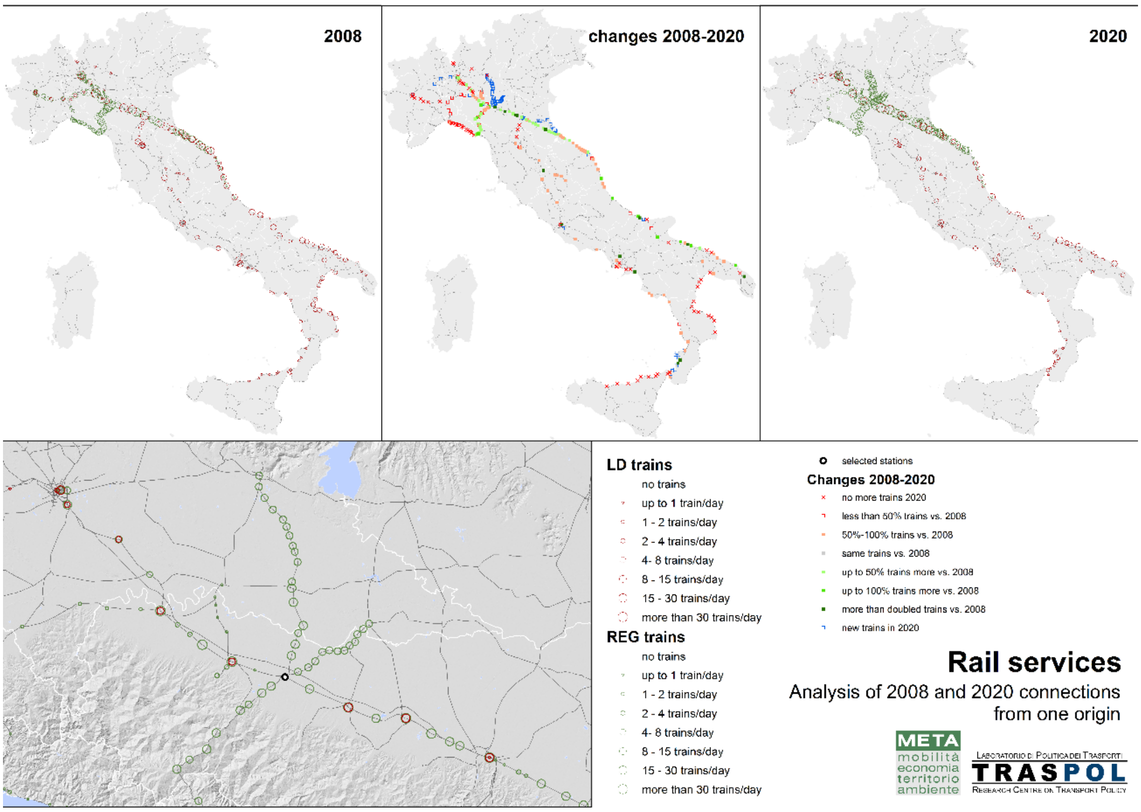


Figure 25 – Spatial evolution of train supply in Parma, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Reggio nell'Emilia

The story for Reggio Emilia was totally different due to the opening of the Mediopadana HS Station, that will be discussed later (section 0), which gave the city accessibility that no other comparable cities have.

The city gained regional connections (not only due to the reopening of local lines since 2018, but also along the corridor), but especially long-distance services boomed. Initially, the city lost conventional and high-speed trains when the new line opened, cutting off intermediate cities from the Milano – Bologna fast connections. But since 2014, with the opening of the new station of Reggio Emilia AV along the line in a new dedicated station north of the city, aligned along the highway, connections initially doubled from 22 to 53 in 2014 and then, thanks to the competition between Italo and Trenitalia, doubled again to 112 in 2020.

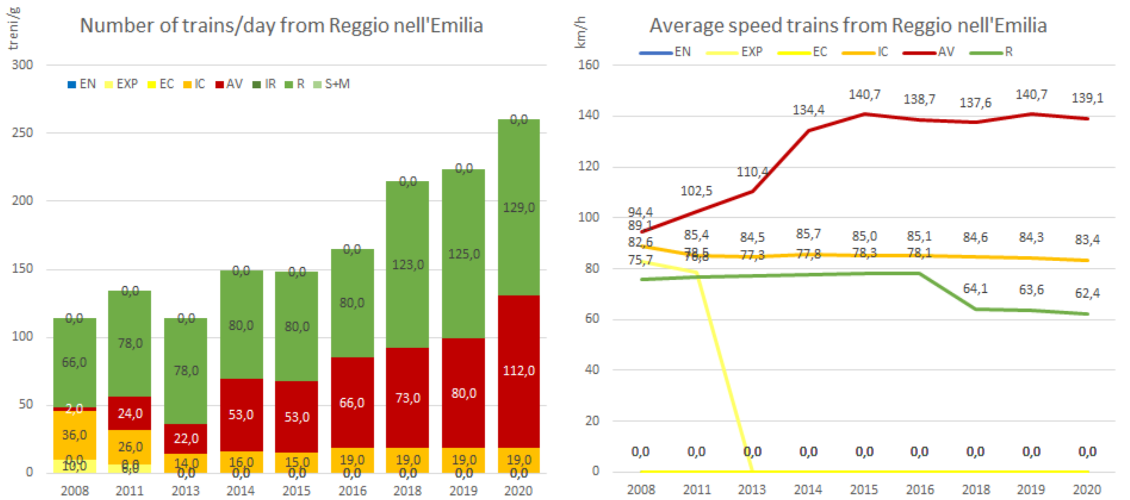


Figure 26 – Evolution of train supply in Reggio Emilia, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Interestingly, Reggio Emilia saw a reduction of national connections like the other Emilian cities, for example, to the very South, to southern Piemonte, to Liguria, even to the Adriatic coast. But at the same time, connections to the cities of the corridor Torino – Naples rose. In other words, Reggio Emilia entered the "elite" of the core cities of Italy but lost the connections with the rest of the country.

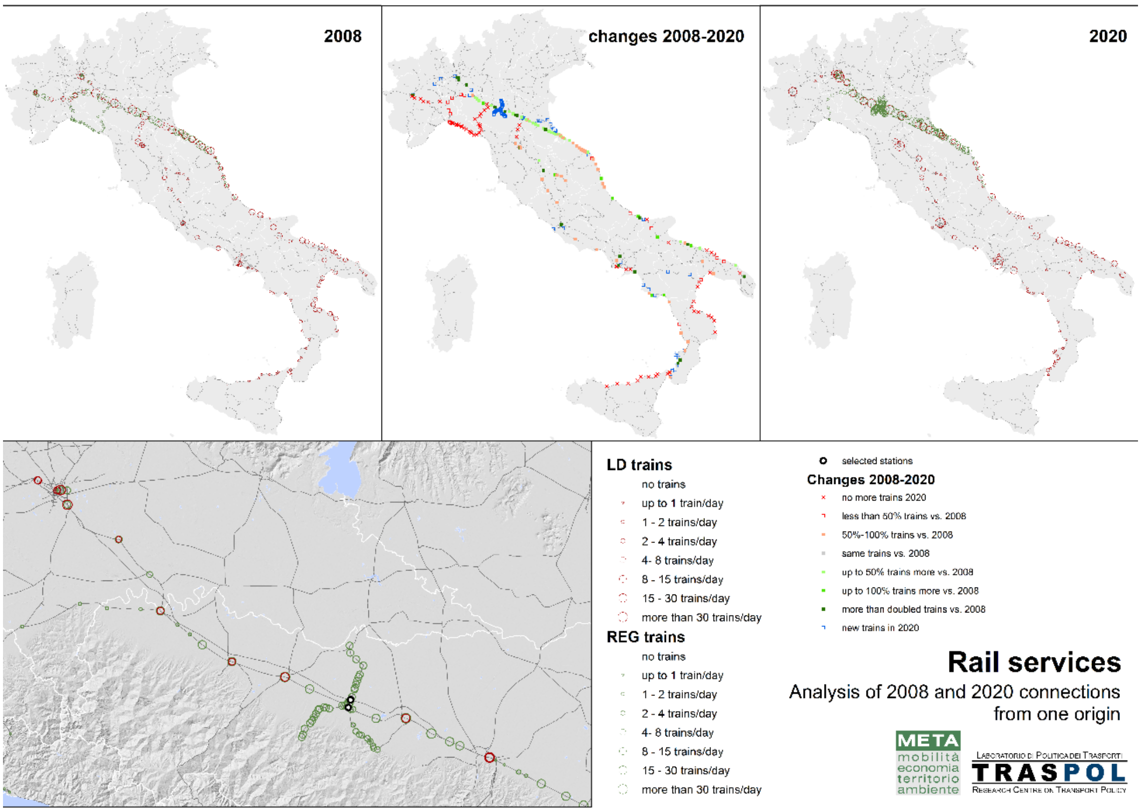


Figure 27 – Spatial evolution of train supply in Reggio Emilia, 2008-2020. Source: META-TRASPOL elaborations on official timetables

Modena

Modena's evolution is like Piacenza and Parma for national connections, which impoverished with the concentration of trains on fast and commercially viable connections. In addition to southern Piemonte, Liguria, Adriatic coast, and South, Modena has also decreased connections with the Brenner axis, which was the historical gate in Emilia. At the same time, the proximity with Bologna benefited Modena in terms of regional trains, which increased of more than 50%.

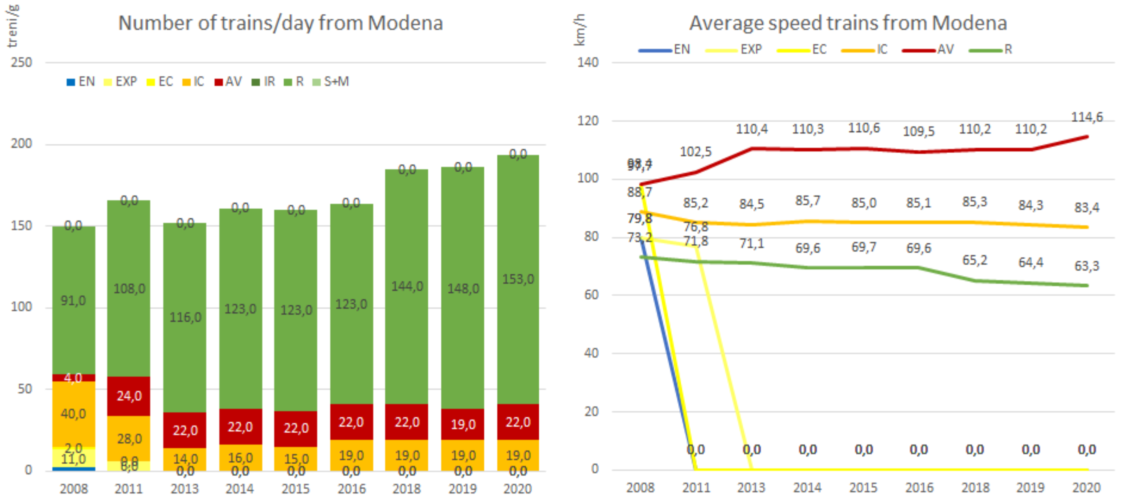


Figure 28 – Evolution of train supply in Modena, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

Bologna

Bologna is acknowledged to be the pivot of the Italian rail system. It is placed not only on the HS corridor, but also on the Brennero corridor and where services from Milano split between the two coasts.

Trains in Bologna increased steadily as we observed in Milano, both for regional and long-distance. The already mentioned progress in implementing a suburban rail system made regional trains rise from 300 to 420 trains/day in the observed period. Long-distance trains passed from 84 (before the opening of the line) to 256 in 2020. Every train from the north to the south must pass in Bologna. The new underground station made commercially sustainable the stop in a “only” 400000 inhabitants city, differently from what happened in Florence. Almost every city of the North has a connection with Bologna, including the neighbouring Veneto which is instead unconnected from the rest of the region. Intercity and PSO trains fell in number already in 2011, losing many direct connections to the remote areas of the South (which remain similarly reachable with a change Napoli or Roma). Interestingly, new destinations are now connected to Bologna via HS, for example, Potenza or Roma airport.

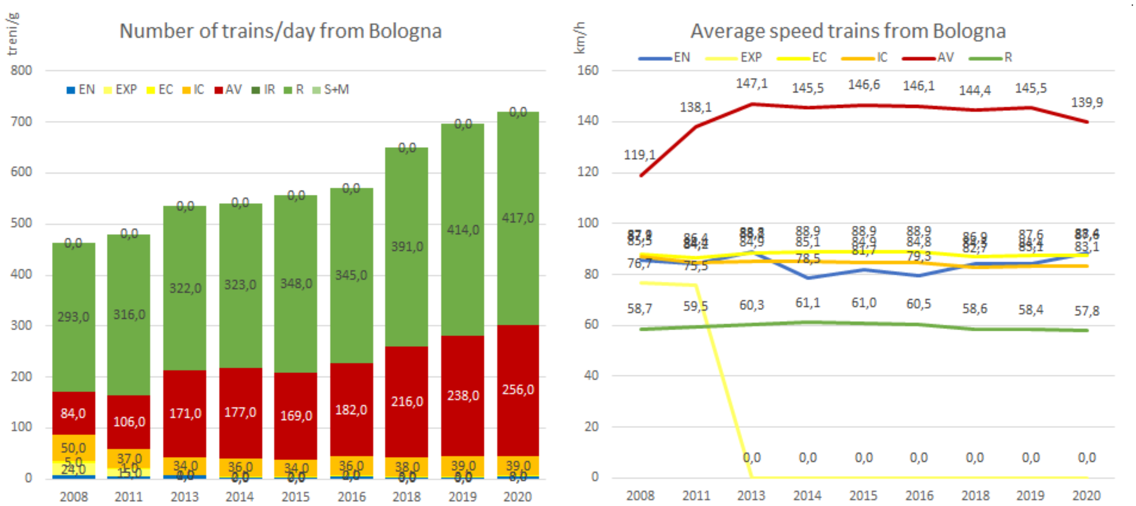


Figure 29 – Evolution of train supply in Bologna, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

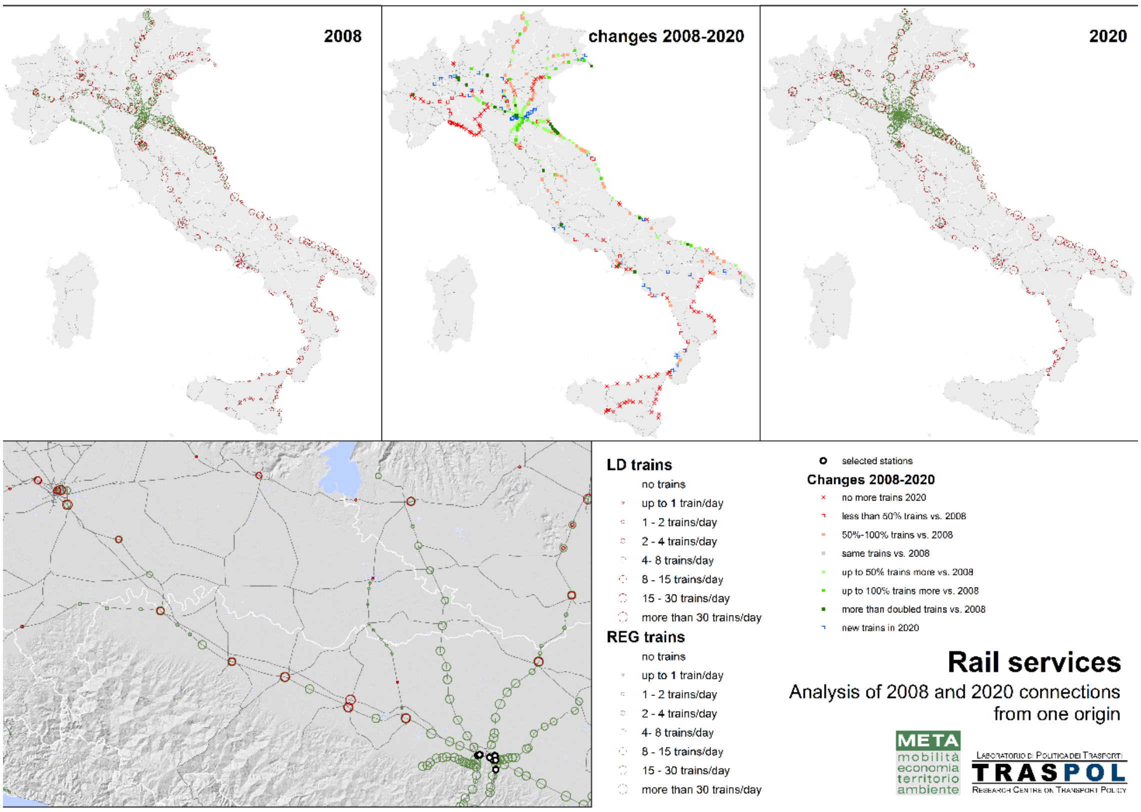


Figure 30 – Spatial evolution of train supply in Reggio Emilia, 2008-2020. Source: META-TRASPOL elaborations on official timetables

Connections with the main national poles

What happened aggregately to cities is not entirely describing the process. A detailed analysis of supply in terms of city pairs is proposed in this section. We will show the evolution of connections and speed from some Emilian cities to Milano, Roma, Torino, and Bologna. As we have shown, this is a subset of Italian destinations, but it is now representing the core of the national rail system, which shrank in extension but rose in density around the HS line. In other words, the loss of direct connections with the entire country is today less problematic than being excluded from the backbone represented by Torino-Milano-Roma-Naples.

The first case of interest is Parma, the second city of Emilia Romagna and an important economic centre. Parma, due to the model adopted, has no HS station. A train could leave from Milan via HS line, leave it at Fidenza, serve Parma central station, and re-enter the HS line before Reggio Emilia AV station (Figure 1). However, this option was not used until 2020, and trains serving Parma use the conventional line for the entire path. In 2020 some of the trains to the Adriatic line were moved to the fast line, skipping Lodi and Piacenza, and saving time. The same does not happen south of Parma, where they remain on the conventional line until Bologna.

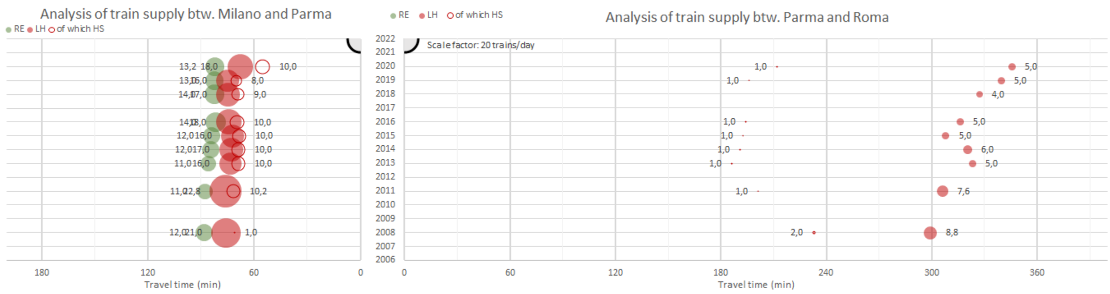


Figure 31 – Evolution of rail performance (speed and daily frequency) of connections Milano-Parma and Parma-Roma. Source: META-TRASPOL elaborations on official timetables.

The analysis of the evolution of connections to the two main national poles is clarifying the impact of the change imposed on Via Emilia cities by the HS line opening. Connections to Milano are basically unchanged: from 21 direct fast connections in 2008 to 18 in 2020, plus 12-13 regional trains. The speed of these services is very similar, and the travel takes about 75' until 2020 when new faster 55' options were added, lowering the average time to 68'.

While to Milano, the connections improved, the same is not valid for Roma. There is just one fast per day and travel time passed from 233' in 2008 to 180/190' after the HS opening to 212' in 2020. Other connections to Roma degraded substantially in number (from 8.8 to 5 per day, see Figure 32) and speed (from 300' to 345'). A travel time of nearly 6 hours means that passengers will interchange in Bologna or drive to Reggio Emilia. Still, the poor accessibility of the city to the rest of the country is evident.

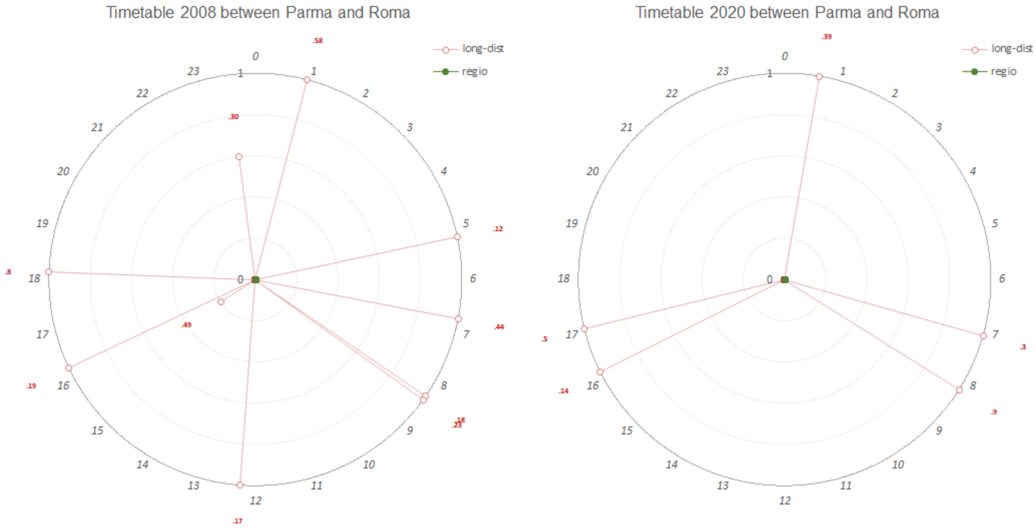


Figure 32 – daily departures from Parma to Roma, in 2008 and 2020. Source: META-TRASPOL elaborations on official timetables.

A similar analysis has been performed from Parma to Bologna and Torino. Regional connections to Bologna are stronger and taking a bit more than 1 hour. Fast connections are about 10 per day and take 50'-55'. Trains to Torino, instead, degraded even more than Roma. From 2 relatively fast connections/day in less than 3 hours, in 2020, connections are just two and travel time reached nearly 4h.

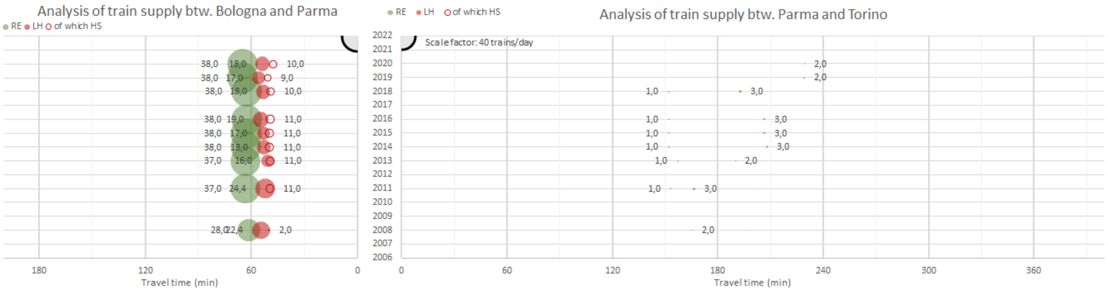


Figure 33 – Evolution of rail performance (speed and daily frequency) of connections Bologna – Parma and Parma – Torino. Source: META-TRASPOL elaborations on official timetables.

The situation is similar in all Emilian cities. For example, Piacenza (Figure 34) has relatively strong regional connections with Milano, slightly increased over time, and few and decreasing fast connections (dropping from 22 to 12). The connections with Roma are the same as from Parma: few and slowing down, forcing passengers to an interchange (probably in Milan, increasing time and cost for the passenger).

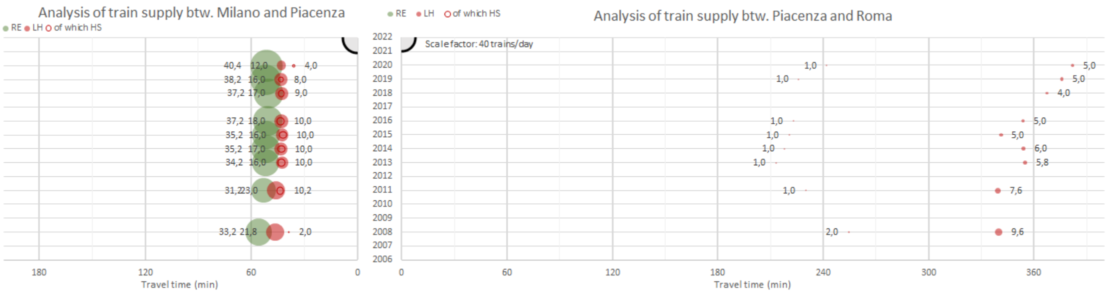


Figure 34 – Evolution of rail performance (speed and daily frequency) of connections Milano-Piacenza and Piacenza-Roma. Source: META-TRASPOL elaborations on official timetables.

A fundamentally different situation is the one of Reggio nell'Emilia. Trains to Milano rose from just 18 to 30 in 2014 and 61 in 2020. The more significant step in 2014 is associated with the opening of the external station of Reggio Emilia AV Mediopadana and the presence of both competitors. From there, fast trains passed from 25 to 54. The quickest connection was about 90' in 2008 and is now 43'. The performance of trains to Roma rose even more: from 1 fast connection to 39 in 2020, passing from 225'to 170' (in 2020 the average is higher but fast faster connections remained). We will discuss in Section 0 the role of this station as a gate for a broader area.

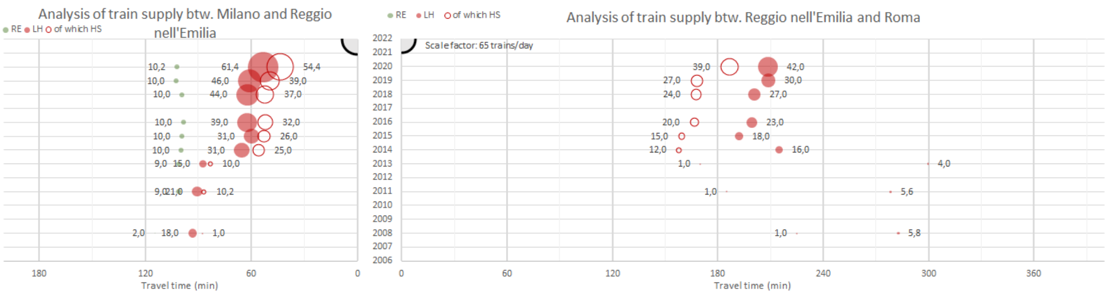


Figure 35 – Evolution of rail performance (speed and daily frequency) of connections Milano-Reggio nell'Emilia and Reggio nell'Emilia-Roma. Source: META-TRASPOL elaborations on official timetables.

The departures' clock from Reggio Emilia to Rome is visually impressive, looking more to a suburban service than a long-distance one from a secondary city (Figure 36).

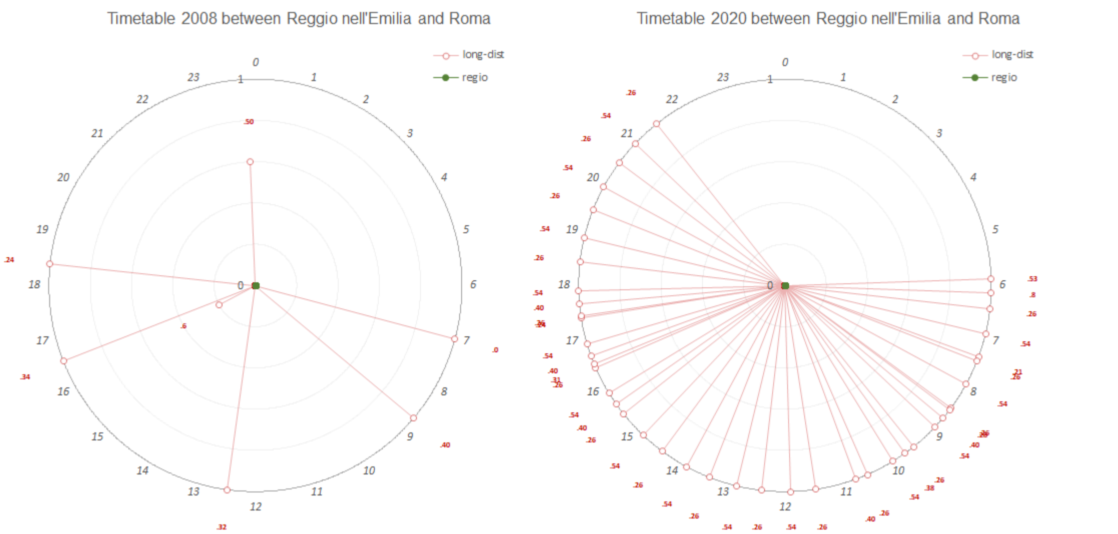


Figure 36 – daily departures from Reggio nell'Emilia to Roma, in 2008 and 2020. Source: META-TRASPOL elaborations on official timetables.

The connections to Bologna and Torino improved, too (Figure 37). Torino was basically unconnected in 2008 while in 2020 connections rose to 22, 21 of which fast (2 hours).

