AN INTERCONNECTIVITY ASSESSMENT OF THE HIGH-SPEED RAILWAYS THROUGH ACCESSIBILITY MEASURE: A REGIONAL CASE STUDY

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ABSTRACT

This paper proposes an approach to the assessment of the interconnectivity level of the high-speed railways in South-West Europe using an accessibility measure. It defines accessibility as the ability for a destination to be reached by using a transport mode at different scales (local, regional, national, international). The accessibility assessment uses a gravity model with variables such as population, travel and waiting times, fares and service frequencies. The innovation of this paper is that it seeks to examine the extent to which the opportunity and possibility to access the high speed rail network by public transport can affect its level of interconnectivity and accessibility on a regional level. It uses such study to also explain whether the existence of the high-speed services has a positive or regressive impact to regional transport. The studied areas are the Spanish provinces of Catalonia, known as Girona, Lleida and Tarragona, each of which have or are scheduled to have high-speed stations.

Keywords: high-speed railways, public transport, regional accessibility, Spain

INTRODUCTION

The high-speed rail network of south-west Europe consists of new and upgraded high-speed rail lines in Portugal, Spain and southern France, regions which over the last decade have become hot spots for tourism and property investment. However, the newly developed high-speed railways in the region face criticisms for limited capacity and poor international connections. As a periphery region, south-west Europe has a comparative accessibility loss in relation to other regions in Europe (Blum et al, 1992). This loss is caused by the large

distances, followed by long travel times, and currently low density high-speed train network. The accessibility loss can also be explained or argued against by the opportunity to access the high speed rail network on national and regional levels.

With that in mind the paper seeks to investigate whether the high-speed railways contribute towards regional and local cohesion by looking at the changes in the accessibility to the high-speed stations from cities which do not have high-speed services.

The structure of the paper is as follows. The paper looks at the various accessibility measures and methodologies that have been applied in previous transportation accessibility studies and which contribute towards the proposed accessibility model in the present paper. Section three discusses the data for the interconnectivity assessment and explains the methodology in applying a popular accessibility measure to a new form of assessment. Section four discusses the results from the regional study. The innovation of this study is that it attempts to find a relationship between the changes in the regional accessibility to the high-speed railways network and the regional cohesion of the transport network which is a precedent to European transport cohesion. The final section of the paper offers concluding remarks and suggestions.

LITERATURE

The literature review focuses on relevant accessibility studies which have been used by other scholars, and which contribute to the model proposed in the subsequent section. For those who are novice in the realm of accessibility studies, detailed explanations and definitions on existing accessibility indicators and their evolution are provided by Geurs (2006), Martin and Reggiani (2007) and Ferreira and Batey (2007).

It is agreed that when a network is more accessible, it is more integrated and more efficient (Vickerman et al, 1999). That means that an improved transport connection between peripheral and core regions can either make it easier for producers from the peripheral regions to market their products in core cities, or expose the peripheral region to the competition of advanced products and services coming from the core areas. This conclusion can be applied not only a European level, but also on a regional level. The high-speed railways network should not only create accessibility between periphery and core European countries, but it should also create accessibility on a regional level. If the accessibility is hindered on a regional level, it can have an impact on the use of the high-speed services in that region and along the network.

Generally, accessibility studies include two elements: vertices (origins and destinations also known as startnodes and end nodes), and their relationship between those nodes called edges (i.e. distance, travel cost, travel time, and activities between nodes). Those elements

have dictated the choice of indicators used by a number of scholars, such as Vickerman, Pirie, Jones, Gutierrez and Urbano, and Bruinsma and Rietveld (Martin et al, 2004). Depending on the focus of the study, accessibility models are classified in location-based (focus on location, distance, and economic potential), infrastructure-based (focus on location and distance), utility-based (focus on passenger behaviour and choice) and time-based approaches (focus on journey times).

A standard approach to location-based accessibility is the economic potential measurement using population or GDP. Such accessibility measure uses the physics gravity model and argues that the accessibility between origins and destinations is directly proportional to the associated demand and attraction of a location, and inversely proportional to the distance, travel time, or travel cost between the locations. The above model assesses the accessibility of one location, while Rodrigue et al (1996) apply the same model looking at the accessibility of both the origin and the destination.

Janic (1996) looks at accessibility as one of the time-based attributes to analyses. He does not provide any formulae, but explains that accessibility takes into account time and space. The time aspect is a certain time of the day, the week, the month, and year during which a train passes through a station. Consequently, it is only at that time that a connection is observed. Vickerman et al (1999) introduce a different measure of time and space accessibility study. They look at key issues such as infrastructure, accessibility, transport costs, and economic development. They use time-space maps, which are not based on distance, but the time it takes to travel between cities. Consequently when the data is interpreted into a map, the map itself is distorted to present the time it takes to travel from one city to another.

With regards to location-based and economic potential accessibility measures Gutierrez and Urbano (1996) evaluate the accessibility impact of the high-speed rail link by using economic accessibility indicators and geographic scale (GIS). In another study Gutierrez (2001) seeks to explain whether the new high-speed network increases or reduces disparities between cities on international, national and corridor scales. For his analysis Gutierrez takes into account railways linking Spain with the rest of Europe (Portugal, France, Belgium, the Netherlands, Luxemburg, The United Kingdom, Germany, Denmark, Austria, Italy and Switzerland).

The above studies provide a good example of the use of the gravity model, however, they extend to accessibility studies on a European Level, which does not provide discussions of the accessibility on a regional level. Accessibility should not include journeys on the high-speed network alone, but also journey to the high-speed station from other cities in the region. Assessing the regional accessibility helps find any disparities which may affect the interconnectivity and cohesiveness of the high-speed network.

Martin et al (2004) focus their study on Spain and the high-speed rail link between Madrid, Barcelona and the French border, which is very appropriate for the work in this paper. The

authors look at the various conceptualisations of accessibility and apply the data envelopment analyses (DEA) which has previously been discussed by Nash (Hensher and Button, 2000). They use indices of location, economic potential, relative efficiency of the network and daily accessibility to carry out the composite accessibility analyses. .

Before arriving to the models used in this paper's study, several points of consideration were raised. The definition of accessibility determines the approach of the study. This paper defines accessibility as the ability to reach a destination (a network) by using a transport mode at different scales (local, regional, national, international). Therefore instead of assessing the accessibility along a network, the paper assesses the accessibility to the network (Martin et al, 2004). Indicators of the definition should include travel times, travel costs and service frequencies to the network from other cities. When accessibility measures are used to assess a transport network, one should take all the involved modes into consideration (Davidson, 1997).
In the following section the paper discusses the terms and methodology of the study on a regional level by looking at the accessibility in the provinces of the Spanish region of Catalonia for year 2008.

TERMS AND METHODOLOGY

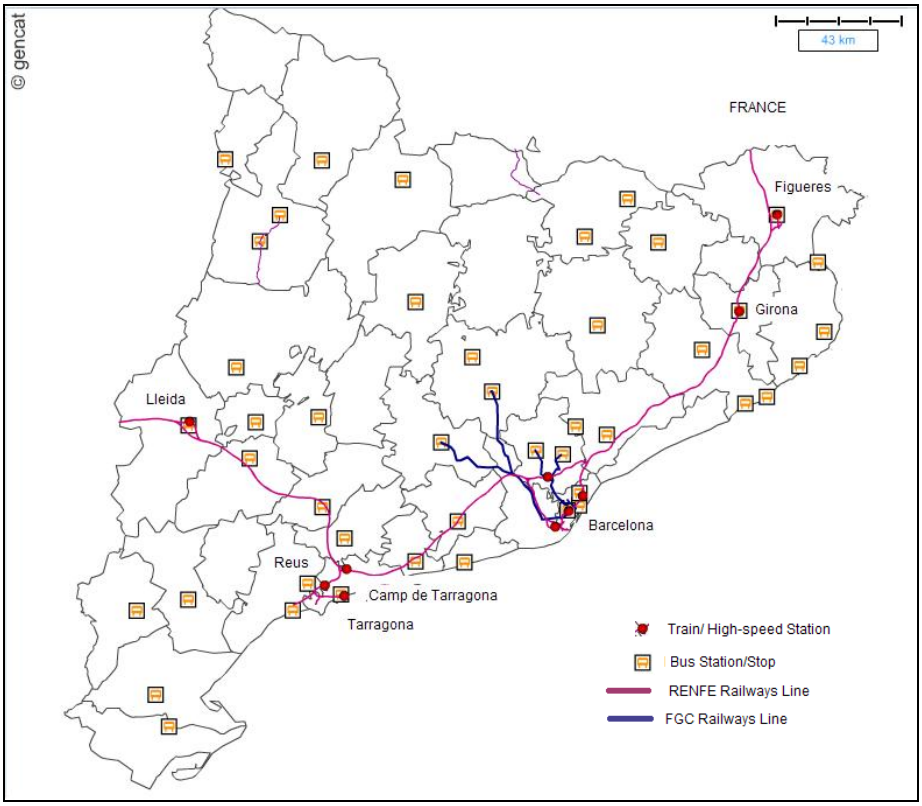
The given definition of accessibility indicates that the interconnectivity of the high-speed rail network is determined by the opportunity to access the network regionally. It can be assumed that the introduction of high-speed services should increase and promote the accessibility from regional cities which do not have a high speed services to the cities which offer high speed services. However, it could also be argued that the new rail network might ignore the regional accessibility and interconnectivity to the high-speed network and focus only on journeys between larger cities. In addition, understanding the relationship between the cities without high-speed services and cities with high-speed services can explain the geographic and socio-economic impact of the new high-speed infrastructure in the studied region.