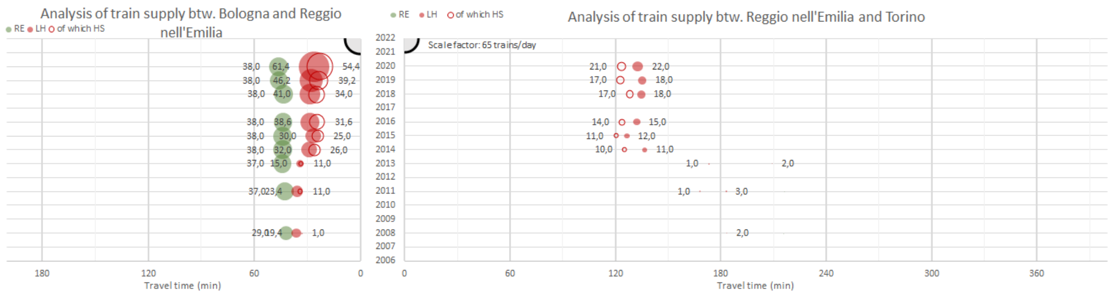


Figure 37 – Evolution of rail performance (speed and daily frequency) of connections Bologna – Reggio nell'Emilia and Reggio nell'Emilia – Torino. Source: META-TRASPOL elaborations on official timetables.

Accessibility to transport services

The above elaborations refer to the rail transport supply from the stations of the corridor. In this section, we model the complex of accessibility to stations and supply at stations. The outcome is a measure of accessibility *to* transport services from the corridor territory.

The metric used is *potential accessibility*, based on the *transport generalised cost to reach stations* weighted by the *number of train services* calling at the station. According to this metric, a similar value of accessibility could derive from a minor station very near to origin or from a highly served station farther. It represents a sort of weighting between the transport cost to the available stations and their importance.

Potential accessibility to railway services: methodology

Potential accessibility is a well-known place-based accessibility measure. It is used to describe an area in terms of cost to reach a range of places, where opportunities are available. Typically, the cost enters in the impedance function and is measured in terms of time or generalised cost. Opportunities at destinations are often measured in terms of population, but other indicators are possible (Beria et al., 2017).

In this case we want to measure the accessibility *to* the railway system and not to the territory *thanks to* the railway service (which will be the core of Section 0). This synthetic measure is able to increase the informative power of commonly used distance buffers from stations, with the “interest” of that station for a user represented by the number of daily trains. In addition, it allows to differentiate the role of the station, which is extremely relevant in this case, between secondary stations supplied only by regional trains and main stations served also by long-distance services.

The indicator is therefore built as follows. The cost of physically reaching the *j* stations of the network rom *i* origins is measured in terms of road *distance*. The opportunities available at stations is the number of *trains* per day from the station. The calculation is repeated for two different years *y*.

$$ACC_{i,y} = \sum_j trains_{j,y} \cdot e^{-\beta \cdot distance_{ij}}$$

To differentiate the role and catchment areas of stations, we differentiate the types of trains *r* in the calculation to produce maps of accessibility to regional transport, to long-distance transport or to rail transport in general.

$$ACC_{i,y} = \sum_{j,r} trains_{j,r,y} \cdot e^{-\beta \cdot distance_{ij}}$$

A key parameter is β, which can be interpreted as a decay factor. A high beta, in fact, will quickly reduce (in terms of distance) the interest of a place. A small beta, instead, keeps a destination interesting even if it is far (typically because not substitutable by a near one). We chose β =0.0005 for regional trains, making them basically not-influent to the accessibility already at 5km (see Figure 38). To the contrary, long-distance trains are typically reached even from farther places, as they are not present everywhere; for this reason we use a β =0.0001.

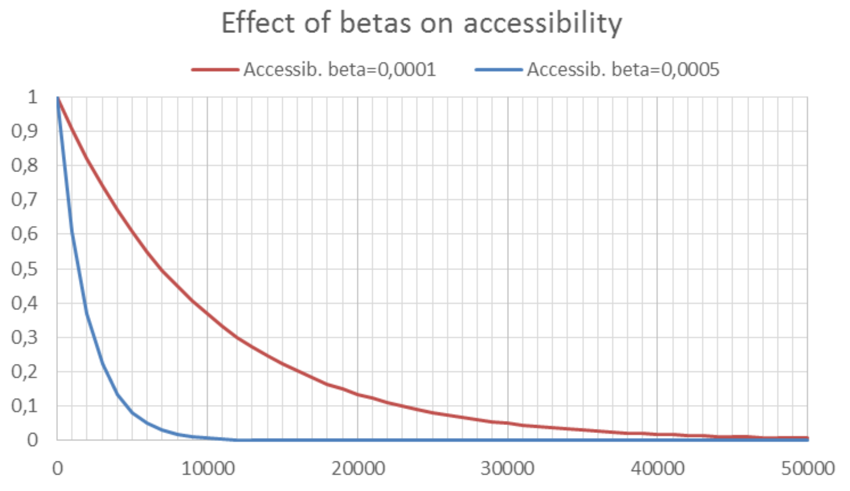


Figure 38. Effect of betas on accessibility (distance in metres)

The number obtained from the potential accessibility formulas does not have a physical meaning and a measure unit. For this reason, it is often presented and mapped as normalized (to the maximum or to the average). In this particular case, we prefer to show the pure number (that ranges between less than 1 and about 640) because a second map is drawn representing the difference between accessibility of 2020 (the timetable before COVID crisis) and 2008 (the last timetable before the opening of the entire high-speed line)

$$\Delta ACC_i = ACC_{i,2020} - ACC_{i,2008}$$

In the 2020 accessibility map of the Regional Portrait (See Map RP 2.2 in Annex I – Regional Portrait to the Final Report of IMAGINE), we can appreciate the two main regional systems: one around Milan (for fifty and more km) and the other between Parma and Bologna. Intermediate cities like Cremona, Mantova, Piacenza, etc. have a clearly lower accessibility as services are less frequent and less varied (for example from Cremona are relatively frequent just towards Milano). However, the map considers the long-distance services, which "explode" the scale of Milano and Bologna and keep slightly visible places such as Fidenza.

This dipolar structure, clearly focusing on the two capitals (both of regional and faster trains), is relatively recent. Tracking the changes in the indicator between 2008 and 2020 (See Map RP 2.3 in Annex I – Regional Portrait to the Final Report of IMAGINE) tells us about the system's evolution since HSR opening (but not necessarily the unique consequence of it). In general, Milano and Parma-Bologna extended their leading role in accessibility, as a clear strategy, especially of the long-haul segment. More in particular, the accessibility of the second circle of towns around Milano is due to the extension of the S-lines system and the line Parma-Bologna, thanks to the capacity freed up of the traffic moved to the HSR line, has been strengthened. The in-between areas of Piacenza and Cremona, instead, saw their role further reduced, making them more marginal than twelve years ago.

A success case: Reggio Emilia AV station

History and supply structure

Reggio Emilia AV Mediopadana is the only Italian HS station located out of the city and served by HS trains only.[11] It is comparable to similar stations in France or Spain, such as Avignone, Valence, Reims, Montpellier, Guadalajara or Limburg Süd. Reggio Emilia AV has been opened in 2013, at 2/3 of the Milan-Bologna line, about 40 minutes from the first and 20 from the latter.

The station is central for the area comprised between the cities of Parma, Modena, Cremona and Mantova. The first two cities are crossed by the new HS line, but are not served, as there is no stop. Consequently, Reggio Emilia AV was supposed to become the reference stop for them, helped by its intermediate position and excellent road accessibility. In fact, RE AV is built next to the A1 highway, not far from entrance gates. Projects to build dedicated lanes for buses and kiss&ride directly along the highway are under consideration (META, 2018).

The station is a landmark: evident from the highway and surroundings. It is an impressive 483m-long building designed by Santiago Calatrava and completed by a suspension bridge north of it. Unfortunately, it suffers from some limits: served by local buses but poorly connected with the territory except Reggio Emilia itself; it is connected with a second regional rail station behind it but lacking significant connections and with low-frequences; parking capacity has been recently expanded due to the structural lack of availability. As Figure 39 shows, users access are primarily by car or taxi. A negligible share uses the regional train. The local bus is used by 10-12% of incoming users (without a car) and as low as 4-5% for outgoing users. For outgoing users, the mode by far most used is the car as a passenger.

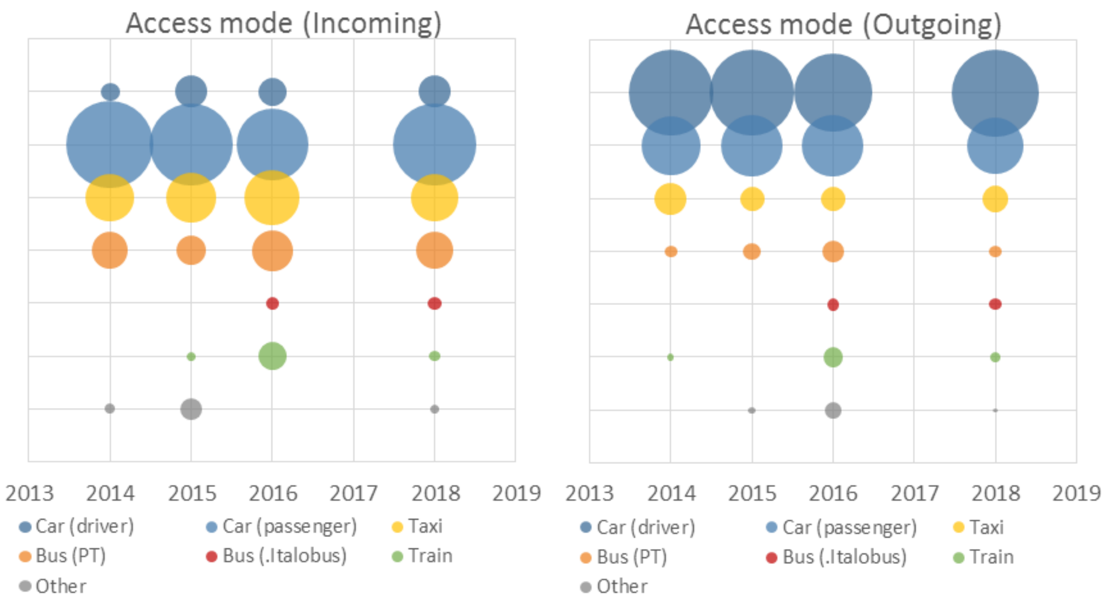


Figure 39 – Access mode for Reggio Emilia AV Mediopadana station. Source: elaborations on META (2014, 2015, 2016, 2018).

Despite these limits, Reggio Emilia AV is considered a success case. Undoubtedly the demand figures grew significantly and are above expectations. Supply increased, too, guaranteeing the mid-sized city of Reggio Emilia accessibility to Milano, Roma and the rest of the fast network well above any peer. Daily services passed from about 30 in 2014 to 82 just before the COVID-19 crisis. The commercial speed of such services decreased slightly, from 152 km/h to 144. This is due to the slight decrease of speed on the entire network

[11] Actually, in the urban area of Naples a new station has been opened in 2017 – Napoli Afragola. It is a station "in line" like Reggio Emilia, but its location is in a highly populated periphery.

to manage delays and capacity and the progressive evolution of timetable, which increased the stops at gate stations such as Milano Rogoredo or extended services south of Salerno using a conventional network.

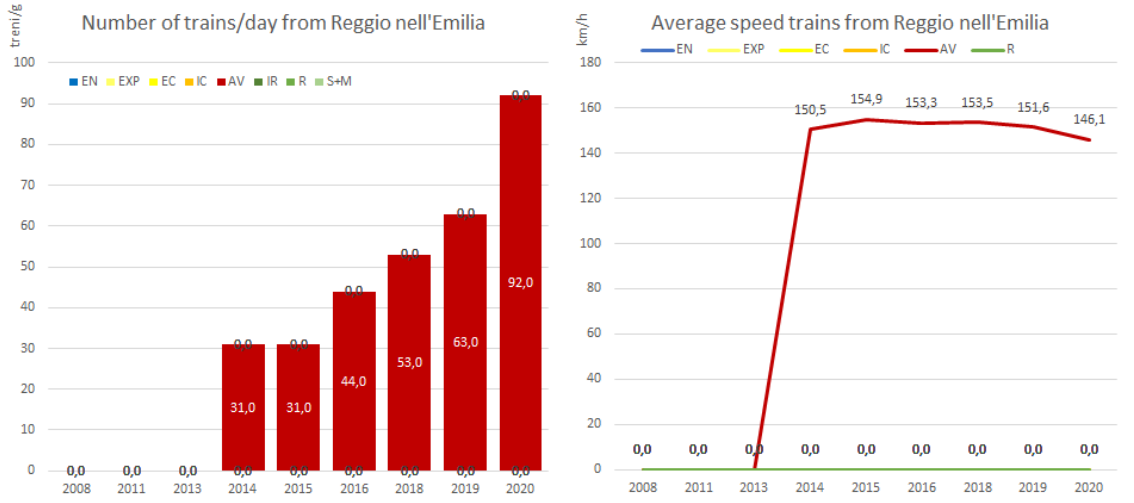


Figure 40 – Evolution of train supply in Reggio Emilia AV, 2008-2020. Source: META-TRASPOL elaborations on official timetables.

The timetable of the station evolved significantly. In 2014 (Figure 41), trains were quite concentrated; for example, trains northwards (Milano or Torino) call between 8 and 10, then 12-14 and then a third longer wave in the evening between 18 and 21. The same scheme is followed southwards. This scheme is typical for daily business users: focused departures in the morning and noon outbound and some in the evening for the return.

Six years later, trains are three times more numerous (Figure 42). Milano-Torino and Roma-South are now regularly served every 30 minutes. Interestingly, Milan is reachable until midnight (which means that one can return Reggio Emilia from Roma at midnight). The last train to Roma is 9:30 pm. Like the rest of Italian high speed, this timetable passed from a peak hour system to a takt-regular system, based on the 30' almost all day long. This guarantees users to choose any time to depart and is adapt to commuters, tourists, etc. Clearly, all these trains are not dedicated to Reggio Emilia, which would never support such a timetable. Still, the city enjoys the in-line station, allowing many trains to stop and go in few minutes. Recently, Reggio Emilia entered also in the trains to Ancona-Pescara-Puglia and in the Perugia-Arezzo ones. Moreover, one train/day directly serves Roma intercontinental airport.

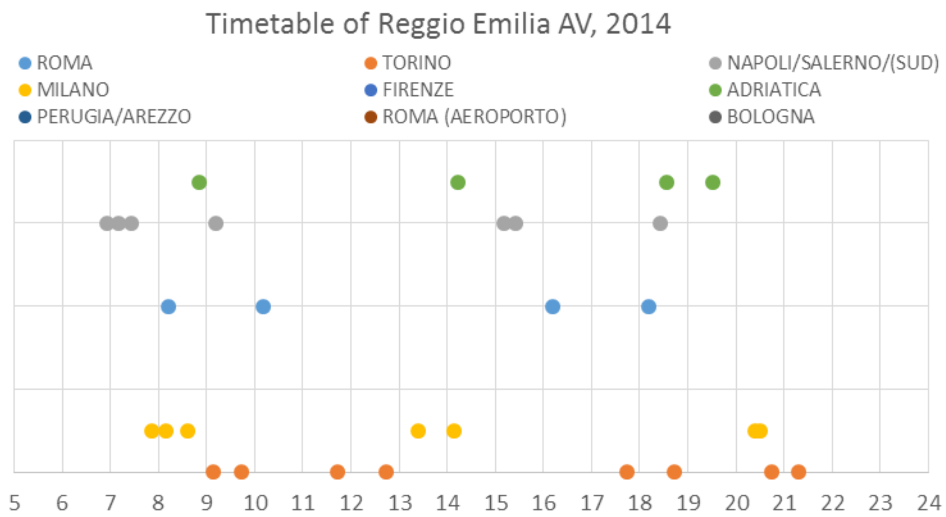


Figure 41 – Timetable of Reggio Emilia AV, 2014. Source: elaborations on official timetables

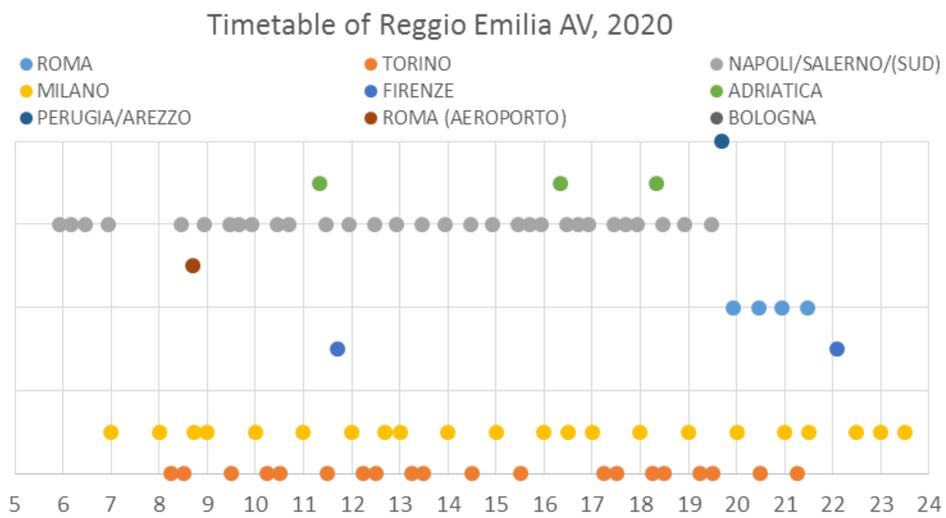


Figure 42 - Timetable of Reggio Emilia AV, 2020. Source: elaborations on official timetables

Another significant element describing the supply of services at Reggio Emilia AV is the presence of Italobus. It is the brand name that *.Italo* train company uses for its connecting buses. Similarly, the business model applied by Trenitalia in other stations is to coordinate dedicated bus rides with HS trains. In this way, cities like Cremona, Mantova, Modena and Parma are included (and sold via website) in the network of *.Italo*. These connecting buses are not sold stand-alone but just in a bundle with the train ride. The number of passengers of this service is limited (see Figure 39), but the service exists for some years and apparently with the satisfaction of users and companies.

Demand

The survey conducted by the consultant META (2014, 2015, 2016, 2018) gives a vibrant picture about the station users; information particularly important since they are not available elsewhere.

In Figure 43, we can appreciate the steep increase of passengers observed in the five years of the survey. We can assume that this trend went on, as in the meantime the supply of trains doubled. In 2018, however, the passengers per day were already above expectations (META, 2018), reaching nearly 4000 passengers per typical working day. These passengers are composed of a 70% approx. of outgoing (i.e., those living in the area and using the station to reach a national destination) and 30% of incoming (i.e. passengers for which Reggio Emilia AV is the destination). This clearly classifies Reggio Emilia AV as a generating station, used mainly by locals for their trips but only limitedly attractive as a destination. This is probably due to the attraction power of the area of Reggio Emilia, not comparable with Milano, Roma or Bologna, but also to the limited accessibility of the station without a car.

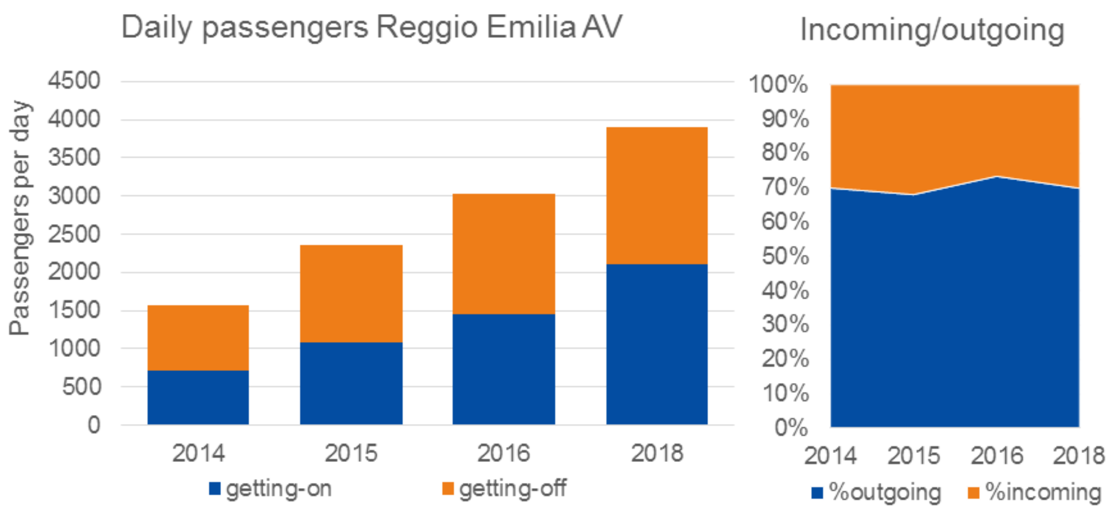


Figure 43 – Daily passengers at Reggio Emilia AV. Source: elaborations on META (2014, 2015, 2016, 2018)

In terms of destinations (Table 2), Reggio Emilia AV users mostly go to Milan, followed by Rome and Naples. It is particularly interesting the information on the frequency of trips[12], that let us know how many are frequent commuters. This phenomenon arose in some Italian cities thanks to the combination of high speed, ample supply, and competition between the two train operators. In Reggio Emilia frequent commuters (travelling more than three times/week) reach the considerable level of nearly 20% of trips to/from Milano and Firenze. In absolute terms, this means 200 passengers/day in 2018 per direction.

Table 2– Destination of trips originated in Reggio Emilia AV Mediopadana; average of years 2014, 2015, 2016, 2018. Source: elaborations on META (2014, 2015, 2016, 2018).

Final destination of the trip		(share) Eve-ryday	(share) 3/4 times/w
Milano	31%	12%	5%
Roma	25%	1%	1%
Napoli	19%	0%	0%
Firenze	6%	19%	2%
Torino	5%	0%	7%

[12] Frequency of trips is available since 2015. Figures therefore refers to the weighted average of the three available years.

Other	14%	9%	5%
	100%		

Going more into detail of travel purpose, Figure 44 shows the evolution over time of the role of the station. Work and business trips (whose borders are feeble in the long-distance) counts for the large majority of trips (60-65% in 2018), both for incoming and outgoing trips. This shows clearly that the role of the station is mainly as a support to economic activities. Interestingly, travellers declaring a “business” purpose jumped since 2016, when train supply started to grow and evolve towards a regular timetable.

Personal trips are pretty stable, as well as the small share of study trips. Tourism and leisure felt since 2016 for incoming and rose for outgoing. In 2015, the Milano 2015 Expo effect was well visible: 11% of trips generated from the station were directed to Milan Exposition.

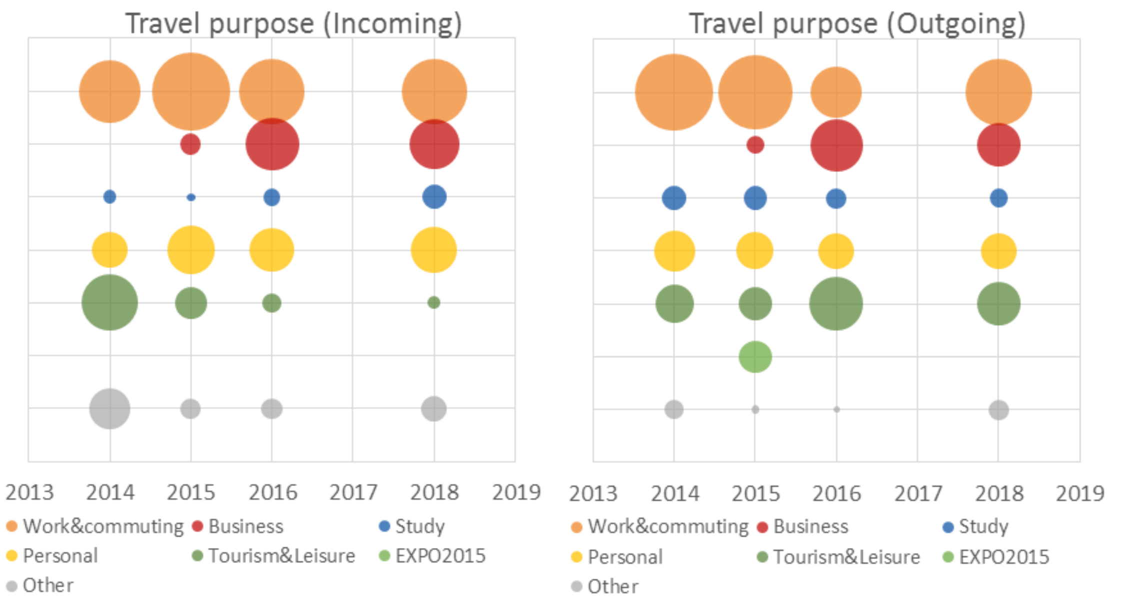


Figure 44 – Travel purpose to/from Reggio Emilia AV Mediopadana. Source: elaborations on META (2014, 2015, 2016, 2018).

To the current work, however, the main question remains at last: if Reggio Emilia AV has been effective in mitigating the lack of direct access to HSR from Emilian cities. If yes, did it push the growth of the area, as expected? While the answer to the last question is left to *Exploring the impacts of high-speed rail infrastructure on the economic development of the urban region and the corridor, producing effects on the territorial cohesion, counterfactual analysis*, in the following we will discuss the extent of its spatial effects.

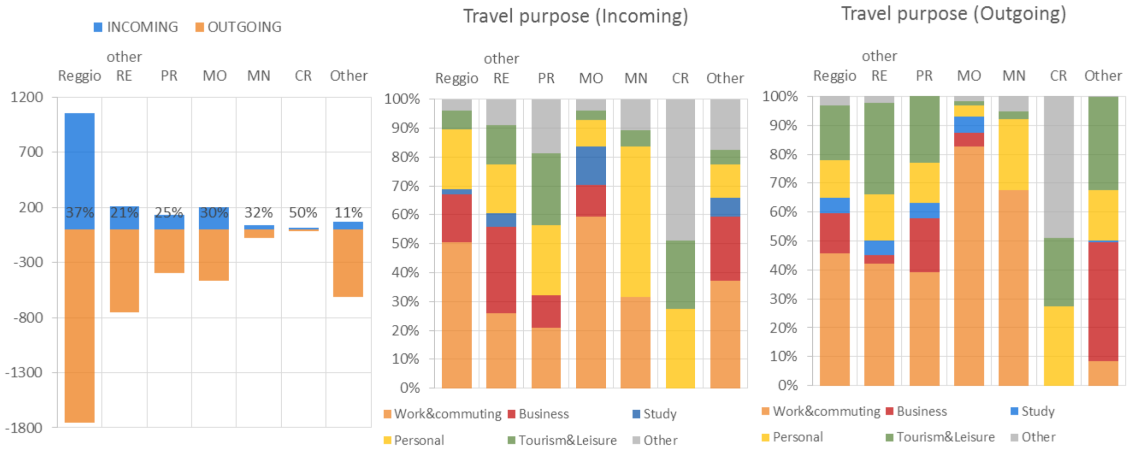


Figure 45 – Origin/destination of passengers calling at Reggio Emilia AV. Source: elaborations on META (2014, 2015, 2016, 2018).

Detailing, as in Figure 45, the leading local origins of travellers, we can see that the large majority of station users come from or go to the city of Reggio Emilia, followed by its province. As already commented, the share of incoming is minoritarian, and for the city reaches the 37%. The entire provinces of Parma and Modena counts, together, for 20% of users. Since the three provinces are comparable for size and economic power, the unbalance is evident, as evident in Figure 46, where the station's catchment areas (incoming and outgoing) are mapped. Reggio Emilia AV is primarily a local station, and its role as the “gate” of the area is limited, especially as an entrance gate. The number of passengers from the four surrounding cities is essential (about one hundred per day), but many more still use the local station on the conventional line. This is not surprising: if the destination is near, such as Milano, the cost of accessing Reggio Emilia AV is offset by the shorter travel time (and also by the higher price of HSR vs. conventional trains).[13] So, Reggio Emilia AV may become a convenient stop just for farther destinations, such as Torino, Firenze, Roma or Napoli. If the traveller is incoming, the lack of public transport makes it even less effective out of Reggio Emilia.

Detailing the analysis with travel purposes, differences are more remarkable. For example, business trips are essential for workers of Reggio Emilia province (about 1/3 of total trips are for business), but negligible as a destination. No business trips to/from Mantova and Cremona use the station and just very few from Modena. Reggio Emilia and Parma are comparable for outgoing tourism, which is negligible from Modena (if they go north for tourism, they go otherwise; if they go south, they probably will use Bologna).

In conclusion: is Reggio Emilia AV a missed opportunity for the territory and valuable just for Reggio Emilia city? Partially yes: the lack of connections except the highway makes it ineffective for many destinations and purposes, leaving passengers in their local conventional station (or in their cars). But the judgement must also consider what has been discussed in section 0: train services from Modena, Parma and Piacenza decreased in number and variety *due to* the tunnel effect of HSR. This is even more extreme in relative terms: smaller places like Rovigo or Reggio Emilia itself gained impressively accessibility *thanks to* the HSR. Thus, the role of important cities such as the mentioned ones is more severe. So, we can say that Reggio Emilia AV effectively mitigated the extreme (relative and absolute) loss of connections of Via Emilia cities caused by the HSR model chosen for the line and by reducing the marginality of Cremona and Mantova. By the way, this “error” dating back to the Nineties when the HS model was chosen, will not be replicated in the Milano-Venezia corridor, under construction and partially revised recently: the line is not a variant line and all cities will be touched by the fast doubling. Of course, it does not mean that all trains from Milano to Venezia will call at every station, but that train companies *can decide to call* if and when demand requires it.

[13] For example: Parma – Milano is 1:08 with conventional fast trains and 40 minutes with the HS from Reggio Emilia, but the travel time (by car) from Parma to Reggio Emilia AV is 33 minutes, not considering the cost and discomfort.