The paper carries out an accessibility assessment in the region of Catalonia, located in North-East Spain (see Map.1). Catalonia consists of 4 provinces, with their corresponding capitals of Barcelona, Girona, Lleida, and Tarragona. The four provincial capitals create the high-speed rail network in Catalonia, which connects to the north with France, to the West with Madrid and other Spanish high-speed networks, and will be connected in the future with Valencia along the Mediterranean Belt. Although the high-speed rail network connects the capital cities of the provinces, it should also promote greater accessibility within those provinces in order to increase the popularity of its service along the high-speed network. The paper looks at the accessibility level to the high-speed network from regional cities in the respective provinces. It offers a comparative study of the regional accessibility to an existing

or potential high-speed rail network. It examines the impact of the introduction of the high-speed services on the regional accessibility to the network. When there is low accessibility to the high-speed network in a region, then there will be lower incentive to use the high-speed network services. And the opposite, if there is higher accessibility to the high-speed network, then there is greater incentive to use its services.

Map 1. Catalunya Region in North-east Spain, including the provinces with capital cities Barcelona, Girona, Lleida and Tarragona

The accessibility is assessed for regional journeys on bus and train services to cities with high-speed rail services. The public transport services in Catalonia are not evenly distributed. Most of the rail, metro and tramways lines are based in Barcelona Metropolitan area, while the rest of the provinces' public transport is provided by bus services (see Map.2). Lleida Province has one conventional rail line which is included in the accessibility assessment.



Source: GENCAT and Own

Map. 2: Pubic Transport Network in Catalonia (Bus stations, Rail Stations, and Links)

The accessibility study uses the gravity model which expresses the relationship between the attraction of a location (node) and its relationship to other locations in the context of travel (journey) mode, travel (journey) time, waiting time, service frequency, and travel (journey) costs (fares) and is presented as follows:

$$A_i^i = \sum_j \frac{P_j}{GC_{ij}}$$

where A_i is the accessibility to the city with the high-speed service, P is the population of the origin or the city outside the high-speed network. The city is identified by the bus regional services that links it to the city with the high-speed service. The $GCij$ is the generalised travel cost between the city with no high-speed service j and the city with high-speed service i.

The generalised travel cost GC_{OD} is developed based on accessibility studies by Chang and Lee (2007) and is presented in the following function:

$$GC_{OD} = \mathrm{T}_t + \mathrm{T}_w + \mathrm{T}_{sf} + \mathrm{T}_c$$

where T_t is the travel time from the city without a high-speed service to the city with a high-speed service; T_w is the waiting time from the time of arrival at the high-speed station and the next available public transport service, or from the time arrival of the last bus station and the next available train service; T_{sf} is the frequency of the transport service, and T_c is the transport cost or fare to use the service. The generalised cost holds a monetary value which means that its variables travel time, waiting time and service frequency are converted from minutes to Euro units using value of time. Since the generalised cost is a combination of journey fares and travel times, those elements can influence individually the level of accessibility, thus help distinguish the ones which have an impact on the accessibility and consequently on the interconnectivity of the network. The Tt or travel time by public transport is chosen according to the direction of travel, and referred as inbound and outbound travel. Inbound travel is the trip from the regional city to the city with the high-speed station. The outbound travel is the journey from the city with the high-speed station to the regional city (See Fig 1).

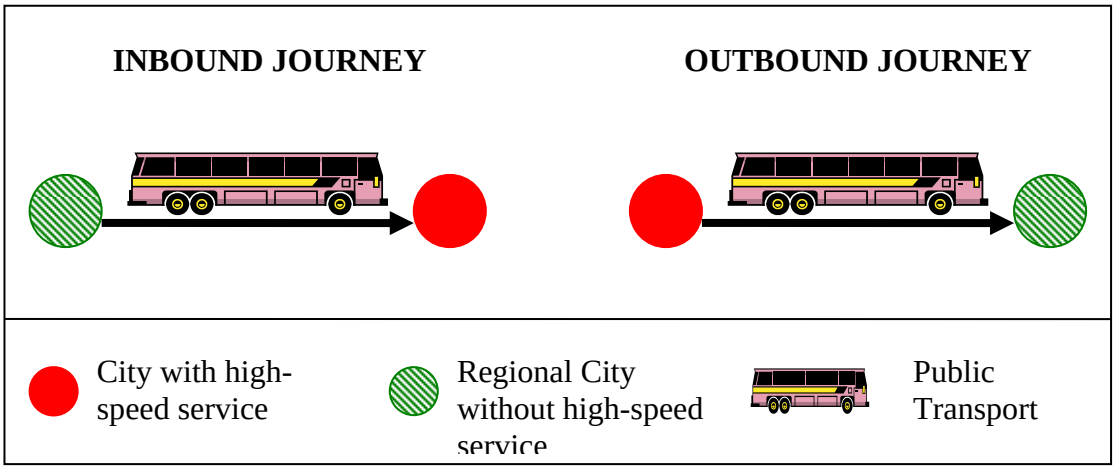


Fig 1. Inbound and Outbound Journeys

The data used for the assessment is extracted for year 2008 and from the transport authorities at each province, ATM Barcelona, ATM, Lleida, ATM, Girona, EMT Tarragona and ATM Camp de Tarragona. Some data was not available on paper or electronically, and was provided via phone interviews. It included, ticket types, zones, bus or train lines, and timetables. RENFE railways operator provided time tables for the high-speed train services for Barcelona, Lleida and Camp de Tarragona, as well as conventional train stopping services for Girona. The timetables of the bus services are set against the arriving and departing times of the high-speed services. Each bus or train timetable is used to calculate the travel time, waiting time, and service frequency. It is assumed that passengers will take

the next available service closest to the departure or arrival time of the high-speed train. Fares for Lleida, Girona and Barcelona are based on the Integrated Tariff System (ITS) which provides an easier travel and faster access for passengers to their destinations within the provinces making the journeys on public transport easier locally and regionally.

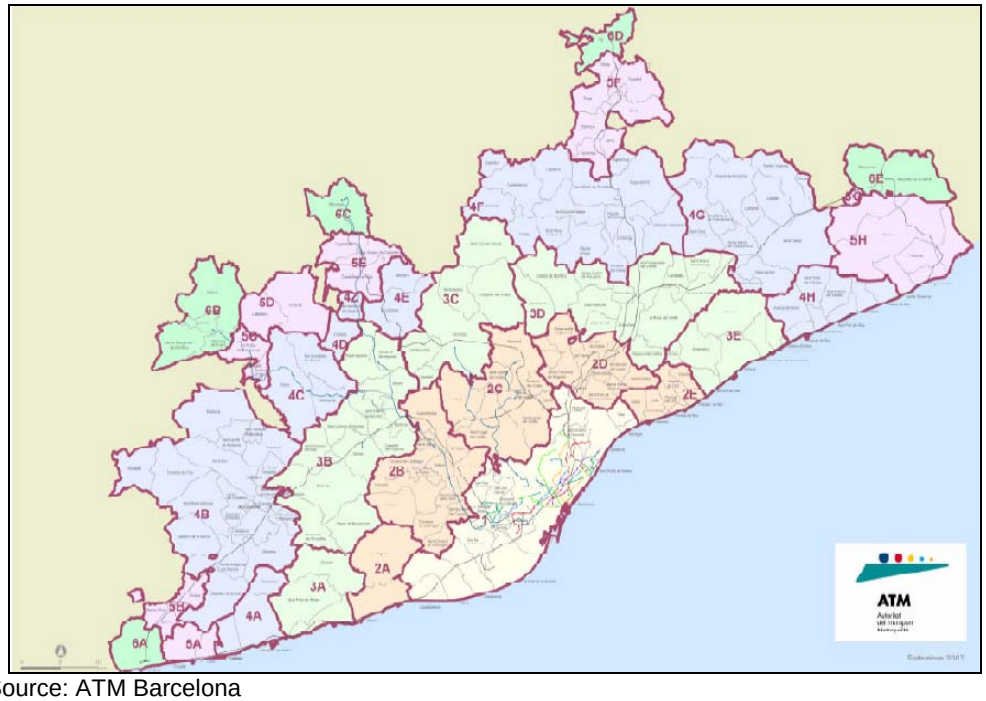
The empirical evidence from the study is interpreted into tables and charts showing higher/lower (i.e. best/worst) level of accessibility and connectivity. This type of study is significant because the accessibility assessment to the high speed network helps to determine the factors that hinder or encourage socio-economic cohesion and consequently affect the interconnectivity of the high speed network on a regional and cross regional level.

DISCUSSION OF RESULTS

During the assessment process a number of observations were made regarding the Catalonia Provinces. Barcelona Province has 208 metropolitan and 307 interurban bus lines, 8 rail lines, 6 metro lines and 6 tramways, creating a very dense and active public transport network. Although the majority of the network is in metropolitan Barcelona, its public transport services extend through six zones covering seven regions (see Map 3 and Map 4). The zonal network is complimented by the ATM Integrated Tariff System, which makes it convenient for passengers to travel by bus, tram, metro and train with the same type of ticket and at a set zonal price. It also became evident that due to the extensively large and complex network, assessing the full regional accessibility for the Barcelona province would not be feasible for this study. Instead, based on an appraisal study on frequency, speed, comfort, and reliability of urban and interurban public transport carried out by the ATM Barcelona Authorities, a series of conclusions were made which help explain the accessibility to the high-speed rail station of Barcelona (Sants). Tramways, Metro, FGC (Catalonia Railways), RENFE railways and some urban bus services ranked highest in the “frequency” and “speed” criteria (see Chart 1). Unlike its leaders who are on set tracks, bus services are a road mode and their frequency and speed can be affected by road congestion or accidents, thus they ranked lower but still above average. In most categories, interurban and urban bus services ranked the same. This could mean that the regional accessibility level in Barcelona Province may be as good as the local one.

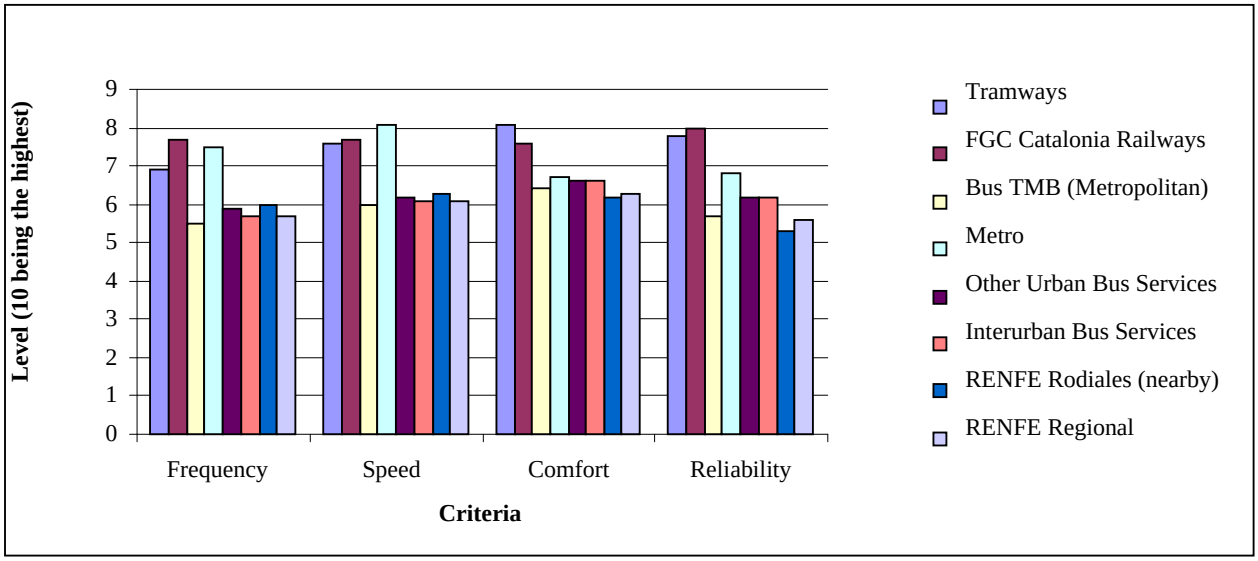
Source: ATM Barcelona

Map. 3 : Barcelona Province and its Regions (2008)



Source: ATM Barcelona

Map 4: Barcelona Province Travel Zones (2008)



Source: ATM Barcelona, Mobility Study 2008.

Chart 1: Appraisal of Public Transport in Barcelona Province (2008)

The regional accessibility assessment for the other Catalonia provinces focused on the timetables of interurban bus lines in each province and one FGC rail line in Lleida. The public transport timetables were set against the time tables of the high-speed trains leaving and arriving at the train station. Some stations like Camp de Tarragona had distinct bus schedules for AVE and AVANT services. The AVANT services are often regional and may provide high-speed services within the Catalonia region, while the AVE services are longer distance and in the case of Catalonia, a rail service between Barcelona and Madrid and eventually between Barcelona and France.

In the study the waiting time of minimum 12 minutes is considered acceptable to allow for the people to transfer form the bus to the train and vice versa. The value of time is determined as 10 Euros per hour for public transport as discussed in Transport II (Robuste 2004). In most provinces the bus stations and the high-speed train stations are locates in walking proximity. In the case of Camp de Tarragona, the bus stops and leaves in front of the train station, thus offering an interrupted connection.

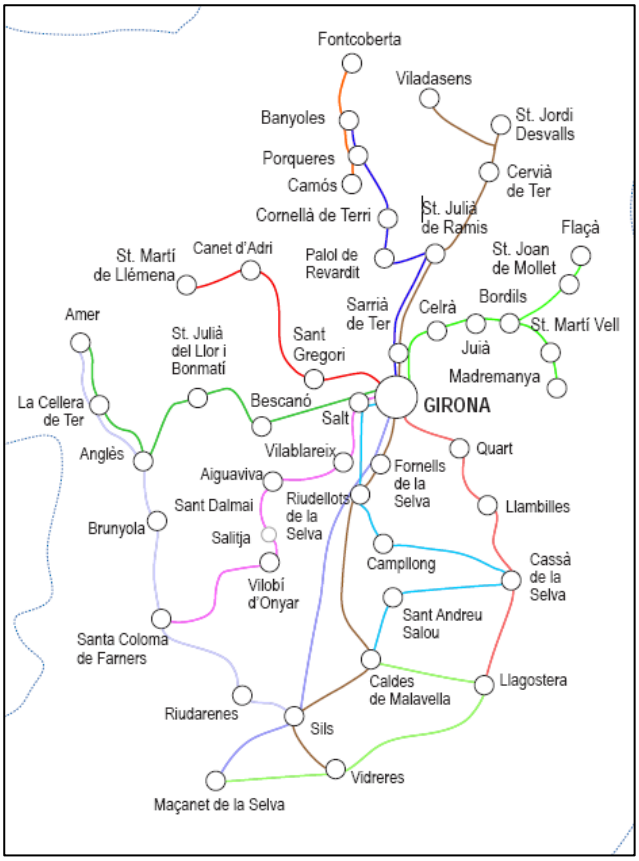
The fares are counted as single journey one-way ticket and dated for year 2008. Where there was no data on the single journey ticket, the price was estimated form the T10 travel card which is used as part of the Integrated Tariff System. The ITS is used by Girona, Barcelona and Lleida and has been introduced in Tarragona in 2009. Since the study for this paper was carried out in 2008, the fares for Tarragona are based on the 2008 Reus-Camp de Tarragona services. Fare for Valls-Camp de Tarragona was estimated as being half of the fare for Reus-Camp de Tarragona. The Tarragona ITS is still being tested and further adjustments are made to provide smooth and more efficient ticketing system (ATM Tarragona 2010).