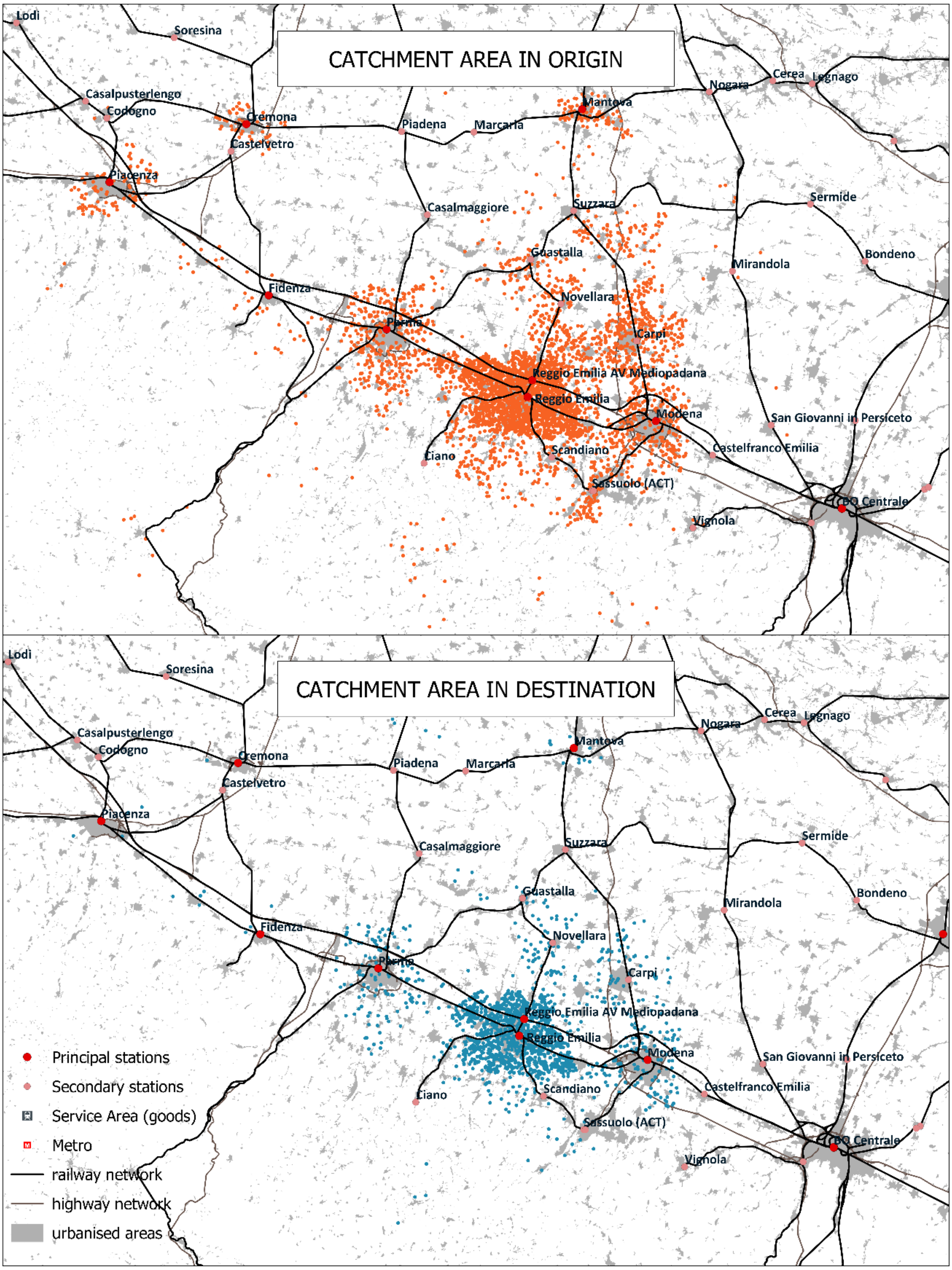


Figure 46 – Catchment area of outgoing (above) and incoming (below) passengers calling at Reggio Emilia AV. Source: elaborations on META (2014, 2015, 2016, 2018).

Long-distance fares in a liberalised market

Fares are one key parameter that determines the travel choices and the performance (speed, comfort) of the services. High-speed lines, accompanied by rolling stock renewal, have pushed rail transport's success, but limitedly to that segment, indeed not covering the entire long-distance mobility of a country.

It is expected that after high-speed introduction, railway undertakings skim part of the improved users' surplus through the increase of fares. Monopolistic situations are particularly favourable for the companies, which can adopt a mix of fares increase and price discrimination to maximise revenues (Beria et al., 2019). Of course these practices do not maximise the number of users, instead exclude some passengers or leave them on lower performing trains.

The Italian situation is peculiar in Europe, with HS network operated by two companies in competition (see 0). Competition is hard to measure, but some facts can be considered.

a) The competitor's share is not marginal, around 30% of the HS market and counting up to 50% of supply on some HS pairs.

b) Even if prices are not as low as in other cases of competition (Tomeš, Z. et al., 2016), they remain lower than in other comparable countries. Moreover, it is undoubted that the quality and quantity of services are undoubted outstandingly high.

In addition, since 2015, coach liberalisation has profoundly changed the market, adding previously non-existing services especially in the North. These services base their competitiveness on price (mainly where rail services exist) or on the directness of connection (where direct rail does not exist, such as towards airports).

This section proposes an in-deep review of rail and coach prices on the leading pair of the corridor, the Milano – Bologna one.

Determinants of rail prices

The average minimum price of a train ticket available 20 days before departure is about €22 and has been stable for three years since November 2016. The mean price per km 8.4 €cent, which is 23% higher than the one for the Milano-Rome route. This is due to the shorter distance of the pair (price per km is inversely proportional with geographical distance) and probably also because of being a subsection of a longer route.

Table 3 – Statistical characteristics of ticket prices in Euro between Milano and Bologna, period: 31.10.2016 - 31.10.2019.

Train company	*Train category*	Mean price	Max price	Min price
.italo	(HS)	29.46	300	9.89
Trenitalia	Frecciabianca	24.51	55	9.89
	Frecciargento	30.03	65	14.89
	Frecciarossa (HS)	35.32	120	19.89
	Intercity	26.00	36.5	7.9
	Intercitynotte	27.03	28.5	7.9
	Regionale	16.79	16.79	16.79
All		**29.22**	**300**	**7.9**

Actually, the prices are far from fixed and depend on a number of different factors, such as:

- Type of service
- Booking date (Date of ticket purchase)
- Operator company (train type)
- Date of a trip (holidays, weekdays, month)
- Departure time
- Tariffs and services (Flexibility and class).

Concerning the **type of train**, PSO services (intercity and intercitynotte) are just slightly cheaper than market ones (.Italo and "frecce" category). Interestingly, on average frecciabianca (conventional market trains, mainly serving the Adriatic coast) is cheaper than intercity. A second noticeable element is that minimum prices (€7.99, available typically for early booking non-refundable seats) of market trains are below the prices for regional trains, fixed at €16.80.

Price discrimination gives passengers the opportunity of reserving discounted tickets under some conditions. Operator companies have several groups of tariffs, which vary in terms of **flexibility** (different rules for re-funding and cancellation of trips), **classes** (for example, economy, first or second class), and per **date of advanced purchase**. Usually, the cheapest tickets are sold first, while full-price tickets remain available until the day of departure if seats are not sold out.

The graph shows the average minimum fares for market and PSO trains according to advanced purchase days: 20th, 10th, 5th, 2nd and 1st before the train departure. The illustration displays an increase in the average price from €25 to €42 for market trains, and from €19 to €28 for PSOs (*intercity* and *intercitynotte*). The variability of the PSO services is lower than for the market ones but still exists. 20 days before departure, market (and faster) trains are just slightly more expensive than subsidised ones.

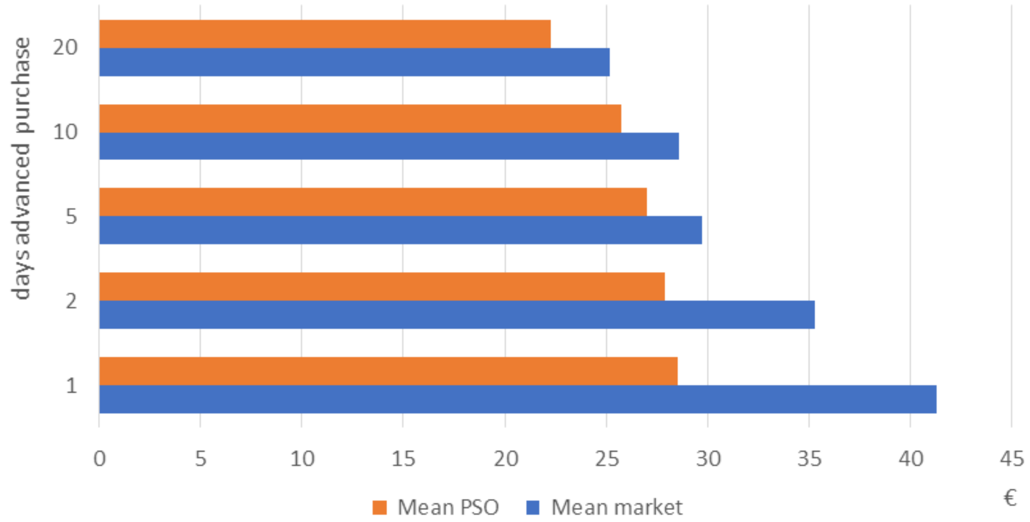


Chart 12 – Average minimum fare on Milano – Bologna pair, per advanced purchase and train type, period 2016-2019. Source: our elaborations.

The two **operating companies** reached a reasonable equilibrium in the last years, with .Italo steadily cheaper than Trenitalia. In particular, during the previous 12 months of observation, .Italo was on average 20% cheaper than Trenitalia for tickets purchased 1 day before departure and 25% for 20-days advance. Previously, especially before 2017, .Italo was "trying" to price at a similar level than Trenitalia, especially for early booking. For example, between November 2016 and October 2017, .Italo was just 9% cheaper (even more expensive in some months) for early booking. The fact that this changed against the newcomer sug-gests that . Italo's strategy was not corresponding to its market power.

Average minimum prices may differ with the **daytime**, reaching maximum values on evening peak hours and going down in the evening and late morning. Variability is, however, limited (Chart 13), especially during the daytime, a sign that the supply of seats is exceptionally well-fitting with demand (no empty trains).

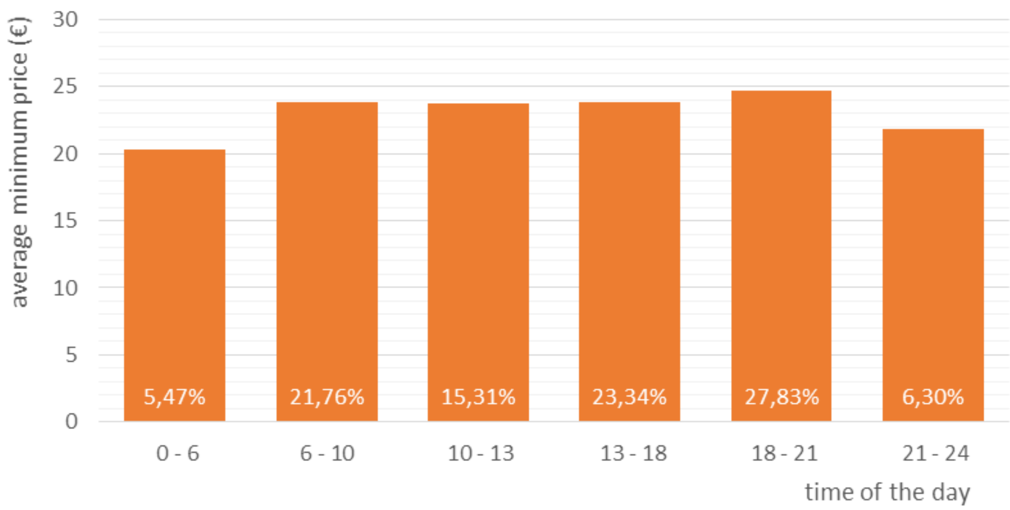


Chart 13 – Average minimum fare on Milano – Bologna pair, per hour of departure, period 2016-2019. Percentage indicates the number of trains in the time-period. Source: our elaborations.

Similarly, also **weekly variability** is scarce (Chart 14). As typical, Friday and Sunday are the most expensive days, sign that weekly commuting influences prices (and load factors).

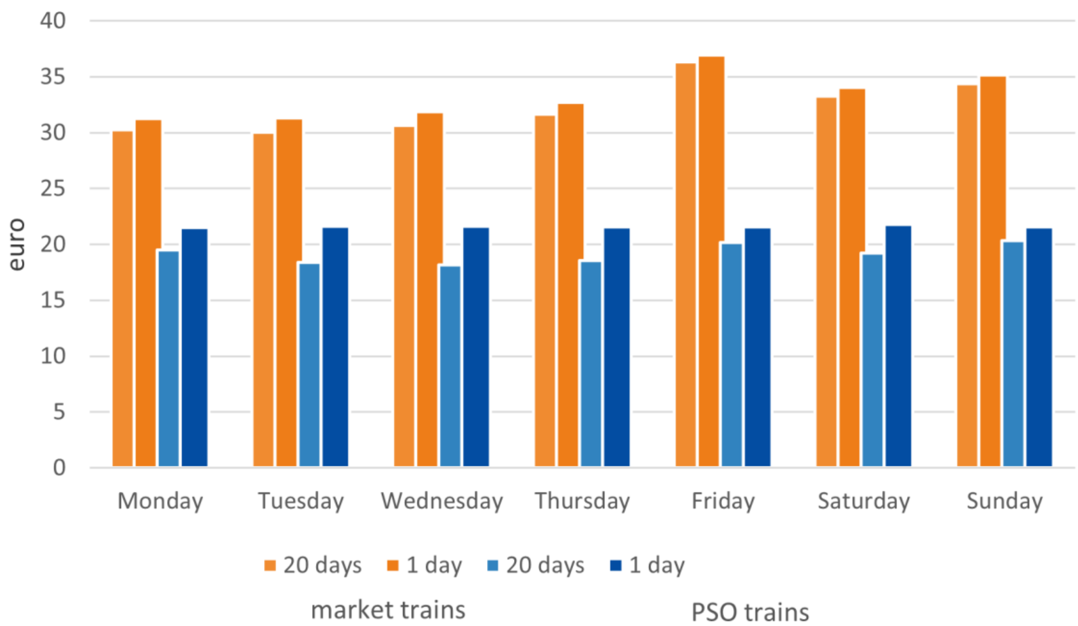


Chart 14 – Average minimum fare on Milano – Bologna pair, per day of departure, period 2016-2019. Source: our elaborations

Time trend of rail prices

Fares were not stable during the three years of monitoring from 2016 to 2019. An increasing trend is observed mainly since the second half of 2018, after a period of relative stability. This increase is visible in the last-day bookings (Chart 15), while early bookings did not change (Chart 16). Consequently, we can suppose that the price strategy has been similar, but load factors increased. By the way, the increase is constant and not a step.

We can also observe slight seasonal changes: prices go up at Christmas and especially Easter holidays and fall in February as described above. However, this variation is less significant than in other Italian routes (Beria P. et al., 2020b).

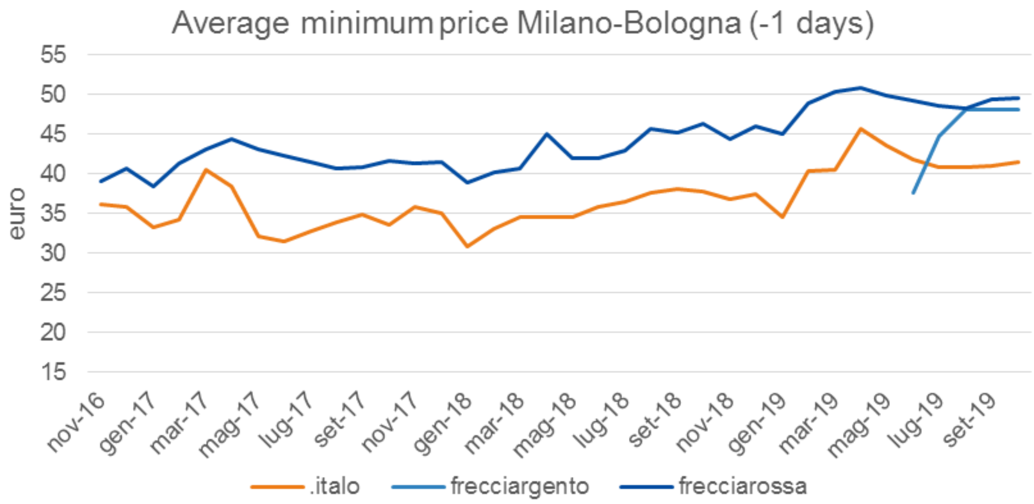


Chart 15 – Monthly average of each train cheapest fare, 1-day before departure, Milano– Bologna, period 2016-2019, by operator/product. Source: our elaborations.

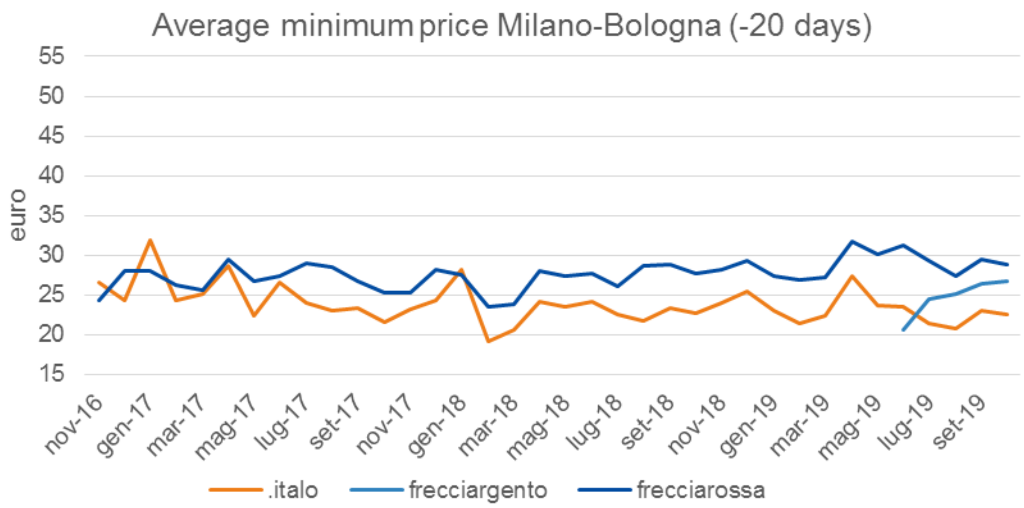


Chart 16– Monthly average of each train cheapest fare, 20-days before departure, Milano– Bologna, period 2016-2019, by operator/product. Source: our elaborations.

In Chart 15 and Chart 16, we can also appreciate the different strategies of Italo and Trenitalia. As already observed, Italo is on average cheaper than Trenitalia (about 7€ on day -1 and less than five on day -20). However, this situation, now reasonably stabilised, was different in 2016-2017. In that period, Italo was pricing on that route a price like Trenitalia (day -20). Probably this strategy did not work correctly because it was changed (since September 2017 Italo prices slightly decreased -20 days before departure) and because the day before departure, Italo's fare was lower than Trenitalia, a sign that load factors could have benefited the latter.[14]

[14] The Frecciargento (mixed-HS trains) appear only in late 2019, but they are just due to a change in rolling stock for some rides (similar travel time).

Coach prices

Coach transport, thanks to its flexibility and smaller vehicles, provides a more significant range of destinations than trains. In this territory, characterised by a strong rail service along the corridor, the coach sector (after liberalisation) introduced new direct connections (for example, from Lombard airports to Emilian cities). Consequently, in this paragraph, we will analyse a broader range of routes that complement the transport supply in the corridor (Figure 47, representing routes above 2% of market share in the area).

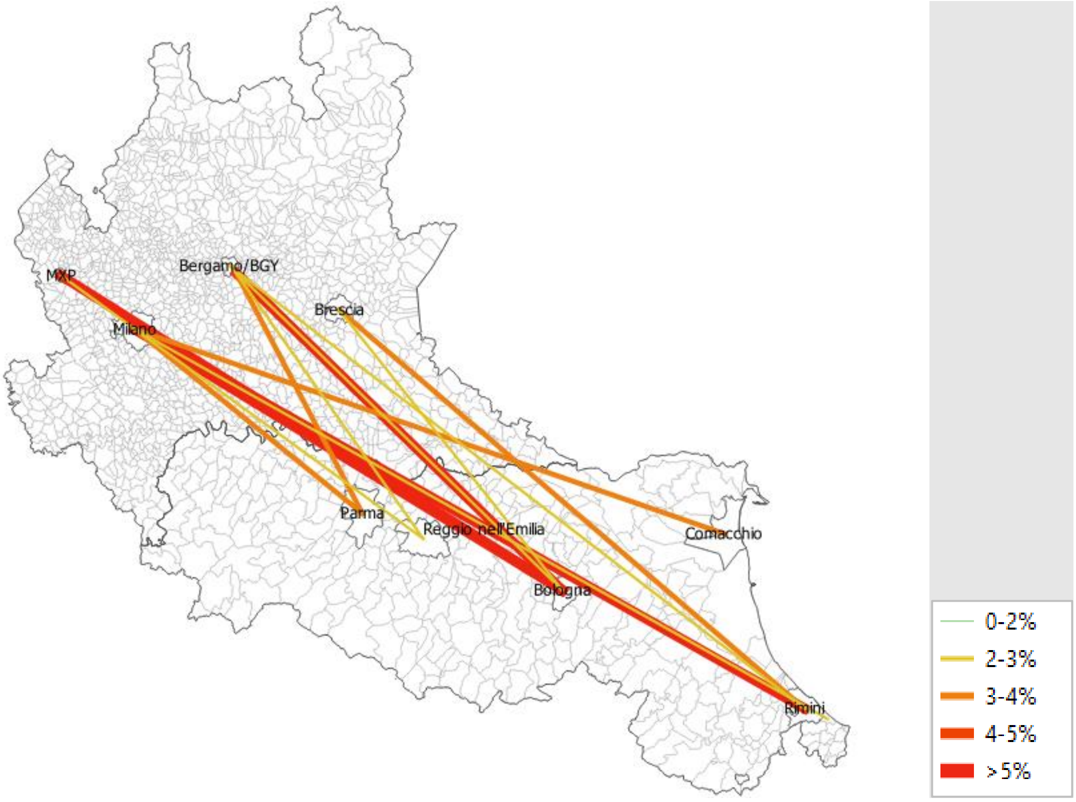


Figure 47 – Coach routes analysed: above 2% of market share. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

The prices vary significantly with distance but also with the type of route (Figure 48). Milano-Comacchio and Brescia-Rimini show the highest prices (more than 8 €cent/km) and both are seasonal routes to tourist destinations. Short routes like the ones to Parma and Reggio Emilia are similarly expensive (6-8 €cent/km). The cheapest routes stay below 5 €cent/km.

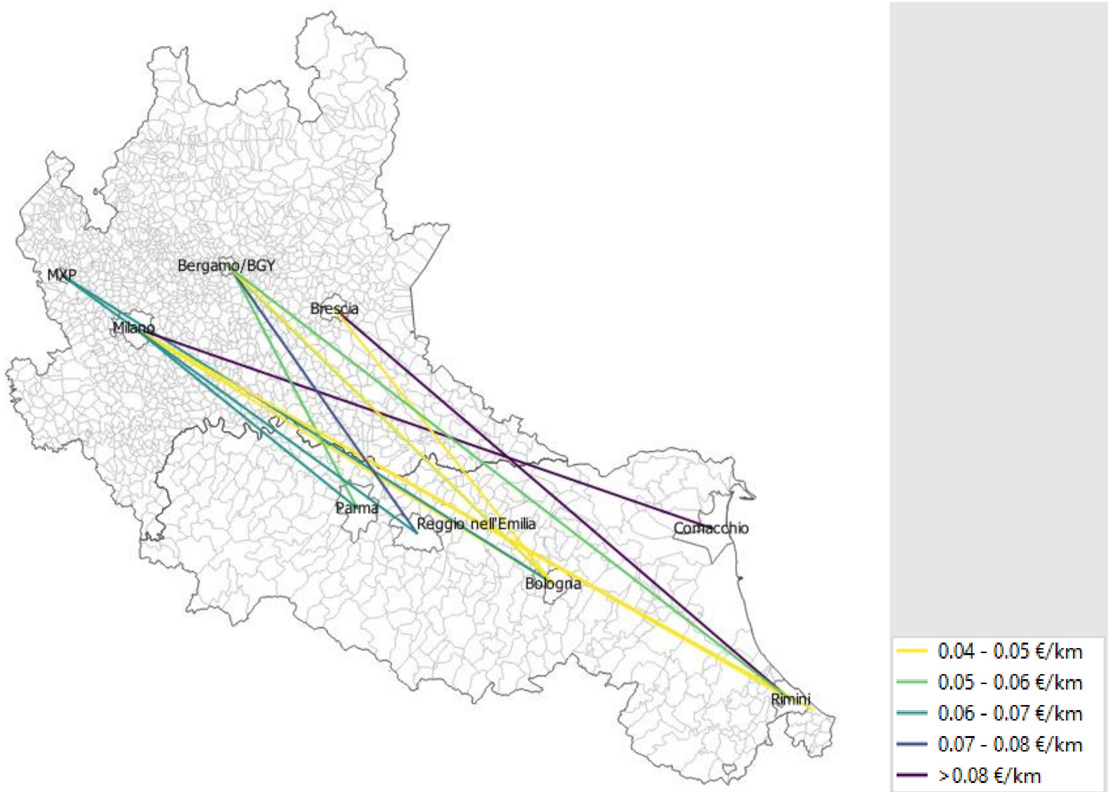


Figure 48 – Price per km of main OD relations. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

In the following figures, we can observe the monthly trends of prices and the corresponding semester average. All pairs in the area have been grouped in five: the Milan-Bologna pair account alone for 17% of tickets sold in the area; the other OD pairs in the corridor (between cities and towns comprised between Milano and Bologna plus Pavia and Cremona to Bologna), accounting for just 6% of trips; the connections with airports and those from anywhere to the seaside, accounting for 29% and 31% of sales respectively; the other pairs in the area, like Como-Bologna or Brescia-Pavia, accounting for 17% of observed volumes bur very scattered.

In Figure 49, we can see that the Milan-Bologna pair is the most variable group in the sample: prices were above 6 €cent/km until the 2nd semester of 2018, when they fell to 5 cents or less. The route is very crowded, and many companies operate on that, allowing for reasonable prices. Moreover, the competition with rail is harsh, and coaches must focus on low prices. In particular, even if the metric is different (observed price 20 days to departure vs. average monthly price sold), the train is about three times more expensive than the coach, which is three times slower. The fall of 2018-2019 prices goes opposite the rise of train prices observed.

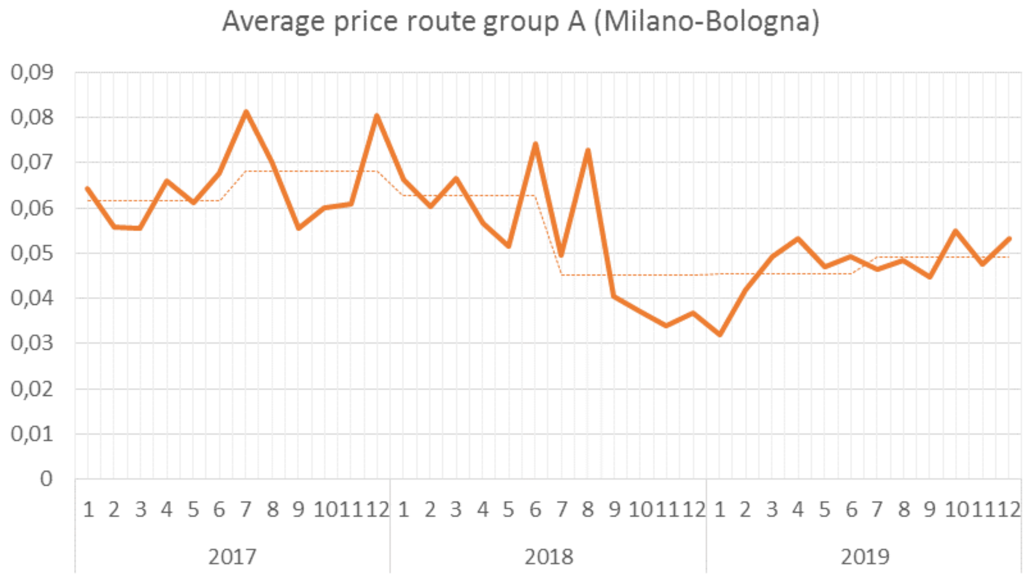


Figure 49 – Coach price per km of Milan-Bologna OD, monthly average. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

The other OD pairs in the corridor (group B, Figure 50) are more expensive, primarily due to the shorter distances. The time trend evidences a more significant seasonal variability, especially in 2018 and 2019, when summer prices went up concerning winter periods. A somewhat similar trend is observed in route group C (the other city-to-city pairs in the area excluding seaside, Figure 51), but on lower prices.