Two scenarios were considered for the accessibility assessment. The best scenario refers to accessibility of a network that has the lowest generalised Cost, or the shorted waiting time or bus frequency. The worst scenario refers to the accessibility of a network that has the highest generalised cost, or the longest waiting time or bus frequency. The results and conclusions of the regional accessibility assessment for Girona, Lleida and Tarragona provinces are discussed in the next section.

Accessibility in the Girona Province

Girona is the only province in Catalonia, which still has conventional lines and the rail services are operated by conventional trains. By 2012, Girona will be upgraded to operate high-speed rail services towards Barcelona and the French border. Despite the rail service difference, an assessment was carried out on the regional accessibility to the Girona train station looking at the buses' timetables and comparing them against the conventional train timetables.

Girona has 7 travel zones with 17 bus lines, 12 of which start and end at Girona, four lines run outside of the Girona city zone, but connect to Girona only via other bus lines; and one which is a direct link between Girona and Girona airport, a hub for low-cost airlines (see Map 5 and Map 6.).



Interurban Lines Stopping at Girona		Zones
100	Olot - Besalu - Banyoles – Girona	1,3
101	Girona – Salt - Riudellots - Campllong - Cassa - Caldes de Malavella	1,7
102	Amer – Girona / Girona – Olot via Amer	1,5 / 1,5,4,3
103	Santa Coloma de Farners – Girona	1,6
105	Llagostera- Girona	1,7
200	Flaçà – Girona	1,2
202	Madremanya – Girona	1,2
300	Girona – Anglès	1,5
301	Girona -Sant Martí de Llémena	1,4
400	Girona – Sant Jordi Desvalls	1,2
500	Vidreres – Girona	1.6
600	Girona – Maçanet	1.6

Source: ATM Girona

Map 5: Girona Province Public Transport Network and Lines (2008)

Map 6: Girona Province Public Transport Travel Zones (2008)

The average accessibility index results for the whole Girona Province indicate that in the best scenario the accessibility for outbound travel is better than the accessibility for inbound travel. This also means that the train station is more accessible for buses leaving Girona than for busses going to Girona (see Chart 2). However, in the worst case scenario, on average, the accessibility for outbound travel is worse than the accessibility for inbound travel.

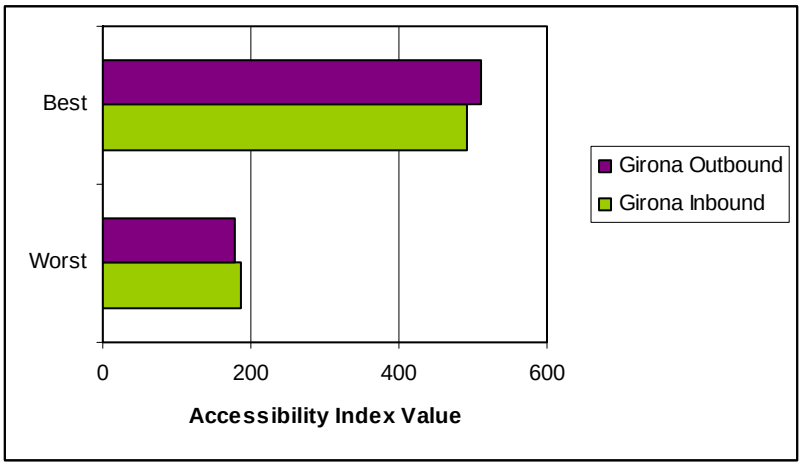


Chart 2. Average Inbound and Outbound Accessibility for the Province of Girona (2008)

As shown on Chart 3, there are big differences between the best and the worst case scenarios of accessibility. Only half of the regional lines have high accessibility levels indicating good accessibility level. The lines with the lowest accessibility levels indicate poor accessibility to the high-speed network.

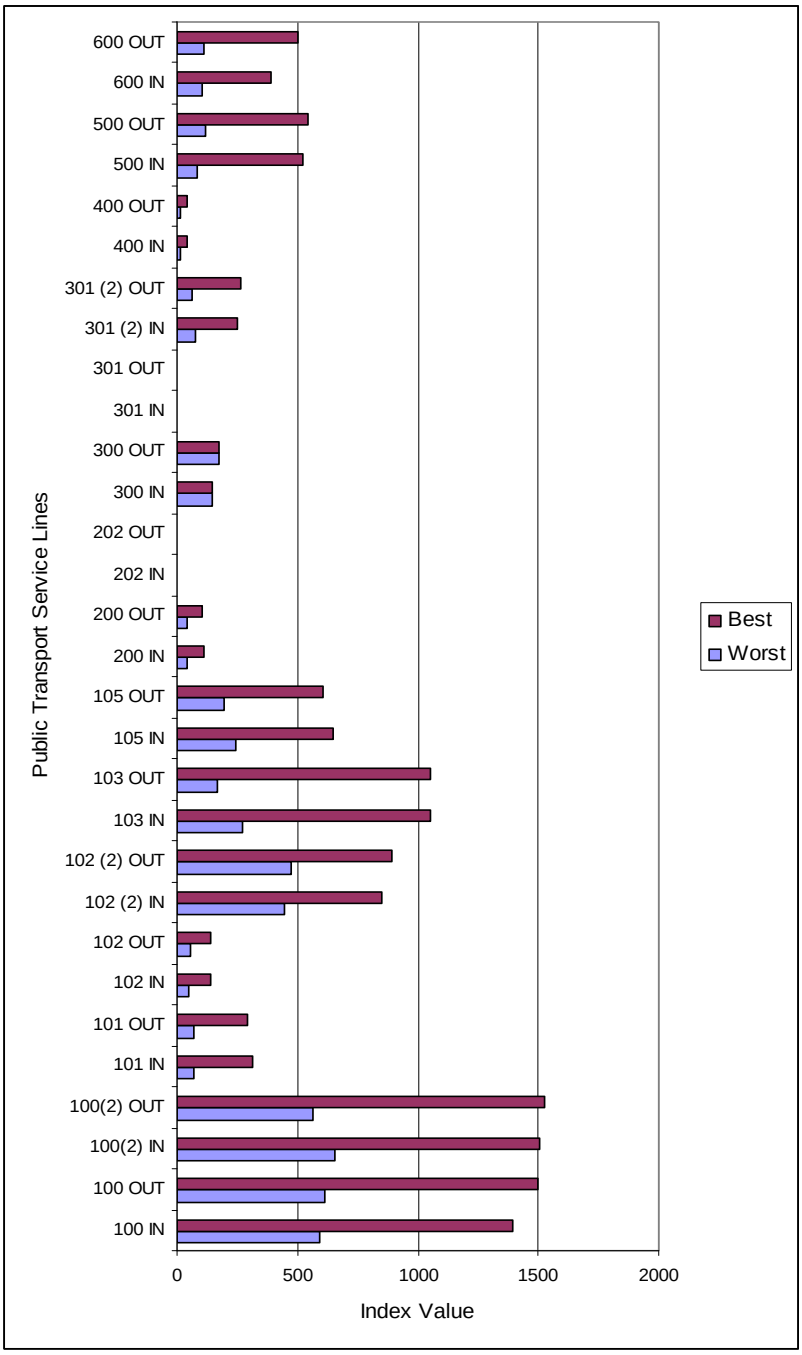


Chart 3. Best and Worst Case Scenarios for Accessibility by Public Transport in Girona Province

It was difficult to find a pattern where the cities with larger population would have lower generalised cost for their regional journey to or from the city with the high-speed station. (See Table 1). Therefore, the interpretation of the accessibility focuses on the generalised cost, and more specifically on the waiting time and service frequency. The fares and the in-vehicle travel times remained the same and they did not show a difference in the accessibility level. The generalised cost values in the worst case scenario are three times greater than the generalised cost values for the best case scenario. This means that there are large time gaps between shortest and longest waiting time in a bus service or between the shortest or longest frequency of bus services.

Table 1. Accessibility Index for the Province of Girona using Public Transport (2008)

Province	Line Number	City	Population (thousands)	Generalised Cost		Accessibility Index		Direction
				longest	shortest	Worst	Best	
Girona	100	Olot	32,903	55.83	23.67	589.31	1390.27	Inbound
Girona	100	Olot	32,903	53.83	22.00	611.20	1495.59	Outbound
Girona	100(2)	Banyoles	18,327	27.83	12.17	658.46	1506.33	Inbound
Girona	100(2)	Banyoles	18,327	32.33	12.00	566.81	1527.25	Outbound
Girona	101	Caldes de Malavella	6,710	97.50	21.17	68.82	317.01	Inbound
Girona	101	Caldes de Malavella	6,710	99.17	22.83	67.66	293.87	Outbound
Girona	102	Amer	2,304	50.33	16.17	45.77	142.52	Inbound
Girona	102	Amer	2,304	39.50	16.17	58.33	142.52	Outbound
Girona	102 (2)	Olot	32,903	73.67	38.67	446.65	850.94	Inbound
Girona	102 (2)	Olot	32,903	69.50	37.00	473.42	889.27	Outbound
Girona	103	Santa Coloma de Farners	11,739	43.67	11.17	268.83	1051.25	Inbound
Girona	103	Santa Coloma de Farners	11,739	69.83	11.17	168.10	1051.25	Outbound
Girona	105	Llagostera	7,764	31.67	12.00	245.18	647.00	Inbound
Girona	105	Llagostera	7,764	39.17	12.83	198.23	604.99	Outbound
Girona	200	Flaca	1,072	25.17	9.50	42.60	112.84	Inbound
Girona	200	Flaca	1,072	25.83	10.00	41.50	107.20	Outbound
Girona	202	Madremanya	238	119.50	28.67	1.99	8.30	Inbound
Girona	202	Madremanya	238	103.83	40.00	2.29	5.95	Outbound
Girona	300	Angles	5,569	38.67	38.67	144.03	144.03	Inbound
Girona	300	Angles	5,569	31.67	31.67	175.86	175.86	Outbound
Girona	301	Sant Marti de Llemana	545	96.67	54.17	5.64	10.06	Inbound
Girona	301	Sant Marti de Llemana	545	83.33	57.83	6.54	9.42	Outbound
Girona	301 (2)	Sant Gregori	3,167	42.50	12.67	74.52	250.03	Inbound
Girona	301 (2)	Sant Gregori	3,167	50.00	12.00	63.34	263.92	Outbound
Girona	400	St Jordi Desvalls	649	56.17	16.17	11.55	40.14	Inbound
Girona	400	St Jordi Desvalls	649	46.17	16.17	14.06	40.14	Outbound
Girona	500	Vidreres	7,430	91.67	14.17	81.05	524.47	Inbound
Girona	500	Vidreres	7,430	64.50	13.67	115.19	543.66	Outbound
Girona	600	Mecanet	6,871	67.50	17.50	101.79	392.63	Inbound
Girona	600	Mecanet	6,871	60.83	13.67	112.95	502.76	Outbound

After examining the bus schedules for the Girona interurban bus lines, it became evident that the bus services ran either not frequently enough or they did not match the timetables of the rail services stopping at Girona. Some timetables indicate that the service is only provided to people going to and returning from work (i.e. lines 101, 103, 300, 400, 500, 600). For outbound travel there are hourly services only in the morning and in the late afternoon. There are no services midday and in the evening. For example bus line 101, 102 and 500 are missing connections for the evening trains which arrive to Girona. This means that people who might be arriving on the late trains will not be able to continue their journey using public transport. The services are very limited and provide poor accessibility regionally.

Differences were found in inbound and outbound travel. Waiting time was often longer for journeys from Girona, than for journeys to Girona. Another example is bus line 100(2) between Banyoles and Girona, which has more frequent bus services than the number of trains that arrive or leave Girona. However, the accessibility level is poor because the time tables are not coordinated between the bus and train services. The waiting times between some bus services and the next available train vary between 2 and over 30 minutes and in some cases over 60 minutes. Because the waiting time drops as short as two minutes, it is impossible to make a connection, an earlier bus has to be taken and in that case the waiting time would increase to 50 minutes. The increasing waiting time raised the generalised cost of the journey, creating a financial barrier to transport accessibility.

The interurban or regional bus schedules for 2008 indicate that time compatibility with train services is not important to transport cohesion in the Girona province. The Girona bus network seems to be designed for people who use public transport to travel around the province only and not be able to take advantage of interregional public transport modes such as rail.

Accessibility in the Lleida Province

The Lleida province has 42 municipalities grouped in two travel zones and serviced by 14 bus lines and one rail link. 13 bus lines start and end at Lleida (see Map.7 and Map 8.). The interurban and urban public transport in Lleida is operated by a number of bus providers under The SARBUS GROUP (in Spanish El Grup SARBUS). The ATM ITS system was implemented from March 2008, making it fairly new (Catalonia Passenger Transport Plan 2008-2012). The public transport network concentration is in the east and north of Lleida province. Only four bus lines and the rail line run into zone 2 providing limited opportunities for regional accessibility and connectivity.

The high-speed timetable was correlated with the train services connected to Camp de Tarragona and to Madrid. These train journeys are often operated by medium-distance high-speed services, which have different time tables from the long distance high-speed services. Although Lleida is on the high-speed corridor connecting Madrid with Barcelona, the high-speed services do not always stop at the city.

Interurban Lines Stopping at Lleida		Zone
101	Lleida-Alfarras	2
102	Lleida-La Portella	1
103	Lleida-Corbins	1
104	Lleida-Vilanova de la Barca	1
105	Lleida-Els Alamus	1
106	Lleida-Puigverd de Lleida	1
107	Lleida.Aspa	1
108	Lleida-Alcano	2
109	Lleida-Almatret	2
110	Lleida-Sunyer	1
111	Lleida-La Granja d'Escarp	2
112	Lleida-Almacelles	1
113	Lleida-Alpicat	1
FCG	Lleida-Balaguer	2

Source: ATMLleida

Map 7: Lleida Province Public Transport Network and Lines (2008)

Map 8: Lleida Province Public Transport Travel Zones (2008)

The assessment of the interurban public transport timetables against the high-speed train timetables leads to a series of conclusions which are supported by examples. Travel concentration is in Zone 1. Regional lines are not fully compatible with the arriving and departing high-speed trains at Lleida due to the long waiting time between rail and bus services. In the Lleida province, there was a clearer pattern where the cities with the lowest population count have the highest generalised cost on both the worst and best case scenarios (see Table 2). This means that the smaller the city the less connected and less accessible it becomes regionally. The greatest accessibility is observed with the FGC train service. Half of the bus services show some level of accessibility, while the rest indicate poor level of accessibility (see chart 4). Finally, in the best case scenario, where the generalised cost holds the lowest value, the accessibility is better for inbound journeys (see Chart 5).