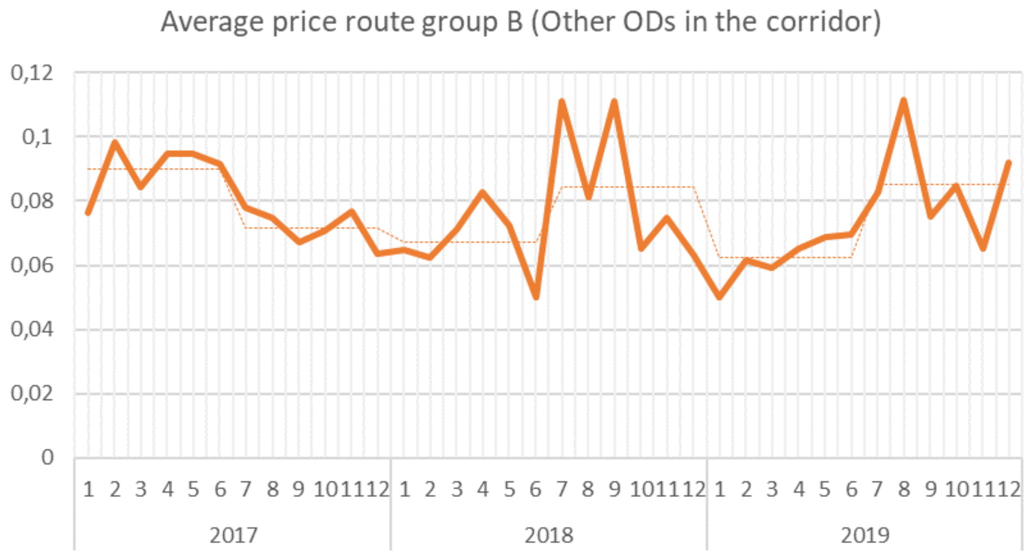


Figure 50 – Coach price per km of other ODs in the corridor (e.g. Modena-Bologna), weighted monthly average. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

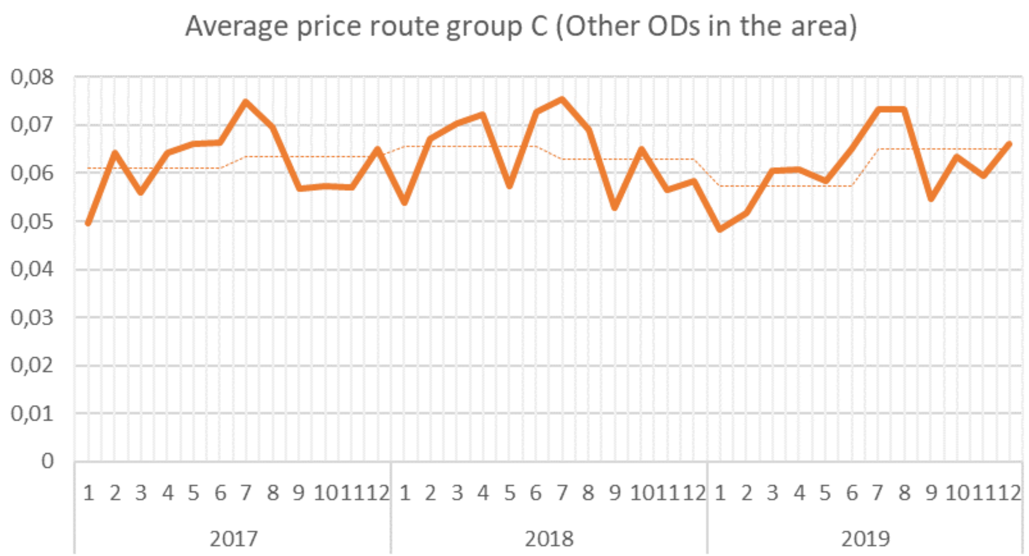


Figure 51 – Coach price per km of other ODs in the area (e.g. Como-Bologna), weighted monthly average. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

Airport routes of group D (Figure 52) and coastal routes of group E (Figure 53) are quite similar per average price and trend. Seasonality is no more pronounced than for "normal" city routes, a sign that when traffic is low (winter volumes are slightly lower than summer volumes), prices do not fall since the routes are dropped or are part of longer routes. Overall, the cost of peak periods (summer) was higher in 2017 than in 2018 and 2019, not differently from the other groups.

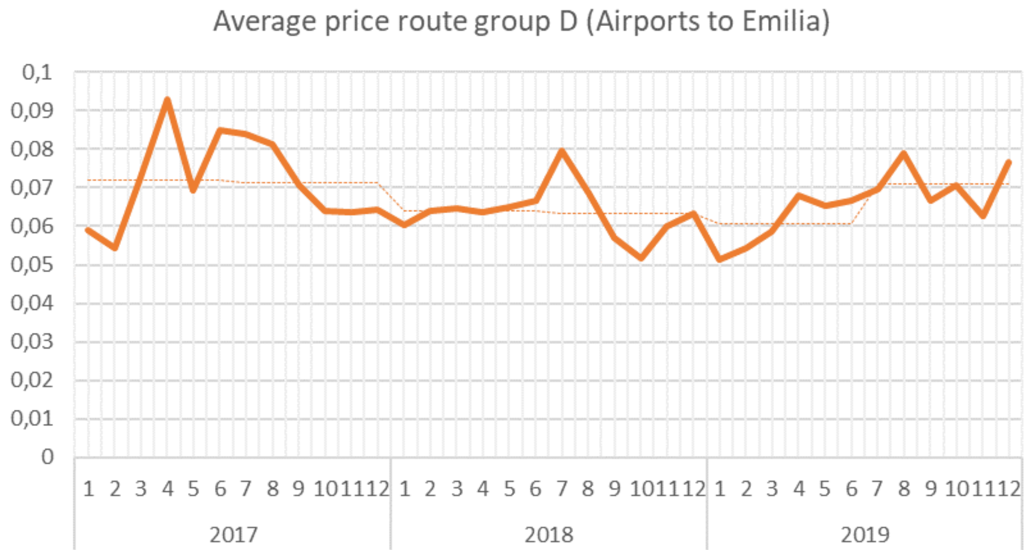


Figure 52 – Coach price per km of airport connections (e.g. BGY-Bologna), weighted monthly average. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

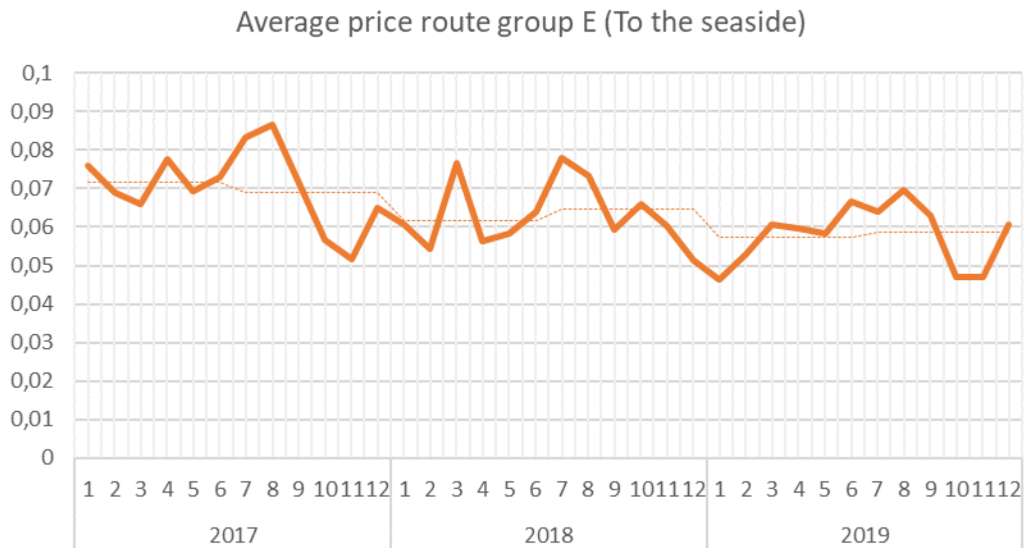


Figure 53 – Coach price per km of seasonal connections to the seaside (e.g. Milano-Cattolica), weighted monthly average. Source: our elaborations on Traspol-Checkmybus database (Beria et al., 2020a).

Comparisons

The previous data are very revealing because continuous but cannot be appropriately used for comparison since they come from different sources and represent other metrics. A third analysis has been performed. It is more limited in time (two 15-days periods in spring and fall), but all data is comparable and refers to published price ten days before departure. It is also detailed per company, even if for the sake of confidentiality coach company names are not disclosed. The analysis is limited to Milano – Bologna pair, and the year is 2019.

The data can estimate the market shares and visualise the different price discrimination strategies in place.

The first coach operator dominates the market in supply with more than 70% in terms of frequency. The second operator remains around 10%, and the others are many but residuals. For none of them, the Milan-Bologna pair is a single service but part of longer lines, which explains their existence.

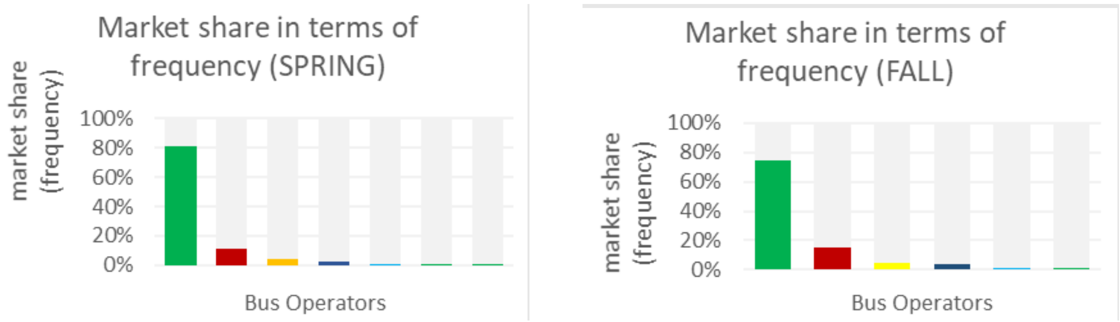


Figure 54 – Coach market shares. Milan-Bologna pair, year 2019. Source: our elaborations on Traspol database.

Comparing prices and price strategies with rail is revealing. As shown in Figure 55, the price distribution shows a similar trend with constant prices for the coach operators. The only difference is just that some operators charge more (6 to 8 €cents/km) than the others (4-6 €cent/km), including the dominant one. Non-market rail prices are higher than liberalised buses but again very concentrated: like the most expensive coaches for regional trains (the first peak of the chart) and as double as expensive for the other services (IC trains, about 50% faster than coaches). It is interesting to note that overall, the non-market trains for 50% of the frequency offer the tickets at the prices of the coach operators. This also indicates a competition between these trains that have comparable journey time like the coaches.

On the contrary, market trains fares are more spread over a range of prices. The market trains include frecciarossa, frecciabianca and NTV/Italo). Prices range between 6 to 8 €cent/km for the cheapest options to 22 to 24 €cent/km for the worst cases. The spread is more in Summer than in the Fall season.

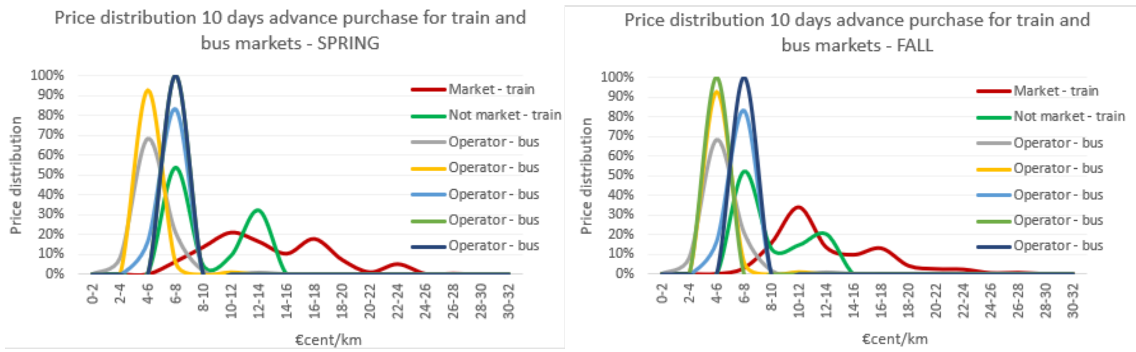


Figure 55 – Coach and train prices comparison. Milano – Bologna pair, the year 2019. Source: our elaborations on Traspol database.

Overall, the average price for the spring season is 10% higher than that of the fall season. A possible decrease in the prices of one operator for the fall season as most of the other operators has no variation in price/km concerning the different days of the week.

During the week, the highest prices (though by a very slight margin) are observed for Friday (average price on Friday for spring season being 0.069 €/km whereas it is 0.057 €/km for the fall season. The lowest average prices for both seasons are observed on Tuesday.

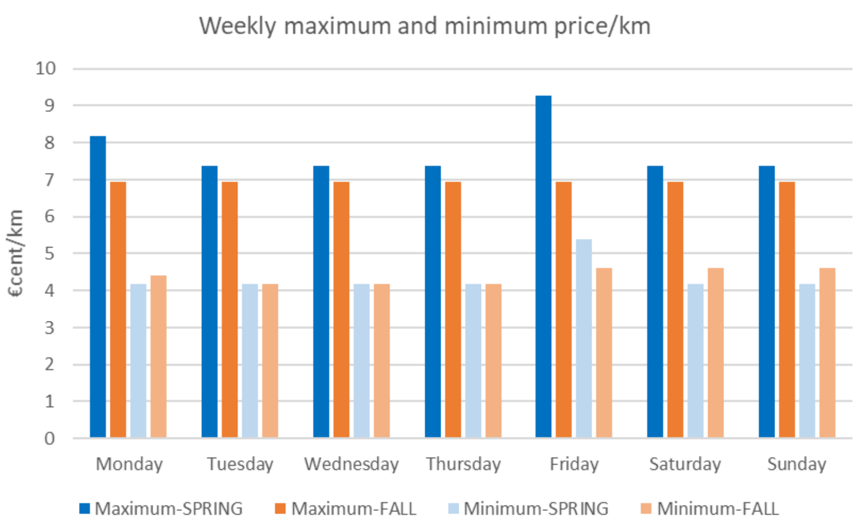


Figure 56 – Coach prices per weekday. Milano – Bologna pair, year 2019. Source: our elaborations on Traspol database.

In conclusion, the route Milan-Bologna, which is among the most expensive ones, is served by many companies, including coach ones. Each company's price discrimination is limited, but passengers can enjoy a broad range of prices ranging from 4-6 €cent/km for cheapest coach companies and regional trains, to 22-24€cent/km for HS trains on peak days. The route prices commonly depend on the advanced purchase, but the variability is somewhat limited. Coach prices reduced in 2020, after a period of stability. Rail prices, instead, increased if purchased shortly before departure, a sign that load factors were growing.

The evolution of accessibility

In the previous sections, we described the mobility demand in the corridor and the evolution of supply. As we have seen, the supply of rail services changed profoundly after the opening of the HS line, not only in the direction of improvement: a faster and much more frequent long-distance service to the main national metropolitan areas, but also a reduction in direct connections from the corridor to other national destinations. At the same time, the new capacity freed from the new line has been used differently. Some regions did not do anything, and regional services impoverished. When investments are made, like in the two regions of the study, most of the efforts have gone to the extension of suburban services and, in Lombardia, in creating a fast regional trains system to Milano. The segment that gained the least attention is undoubtedly that of interregional trains.

In this section, we propose a general measure to describe and weigh all of these changes. Similarly to what we did in Section 0 for the access *to* train services, we calculate the potential accessibility and its evolution from the corridor to the rest of the country. The attractiveness of a zone is measured according to two weights: population as a proxy of general destinations, and tertiary centres, as a proxy of business trips.

The following two sections detail the methodological aspects, while the final Section 0 presents results and comments.

Methodology/1: the transport model i-TraM

Most of the literature on long-distance accessibility uses the same measures of impedance used at the local scale: distance (Alampi and Messina, 2011; Holl, 2007; Keeble et al., 1982; Östh et al., 2015) or, in most advanced applications, travel time (Axhausen et al., 2011; Brödner et al., 2014; Dewulf et al., 2015; Reggiani et al., 2011; Rosik et al., 2015; Spiekermann & Schürmann, 2007; Stępniak & Rosik, 2015; Duran-Fernandez & Santos, 2014; Geurs & van Eck, 2003; Gutiérrez & Urbano, 1996; Ortega et al., 2012; Vickerman et al., 1999). However, in long-distance transport, travel time is undoubtedly relevant. Still, another two elements must be considered to have a realistic picture of travel choices: fares and inconvenience of access and egress. For this reason, a limited number of more advanced applications prefer to use the generalized cost, which includes all of these elements (Beria et al., 2017; Condeço-Melhorado et al., 2011; Jacobs-Crisioni et al., 2016; Bentlage et al., 2013). The apparent drawback of generalized cost is not represented by the accessibility calculation itself but by the necessity to have such measure for an entire country or similar area, which means to have a complete transport model including all long-distance services.

In this application, we use a proprietary transport model (i-TraM)[15], whose main characteristics are summarized in the following.

I-TraM is one among the few national-scale transport model existing and working in Italy. It is a full 4-steps model capable of simulating the entire Italian transport system from demand generation to path choice, based on zoning of 1764 zones. All demand components are simulated (both commuting, occasional and tourism) and the supply of all modes is present in the database. The tool is mainly dedicated to the study of long-distance demand, but of course, also local demand is present (for example, to forecast congestion conditions correctly), in all modes.

I-TraM is based on nuts-5 zoning (sub-provincial or sub-municipal in large cities), for a total of 1764 zones. This level of detail allows not only to simulate long-distance demand properly but is also suitable for regional-scale simulations and to correctly estimate the congestion of the road network around urban areas.

As mentioned, the model is a classical 4-steps model, capable of generating total and modal matrices and iteratively assign them to the networks. It comprises all transport modes, excluding regional and urban buses. Mass transit in cities is included and all rail, coach, air, and ferry services.

[15] For a complete description, please refer to Beria et al. (2019) and to www.metaplanning.it/atlante

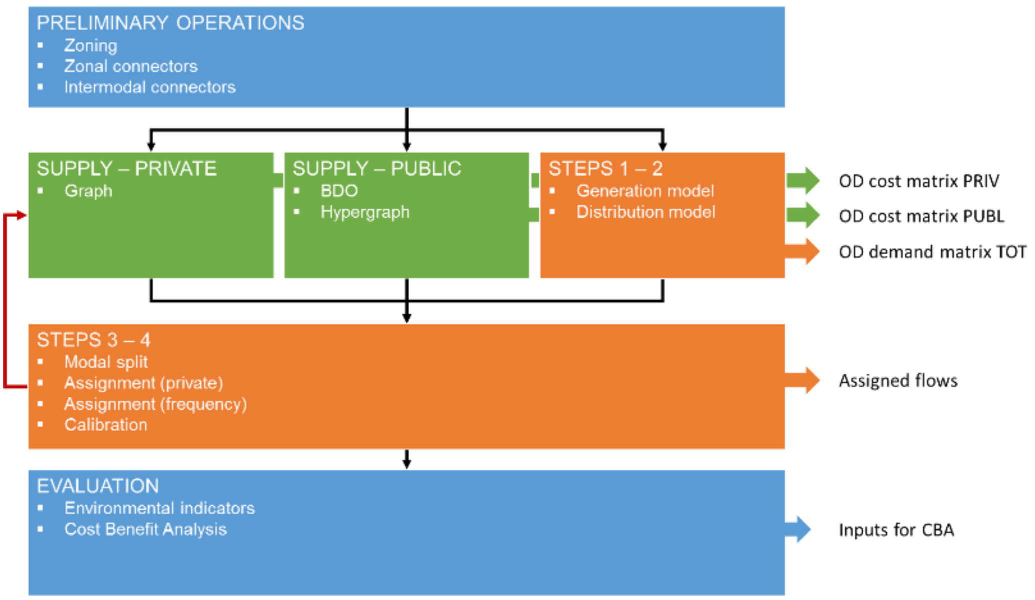


Figure 57 – General structure of i-TraM model

The core of supply modelisation is represented by the road network and by the “BDO” (timetables database) of public transport. The core of the BDO is the *ride*, which is characterised by:

- One timetable and one yearly calendar
- Stops, georeferenced over the infrastructure graph and associated to zonal objects (municipality, province, zones, etc.)
- Qualitative attributes, such as the name of the line, the mode, the company, etc.

The public transport network is built using specific BDO queries to get all the rides running on a typical business day. Rides and lines are then processed using GIS and database routines that aggregate rides into frequency service lines based on their schedule.

The connection of BDO and of the network is based on the calculation of Generalised Costs (from now on “GC”). The GC derives from the usual definitions (Ortuzar and Willumsen, 1990) and considers the assumptions made in Table 4.

Table 4 – Assumptions for the calculation of the generalized cost

	Origin zone	***Access to airport / station***	***On board***	***Hubbing***	***On board***	***Egress from airport / station***	***Destination zone***
CAR	***CAR***						
COACH	*car passenger*		**COACH**	if possible	**COACH**	*public transport*	
TRAIN	*public transport*		**TRAIN**	if possible	**TRAIN**	*public transport*	
AIR	*car passenger*		**PLANE**	if possible	**PLANE**	*public transport*	

GC is differentiated among private (car) and public transport modes. The private car GC is:

$$GC_{car=}[t^{car}VOT + cD + \gamma P_{toll}^{car}] \qquad \textbf{Equation 1}$$

Public transport options include more components of GC:

$$GC_{coach=}\left[\gamma t^{accCAR\_pax}VOT + \gamma P_{toll}^{car} + cD\right] + \left[\sum_{i=1}^{N}(\gamma t_i^{co}VOT + P_i^{co})\right] + \left[\gamma t_w^{hub}VOT_w + I_w^{hub}\right] + \left[\gamma t^{egrPT}VOT + P^{PT}\right] \quad \text{Equation 2}$$

$$GC_{train=}\left[\gamma t^{accPT}VOT + P^{PT}\right] + \left[\sum_{i=1}^{N}(\gamma t_i^{tr}VOT + P_i^{tr})\right] + \left[\gamma t_w^{hub}VOT_w + I_w^{hub}\right] + \left[\gamma t^{egrPT}VOT + P^{PT}\right] \quad \text{Equation 3}$$

$$GC_{air=}\left[\gamma t^{accCAR\_pax}VOT + \gamma P_{toll}^{car} + cD\right] + \left[\sum_{i=1}^{N}\left(\gamma t_i^{air}VOT + P_i^{air}\right)\right] + \left[\gamma t_w^{hub}VOT_w + I_w^{hub}\right] + \left[\gamma t^{egrPT}VOT + P^{PT}\right] \quad \text{Equation 4}$$

The generalized cost includes for the collective modes also a price/tariff component *P,* defined for every route as:

$P = p_0 + \rho D$ **Equation 5**

Where:

D is the distance

ρ is the fare component proportional to distance,

p_0 is a fixed component.

The parameters p_0 and ρ are calculated based on real tariffs extrapolated from transport operator websites; they vary according to the type of service, purchasing period and presence of competition. For a more detailed description, see model documentation (Beria et al., 2019).

The model's demand-side consists of the simulation of OD matrices (per mode|purpose) and assignment on the network (road and PT services). Matrices include 5 primary travel purposes, two systematic (Home-to-School and Home-to-Work), and three occasional (business, personal, free time). There is no distinction between “short-” and “long-distance”, but trips will characterised by being done during the day or involving a sleepover. Table 5 contains such classification.

Table 5 – Classification of daily trips in i-TraM.

Group	Travel purpose	Sub-group daily trips	Sub-group sleepover trips
1	**STUDY**	Home-to-School	/
2	**WORK**	Home-to-Work	/
3	**BUSINESS**	Business	Business
4	**PERSONAL TRIPS**	Personal	Personal
5	**FREE TIME**	Leisure	Holidays
6	**FREIGHT**		

Each demand component is described by different socio-economic parameters (i.e. value of time) and uses specific supply attributes (i.e. transport services fare). Since each demand component can be described by different statistical datasets, the estimation methodology is based on three approaches:

- **Systematic daily trips** are mainly modelled on the basis of Census O/D matrix describing home-to-school and home-to-work mobility, updated and adapted to the 1764 zone structure (which required several split for main urban areas;

- **Occasional daily trips** are estimated through a 3 step demand model (generation → distribution → modal split) based both on ISFORT survey parameters and on the description of the structure of mobility attractors at NUTS-5 level for 30 different “micropurpose” layers;
- **Occasional sleepover trips** are mainly modelled based on ISTAT and ONT-Bankitalia tourism statistics.

Each component has been estimated at generation, distribution and model split (public/private) level, using generalised cost matrices adapted to the socio-economic groups interested to single purposes.

Methodology/2: the definition of accessibility

Thanks to the transport model i-TraM, we will compute accessibility indicators adapting a previously applied methodology (Beria et al., 2017), but reaching a much higher level of spatial detail and comparing the two periods before and after HS opening (2008 and 2020). As opposed to most long-distance accessibility studies, we will consider all components of generalised cost, as suggested by Koopmans *et al*. (2013), and not only time.

Potential accessibility is a *location-based* measure, as defined by Geurs and van Wee (2004). It is composed by a measure of the attractiveness of destinations, M_j, and by a distance decay function f:

$$A_i = \sum_{j=1}^{n} M_j \, f(\beta, x_{ij})$$

Equation 6

One of the most common formulations of *distance decay functions* is *exponential decay*. The resulting definition of *potential accessibility* is (Geertman & Ritsema van Eck, 1995):

$$A_i = \sum_{j=1}^{n} M_j e^{-\beta x_{ij}}$$

Equation 7

Destination attractiveness

In the current application, we use two different measures of destination attractiveness.

The first is the simple population of zones. This proxy of attractiveness is general and assumes the substitutability of destinations. It could be seen as a proxy of personal purpose trips mapped in Figure 58, left.

The second measure describes the importance of destinations for non-personal trips, for example, business or administrative trips. The weights, in this case, must be much more concentrated, as for this kind of trip the attractiveness of a small provincial capital is higher than a similarly populated but empty of functions peripheral town. To proxy this difference, we consider tertiary jobs according to the 2011 ISTAT census, which includes high-level functions and commerce, tourism, etc. We subtract the average per capita value and keep only positive values, putting 0 to the others. In other words, if a zone has just local tertiary jobs, it is excluded from the destinations and destinations above the threshold are weighted according to the jobs above the threshold. Figure 58, right, depicts the selection.

The resulting map of destinations is significantly more concentrated. The South is empty of tertiary attractors, decreasing its computed accessibility level significantly but representing the lack of business concentrations differently from the North.

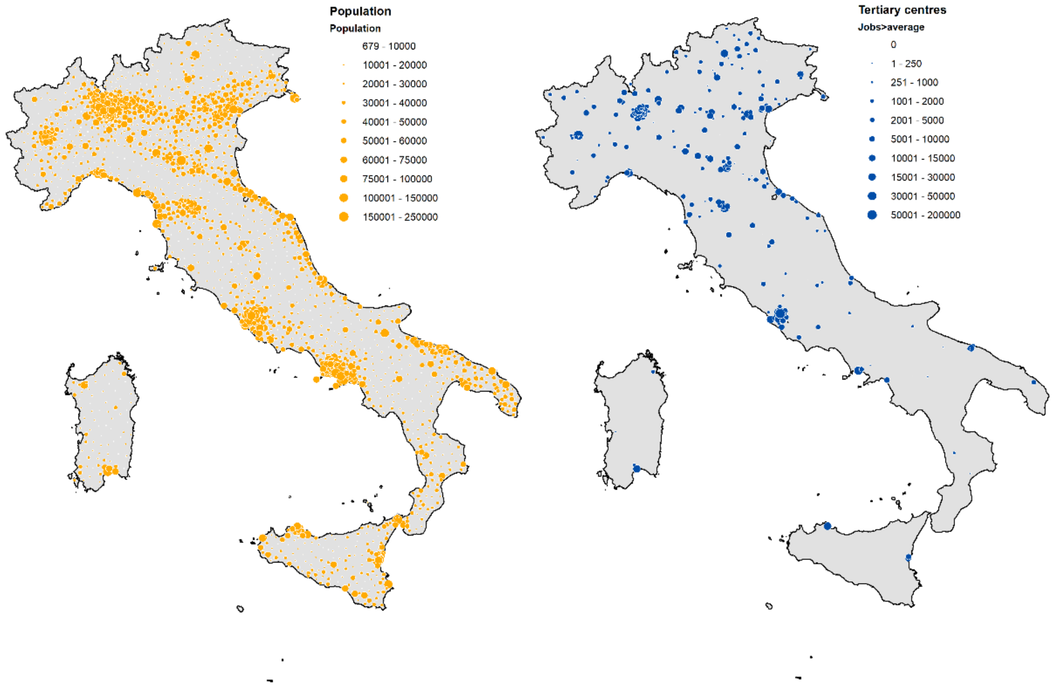


Figure 58 – Distribution of attraction weights. Our elaborations on ISTAT, 2011.

Distance decay function

The generalised cost described above includes both time and monetary components and thus represents a better description of travel impendence. For this application, we consider only public land transport (rail and coach), excluding air transport (that would significantly improve the accessibility of Southern cities but also reduce the interpretability of the results in terms of the effect of rail transport. Similarly, we exclude private transport. The generalized cost computed is the weighted average of the best multimodal combinations from origin to destination. In other words, the generalized cost is not one of the best paths, but a combination of the paths possibly chosen by travellers, resulting in more realistic.

The generalized cost is computed for two periods: 2008, before the opening of the HSR and 2020, the last year before COVID crisis. The entire rail timetable differentiates the two periods and changes do not refer to HS line only. For this reason, the result will not be the change in accessibility due to HSR, but the change of real overall accessibility due to every transport service. Of course, this makes the result less readable, but at the same time it would be impossible to establish which changes are attributable to HSR and which are not.

The generalized cost enters in the two following formulas, computing the potential accessibility.

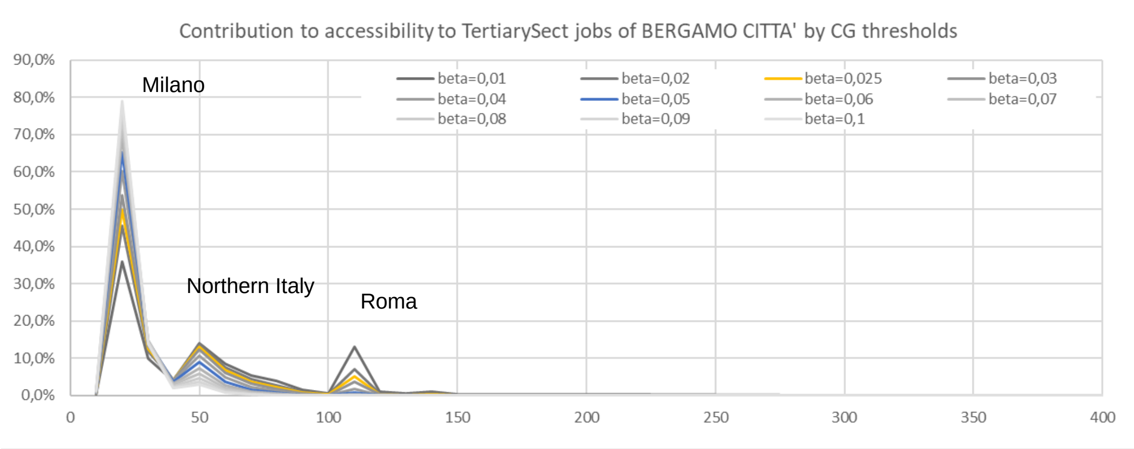
$$PApop_i = \sum_{j=1}^{n} Population_j \cdot e^{-\beta c_{ij}} \quad \textbf{Equation 8}$$

$$PAjob_i = \sum_{j=1}^{n} (0;\ Tertiaryjobs)_j \cdot e^{-\beta c_{ij}} \quad \textbf{Equation 9}$$

A key ingredient of the distance decay function is beta. Beta represents the users' cost sensitivity. Generally speaking, high betas nullify the contribution of "far" destinations. On the contrary, a low beta means that space and cost does not matter and will produce homogeneous accessibility values. The choice of a beta is crucial to get meaningful results and depends on the purpose of the analysis (there is no "right" one, unless a certain segment/purpose of demand is calibrated).

The examples in Figure 59 clarify the issue. Bergamo is located relatively near to Milano and is well connected via regional trains. The series represented in the figure shows the contribution to its accessibility (which is the integral of the functions before normalisation) of all destinations classified by generalized cost classes. Concerning advanced-tertiary accessibility, the first peak is mainly made by Milano, which is near and very large. The second peak (40-80 € approx.) is made of different destinations, mostly in northern Italy.

For example, the most significant component of 40-50€ class is Torino, followed by Genova and Padova. These places are "farther" than Milano and also smaller as attractors. The third peak is primarily due to Rome, a considerable attractor, but its cost is much higher than to Milano. When the population is considered an attractor (below chart), functions are more continuous because a broader range of localities contributes to the indicator.



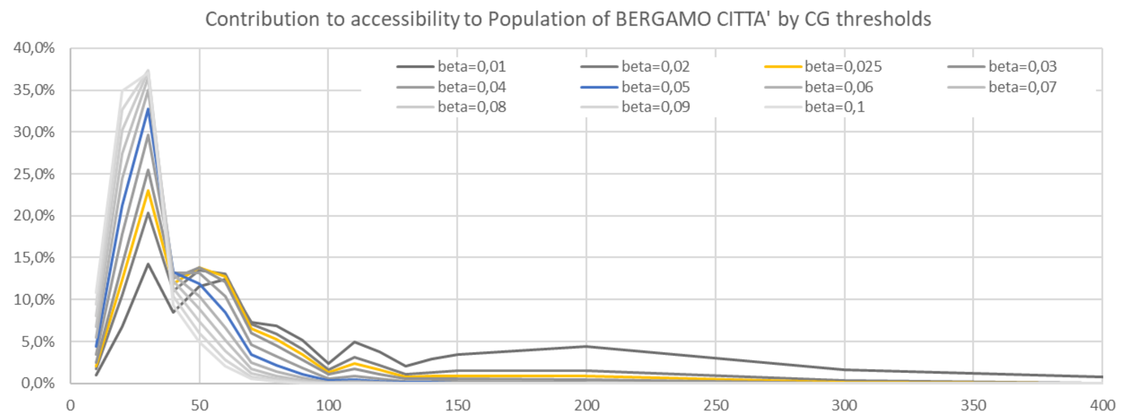


Figure 59 – An exemplification of the effect of betas. Our elaborations on i-TraM.

For the comparison of accessibilities before and after HSR, we pick a beta of 0,025. The value does not depress far destinations (which are those typically interested by HSR), but keeps essential differences among zones, as will be evident in the following.

To exemplify, in Figure 60 we compare five zones: Milan centre (MIL00) and an area of the hinterland (MIL92), Bergamo (BGM00), Rome centre (ROM00) and a very remote area in central Italy (CBS92). In terms of tertiary, Milan and Rome accessibility is primarily due to themselves (Rome is smaller than Milan because tertiary jobs are similar while transport costs within the city are more considerable). Milan similarly influences Bergamo and the periphery of Milan. The second peak for them is the complex of northern Italian cities as described above. Then comes Rome with the third peak. The accessibility is due basically to Rome only (the peak at 80-90€) in the remote areas.

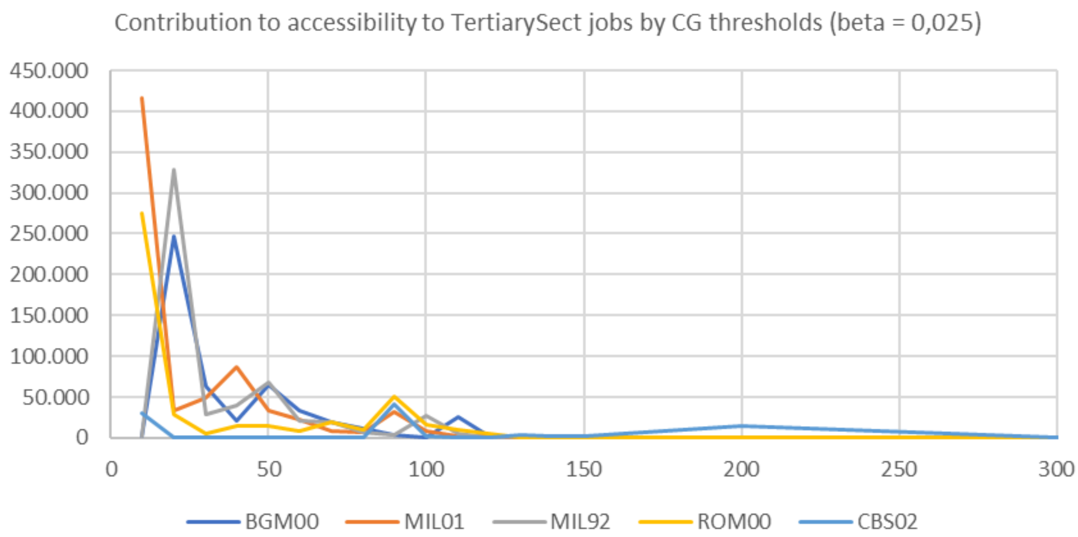


Figure 60 – Examples of accessibility values. Our elaborations on i-TraM.

Normalisation

The PA_i value is an adimensional number whose value has no straight meaning, depending on the number of zones. For this reason, accessibility values are always normalized. In this case, we divide the PA_i by the average value of the series, obtaining 100 for the zone with accessibility equal to the Italian average. Consequently, the nearest to 100 the values found are, the more the country is homogeneously accessible.

Comparison requires further steps. We propose two measures. One is the **difference of the normalized accessibility**, referred to 2008 national average. For example, a zone could obtain an index of 90 in 2008. A normalized difference of +20 means that in 2020 the accessibility is 110 with respect to the average of 2008. The second is the simple difference of absolute accessibility in 2020 minus 2008.

Results

Figure 61 and Figure 62 represent the accessibility index for the two attractors in 2008 and 2020, each normalized with respect to the national average of that year. The maps of the population look less homogeneous concerning tertiary ones. The reason is that the latter depends primarily on the effect of Milan, while population accessibility is made of the contributions of many more spread population spots.

Also, we can appreciate that the two regions, despite being by far the most connected and populated of the country, also include areas well below the national average. These areas are generally located in the mountains, even if, in some cases, these are not depopulated areas.

The increase in accessibility is evident between 2008 and 2020. However, the growth is observed everywhere and along the HSR. This is because in the decade, the HSR was not the only rail improvement in the two regions. For example, it is evident the extension of the suburban rail system in Milano also to South and East, while originally it was mostly in the Northwest section. Concerning Emilia Romagna, Bologna catchment area saw a rise in accessibility, for the same reasons. In addition, in a well-connected are like this one, the benefits of Milano and Bologna improvements also spread to neighbouring zones.

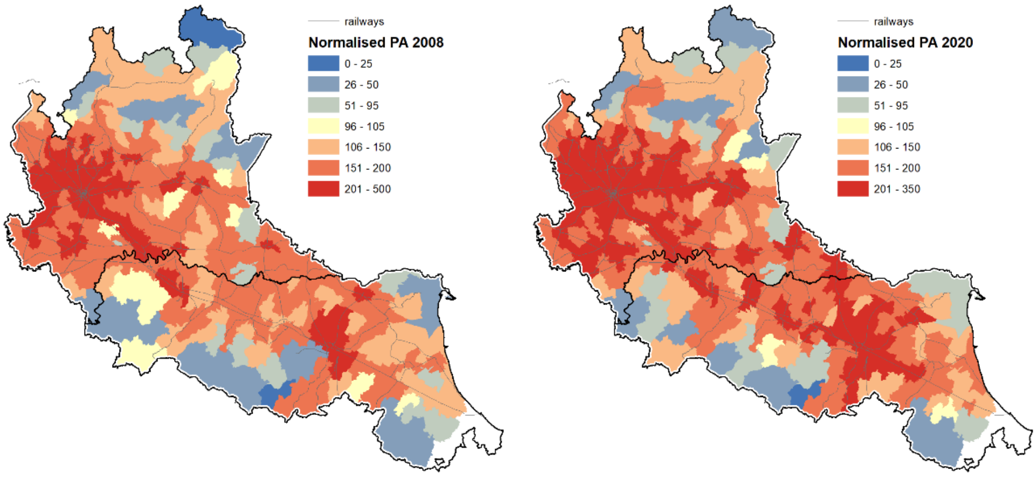


Figure 61 – Potential accessibility to population, normalised index (100=average of the year), in 2008 (left) and 2020 (right). Source: Our elaborations on i-TraM.

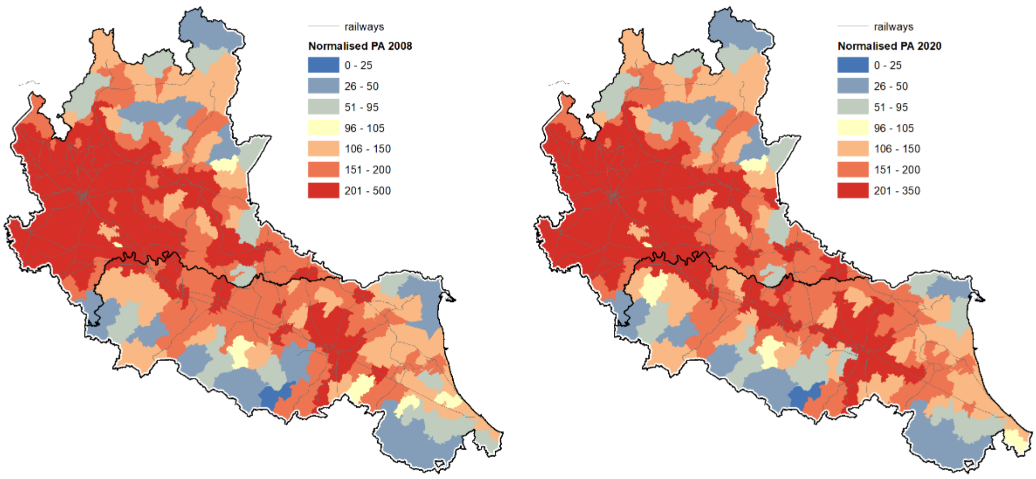


Figure 62 – Potential accessibility to tertiary centres, normalised index (100=average of the year), in 2008 (left) and 2020 (right). Source: Our elaborations on i-TraM.

We can better appreciate the difference through Figure 63 and Figure 64. The most significant accessibility gain is comprised in the area between Reggio Emilia, Ferrara and Rimini. It results from suburban system improvement plus HRS opening (including services on the Padova – Bologna – Rome corridor).

To comment on the analysed Milan-Bologna corridor, Figure 64 is more evident. It shows the different direct and indirect impacts of the HSR between the northern section (south of Piacenza to Parma) and the southern one (Reggio Emilia to Bologna). While the latter is a clear winner for the overlapping of regional and HRS services (the HSR in particular for Reggio Emilia), in the first, the gain is significantly lower. We can in fact, affirm that the areas of Cremona, Fidenza and Parma are the only ones in the two regions that did *not* improve their accessibility conditions substantially.

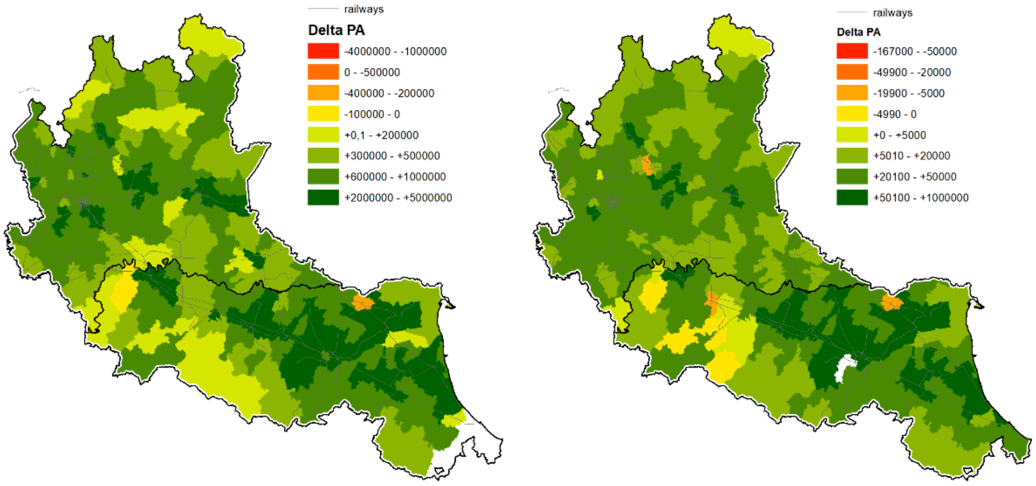


Figure 63 – Absolute change in potential accessibility, to population (left) and to tertiary centres (right). Source: Our elaborations on i-TraM.

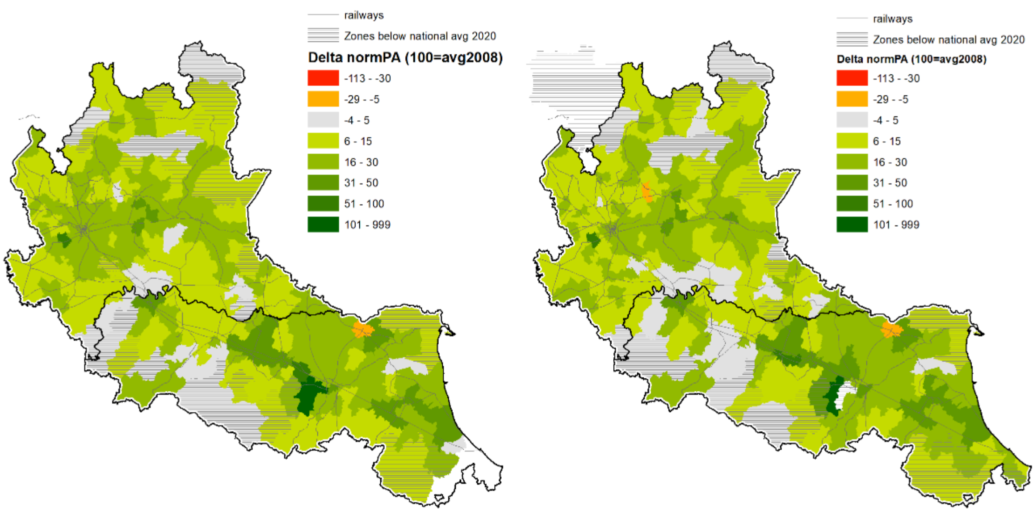


Figure 64 – Difference in normalised potential accessibility (100= average of 2008), to population (left) and to tertiary centres (right). Source: Our elaborations on i-TraM.

Comparing high-speed corridors in Europe

HSR models in the academic literature

Perl, A.D. et al., 2015 identifies and explores three strategic models of HSR development: (1) exclusive corridors (i.e., example, Japan), (2) hybrid networks - both national (i.e., France and Germany) and international (i.e., European Union), and (3) comprehensive national networks (i.e., Spain). Evaluations of these models yield outcomes oscillating between positive deductions of the corridor and national hybrid models to highlighting the imperfections and uncertainties of the international hybrid and comprehensive national network models. Japan's experience demonstrated that HSR worked well in linking megacities with a high population density and served by elaborate public transit systems. (Ha et al., 2011) made a cumulative impact assessment comparing the domestic air travel and high-speed technology, thereby observed that the Tokaido Shinkansen corridor had a less environmental impact even when the emissions of the infrastructure construction were considered. But Japan also demonstrated that a corridor strategy could not be expanded beyond megacity connections without spending copious amounts of money.

The success and shortcomings of the corridor strategy prompted railway designers to choose a different strategy for implementing HSR in Europe. A hybrid system was designed in Europe that was a blend of the new HSR infrastructure accompanied by the operation of conventional speed trains along interconnected branches integrating with regular trains. Using the existing rail infrastructure, it became possible to multiply the number of origins and destinations and create a more elaborate and integrated network. In Europe, the hybrid design of HSR infrastructure was intended to expand freight rail capacity by clearing conventional trains off congested track segments and shifting travel and boosting ridership to higher and better performing HSR along routes where market shares were falling previously.

France was the second country in the world to initiate the development of a HSR system in 1981 following Japan and the first in Europe by inaugurating the Trains à Grande Vitesse (TGV) connecting provincial capitals, Dijon in Burgundy and Lyon in the Rhone-Alps (425 km) in 2 hours. This route, the Paris-Lyon and the Sud Est corridor, having generated ridership of 25 million annual passengers, has been recognized as both financially and socioeconomically justifiable. The modal split of rail increased by about 30% and the modal share for air transport reduced by 24% between the years 1981 and 1984 (European Commission, 1998; Dobruszkes, 2011). Today, France has 1,896 km of dedicated TGV lines connecting major cities to Paris and carrying 128 million passengers per year (in 2008) at a top speed of 320 km/h. The design was a radial network of high-speed links centered on Paris. Levinson, 2012) described the network as a “hub-and-spoke” that connects a hub city to secondary towns in a tree-like architecture.

In the almost four decades passed since its implementation, the HSR Paris-Lyon and Sud-Est link has increased links with the centre by reducing the “temporal distances” between them. Roth (1990) asserts that “the TGV modifies the spatio-temporal relationships between cities... and therefore influences the behaviour of potential and actual users”, which in turn eventually leads to changes in the “social and economic relationships between” these cities. He also observes that the “psychological weight of a trip” is determined not only by the “temporal distances” but also the quality of the service such as frequency, “comfort”, “ease of access”, and other factors that “ease” the trip. He claims induced traffic to be of significant impact as Parisians increased their business journeys to the Rhone-Alps province (of which Lyon is the capital) by 52% for service trade, while the residents of Rhone-Alps increased their trips to Paris by 144% for the same purposes. In addition, surveys showed that the number of overnight stays by TGV passengers fell after the introduction of HSR from 74 to 46% (between 1981 and 1985). Thus, the reduced “temporal distance” between Paris and Lyon due to HSR service has led to changes in the mobility behavior of users and generated a high number of one-day roundtrips. This growth in business trips between Paris and Lyon attests to combining these two cities into one daily activity zone, i.e., megacity region.

However, despite the connection to the TGV, the intermediate cities, Le Creusot and Macon, have not experienced the same levels of interaction or visible growth as Paris or Lyon. This effect on the principal cities (Paris and Lyon) and the intermediate cities (Le Creusot and Macon) will be discussed later. This can be explained by the very low frequencies of HSR services provided in these cities (8 vs. 30 trains/day in Paris). Both the TGV Nord and the Parisian interconnection branch have evolved to an interregional system contrary to the traditional radial system. Specifically, the intraregional services along the Nord-Pas-de Calais region have a different model (Auphan, 2002). On the one hand, the international connection helps to serve a large number of small cities and on the other hand, conventional regional trains (TER) operated through the HSR line connecting the cities of Calais, Boulogne, Dunkerque and Arras with Lille, thus developing a regional strategy to facilitate reaching major regional cities in no more than an hour from the regional capital (Menerault & Barré, 2005).

Germany started developing its HSR network not very long after France. The German network is more decentralized than France's since there is no origin or principal city in the German urban system. Its first two Inter-City Express (ICE) high-speed lines were inaugurated in 1991, with upgraded links between Hannover and Würzburg and between Mannheim and Stuttgart. In 2002, Germany opened its first newly built passenger dedicated ICE line for 177 km between Cologne (Köln) and Frankfurt am Main. The speed of 320 km/h helped to reduced the journey times from 2hr 15min to half. Germany has since then established network of 1,285 km of ICE lines, serving the major German cities as well as destinations in neighbouring countries at top speed of 330 km/h. The new ICE line effectively links two of Germany's most economically sound regions, the Rhine-Main area (population 3 million) and the Rhine-Ruhr region (population 10 million). Levinson (2012) describes the German model as a flatter, less hubbed, decentralised HSR network, reflecting both the country's strong federalism and the principal of favouring polycentricity. The HSR link serves to overcome the problem of short distance flights between major city centres and creating a regional hub by linking together many cities thereby allowing regular commuting due to the proximity and reduced travel time. The city pair Cologne-Frankfurt is a prime example of the benefits from a shift from short distance air services to high-speed railway. This ICE route acts as a feeder to airports and has raised the competitiveness of rail against short haul flights and car trips.

In Germany, factors including more mountainous terrain and consequently a demand for tunneling to mitigate environmental effects, a more dispersed urban system, and to accommodate the freight load on the HSR infrastructure, construction and operating costs have been higher than in France thus resulting in lower financial rates of return. Still, German HSR serves approximately 67 million passengers annually (Albalate and Bel, 2012), and the average net revenue per train-mile of the ICE service as of 1994 was 1.7 times higher than the average for its other long-distance passenger trains (Ellwanger and Wilckens, 1994).

The findings and evidence from the existing studies lead Melibaeva et al. (2011) to conclude that smaller cities Montabaur and Limburg, previously not connected to conventional rail, were affected positively because of improved proximity to the major centers of Frankfurt and Cologne. Daily commuting trips from Montabaur and Limburg to Frankfurt have increased since the ICE operation started, thus bringing these cities. This increase is due to increased residential inflow to Montabaur and Limburg, attributed to the new ICE access. City planning experts believe that this has induced migration to smaller or intermediate cities near the ICE because of lower costs and higher quality of life. The population gains triggered by the ICE railway station are considered very important for the region's future development. The induced migration is expected to offset the expected loss of population caused by demographic changes such as a decline in natural population growth and stabilize the population size of the Montabaur region and the Westerwald district.

In Spain, the first high-speed railway started services in 1992, between Madrid and Seville, with intermediate stations at Ciudad Real, Puertollano and Cordoba followed by over 2000 km of HSR expansion throughout the country since 2003. The central government's programme for high-speed rail since 2000 was to connect the country's political and economic capital, Madrid, to all the provincial capitals by high-speed rail in less than 4 h. A comprehensive national system of high-speed lines is being developed using a predominantly radial network centred on Madrid. The Spanish system design integrates both the high-speed AVE (Alta Velocitad Espanola) trains to operate exclusively on high-speed rails and the conventional Talgo, Altaria, and Alvia trains that use both high-speed and conventional infrastructure. The findings of Monzon, A. et al., 2019 show that the 25-year (1990-2015) development plan of the HSR network in Spain has reduced connecting times in most cities and improved accessibility levels by an average of 49% nationwide. At the same time, better rail connections have reduced disparities among regions and achieved higher levels of territorial cohesion in the distribution of accessibility.

Interestingly, the most significant benefits are not concentrated in the larger cities like Madrid and Barcelona, but in small to medium ones with a relatively worse situation in 1990. The Spanish design has evolved from connecting only major centres to boost the economy to connecting peripheral areas thus fulfilling cohesion goals. This has led to an overall improvement in territorial imbalances in accessibility. This development has been accompanied by evidence of a mode substitution effect: in the 1998–2016 period, long-distance rail passengers increased by 200%. In the same period, air traffic declined on major routes competing with HSR services, for example, Madrid-Seville (25% drop in air traffic, 63% rise in rail traffic), Madrid-Barcelona (34% and 874%) and Madrid-Valencia (42% and 470%) (de Ureña et al., 2021).

In the next section, some case studies of existing corridors and their effects on neighbouring cities will be discussed.

HSR corridors and intermediate cities

Recent European policies have territorial cohesion as one of their main goals and current polycentric development to achieve more balanced and sustainable territories. This is consistent with the idea that the development of new HSR should be complemented by the improvement of conventional secondary networks, instead of solely responding to projections between major cities. This type of integration is thought to ameliorate the negative aspects common to agglomerations, such as rising prices, urban sprawl or traffic congestion and emissions related to high commuting flows to the main centres (Veneri & Burgalassi, 2012). The spillover or induced effect resulting from HSR investments (Gutiérrez et al., 2010) also has cohesion effects. An example is that cities without HS services, e.g. Santander and Aviles in the north or Cadiz in the south, display similar improvements as others with high-speed rail services and stations. The reason is the possibility of such cities to merge with major economic centres by partial high-speed connections. In other words, investments in secondary rail networks can significantly improve the effects of new HSR links on territorial cohesion.

Thus, the pivotal question is how HSR affects small cities, and intermediate cities in the surrounding areas. HSR facilitates, in most cases, polarisation between first and second level cities. Other cases are deducing that some small and intermediate cities have experienced HSR induced development (Garmendia, Romero, Ureña, Coronado, & Vickerman, 2012). Yin et al. (2015) show that the disparity between HSR-connected and unconnected cities and regions tends to grow. Coronado et al. (2019) compare the long-term population evolution of HSR cities with similar non-HSR ones, finding in which cases HSR induces greater/lesser growth. Bruinsma and Rietveld (1993) argue that the differential increase in accessibility that accompanies HSR may increase spatial inequality and centralisation. Gutiérrez, González, and Gómez (1996) argue that the reduction of space by HSR in Europe will be non-uniform and unbalanced between the principal serving cities and their hinterlands. Vickerman, Spiekermann, and Wegener (1999) confirm the likely unevenness of space contraction in Europe while also pointing out that served cities improve their ‘notoriety’ and ‘modernity’ image in the short term. Moyano et al. (2019), using an efficiency analysis of all HSR Spanish connections, show that large cities located at ends favour business demand, while intermediate cities perform more efficiently for tourism. De Urena, J.M. et al., 2009 explains the territorial implications on big intermediate cities along HSR lines and on the regional system of smaller cities at national, regional, and local levels, thus clarifying to what extent HSR opens new complementary and contradictory possibilities for urban development. Cavallaro, F. et al., 2020 have investigated whether the opening of the Italian HSR system has caused social and spatial equity changes on the towns of Asti and Alessandria, which have become secondary since the opening of Turin-Rome via Milan and Bologna, revealing that a trade-off between efficiency and equity in the design of HSR lines might exist. They adopted a monomodal approach and assessed this issue through two indexes (Social and Spatial counterparts). The results are driven by a potential spatial and social mismatch, as higher-income citizens (generally located in those cities served by HSR lines) seem to profit the most from the performance advantages and afford the higher cost. The inclusion of these aspects in the planning process can assure and evaluate social and spatial equity impacts, thus overcoming difficulties in performing Cost-Benefit Analysis to solve such issues. The social equity issue was also raised by (Beria et al., 2016). They explained how introducing a higher level of service represented by HSR is often related to disrupting and eventually quitting the distance-based fare system and opening to a market approach. Chen and Haynes (2017) address the complexity of the correlation between HSR development and economic disparity. In general, scholars who have studied implications from HSR within European contexts noticed that the opening of HSRs has not led to economic growth but rather to a redistribution of economic activities within regions, with some negative effects on smaller cities.

Some of these case studies have been tabulated below, stressing on the inferences drawn with respect to the cities involved.

Table 6 – Case Study of Madrid – Barcelona & Madrid – Seville (source: adapted from de Ureña et al., 2009)

Corridor	Distance	Duration	Cities studied	Inferences
MADRID – BARCE-LONA	607 km	2h 50m	Zaragoza	1. Zaragoza has successful in modernising the traditional old-style urban centre into a national/ international cen-tre. 2. The number passengers in HSR services for Cordoba and Zaragoza stopovers represents on average around 50% of those passengers travelling between these cit-ies.
MADRID - SEVILLA	470 km	2h 20m	Cordoba	3. As an induced effect, journey time from Pamplona and Logrono to Madrid has dropped by 35%. 4. Cordoba saw the creation of an urban project over 90 hectares of railway and industrial land adjacent to the traditional business centre. 5. Cordoba has regained its regional position, be-cause of a regional strategy and the HSR junc-tion at Cordoba, permitting exchanges with Puente Genil, Antequera and Granada – Puente Genil and Antequera through the HSR regional services, and Granada through the tradi-tional Madrid–Granada long-distance services. 6. Integration of railway areas and urban belts in Cordoba has helped achieve this goal. 7. The two case studies include many public transport fa-cilities at urban and intercity levels.