Table 2. Accessibility Index for the Province of Lleida using Public Transport (2008)

Province	Line Number	City	Population (thousands)	Generalised Cost		Accessibility Index		Direction
				longest	shortest	Worst	Best	
Lleida	101	Alfarras	3,163	87.50	10.17	36.15	311.11	Inbound
Lleida	101	Alfarras	3,163	35.17	13.83	89.94	228.65	Outbound
Lleida	102	La Portella	816	109.50	17.17	7.45	47.53	Inbound
Lleida	102	La Portella	816	48.00	24.00	17.00	34.00	Outbound
Lleida	103	Corbins	1,370	65.00	9.33	21.08	146.79	Inbound
Lleida	103	Corbins	1,370	51.17	14.50	26.78	94.48	Outbound
Lleida	104	Vilanova de la Barca	1,181	77.50	9.83	15.24	120.10	Inbound
Lleida	104	Vilanova de la Barca	1,181	100.00	7.00	11.81	168.71	Outbound
Lleida	105	Els Alamus	724	155.00	86.00	4.67	8.42	Inbound
Lleida	105	Els Alamus	724	86.00	42.00	8.42	17.24	Outbound
Lleida	106	Puigverd de Lleida	1,356	93.33	15.33	14.53	88.43	Inbound
Lleida	106	Puigverd de Lleida	1,356	50.17	15.33	27.03	88.43	Outbound
Lleida	107	Aspa	262	157.50	91.00	1.66	2.88	Inbound
Lleida	107	Aspa	262	125.67	71.33	2.08	3.67	Outbound
Lleida	108	Alcanó	244	156.67	84.33	1.56	2.89	Inbound
Lleida	108	Alcanó	244	127.83	67.83	1.91	3.60	Outbound
Lleida	109	Almatret	415	163.33	87.67	2.54	4.73	Inbound
Lleida	109	Almatret	415	134.50	74.50	3.09	5.57	Outbound
Lleida	110	Torres de Segre	2,055	76.67	18.50	26.80	111.08	Inbound
Lleida	110	Torres de Segre	2,055	103.83	19.50	19.79	105.38	Outbound
Lleida	111	Granja D'Ecarp	1,024	91.67	21.00	11.17	48.76	Inbound
Lleida	111	Granja D'Ecarp	1,024	56.83	22.00	18.02	46.55	Outbound
Lleida	112	Almacelles	6,295	82.50	16.00	76.30	393.44	Inbound
Lleida	112	Almacelles	6,295	66.33	16.17	94.90	389.38	Outbound
Lleida	113	Aplicat	5,900	32.00	11.67	184.38	505.71	Inbound
Lleida	113	Aplicat	5,900	32.67	13.00	180.61	453.85	Outbound
Lleida	FGC	Balaguer	16,341	59.33	16.00	275.41	1021.31	Inbound
Lleida	FGC	Balaguer	16,341	59.33	18.33	275.41	891.33	Outbound

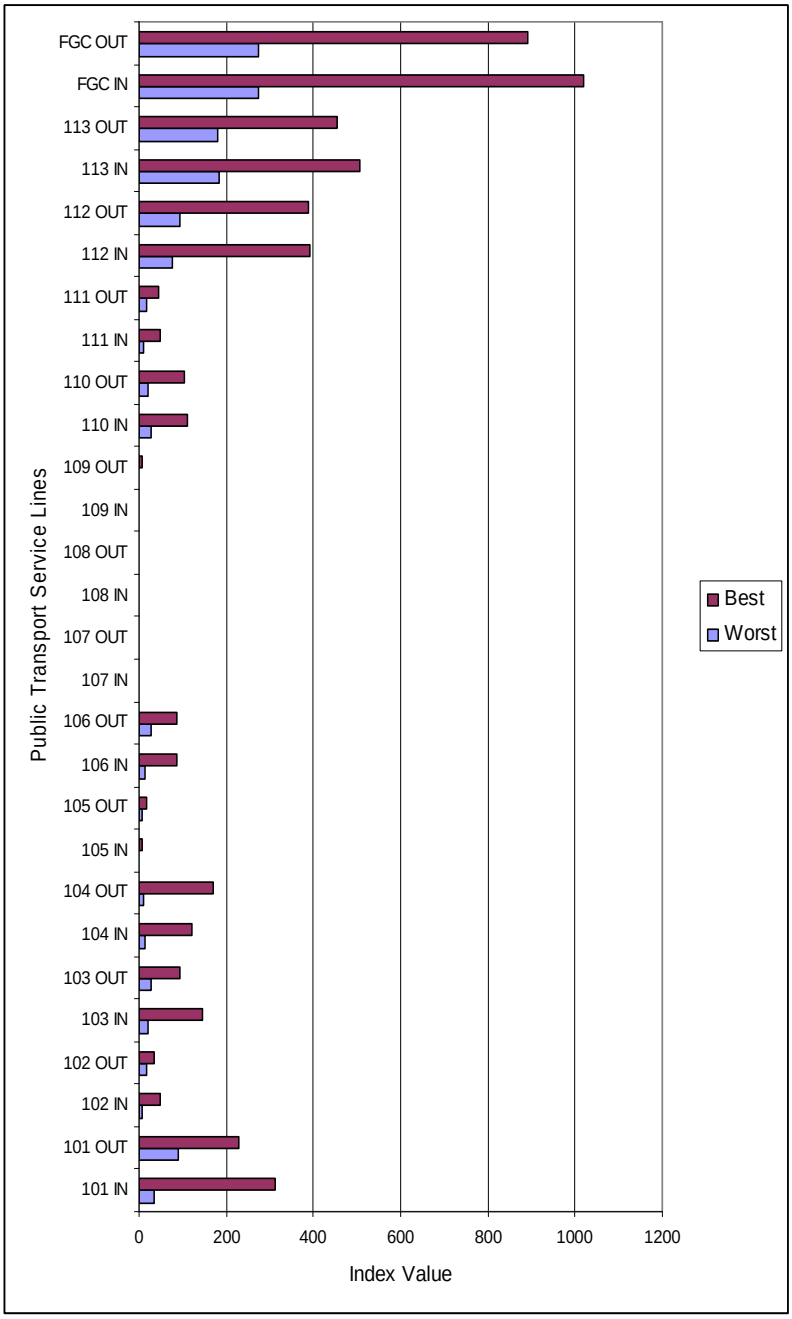


Chart 4. Best and Worst Case Scenarios for Accessibility by Public Transport in Lleida Province

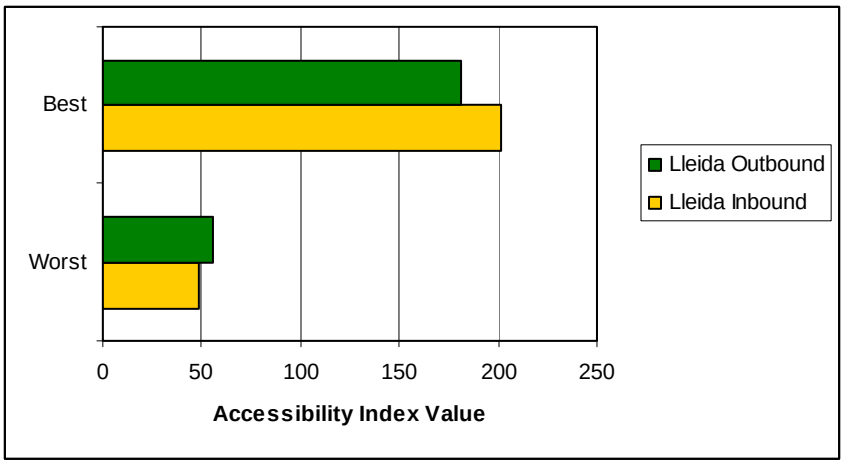


Chart 5. Average Inbound and Outbound Accessibility for the Province of Lleida (2008)

From all the regional bus and train services, only one line has a waiting time less than 30 minutes for inbound travel (line 112), and another line has less than 30 minute wait for outbound travel (line 107). However, that said, unlike line 112, line 107 has only 2 services a day each way making the accessibility and interconnectivity very insignificant. The long waiting time at the station decreases the overall accessibility level for all public transport journeys to and from Lleida. The accessibility level is greater for journeys from Lleida high-speed station to the province, with the exception of three bus lines (lines 109, 112, 113).

As observed in Girona, a bus line such as 101 offers frequent bus service, but the time table is not coordinated with the one of train services. Furthermore, there are no bus services for evening trains. 111 is another line that does not provide a connection for evening train services.

Another case is where there is a bus service, but there are no trains operating at that time. Line 104 to and from Vilanova de Barca has frequent services every hour in the morning, but only one provides a link with the least waiting time between the bus and train services. Line 105, 107,108 run twice a day with a service in the morning for inbound travel and a service at night for outbound travel. The possible explanation for the last three lines is that the bus service is available only for people going to and coming back from work or study.

Accessibility in the Tarragona Province

The data for the Camp de Tarragona services was collected by ALSA Group. At the time of the study there was no ATM Tarragona, nor ITS.

Tarragona province differs from the other provinces in the fact that it has a high speed station in Camp de Tarragona which is not the province capital. Instead, most of the regional public transport services run to and form capital city of Tarragona and Reus, both of which a

located approximately 15 km from Camp de Tarragona. In 2008 connections to Camp de Tarragona were only provided by three bus services to and from Tarragona city, Reus and Valls. The population in those cities is high in comparison to most of the regional cities in the Lleida and the Girona provinces (see Table 3). The generalised costs are comparatively low too, but they do not reflect the population size of the cities as it was observed in the Lleida province.