Table 7 - Case Study of Brussels-London, Paris.London & Brussels-London (source: adapted from de Ureña et al., 2009)

Corridor	Distance	Duration	Cities studied	Inferences
BRUSSELS – PARIS	307 km	1h 30 m	Lille	1. The number of passengers in HSR services for Lille rep-resents on average around 66% of those passengers travelling between these cities. 2. The introduction of regional HSR services between Lille and the three regional coastal cities to its north-west (Calais, Boulogne and Dunkerque), reduced the journey time to half for Lille.
PARIS – LONDON	451 m	2h 30m		3. Establishment of Euralille project has created a new city centre, and is helping bolster and market Lille as an in-dividual identity. 4. Lille has chosen a central or semi-central location for their HSR station, adjacent to the existing business cen-tre with abundant land available for redevelopment. Thus, a juxtaposition of modern and traditional urban ar-eas within city area has given positive results.
BRUSSELS – LONDON	317 km	1h 57 m		

				5. Lille HSR station has meeting areas where professionals can meet and work rather than traveling full distances. 6. Lille has become key for railway certification and has attracted several international accountancy firms and major offices of some national banks.

Table 8 - Case Study of Paris-Lyon & Sud-Est (source: adapted from Melibaeva et al., 2011)

Corridor	Distance	Duration	Cities studied	Inferences
HSR Sud-EST PARIS - LYON	425km	2h	Paris, Lyon, Macon and Le Creusot	1. Parisians increased their business journeys to the Rhone-Alps province by 52% for service trade, while the residents of Rhone-Alps increased their trips to Paris by 144% 2. Total business travel on the corridor increased 56%, and those made for sale/purchase of services by 112%. 3. Round trips with origin Paris have a higher increase rate as compared to those trips with origin Lyon. 4. The number of overnight stays reduced from 2.3 days in 1980 to 1.7 days in 1992. 5. Increase of 43% in office space in Lyon (1983-1990) 6. Macon registered a 13.5% increase in employment between 1999 and 2006 while neighbouring cities lost jobs. 7. La Creusot had almost no local economic impact in terms of new jobs, firms or commercial expansion. 8. Grenoble and Geneve lost their businesses to Lyon. 9. The HSR along with the hospitality infrastructure development and promotion strategy have made Lyon a growing tourist destination.

Table 9 - Case Study of Cologne-Frankfurt (source: adapted from Melibaeva et al., 2011)

Corridor	Distance	Duration	Cities studied	Inferences
COLOGNE - FRANKFURT	180km	1h	Limburg, Montabaur and Siegburg	1. Frankfurt attracts 80% of daily commuters on the ICE line from Limburg and about 60% of commuters from Montabaur. 2. The ICE connection has reinforced and accelerated migration process towards Montabaur and Limburg. 3. Limburg accounts for about 2,500 people using its ICE station daily, and between 2003 and 2005 this number grew by 32%. 4. About 20% of the Montabaur ICE commuters and about 15% of the Limburg ICE commuters moved there from

				the neighbouring large metropolitan areas because of the ICE improved speed and accessibility. 5. Surveys have shown that 90% of Sieburg passengers travel to and from Frankfurt, and about three quarters of the passengers use the train for business or commuting. 6. Almost 3% of the ICE-users from Siegburg have migrated here because of the ICE connection.

Table 10 - Case Study of Turin-Rome via Milan and Bologna (source: adapted from Cavallaro et al., 2020)

Corridor	*Distance*	*Duration*	*Cities studied*	*Inferences*
TURIN – ROME VIA MILAN AND BOLOGNA	724 km	4h	Turin, Genova, Asti and Alessandria	1. Between 2002 and 2019, the scenario of lower Piedmont and Liguria has evolved positively in terms of spatial equity, since the SpREI (Spatial Equity Index) is positive in the four cases analysed. 2. The spatial equity index rises by 216% and 243% respectively for Alessandria and Asti 3. Reduced travel time leads to the best performances in terms of SpREI, which is more than 2 times higher than Asti and almost 14 times higher than Genoa. 4. Alessandria and Asti register the highest increase in SoREI (Social Equity Index) (+146% and +127%, respectively), while the cities of Turin and Genoa show lower values (+101% and 98%, respectively). 5. The evolution of fares has penalized the towns of Alessandria and Asti, where the average increase of ticket prices to/ from Rome between 2002 and 2019 is equal to 146% and 127%. 6. Turin and Genoa saw a lower increase in fares (+93% and 100% respectively). Genoa is an interesting case: for “early birds” fares in 2019 had even decreased by 10%. This is because Genoa is not located on the main HSR lines and is served by a good number of conventional long-distance trains subsidized by the ministry.

Analysis of comparable corridors in Europe

We conclude this section with a specific comparative analysis of HSR corridors with similar characteristics than the Milan-Bologna one.

In **Error! Reference source not found.**, we can see the speed variability along the various high-speed sections of Europe (speed >200 km/h). The network is mainly concentrated in Spain, France, Italy, plus branches in Germany, UK and elsewhere. Except few cases, these networks are still predominantly national. The networks of France and Spain are mostly radial, under the respective urban structure. Italy is more linear (and will remain such also after the extensions in construction), with the three poles of Milano, Bologna and Roma. Germany did not develop a properly said network but upgraded or built single fast lines as a part of an integrated network with the remaining conventional lines.


NUTS 3 Zones
Speed km/hour
200 - 230
230 - 260
260 - 300
>300
Oslo
Stockholm
Linkoping
Goteborg
Jankoping
Glasgow
Aarhus
Copenhagen
Manchester
Birmingham
Bristol
London
Groningen
Hamburg
Amsterdam
Hannover
Berlin
Warszawa
Brussel
Cologne
Lille
Sachsen
Wroclaw
Frankfurt
Prague
Krakow
Ostrava-mesto
Brno-mesto
Paris
Karlsruhe
Rennes
Seine-et-Marne
Strasbourg
Baden-Wurttemberg
Munich
Linz (Stadt)
Wien
Budapest
Maine-et-Loire
Cote-d'Or
Vienne
Bolzano
Trento
Zagreb
Rhone
Lyon
Milano
Verona
Venezia
Padova
Torino
Gironde
Modena
Bologna
A Coruna
Cantabria
Bilbao
Gipuzkoa
Toulouse
Firenze
Rimini
Splitsko-dalmatinska
Leòn
Pyrenes-Atlantiques
Marseille
Livorno
Porto
Valladolid
Huesca
Pyrenes-Orientales
Gerona
Aveiro
Guarda Salamanca
Zaragoza
Barcelona
Roma
Madrid
Benevento
Bari
Oibia-Tempio
Napoli
Avellino
Caceres
Salerno
Lecce
Lisboa
Valencia
Cagliari
Faro
Huelva
Cordoba
Jaén
Sevilla
Granada
Palermo
Cadiz
Malaga

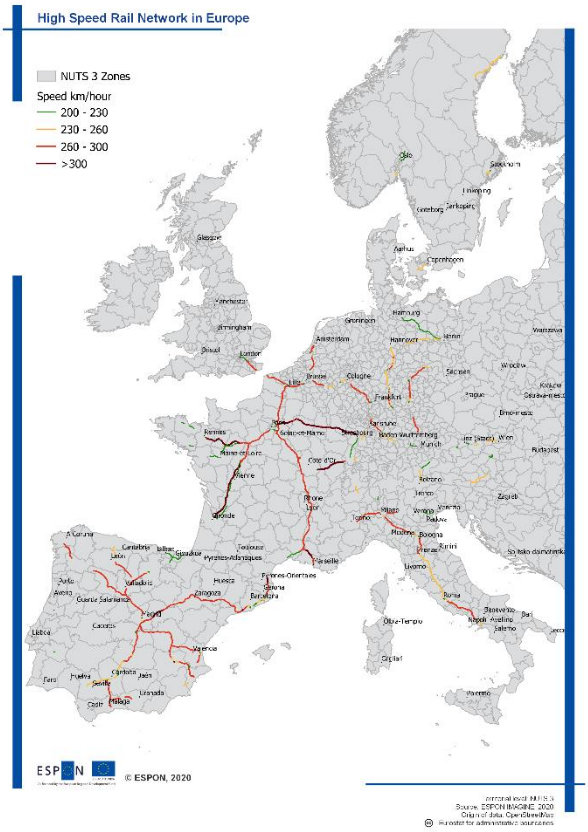
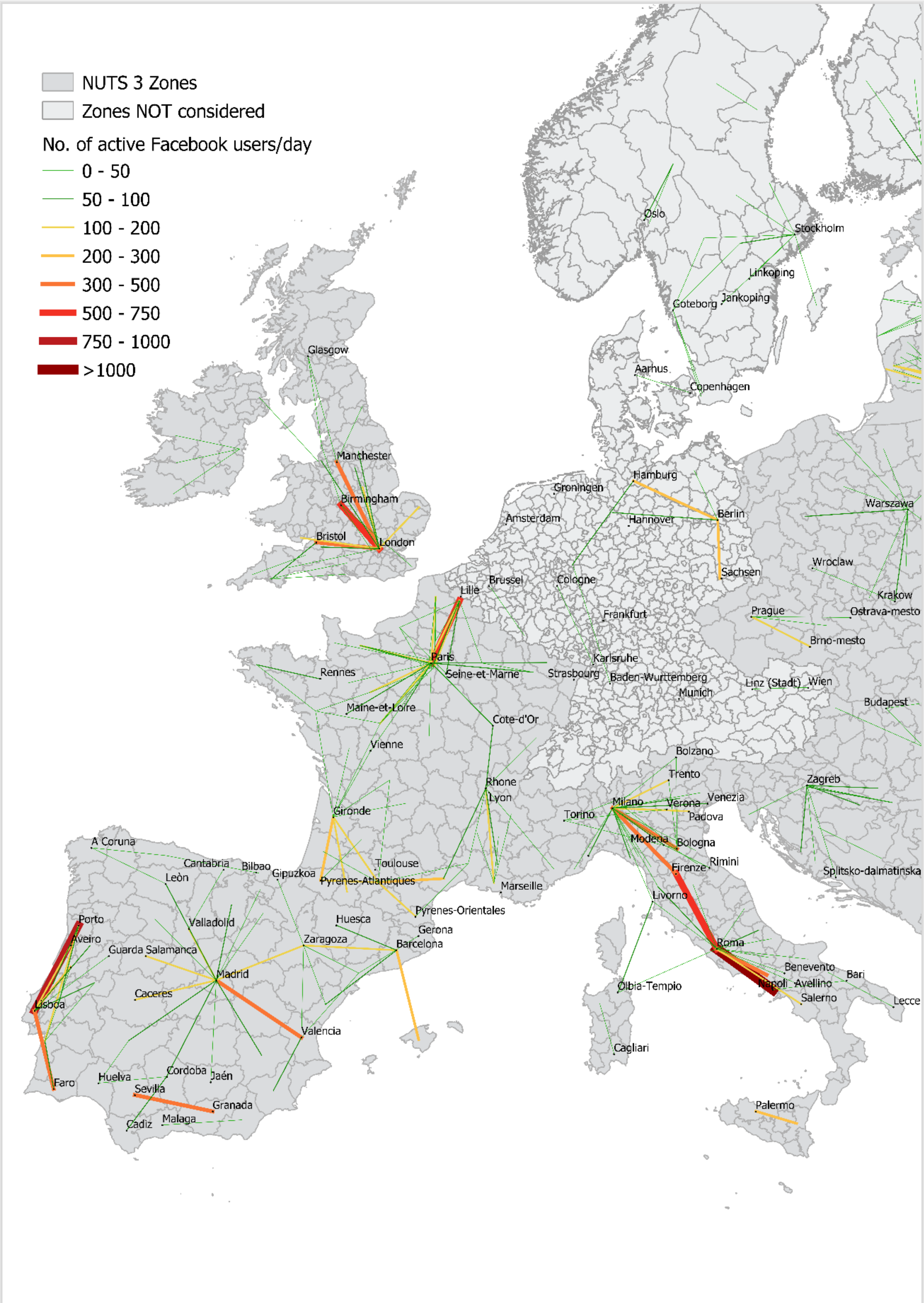


Figure 65 – High Speed rail network in Europe. Source: our elaborations on Openstreetmap data.

We have no figures about the rail demand of these corridors. For this reason, we use as a proxy of the relevance of European intercity relations the already described (Section 0) *Movement between Administrative regions* (NUTS-3) for 2020, made available by Facebook. Cross-border flows are unfortunately not available in the datasets and some countries due to a lack of data or different spatial detail. For better visualization and maintaining relevance, only those connections are chosen that are 150 – 300 km apart. The flow indicated here is the daily flow (for all modes of transport and purposes of travel) from one NUTS-3 region to another.


NUTS 3 Zones
Zones NOT considered
No. of active Facebook users/day
0 - 50
50 - 100
100 - 200
200 - 300
300 - 500
500 - 750
750 - 1000
>1000
Oslo
Stockholm
Linkoping
Goteborg
Jankoping
Aarhus
Copenhagen
Glasgow
Manchester
Birmingham
Bristol
London
Hamburg
Groningen
Amsterdam
Hannover
Berlin
Warszawa
Sachsen
Wroclaw
Brussel
Cologne
Lille
Frankfurt
Prague
Krakow
Ostrava-mesto
Brno-mesto
Paris
Karlsruhe
Rennes
Seine-et-Marne
Strasbourg
Baden-Wurttemberg
Munich
Linz (Stadt)
Wien
Budapest
Maine-et-Loire
Cote-d'Or
Vienne
Bolzano
Trento
Rhone
Lyon
Zagreb
Milano
Verona
Venezia
Torino
Padova
Gironde
Modena
Bologna
A Coruna
Cantabria
Bilbao
Toulouse
Gipuzkoa
Firenze
Rimini
Splitsko-dalmatinska
Leòn
Pyrenes-Atlantiques
Marseille
Livorno
Porto
Valladolid
Huesca
Pyrenes-Orientales
Aveiro
Gerona
Zaragoza
Barcelona
Roma
Guarda
Salamanca
Benevento
Bari
Madrid
Napoli
Avellino
Olbia-Tempio
Caceres
Salerno
Lecce
Lisboa
Valencia
Cagliari
Cordoba
Huelva
Jaén
Faro
Sevilla
Granada
Palermo
Cadiz
Malaga

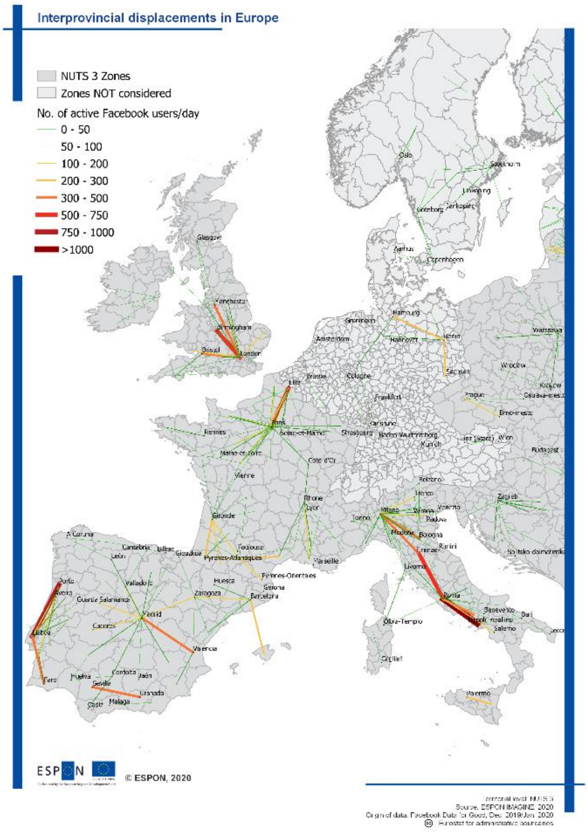


Figure 66 – Interprovincial displacements (No. of FB users/day). Source: our elaborations on Facebook data.

Superimposing the two illustrations helps us identify major displacements and check whether HSR infrastructure could be critical in that respect. Actually, the two maps are only partially coincident, in particular where a fast line does not serve relevant flows. The corridors mentioned in section 0 are, however clearly visible.

The radial system of Madrid and its corridors with Seville and Barcelona can be visualised in the figure above and have a substantial weight in terms of daily flow. The only connections that have higher flows than these corridors are Madrid's connection with Valencia and Sevilla with Granada. The centralisation of the railway network or transport infrastructure in general around Paris cannot go unnoticed and the flow that is along the HSR infrastructure of Paris-Lyon and Sud-Est corridor. An interesting observation would be dominant flows between the provinces of Paris and Lille which could validate the positive effect of Paris - London corridor on the municipality of Lille and its province mentioned in the above sub - section. Italy and its differently designed network to connect the main metropolitan cities stands out with considerable flows along the Torino-Napoli corridor. The weightage of Milan-Bologna is of considerable importance and stands out not only in the national context but also in the European context with flows like the Madrid-Valencia connection.

To make a further step, we analyse a selection of these corridors, including some with an HS partially or fully operative, and others with HS lines in the project (e.g. London to north and Prague-Brno). The list of corridors is in Table 11. The differences of population density and urban structure across the corridors can be appreciated visually in Figure 67, Figure 68 and Figure 69.[16]

[16] Sources of data: https://op.europa.eu/webpub/eca/special-reports/high-speed-rail-19-2018/en/ and https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php

With few exclusions, HS line branches of 150-300 km cross territories that are substantially empty of significant settlements and thus effectively connect the urban poles at the extremities (e.g., Madrid – Zaragoza). More similar to the Milano- Bologna line is the Tours-Bordeaux (but the density of intermediate centres is lower), Lyon-Marseille, Zaragoza-Barcelona, and to a higher extent the London-Birmingham. Interestingly, in all of these cases, the intermediate poles are served by intermediate stations or stops: Poitiers and Angouleme interconnections on the Tours-Bordeaux, Leida interconnection and Camp de Tarragona in-line station for the Zaragoza-Barcelona and Avignon and Aix-en-Provence in line stations on the Lyon-Valence-Marseille. Concerning future projects, the Praha-Brno line is under discussion whether to connect also the intermediate city of Pardubice and the British line is actually a complex system of fast lines, interconnections and in-line stations exactly to cope with the territorial structure.

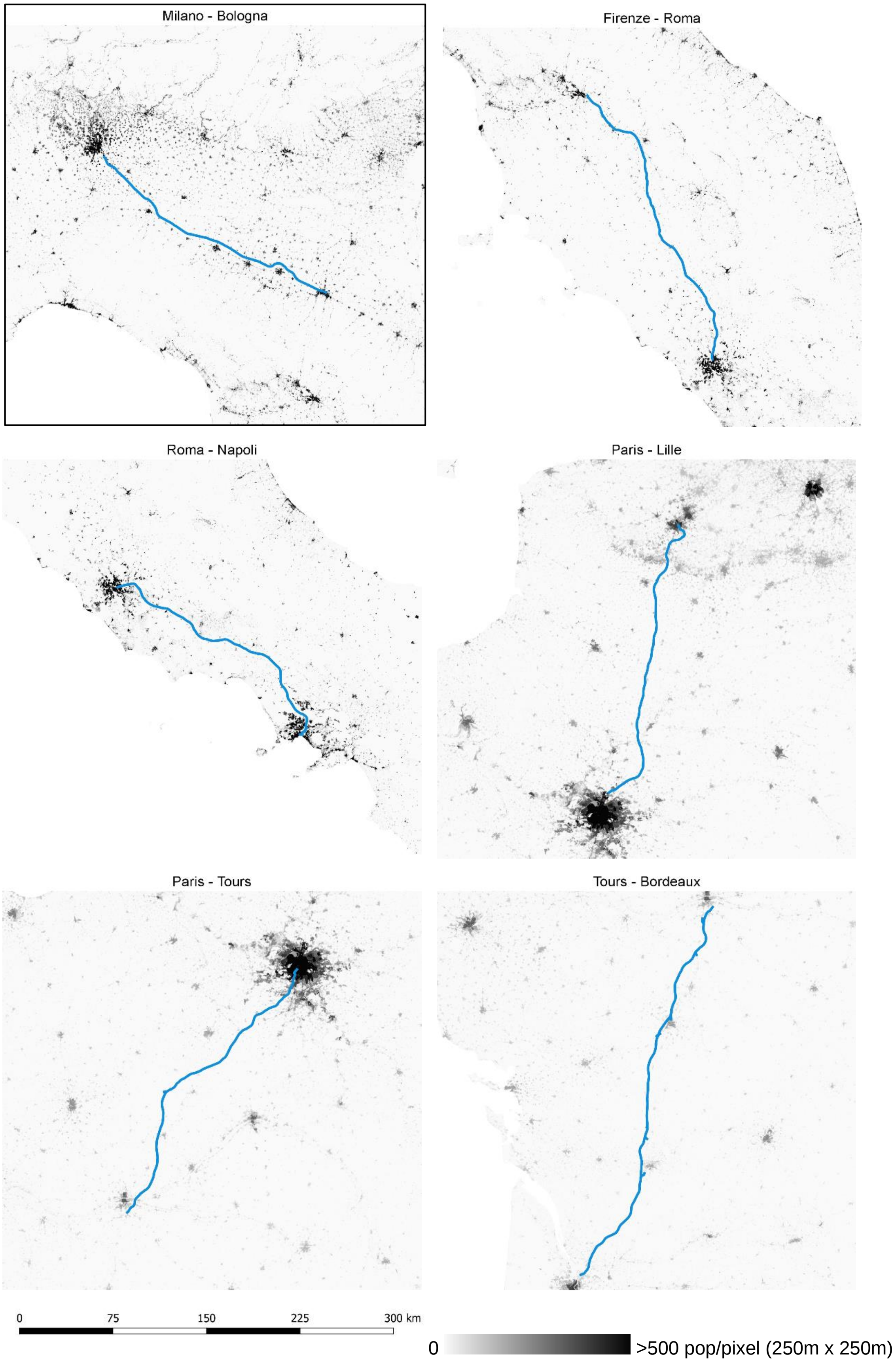


Figure 67 – Populated areas along high-speed railways (group 1). Source: GHSL - Global Human Settlement Layer.

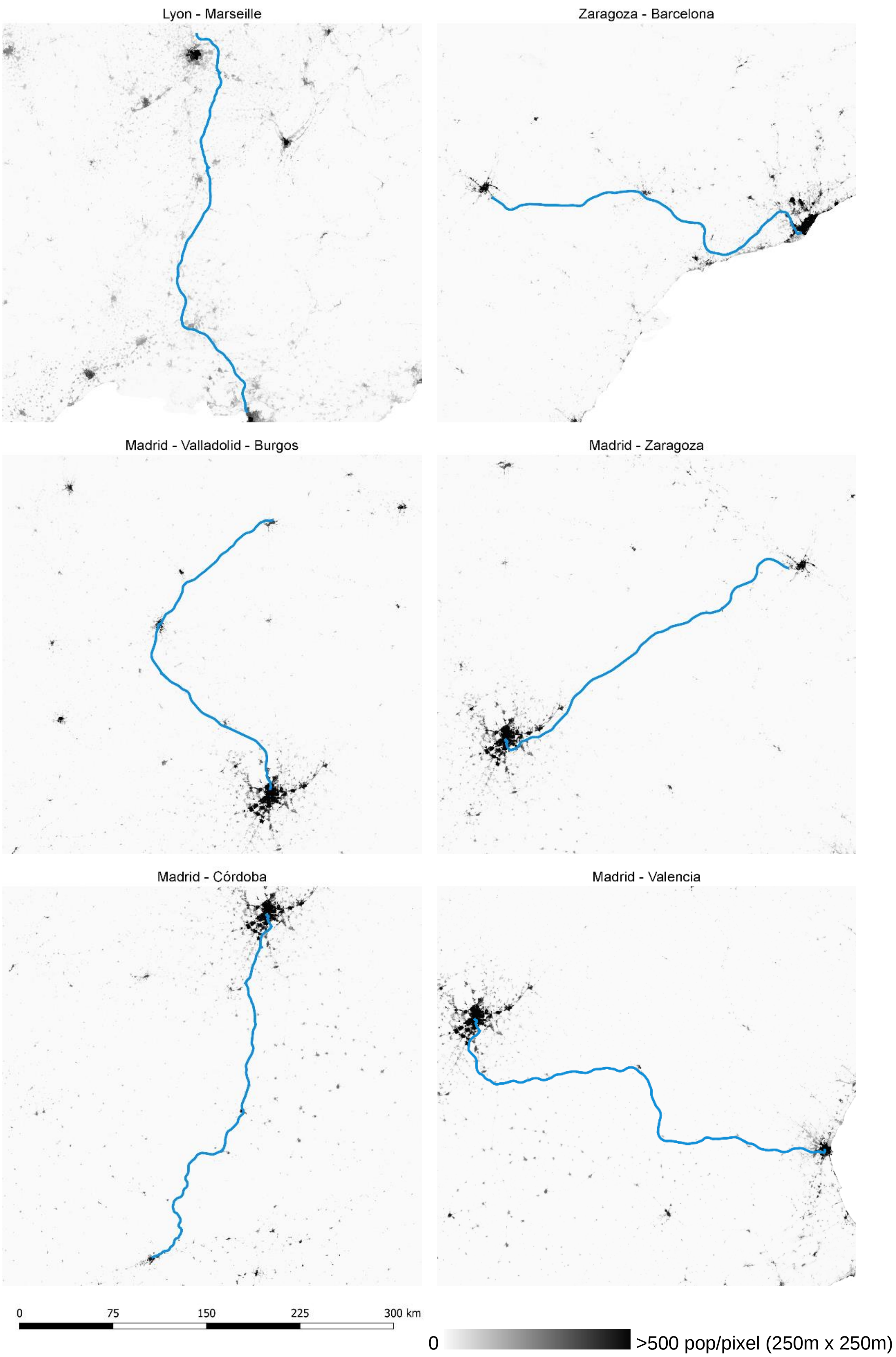


Figure 68 – Populated areas along high-speed railways (group 2). Source: GHSL - Global Human Settlement Layer.

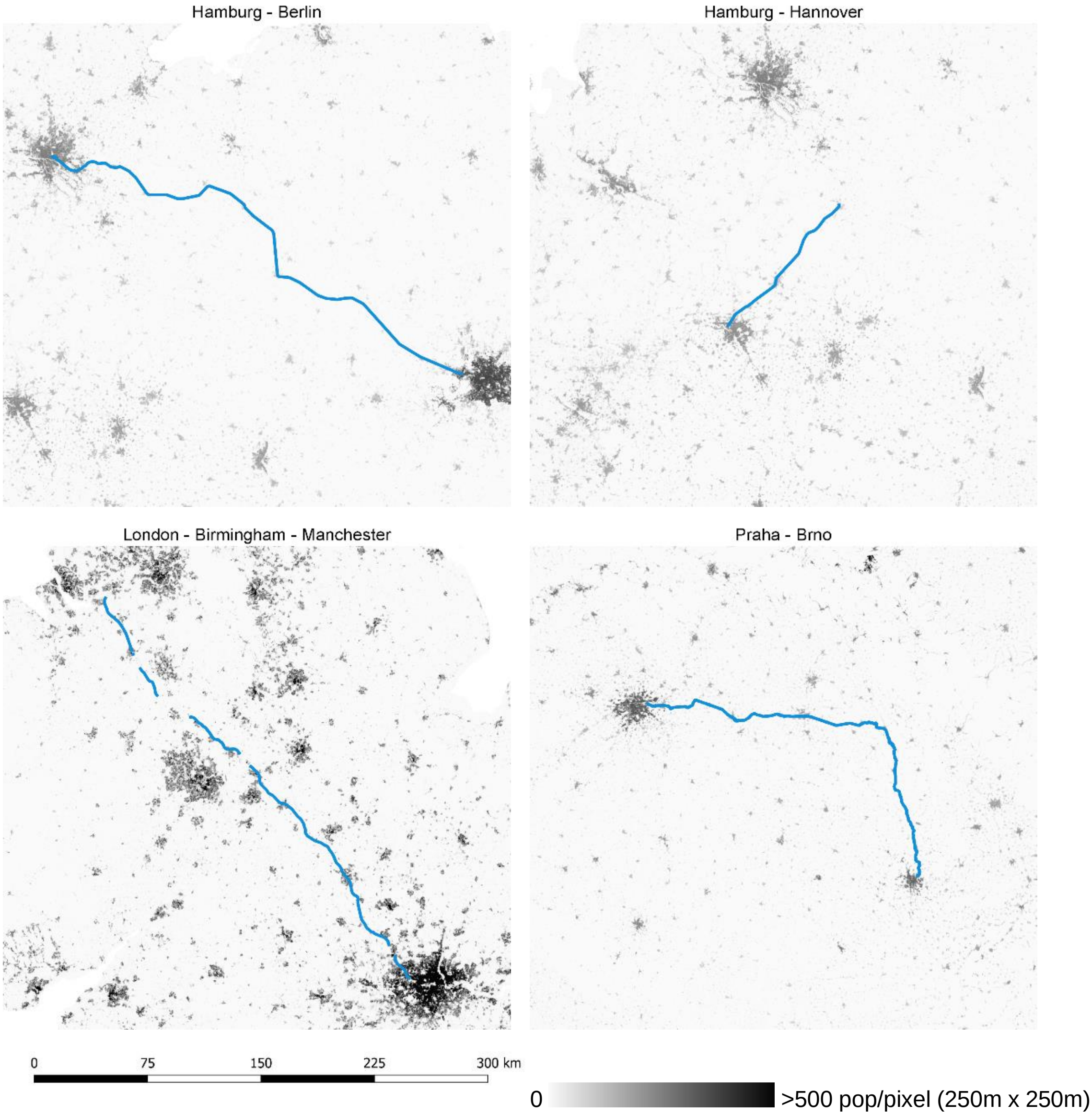


Figure 69 – Populated areas along high-speed railways (group 2). Source: GHSL - Global Human Settlement Layer.

To visualise more synthetically these findings, we computed three simple indicators made by the *ratio between intermediate areas and extremities of the corridor*, in terms of population and GDP. In particular, we associated corridor data related to population (of NUTS-3 and metropolitan areas) and GDP (of NUTS-3). Territorial units have been manually classified into "Extremities" if they belong to the extremities cities of the corridor[17], for example, Milano and Bologna or the entire Grand Paris and the Nord of France for the Paris - Lille. Similarly, "Intermediate" are territorial units crossed by the line. The results of the indicators are presented in Table 11 and plotted in Chart 17 and Chart 18.

[17] The NUTS3 data comes from ESPON database. Cities and Greater Cities are defined according to Eurostat classification ("A City is a local administrative unit (LAU) where the majority of the population lives in an urban centre of at least 50 000 inhabitants"). NUTS3 and Cities were selected when the corridor intersects the area and the main city in NUTS3 is interested in the line (not too far / there is a station in the main city linked with the line).The selected cities are directly interested by the high-speed railway line even if there is not a station of HS.

Table 11 – Comparison of HS corridors in Europe by polarisation level. Source: our elaborations based on ESPON and Eurostat data.

		Ratio intermediate/extremities		
Corridor	*Country*	*Population (2019) NUTS3*	*GDP (2018) NUTS3*	*Population Cities*
Milan - Bologna	**IT**	**0,514**	**0,359**	**0,372**
Firenze - Roma	IT	0,107	0,076	0,031
Roma - Napoli	IT	0,191	0,117	0,000
Paris - Lille	FR	0,267	0,112	0,031
Paris - Tours	FR	0,172	0,047	0,000
Tours - Bordeaux	FR	0,351	0,308	0,110
Lyon - Marseille	FR	0,275	0,210	0,176
Madrid - Zaragoza	ES	0,034	0,020	0,015
Zaragoza - Barcelona	ES	0,189	0,185	0,035
Madrid - Valencia	ES	0,021	0,016	0,037
Madrid - Córdoba	ES	0,158	0,096	0,030
Madrid - Valladolid - Burgos	ES	0,118	0,090	0,073
London - Birmingham - Manchester	UK	0,678	0,000	0,091
Hamburg - Berlin	DE	0,118	0,057	0,000
Hamburg - Hannover	DE	0,152	0,076	0,061
Praha - Brno	CZ	0,758	0,403	0,054

Table and charts confirm the intuition of the maps. The Milan-Bologna is the most multipolar if cities are considered, followed by two French lines. Many corridors have a relative weight of intermediate cities of 1/10 or less with respect to the northern Italian line, including the Firenze – Roma section. The calculation based on NUTS-3 is rougher since it depends on the size of the administrative units, for example, very small in the UK and very large in France and Spain, sometimes including cities that are entirely unrelated to the corridors allows to consider also GDP.

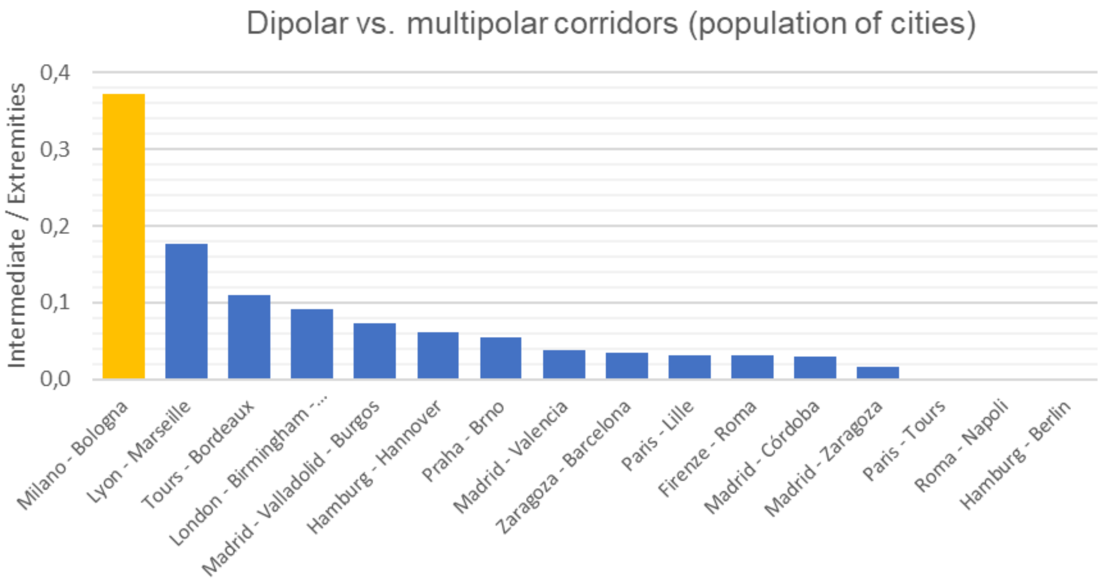


Chart 17 – Relative weight of intermediate Cities vs. extremity poles for a selection of European corridors, year 2019. Source: our elaborations based on ESPON and Eurostat data.

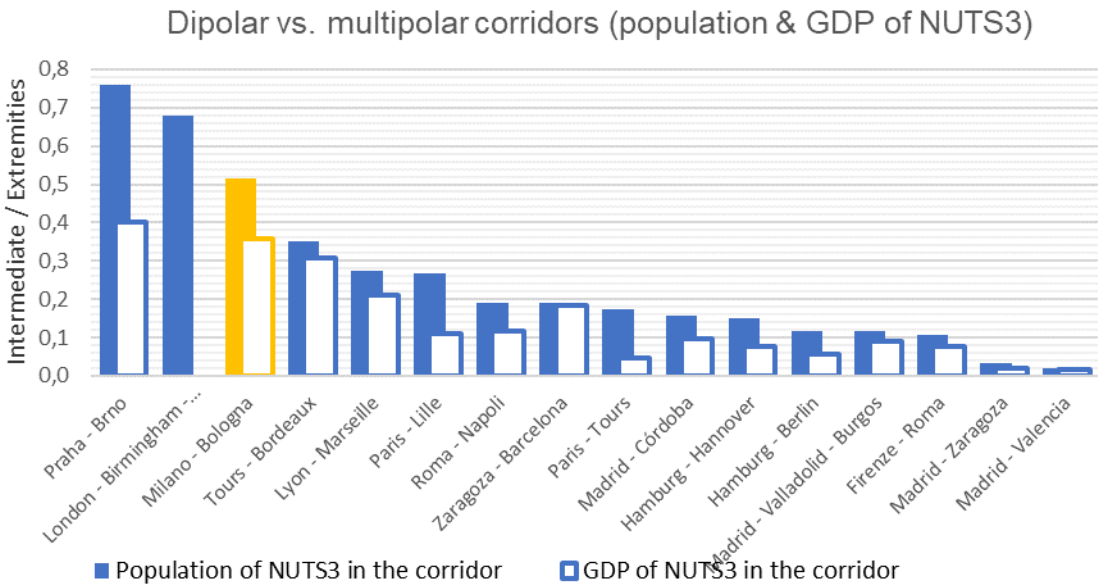


Chart 18 – Relative weight of intermediate NUTS3 vs. extremity poles for a selection of European corridors, year 2019. Source: our elaborations based on ESPON and Eurostat data.

Policy recommendations

The in-depth analysis of demand, supply, and accessibility in the corridor Milano – Bologna, and from it to the rest of the country and Europe, was a specific objective of the IMAGINE Project. This section summarises the main findings to introduce policy recommendations for the local context and the broader EU perspective.

The introduction of the HSR line and service along the Milan-Bologna corridor in 2009 followed the model of pure-high speed: the new fast line is separate from the conventional one, and all intermediate stations are skipped. This model replicates the original French model of HSR, introduced two decades before, which was thought for the connection between far and strong poles separated by low-density areas, as it happens – for example – between Firenze and Roma. This model has generated critical positive effects of integration between main Italian cities, including Milano and Bologna, who captured most of the benefits of the investment. However, the effects on the Milan-Bologna urban region are more complex to be evaluated, including both positive (strengthening the connections between these two cities and the rest of the country) and negative ones (relative exclusion of 2nd tier cities from the national network). This synthetic evaluation is nowadays also shared at the national level. The most recent projects, such as the HSR between Milano and Venezia, will adopt a different model: lower speed, higher connectivity of intermediate cities and, hopefully, better integration with regional transport. These are the keys to a more appropriate and effective role of HSR in the Italian context, especially in the country's north, characterised by a dense, polynuclear and interconnected territorial and urban structure.

The analysis of the Milan-Bologna urban region, from the mobility of people, shows, in particular, a consistent process of regionalisation of mobility dynamics, which makes this urban region peculiar and challenging for the sake of the design of mobility policies. In fact, the intercity mobility between the cities of the corridor is above the average of the area: it serves an interlinked and economically flourishing territory, made of compact and lively cities at a relatively short distance. However, even though conditions are ideal for rail transport at the local and regional level, the use of trains is below comparable corridors in Northern Italy: just 28% of intercity trips use public transport, vs. levels of 35-45% in other similar situations.

The cause is probably attributable to the weakness or lack of an interregional rail policy focusing on intermediate distances and services. The regional public actors in charge of local mobility policies are focused on suburban/metropolitan transport and the market ones on serving the demand of fast long-distance mobility. In addition, Milan, despite the introduction of an underground railway link dedicated to regional trains, keeps working as a sort of “barrier” to anything directed north of it, preventing the introduction of bypass services from Emilian cities to the northern Lombardia and Switzerland.

In fact, the two regions, Lombardia and Emilia Romagna, in different times, invested a lot in the improvement of a suburban rail system serving the regional capitals (See sections 0, 0 and 0). These systems are additional to historical services and have been facilitated by the new capacity also generated by implementing the HSR Milan-Bologna. The Lombard one and the Bolognese one at a smaller scale can be seen as success stories in terms of patronage and modal change. In both cases, the two regions have been the most active in supporting regional mobility in the last decades.

The introduction of the HSR between Milano and Bologna generated of course, direct and visible effects of connectivity among the two regional capitals and the rest of the country, producing the expected effects even in terms of competitivity of the HSR to the air-based offer. For example, the average travel time of faster trains from Bologna to Rome passed from 170 to 140 minutes and from Milano from 277 to 206 in 2019. But the real difference is made by the variety of connections, passed from 50 and 26 per day from Bologna and Milano respectively, to 122 and 90 in 2020.

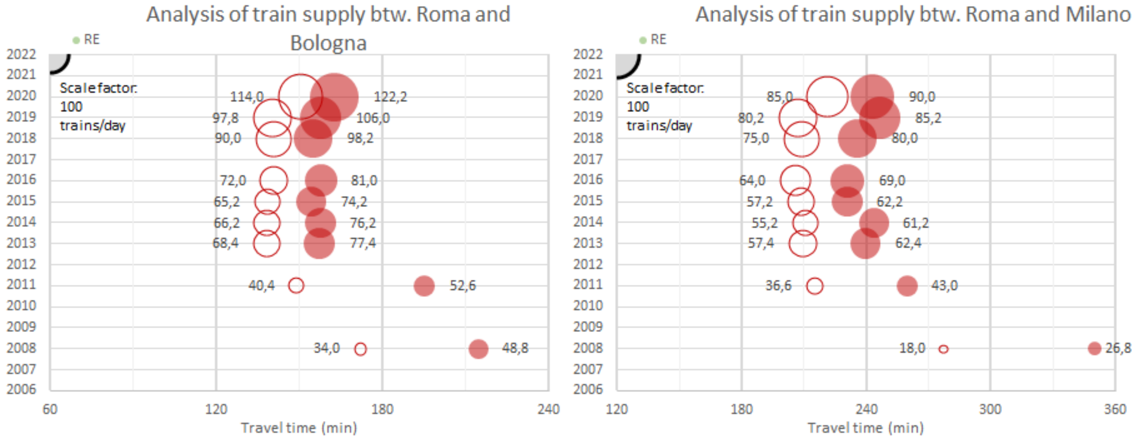


Figure 70 – Evolution of rail performance (speed and daily frequency) of connections Roma – Bologna and Roma – Milano. Source: META-TRASPOL elaborations on official timetables

Moreover, it must be noticed that the extra capacity on the corridor created by the new HSR line, together with the high potential demand, is at the root of the successful Italian experience of head-on competition in HSR between the incumbent service provider, Trenitalia, and a newcomer, .Italo. The consequences have been: a huge increase in HS train frequency, a rise of load factors, and the non-predatory price strategy of the incumbent (see section 0). Overall, these ingredients allowed a significant demand increase. The demand is distributed across all travel purposes. A significant phenomenon of long-distance commuting has been observed between the two poles and the intermediate station of Reggio Emilia AV (about 20% of total demand to Milano).

Unfortunately, the same cannot be said as regards the national connections (and consequently the national-scale accessibility) of intermediate cities between Milano and Bologna; these, in fact, have been reduced due to the shift of most of the long-distance connections to the HS line, as discussed in Section 0 and 0. In terms of national connectiveness, Piacenza, Fidenza, Parma and Modena can be considered as losers. Of course, they got a specific benefit, together with the neighbouring Pavia and Cremona, from the HSR thanks to interchange connections (documented in Section 0). Still, overall their accessibility/connectivity rank reduced with respect to comparable cities located elsewhere (e.g. Verona, Padova or even Rovigo and Ferrara). They lost direct connections with the Centre and the South of the country and with Piemonte (and Veneto, which remains unconnected from Via Emilia cities by rail since ever). Overall, the HS polarised the mobility of the corridor significantly, instead of spreading benefits around it.

An exception is found in relation to the external intermediate station of Reggio Emilia Mediopadana AV, which is one of the few extra-urban and intermediate HSR stations in Italy and by far the most successful one (See Section 3.5). Its aim, from its origins, was to serve a wider regional basin, characterised by being one of the most dynamic and competitive territories in Italy based on industrial districts, which since the seventies are intensively contributing to the national economy. Its localization was the result of a vigorous and participated local debate, opposing different regional cities, and at the same time an interesting innovation, introducing a hybrid in the original HSR model. As for today, seven years after its completion, the Mediopadana station serves mainly as an outgoing station (used by locals to reach other national destinations) rather than for the incoming (few users using it as a destination and only to Reggio Emilia itself). Then, its principal merit was to *mitigate* the loss of connections of Via Emilia cities caused by the HSR model chosen for the line, rather than a real opportunity of the surroundings to become a new centrality. The city of Reggio Emilia in this respect, is a net gainer from the HSR. At the same time, the station's actual capacity of attraction to the other regional capitals is still limited due to the lack of direct public transportation from Parma and Modena.

Given these premises, some broad policy suggestions can be advanced, focusing mainly on mending a powerful territorial machine. They all go in the direction of tightening its internal and external natural relations, mainly by recognising the continuity of the corridor rather than its dipolar structure.

Main challenges and opportunities for a new role of the HSR in support of the Milan-Bologna Urban Region

The Milan-Bologna corridor – due to its urban-territorial and socio-economic structure is nearly a *continuum of mobility*. This situation contrasts with a typical HS line service, based on a few HS stations as the one here adopted, which naturally creates a "tunnel effect". As a result, giving evidence of this mismatch, local communities push at least to replicate the experiment of Reggio Emilia AV also in other cities, for example, in Parma. Evidently enough, this is a sub-optimal solution within the existing model. Extra stops are, in fact, incompatible with the level and type of fast services expected, and a new station would cannibalise the role now played by Reggio Emilia. Moreover, this would require significant investments in mass transit at the local level and erode the much-needed capacity of the line.

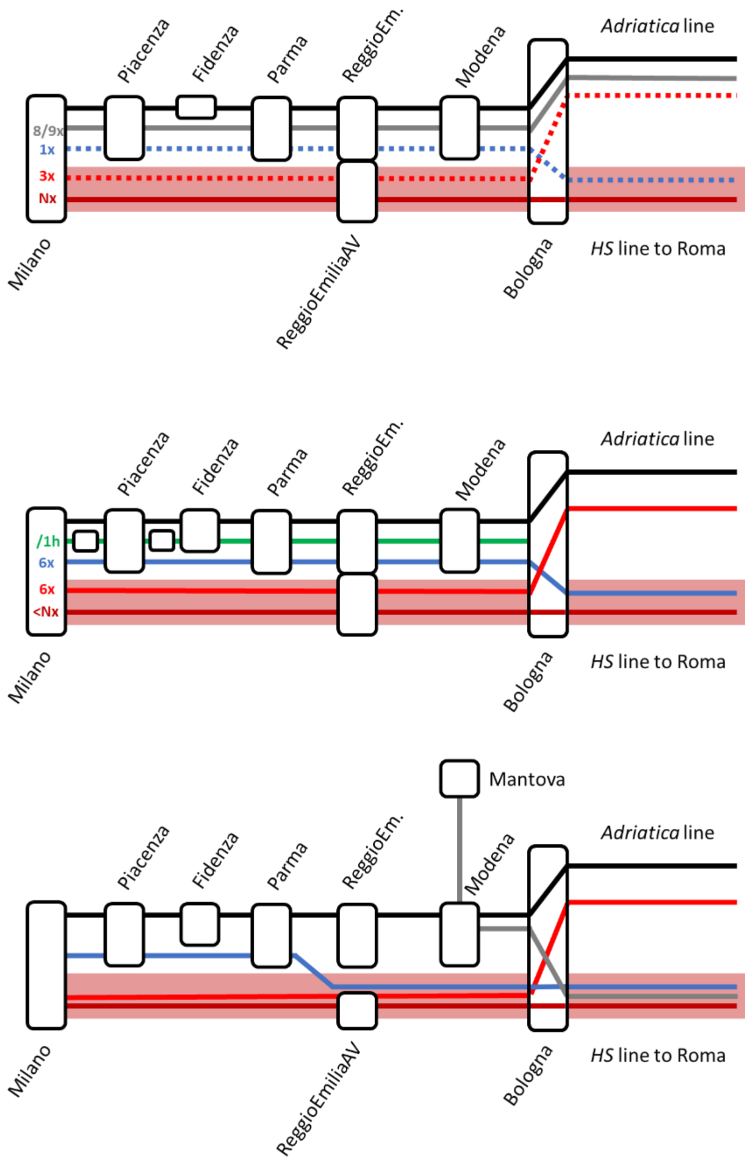


Figure 71 – Schematisation of current and proposed rail services in the corridor.

From a pipe to a backbone: a new service model for HSR

This first and more significant challenge to strengthen the role of HSR within the Milano-Bologna region could be tackled by rethinking the opportunities to use better the numerous interconnections (rarely used) between the HS line and the conventional ones. This could allow for the introduction of mixed-HS services (widely used by both operators elsewhere in the country: Bergamo/Verona/Bolzano – Roma, stops in Chiusi and Terontola, extensions to Potenza/Reggio Calabria/Taranto, etc.) to re-establish and improve the con-nections between the intermediate cities of the corridor to the capital and the south of the country. This kind of services could deposit benefits of the HS line also in the cities excluded from the network up to 2020, without worsening the performance of Milan's fastest direct trains to Rome.

As explained in Figure 71 the current scheme of services on the line (excluding regional trains) is illustrated: the trains heading to Rome use the fast line between Milano and Bologna. The trains to Ancona and south along the Adriatic corridor use the conventional tracks between Milano and Bologna serving the intermediate cities. Recently, 3 Frecciarossa branded trains/day per direction, use the HS line until Bologna and then pass to the Adriatica line, with a reduction of approximately 1h in the travel time between Milan and cities south of Rimini. This happens, once again, at the expense of intermediate cities along the Emilia corridor. Just one HS train to Rome is using the conventional line serving all provincial capitals.

A different scheme could introduce the first set of opportunities to mild the hierarchisation effects produced by the HSR introduction: all the trains from the Adriatica line (serving Ancona, Pescara, etc.) could pass to the HS line, saving 1h and improving the accessibility significantly for distant destinations. Instead, the Emilian cities would be served by more numerous HS trains entering the HS line in Bologna and following to Rome and South. In this scheme, the only lost direct connections are those from the Adriatica to the Via Emilia cities, but these connections (less meaningful than to Milan and Rome, both improved for all) would remain guaranteed by existing IC trains and RegioExpress trains (e.g., Piacenza-Rimini). There is also room to specialise the RegioExpress trains Milan-Bologna (see next section) in this scheme.

To evaluate demand and sustainability, a further scheme considers the opportunity to split the trains from the Emilian cities to Rome and use the interconnections. For example, some rides could start in Milano and proceed along the conventional line to Parma and pass to the HS line up to Rome. A second service could serve Mantova, Modena and Bologna, where the fast line is reached.[18] This option makes travel time to Rome even more competitive but could be unsustainable for companies due to limited demand and must therefore be assessed more carefully. It must be noticed that the operators could have *already* applied this scheme from Via Emilia to Rome, but they did not, except for one couple of trains/day. This can mean that it could be more effective in terms of revenues and margins to force those passengers to interchange in Bologna rather than serving them directly or losing them. To overcome this problem, local communities, which could benefit from faster direct services, could subsidise the operator to cover the extra costs of the stop (e.g. Arezzo or Chiusi) or of the extension (e.g. Taranto). This solution is, however non-efficient as it is independent from the actual number of users and could generate an over-subsidization; an alternative solution could be a semi-market solution: a subsidy per passenger (and not per km) is given to any operator providing a certain service, to stimulate the ramp-up of these services and at the same time provide a service which is more suited to the needs of most of travellers.

A new interregional connectivity: A new model for an integrated regional offer

The mobility along the Milan-Bologna corridor is not just concentrated between the two capitals. The role, size and distance of all intermediate cities require an intermediate level of service between HSR and regional trains. This intermediate level is guaranteed by market trains with compulsory booking (Frecciargento and Frecciabianca) or by slow regional trains. In both cases, the solution is far from optimal for short-range intercity mobility.

The 10 regional fast trains linking Milano and Bologna, in fact, are slow not only because of calling at smaller towns, but also because serving as suburban trains within the Bologna metropolitan areas. While Lombardia Region chooses to specialize (where possible) suburban trains from RegioExpress ones within the regional borders, the same did not happen with the interregional trains to Emilia Romagna. The result is that RegioExpress trains are up to Parma, but then call at *every* station, including some very minor ones, and becoming ineffective for both demand segments (the interregional because of low speed and the suburban because of low frequency).

A reorganization of these trains, which could probably include an increase of frequency at least to hourly schedules, would be functional to support the everyday mobility of the corridor, which is perhaps inhibited also by the price and by the need to reserve the seat in advance. In fact, the corridor presents the best

[18] Of course Reggio Emilia does not need to be served directly, thanks to the external station. Similar schemes could be assessed (even if demand and travel time could be not competitive) to reach also Alessandria, Cremona, Pavia, Brescia, coherently with the concept of *Alta Velocità di Rete* already present in the national programmes.

conditions for fast regional trains: very compact and near cities, no sprawl, a very interdependent territory, high-rank functions in all cities (universities, headquarters, etc.).

Moreover, the possibility to extend some of these trains to the largest cities north of Milan (Monza, first of all) via the urban stations of Rogoredo and Lambrate, skipping Milano Centrale station, could serve many sparse and unserved relations that now are hidden by the already mentioned “dam effect” of Milan.

Better integration with local transport

While the focus of HS-centred policies is mainly at the regional scale, also local public transport holds an essential role in amplifying the territorial effect of investment.

The case of Reggio Emilia AV is extremely clear: the station works mainly for outgoing traffic since the incoming one – which clearly does not have a car – must rely on public solutions. Taxi is functional just to short-range business destinations, and buses proved insufficient to spread the accessibility to destinations different from Reggio Emilia city centre.

No mass transit investment can be conceived just to serve as a feeder for long-distance demand – because demand is too scant for it and because it would be difficult to justify the public investment in the line and service. However, important projects are already at stake and could be pushed and designed in a better-integrated manner:

a) Bologna is starting a 4-lines plan to reintroduce modern tramways. A reliable and frequent mass transit network – even if not comparable to a metro network – can effectively distribute travellers in the urban area. Line 1, in particular, is going to serve the fairground and the city centre.

b) Milano is working to improve the integration of stations served by long-distance trains with urban and regional transport. A new circle line should distribute passengers from the gate-station of Rogoredo to the periphery of the city and to the north, in the newly developed research-university and business pole of MIND, where another HS station is already present, initially being realised to serve Expo2015 (Rho-Fiera AV). In Segrate, East of Milano metropolitan area, a new gate station for the Milano-Venice HS line is in the definitive design phase. All of them are connected with the centre of the city by metro and by rail to the peripheral areas, significantly broadening the catchment area of HS. All of them can be used to create bypass specialised HS services with interesting network effects. For example, in 2020, trains from Torino to Rome calling at Rho Fiera and Rogoredo (but not Centrale) have been introduced. A similar scheme could be applied to the other directions.

c) Reggio Emilia, similarly to Bologna, is building a tram line to connect the HS station with the centre.

However, other solutions could be considered for their relative simplicity and little cost.

d) Reggio Emilia AV can be equipped with a passing bus station directly accessible from the highway, making it a very effective intermodal node. This station could allow extremely efficient stops for north-south coaches and the restructuring of dedicated express buses (Freccialink and Italobus) as HS feeders from Cremona/Parma and Modena/Mantova.

Figure 72 – Schematisation of proposed bus connections with Reggio Emilia AV motorway interchange node.

e) The same Reggio Emilia AV is connected with a station of the regional line to Guastalla/Mantova. Unfrequent and slow services serve the line, and the effect is negligible: too infrequent from Reggio Emilia, too slow from northbound and unconnected with Mantova. A general reconsideration of the line's service could look more at mid-distance relations (e.g., Mantova). It could also be attractive as a feeder instead of as a local line slowly serving smaller municipalities.

Lessons learned: how infrastructural corridors can better support urban regions connectivity

Every line and corridor is different from the others, and the findings' transferability must be considered having in mind case's peculiarities. Nevertheless, some of our results for the Milano – Bologna HSR can be extended and generalised.

1) *Territory matters.* The characteristics of the territory crossed matter a lot in explaining successes and failures. The main lesson learned from the Milano – Bologna case is that the trade-off between higher speed and loss of connection for intermediate cities must be carefully weighed. Most of the rest of Italian HSR involves cities separated by low-density areas (e.g., Rome – Napoli or Rome – Firenze) or adopts a different model (e.g., Milano – Venice will serve all intermediate cities). On the contrary, the Milano-Bologna is adhering to the fully separated HS logic, which is not appropriate for the areas crossed. Given that, in the range of 100-200 km, the time gain of a line running at 300 km/h vs. one at 200-250 km/h is in the range of minutes, the bypass of intermediate destinations must be carefully addressed. A flexible (but more expensive) solution made of a more porous line with interconnections could be considered in similar conditions. Several international experiences are going in this direction. See, for example, the recent case of Switzerland and Germany and the French and the Spanish context (Scholl. 2019)[19]

2) *The tunnel effect can be superseded with an integrated mobility offer.* HSR shall be part of a larger train mobility offer. In terms of benefits, the Milano – Bologna HSR was successful because of the contemporary presence of two conditions: speed and saturation of the conventional line. If both exist (and not only speed), we can expect benefits for the unserved cities thanks to the improvement of conventional services. If the conventional line is underused, the switch to the HS line of fast services will benefit the extremities. Still, few or no benefits (or even losses under some circumstances), will deposit in the intermediate territories.

3) *Intermediate cities can be integrated into the HSR offer.* Extra-urban HSR stations have been used extensively in Europe for various reasons. Sometimes just political, some other as a part of a structured accessibility strategy involving multimodality and interconnections and differentiated objectives (for example, within policies for promoting tourism and cultural-entertainment attractions). Reggio Emilia AV is a success story for patronage because it serves a populated and economically very lively territory and is well accessible by motorway. This success is, however, limited by the lack of effective interconnections with the enlarged area. In particular, it is not served by regional trains (except a very secondary line), so travellers less use it to/from the neighbouring cities that prefer to remain on conventional service. In a broader perspective, HSR corridors can highly benefit from intermediate stations when part of more comprehensive mobility policies, offering the opportunity to diversify the offer and the service.

4) *The long-term community can be a resource or a threat to the labour market*. Under some conditions (that for the line are represented in particular by the attractiveness of important urban poles, like Milano) the phenomenon of HS commuting could become relevant, reaching shares of 10-20% of total travellers or more. The rise of such mobility patterns should be assessed carefully: if involving weak cities and territories, this could become a severe threat for them, exacerbating the already existing territorial disparities. On the contrary, in corridors characterised by a balanced profile of economic competitiveness, it represents a healthy way to extend labor markets, benefiting the enterprises. This is especially important in some sectors, like creativity and cultural activities, which can reduce the costs of distance while capturing the value of quality of life.

[19] It is always important to remember the regulatory context: HS is usually a market service, so no planner can force an operator to serve intermediate cities unless a PSO is imposed (at a cost). So, the use of interconnections to serve intermediate cities remains, at the moment of design, a possibility and not a guarantee.

Exploring the impacts of high-speed rail infrastructure on the economic development of the urban region and the corridor, producing effects on the territorial cohesion, counterfactual analysis

This final chapter provides a complementary perspective on the impact of the HSR on the Milan-Bologna urban region. It develops a proper counterfactual assessment that, on the one hand, adopts quantitative indicators related to the change in the economic structure and competitiveness of the different areas of the urban region, and on the other hand, uses data coming from alternative sources and classified at NUTS3 scale.