Table 3. Accessibility Index for the Province of Tarragona using Public Transport (2008)

Province	Line Number	City	Population (thousands)	Generalised Cost		Accessibility Index		Direction
				longest	shortest	Worst	Best	
Tarragona	Tarragona city	Tarragona City	137,536	34.17	5.77	4025.44	23850.17	Inbound
Tarragona	Tarragona city	Tarragona City	137,536	33.33	6.55	4126.08	20997.86	Outbound
Tarragona	Reus	Reus	107,770	42.33	10.88	2545.75	9902.30	Inbound
Tarragona	Reus	Reus	107,770	48.50	10.72	2222.06	10056.30	Outbound
Tarragona	Valls	Valls	24,710	39.33	4.33	628.22	5702.31	Inbound
Tarragona	Valls	Valls	24,710	37.17	4.17	664.84	5930.40	Outbound

It must also be noted that unlike the above provinces separate, bus schedules exist for the AVE (long-distance) and the AVANT (medium-distance) high-speed services stopping at Camp de Tarragona. Most of the waiting time was between 14 and 16 minutes, which provided a good connection and accessibility to and from the high-speed station. All bus lines connecting with Camp de Tarragona show slightly higher level of accessibility for inbound journeys (see Chart 6).

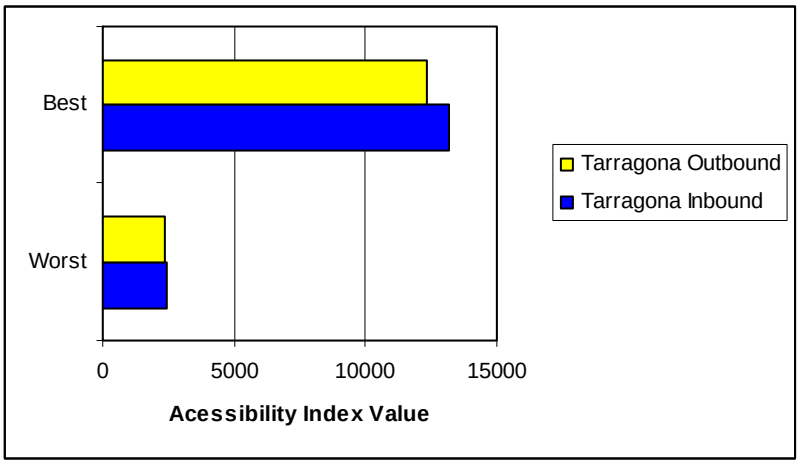
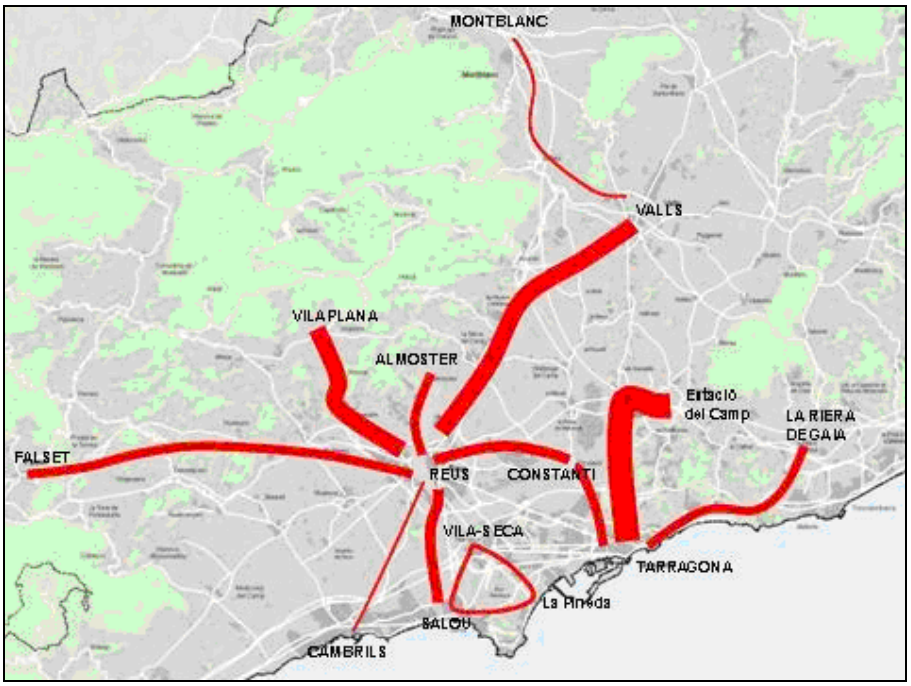


Chart 6. Average Inbound and Outbound Accessibility for the Province of Tarragona (2008)

Only, at one morning service the waiting time dropped to as short as 9 minutes. Although this is a short time, it is assumed that because the bus stops and leaves at the train station, passengers might be able to still make a connection with the train service. However, if there are delays due to accidents, road congestions, or weather disruption, the waiting time may be too short. If the next or earlier available service is taken, then the waiting time could increase to almost an hour.

Despite the above findings, the fact that the Camp de Tarragona is connected to only three cities in the province of Tarragona cannot be ignored. This already indicates that the regional accessibility to the high-speed station is limited. Camp de Tarragona is a new station and the public transport network is still very strongly concentrated around the capital city of Tarragona and Reus (see Map. 9). Tarragona city has a train station with conventional rail services, and Reus airport hosts low-cost airlines. Consequently, the traffic flow and concentration of bus services as well as their frequency remains in Tarragona and Reus. The line shown between Camp de Tarragona and Tarragona city on Map 9. is the thickest meaning that it offers the most frequent bus service with 8 buses per day in each direction. The frequency of the bus service may indicate greater accessibility between Tarragona city and Camp de Tarragona, but the lack of other links to Camp de Tarragona from other areas of the province indicates poor connectivity on a regional level.



Source: ATM Tarragona

Map 9: Tarragona Province Public Transport Services and Frequency 2008

When the accessibility assessment was carried out, a difference was observed in the waiting time between the bus service and the train services connecting to Lleida and Barcelona. The waiting time for journeys to and from Lleida were shorter than the waiting time for journeys to or from Barcelona. This explains a setback in the compatibility in the timetables between the bus services in Camp de Tarragona and train services to and from Barcelona. Considering that the majority of the traffic flow is to and from Barcelona, and that Barcelona is a major metropolitan area in Catalonia, it should be expected that the waiting time would be as short as possible. Yet the results indicated otherwise. It can be concluded that because of the longer waiting time, the generalised cost would increase for both business and leisure travellers, worsening the accessibility to and from the high-speed network. This would indicate lower use of the public transport and possibly lower use of high-speed services between Camp de Tarragona and Barcelona. In other words, like Girona, travellers will use car or bus services to travel between Tarragona and Barcelona, avoiding the high-speed rail services.

Comparisons between Girona, Lleida and Tarragona Provinces

After the assessment of each province, the three provinces are compared against each other offering further results and common and different factors.

Girona and Lleida have the same number of bus services, although Lleida has an additional rail service (see Chart 7). In both provinces only half of the services provide some level of accessibility to the high-speed network. Both provinces share the same problem of inconsistencies in the bus timetables and the lack of coordination with the stopping and leaving rail services. This indicates that the services focus only on regional bus services to and from the capital cities of Lleida and Girona. Consequently, providing a public transport link to the high-speed station becomes regionally less important.

Tarragona, on the other hand, shows the lowest number of bus services, but the highest level of accessibility. The reason for that, and as noted earlier, is that unlike Girona and Lleida, the bus services connecting to Camp de Tarragona are specifically introduced to provide access to the high-speed network. When the average inbound and outbound accessibility are compared in the best and worst scenarios, Tarragona leads the group as best accessible, followed by Girona and Lleida (see Chart 8 and Chart 9). A significant difference between the three provinces is that the population in the Tarragona regional cities which connect to the high-speed network is much larger than the population in the regional cities of Girona and Lleida. This means that the designated bus services intentionally connect larger cities and ignore the smaller cities in the rest of the province.