HSR infrastructure and returns on investments

Economic-related returns

In the academic literature, a lot has been written about the impact of HSR on various economic outcomes, such as the regional GDP, the gross value added (GVA), the labour market, etc., mostly finding positive effects. Specifically, three recent studies deserve to be mentioned since they focus on European experiences (Germany, Spain, and Italy).

Ahlfeldt and Feddersen (2018) analysed the German HSR line linking Cologne with Frankfurt. They found positive effects of HSR on GDP, per-worker GDP and workplace employment: the economic growth came through an increase in labour productivity. Moreover, the results showed that firms in Montabaur and Limburg (two intermediate stops) had drawn employees from a broader labour market since the opening of the HSR.

Concerning the Spanish case, Carbo et al. (2019) evaluated the impacts of the HSR line connecting Madrid and Barcelona on the GVA, labour productivity, total employment, and the number of registered firms. The results showed positive and significant impacts from HSR on labour productivity, GVA, and the number of firms. Specifically, the average treatment effects for provinces with stops on the HSR network were 2.4% for GVA, 3.3% for the number of firms, and 1.1% for labour productivity. There were no significant effects on employment.

Finally, Cascetta et al. (2020) investigated the Italian case. They found a positive effect of HSR services on per capita GDP by applying econometric techniques: +2.6% increase in 10 years. Moreover, HSR in Italy contributed to a significant increase, on average, in transport accessibility (+32%) for the zones along with the HSR network, while only marginal for the others (+6%), and it decreased equity in terms of users' travel time accessibility by 11%, increasing the differences between the zones served by HSR and those not.

Other returns on heterogeneous dimensions and outcomes

Looking at the HSR impact on various outcomes, different from the strictly economic ones described above, several studies investigated the effects of HSR on the tourism market, especially in Italy. Specifically, Pagliara and Mauriello (2020) evaluated the variables affecting tourists' choices and specifically the impact of HSR on Italian and foreign tourists. Pagliara et al. (2017) found that the effects of HSR on the number of Italian visitors and the number of nights spent at destination are positive in all the municipalities along the HSR network.
Instead, Albalate and Fageda (2016) examined the Spanish case, providing mixed evidence about the impact of HSR accessibility on tourist outcomes. Indeed, on the one hand, they found that air traffic is negatively affected by HSR, and air traffic is a strong predictor of tourist arrivals, suggesting a negative indirect effect of HSR on tourist outcomes. On the other hand, they found a positive but weak HSR direct effect on tourism.

Although there is a growing interest in the European HSR case studies, the literature on HSR in China is much more flourishing. For example, concerning the role of HSR building in fostering innovation, Yang et al. (2021) found that HSR significantly promoted innovation growth (+14.7%) and innovation convergence (+5.9%) in China.

Zhu et al. (2020) studied the effects of HSR on urban land expansion in 35 Chinese megacities. The results showed a 9.5% increase in the urban land expansion index after HSR opening with a time lag of five years, and each newly added station increases the urban land expansion index by 2.4%. These results are due to the industrial agglomeration effect of HSR and the incentive effect of local governments' land finance alongside the development of HSR.

Finally, Zhao et al. (2021) investigated how green HSR is, finding that HSR can improve air quality in Chinese counties.

Milan-Bologna HSR corridor: a counterfactual approach

Reasons to apply evidence-based programmes' evaluation

The evaluation of socio-economic programmes, through evidence-based statistical analysis, is an ever more frequent habit to drive policy-makers future decision-making processes. Projects aimed at increasing the overall well-being of a certain targeted population require such practices very seriously, especially when disbursements are heavy (Cerulli, 2015). In transport investments, the enhancement of cross-regional and cross-national infrastructures is commonly seen as a public intervention aimed at expanding mobility opportunities, fostering economic growth and increasing household and individual incomes. Such effects are supposed to derive from the openness towards new employment and business opportunities, and public programmes – like creating a HSR line or modernising an existing station – are expected to produce spillovers for the desired population.

The importance of transport investments has been reaffirmed in the recent programme Next Generation EU (NGEU), the massive European plan of financial interventions to face the Covid-19 crisis. In this context, the Italian PNRR plan (Piano Nazionale di Ripresa e Resilienza) has allocated 31.4 billion euros to transport infrastructure for sustainable mobility. 4.64 billion are destined to set new HSR connections in Southern Italy (passengers and freight) and 8.57 billion shall strengthen the HSR routes between Northern Italy and Europe (PNRR, 2021, p. 157).

Whereas the public resources are limited and the economic and social sectors to support are multiple (education, health care, welfare, labor market etc.), policy-makers may claim for additional resources whether ahold of certain and verifiable results deriving from previous policies (Murnane and Willet, 2011). Along these lines, in order to demonstrate to have made good use of public funds, government and policy-makers need good and practical information about the impact of specific policies on the 'treated' subjects, and the counterfactual methods for the programmes' evaluation are increasingly considered as potent tools for individuating the causal effect of a policy on a group or a class of subjects, by simulating the impact on the 'potential outcome' under construction of a quasi-experimental design (Morgan and Winship, 2015).

The gold standard of the evidence-based evaluation relies on the comparison between an observed outcome – after the outset of a programme – and the same result synthetically rebuilt if the programme had never existed. The difference between the two observations, positive or negative, may be ascribed to the policy intervention, and any possible causation can be defined as the program's effect.

Identification strategy and data overview

The counterfactual methodology helps quantify the HSR policy's effects on the treated territories within the Milan-Bologna macro-regional corridor, compared to other areas that did not directly receive the policy. This study focuses on the per capita gross value added (GVA) as the main outcome variable of interest based upon previously mentioned literature. The HSR corridor Milan-Bologna became operational in 2008 with the modernisation of the dipole stations of Milan and Bologna, while in 2013 the intermediate area of Reggio Emilia entered the program, with the opening of the Mediopadana HS station. These three areas are the case study subjects and are identified as the units 'treated' by the programme within the corridor.

Given a longitudinal data availability from multiple national and European sources (ISTAT, Eurostat), data are handled at NUTS-3 level, to capture the sprawl of the policy effects at a provincial scale, and – among the various – the synthetic control (SC) method was regarded as preferable, because of its immediacy in the results visualisation.

The ingredients for the SC are synhtetisable in the following three:

1. the potential outcome of the model, which is expressed by the per capita GVA at the NUTS 3 level;
2. the 'treatment' status, which consists of a dummy variable equal to 1 for the NUTS-3 units of Lombardy and Emilia Romagna directly involved into the HSR programme (Milan, Bologna and Reggio Emilia) and equal to 0 for all the possible control NUTS 3 Italian provinces that did not receive the same treatment in the same period. Simultaneously, from the time-related view, the same dummy has value 1 if the period (panel is yearly-based) is subsequent to the outset of the programme (i.e., 2008 in case of Milan and Bologna, while it is 2013 in the case of Reggio Emilia) and has value 0 if the period is antecedent to the policy start.
3. the set of covariates (or confounding), necessary to face the problem of non-random selection on the observables and to create the appropriate 'quasi-experimental' design for the evaluation. They allow control for economic, demographic, employment, road freight, migrations, and innovation.

Although, in some cases, literature suggests to aggregate in a single unit some units receiving a joint treatment (Kreif et al., 2016), we believe in this case that the SC should be carried out individually among the treated units to catch eventual heterogeneities of the program. Moreover, SC is effective when we have at our disposal a consistent number of years before and after the introduction of the program; another precondition to guarantee the method applicability is that the programme must not have been interrupted (continuous treatment) and that the control units shall not have experienced similar programmes, at least in the same period of the treated units.

The SC is based upon a system of weights $\Omega = (\Omega_1, \ldots, \Omega_j)'$ that are assigned to each of the *j*- control provinces in the following way:

$$\Omega_j \geq with \sum_{j=1}^{J} \Omega_j = 1$$

and the weights are selected in the way that the 'synthetic' outcome of the treated unit will look like as much as possible to the outcome before the HSR policy. Such weights should be able to minimize the distance D(Ω) between the predictor of treated units and the weighted predictors of all the control units (Abadie and Gardeazabal, 2003). The vector of weights is thus defined as follows:

$$D\Omega = (x_1 - X_0\Omega)'V(x_1 - X_0\Omega)$$

where x_1 is the (K*1) vector of covariates predicting the growth in the different desirable potential outcomes, X_0 is a (K*J) matrix of values for the potential *j*- control provinces, *V* is a diagonal matrix with non-negative values which are able to reproduce the best synthetic on the basis of the predictors.
The weighted counterfactual of y (in absence of the HSR program) is:

$$y_1^* = y_0 \times \Omega^*$$

where y_1^* is a (T*1) vector of real data about the potential outcome variables in 'treated' NUTS-3 province, y_0 is a (T*J) matrix of real data about the same outcome variables observed in the 'control' provinces.
By joining the case study, we collected a panel data from 2000 to 2018: this allows us to adopt a 8-year pre-treatment period for Milan and Bologna provinces (policy starts in 2008), and a 13-year pre-treatment period for Reggio Emilia (policy starts in 2013). We use a pool of other 97 Italian provinces (NUTS 3) to extract weights for an optimal counterfactual. On such basis, the first equation can be rewritten as:

$$0 \leq \Omega \leq 1; \sum_{j=1}^{97} \Omega_j = 1$$

where Ω_j are weights ranging from 0 to 1 and assigned to each of the $\Omega_1 \ldots \Omega_{97}$ control provinces (NUTS 3). Accordingly, $x_1$becomes a vector of $(x_1 \ldots x_{12})$covariates (described in Table 12), while X_0becomes a $(X_1 \ldots X_{97})$matrix of values for all the *j*- potential controls. The set of covariates, all at NUTS 3 level for the period 2000-2018, is described in the following table.

Code	Variable	Time	Source
x_1	Employment (number)	2000-2017	Eurostat
x_2	GDP per capita (€ per inhabitant)	2000-2017	Istat
x_3	Road freight transport by provinces of unloading, all transported goods (thousand)	2000-2018	Eurostat
x_4	Road freight transport by provinces of loading, all transported goods (thousand)	2000-2018	Eurostat
x_5	Institutional quality index (IQI)	2004-2012	IQI dataset
x_6	Released patents	2000-2018	UIBM
x_7	Released trademarks	2000-2018	UIBM
x_8	Resident population	2000-2018	Istat
x_9	Inflow migration in the *i*-province	2002-2018	Istat
x_{10}	Outflow migration from the *i*-province	2002-2018	Istat
x_{11}	Business demography	2000-2018	Infocamere
x_{12}	Gross value added at basic prices (lagged *y*)	2000-2017	Istat

Table 12 - Covariates description, NUTS 3 level

Consistent with strictly related literature (Carbo et al., 2019), the gross value added at basic prices (GVA) was considered as the outcome variable, because it well approximates the regional productivity (Barzotto and De Propis, 2019). The same variable is also included in the list of covariates when the SC is performed to account for lagged effects of the outcome variable. The choice of the x_1 set of covariates is driven by the need to control for everything that may affect the outcome but not the treatment assignment.

For each of the treated units (Milan, Bologna, Reggio Emilia) we report the values of the predictor balance, which correspond to the balancing properties that ensure the stability of the SC. It shows the observed value of the treated unit and the value synthetically rebuilt if the policy had not intervened. The results of the SC are visualised in the respective graphs.

Effects of HSR on pole areas (Milan and Bologna HS)

In case of Milan, the HSR started to be operative in 2008 with the enabling of the central station (Milano Centrale) to the HS services. Later, in 2012, Porta Garibaldi station, located in the trendy neighbourhood of Garibaldi-Repubblica, was introduced to the HSR, becoming a multifunctional centre with large daily volumes of commuters and tourists. On such a basis, we considered the period 2000-2007 as pre-treatment and the year 2008 as the time-bandwidth indicating the program's starting date, but in the SC graph, we also include the reference year of 2012. The following table reports the predictor balance for Milan.

Covariates	Time (averaged)	Treated	Synthetic
x_1	2000-2007	1,665,514	1,745,762
x_2	2000-2007	41,300	33,717.4
x_3	2000-2007	74,594.8	42,077.2

Covariates	Time (averaged)	Treated	Synthetic
x_4	2000-2007	65,516.8	37,872.4
x_5	2004-2007	0.805	0.684
x_6	2000-2007	16,521.1	4,454
x_7	2000-2007	10,940.6	4,598.2
x_8	2000-2007	3,045,960	3,525,276
x_9	2002-2007	135,739.7	101,317
x_{10}	2002-2007	115,243.7	75,246.8
x_{11}	2000-2007	321,467.5	219,586.1
x_{12}	2000-2003	103,625.3	102,105.8
	2004-2007	119,350.4	120,565.9

Table 13 - Predictor balance, Milan HS, NUTS 3 level

The balancing properties, in case of Milan, face partially the problem of counterfactuals identification, basically because if we exclude other provinces receiving the same programme in the same period (or previously), there remains few control units within the pool of Italian provinces that can be compared to Milan, basing upon observable characteristics.

However, the long period used in the panel data helps to keep reasonable reliability of the scores. Moreover, as visible in Figure 1, the almost perfect overlapping in the pre-treatment period can reassure us about the model goodness of fit to the proposed data. Given that the programme started in 2008, we averaged the covariates over the pre-treatment period 2000-2007.

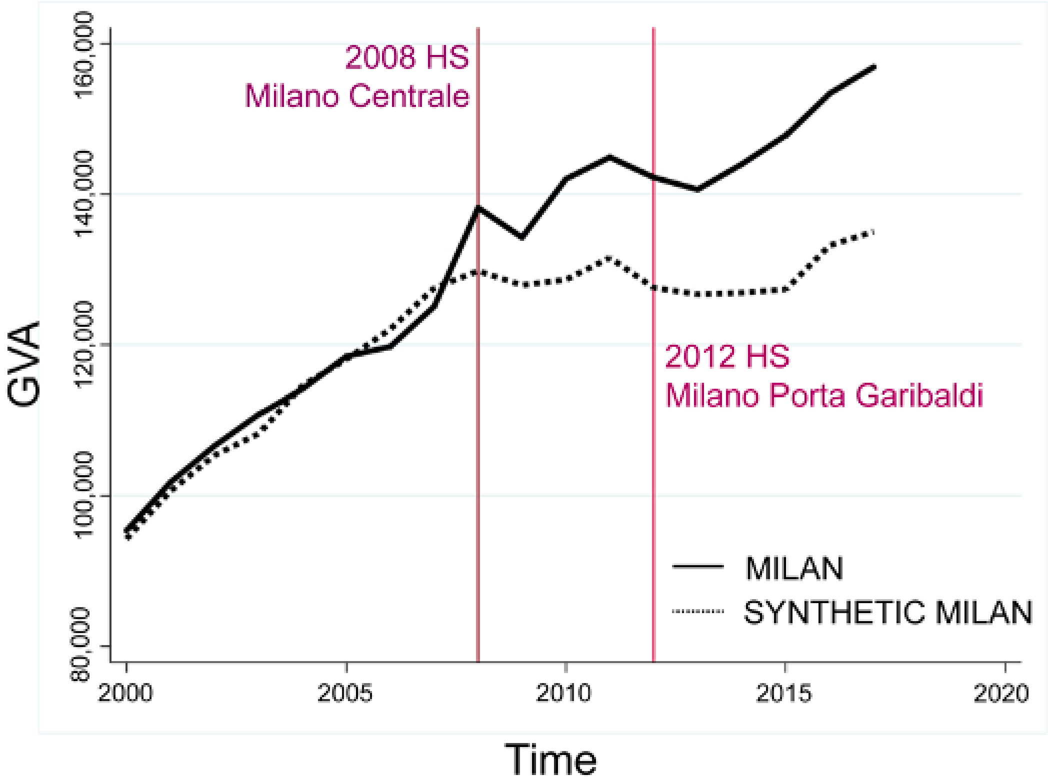


Figure 73 - Synthetic control for Milan (NUTS 3). Outcome: GVA at basic prices

In Figure 73 we observe the difference between the observed and synthetic GVA outcome, with a visible jump both in the proximity of the first HSR opening and after the enabling of the second HS station of Porta Garibaldi. The SC identified as the closest unit weight (controls) the other NUTS 3 provinces of Bozen, Verona and Padua.

As concerns the Bologna HS station, it started operating in 2008, being the counterpart of the dipole that encloses the macroregional corridor Milan-Bologna. In the same way as Milan, we averaged the pre-treatment covariates over the period 2000-2007 and we report the balancing properties in the following table.

Covariates	Time (averaged)	Treated	Synthetic
x_1	2000-2007	479,171.4	479,524.9
x_2	2000-2007	33,662.5	29,504.7
x_3	2000-2007	27,812.7	29,939.7
x_4	2000-2007	23,465.6	28,374.9
x_5	2004-2007	0.677	0.669
x_6	2000-2007	779.1	1,641.3
x_7	2000-2007	983	885.7
x_8	2000-2007	924,101.3	1,056,123
x_9	2002-2007	38,572.3	37,325.9
x_{10}	2002-2007	29,189.1	29,630.4

Covariates	Time (averaged)	Treated	Synthetic
x_{11}	2000-2007	86,865.2	92,299.9
x_{12}	2000-2003	25,818.5	25,804.2
	2004-2007	29,312.2	29,322

Table 14 - Predictor balance, Bologna HS, NUTS 3 level

In the case of Bologna, the predictor balance is more accurate, probably due to the more significant number of comparable NUTS 3 areas based on the selected covariates. This is also visible in Figure 1, where the overlapping in the pre-treatment is quite satisfactory for our purposes. In this respect, the SC individuated the provinces of Verona, Venice, Salerno, Bari, Brindisi and Siracusa as closest control units to produce the Ω^*.

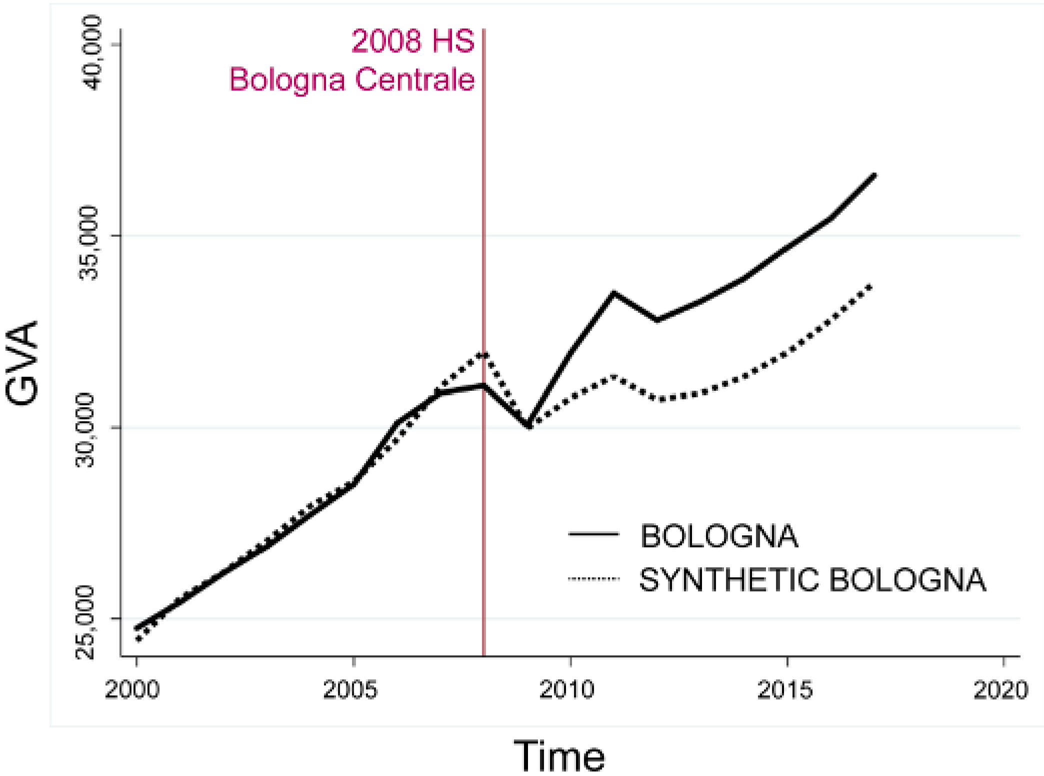


Figure 74 - Synthetic control for Bologna (NUTS 3). Outcome: GVA at basic prices

Also in this case, we observe a clear difference in outcome between the observed and synthetic trend, after the start of the programme in 2008. All in all, we observe that in pole areas the effect of the HSR programme on GVA has been consistent as early as the policy started. Results will be deeper discussed in section 1.2.5.

Effects of HSR on intermediate areas (Reggio Emilia HS)

The case of Reggio Emilia is singular because the Mediopadana has been the first HS station not located in a pole area, which, in all the other Italian cases of HSR, correspond to the regional capital hosting the HS station concerned (Turin, Naples, Venice, Milan, Bologna, Florence, Rome). Unlike the dipole Milan-Bologna, the Mediopadana HS station opened in 2013 and for such reasons, the covariates are here averaged over the period 2000-2012. This resulted in advantages and disadvantages for the analysis, because if, on the one hand, there are more periods we can include in the pre-treatment (thus implying a more accuracy of the predictor balance), on the other, less observable periods are available in the post-treatment, which could be considered a limit to the effective observation of the policy effects. The following table returns the predictor balance for Reggio Emilia NUTS 3.

Covariates	Time (averaged)	Treated	Synthetic
x_1	2000-2012	237,376.9	255,334.4
x_2	2000-2012	32,361.5	26,517.5
x_3	2000-2012	22,823.4	19,469.1
x_4	2000-2012	20,271.1	20,468.7
x_5	2004-2012	0.714	0.680
x_6	2000-2012	223.3	164.3
x_7	2000-2012	535	522.8
x_8	2000-2012	483,942.2	571,437
x_9	2002-2012	20,148	20,402.2
x_{10}	2002-2012	13,512	15,795.9
x_{11}	2000-2012	51,633.5	54,970.3
x_{12}	2000	11,581.6	11,571.6
	2005	14,210	14,200.6
	2009	15,076.2	14,998.6
	2012	15,073.1	15,090

Table 15 - Predictor balance, Reggio Emilia HS, NUTS 3 level

For analogous reasons than in Bologna case, we have a larger number of units that the SC individuates to be close to Reggio Emilia and upon which Ω^* is computed. In particular, the estimation denotes the provinces of Treviso, Rimini, Palermo, Caltanissetta, Siracusa and Sassari as best control units for the treated one, within the pool of Italian provinces. In this case, we observe very close values between treated and synthetic, ensuring a reasonable accuracy of the estimations.

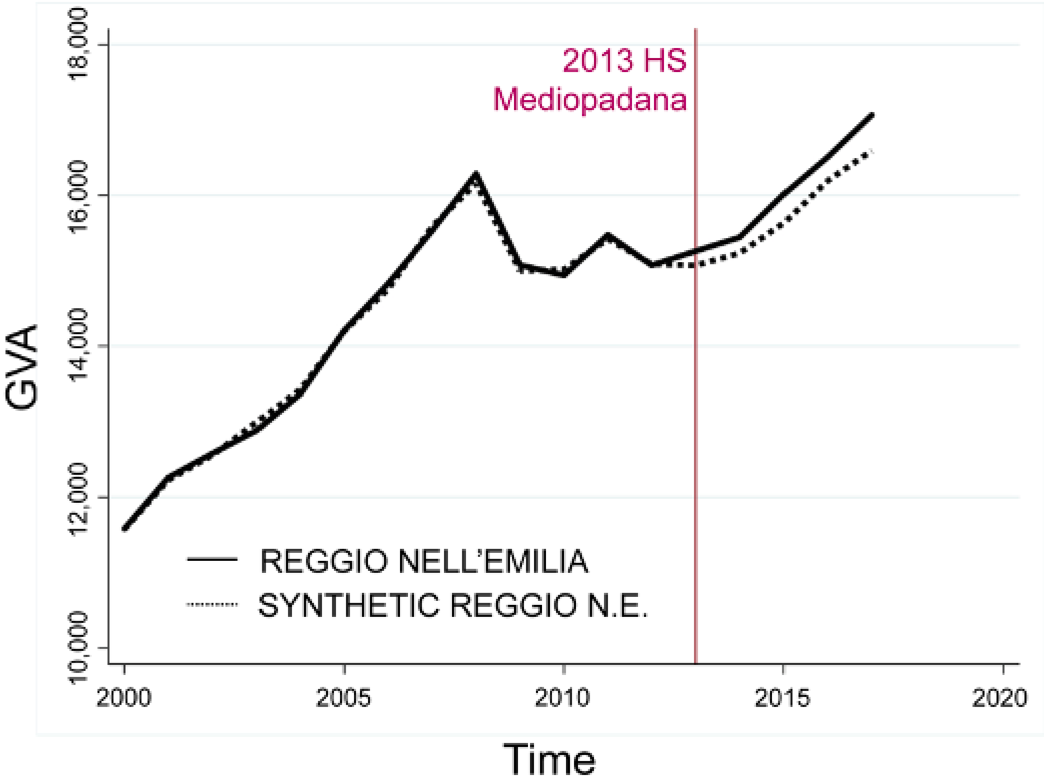


Figure 75 - Synthetic control for Reggio Emilia (NUTS 3). Outcome: GVA at basic prices

Due to the larger pre-treatment period, we probably observe a substantial perfect overlap, meaning that the model fits the data well. From Figure 75 a positive effect emerges, but, differently from the pole areas of Milan and Bologna, the magnitude seems to be lower.

Policy considerations and insights for the 'non-treated'

The results of the SC return significant baseline evidence, that is HSR has positively impacted the regional productivity at NUTS 3 level over the macroregional corridor Milan-Bologna. However, some differences arise, especially in terms of geographical heterogeneity: while the pole areas of Milan and Bologna exhibit a higher magnitude in the effect, in the intermediate area of Reggio Emilia the policy effect is slightly noticeable. In particular, in the case of Milan, after the outset of the programme in 2008 we observe an outcome that immediately starts to diverge compared to its synthetic counterfactual.

Moreover, if we look at the 2012 time bandwidth, the year when the second HS station went into operation (Porta Garibaldi), the trend is being consolidated, and a progressive deviation between the two lines arises. In practical terms, the gross value added as a proxy of provincial productivity accounts for a difference of about 20,000 euros per capita in the case of Milan due to the policy intervention. In other words, in the absence of the program, productivity would have increased at a slower speed. However, future insights should be dedicated to exploring the heterogeneities of GVA, and they should consider the fabric of the territory itself. The service branch of GVA might likely have a different weight as against the manufacturing one, or also in respect to other types of sub-asset classes.

Similarly, in the case of Bologna we observe a difference in outcome between the treated and the synthetic line. Except for the year following the programme outset (2009), where a downturn is observed in both the lines beginning with 2010, we follow a constant increase in the outcome variable. The policy effect emerges to an extent of around 3,000 euros per year capita GVA. The magnitude is not as substantial as in the case of Milan, but this should be interpreted in the light of the average values of per capita GVA in the area concerned. In this case also, without the programme outset, the GVA would have grown at a lower intensity and this let us assume that the HSR policy has played a part in the productivity dynamics of Bologna province.

The same can not be said when we talk about the intermediate area of Reggio Emilia. Whereas a slight positive effect emerges, which is visible at least in the gap at the right extreme between the treated and synthetic line, it seems that the HSR programme still fails to boost the productivity in the case of Reggio Emilia. Reasons can be multiple. As noted above, one main limitation can be ascribed to the period of observation: if we consider that the effects of a transport infrastructure investment may require some years before to come forward, it is reasonable to suppose that the net effects of the HSR may be recognisable only in the next years, given that the programme started only around the middle of 2013. Another facet may regard the functional role of the Mediopadana HS station: it is more an intermodal station than a multifunctional one, because of its location in a peripheral space of the Reggio Emilia city centre, making it a landmark of many short and long distance commuters that may have their business hubs in other neighbor provinces or even in other regions. In this event, the province level may not be appropriate to determine the sprawl effect of the Mediopadana HS station, but possible spatial autocorrelations may occur.

All in all, the three types of results seem to lead to an underlying insight: the HSR may act as an accelerator of certain development pathways already established in the place receiving the program. The location of HS stations in higher-ranking central places (cities, metropolitan areas) is likely to enhance the service intensity as part of GVA (like in Milan and Bologna). In contrast, the choice to localise HSR investments in second-order places may push other types of economic activities (manufacturing, industrial, tourism), depending on the place’s distinctiveness (as in Reggio Emilia). These findings suggest that location choices of transport investments should be place-led (Di Matteo, 2021), because this may result in the success or failure of the program, and, in many cases, the quality of institutions is paramount to avoid ‘white elephants’ (Rodriguez-Pose et al., 2018).

The case of the Milan-Bologna corridor emphasises the issue of non-random treatment assignment, because – if we except Milan and Bologna, which could follow the rationale of developing metropolitan areas (also on account of Law 56 of 2014) – the location choice of Reggio Emilia to expand HSR services is basically political-led. As a result of this, many other provinces, excluded from the program, are only partially interested in the sprawl effects of HSR, whose indirect effects are more difficult to evaluate. A passage of the PNRR (Mission 3, Investments 1.5 and 1.6, p. 162) could be relevant for this purpose, where a strengthening of metropolitan railway nodes and regional railway lines is planned to support the demand for mobility to and from metropolitan areas and second-order places, but also to integrate the HSR with regional transport systems. In the case of provincial capitals of the corridor Milan-Bologna, which were excluded from the HSR program, the creation of fast regional rail links and the reinforcement of intermodality can help raise both passenger demand and goods transport capacity. Therefore, institutions of provinces potentially exposed to the programme are suggested to pay close attention to the mix of interventions envisaged by the PNRR to become actively involved in such a plan of investments.

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