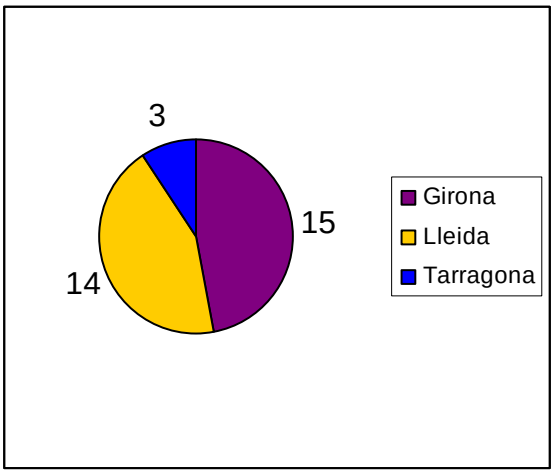


Chart 7. Number of Public Transport Lines connecting to the Cities with High-speed station (by Province, 2008)

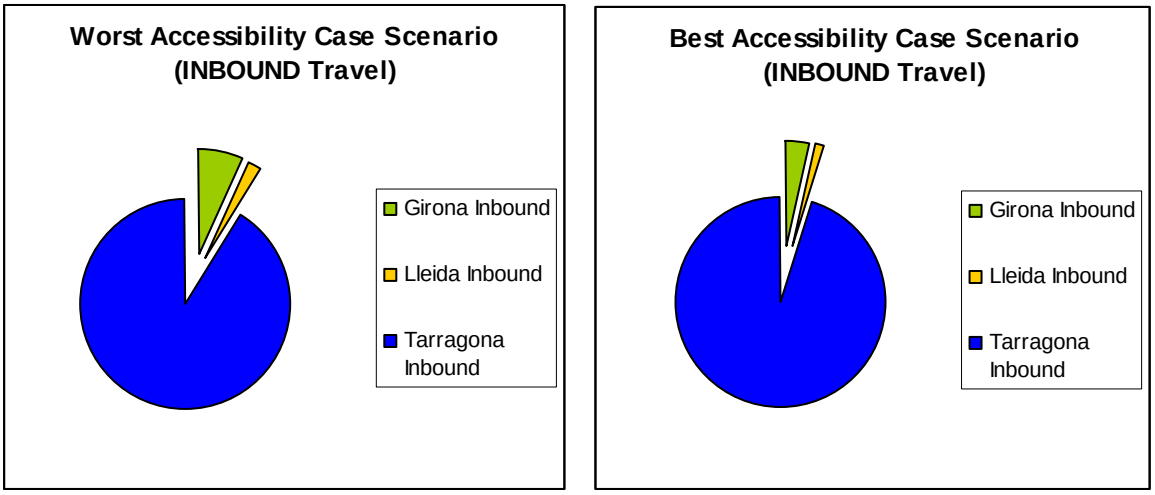


Chart 8. Average Accessibility for Inbound Travel by Province (2008)

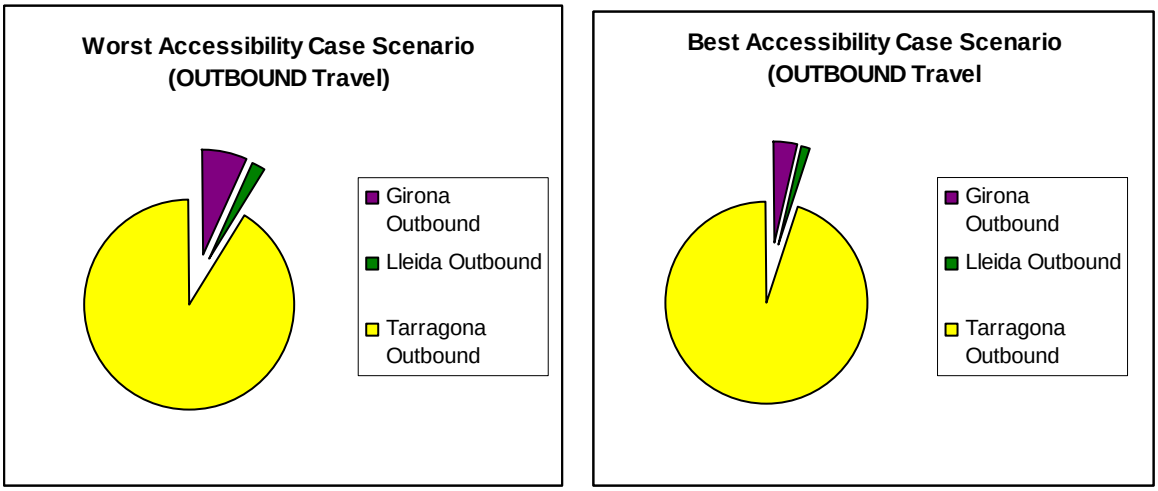


Chart 9. Average Accessibility for Outbound Travel by Province (2008)

CONCLUSIONS

The purpose of this paper was to assess the accessibility to the high-speed railways in south-west Europe on a regional level through an accessibility measure, which can have an impact on the use of the high-speed services in the region. The accessibility assessment is based on the gravity model with variables such as population, travel time, waiting time, service frequency and ticket fares.

In theory, the existence of high-speed rail services should promote greater accessibility on a regional level. However, in practice, that does not seem to be the case. Although the high-speed rail service exists, there is overall poor accessibility to the network by public transport from cities that do not have a high-speed service. The barriers lie in (1) the limited number of bus services connecting to and from the regional cities, (2) the lack of coordination between timetables for both rail and bus services, and (3) the high generalised costs, which are driven by long waiting times or not frequent enough services. In reality Camp de Tarragona should ranks as the high-speed station with the worst accessibility, due to lack of sufficient regional transport links. Girona and Lleida falls behind due to the limited frequency of public transport services which focus on people travelling mainly to and from work. Geographically, Girona has a comparatively well balanced public transport network around the province; however, the bus schedules need to be made compatible with the train schedules in order to encourage people to use public transport and high-speed railways. It is understandable that until the train station and the rail infrastructure are upgraded for high-speed services in Girona, such recommendations cannot be considered.

On a positive note, all provinces have introduced an Integrated Tariff System providing for smooth and easy travel on public transport. Many of the bus lines are served by different operators who have become part of the integrated pubic transport system. This is a step forward toward a well connected and integrated transport network that gives passengers a wider choice of services without the need to buy a ticket for every zone or operator. However, the ITS integration is satisfactory only to the passenger's convenience to use of public transport, but it does not create the most efficient time table coordination. With the exception of Barcelona Province, each province has shown that the ITS focuses on public urban and interurban transport without taking into consideration the high-speed network.

Based on the study, the high-speed network does not justify the accessibility on a regional level. People may use public transport within each province, but they will not use it to connect to the high-speed rail services and commute between regions. Girona is located along the Mediterranean coast and will become the last high-speed station in Spain on the way to France. Furthermore, Girona has a popular airport for low-cost airlines, making it even more attractive to travel to and from. It has a strategic location; therefore it is significant that public transport is integrated not only in the ATM ITS system alone, but also in its timetables, minimising waiting time between services and increasing bus frequencies in order to provide faster and more accessible transportation to and from the train station. If this is not achieved, the regional transportation to or from the Girona train station by pubic transport will remain inconsistent and less attractive for travellers. People will either not use the bus service, and opt for a car, or they will simply disregard the bus or train journey, and travel around the Girona province and towards Barcelona or France by car.

At the current network and available services, the cost to achieve interregional public transport travel will be high and affordable to only few. High-speed rail services already raises concerns that they are an expensive mode and it is only used for business travel and those who can afford it. So by having poor regional accessibility to the high-speed network, this concern will be re-enforced and could become a reality. This raises a number of questions: (1) Whom are the high-speed services running for, (2) Is high-speed rail for businessmen and financially privileged only, and (3) Can efficient intermodal public transport exist when currently it is being suppressed by the lack of coordinated bus services. If high-speed services are not integrated regionally through other public transport services, then their benefit will be limited to only those who travel along the high-speed rail network and live in the cities with high-speed stations.

Introducing more public transport links, increasing their frequency and decreasing the waiting times by matching their timetables with the ones of the high-speed train services will create an integrated and cohesive transport network in all the provinces and increase accessibility and connectivity to the high-speed network. The socio-economic impact will be greater encouraging passengers to travel using different public transport modes including high-speed rail for work as well as leisure.

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