360. revista de alta velocidad

2018 - número 6

INTERNATIONAL CONGRESS ON HIGH-SPEED RAIL (Vol. II)

- Impacts on Mobility
- Urban Impacts
- Territorial and Enviromental Impacts
- General and Network Aspects of HSR

International Congress on High-speed Rail:
Technologies and Long Term Impacts
Ciudad Real (Spain), October, 2017

Escuela de Ingenieros de Caminos, Canales y Puertos de Ciudad Real
UNIVERSIDAD DE CASTILLA-LA MANCHA

FUNDACIÓN DE LOS FERROCARRILES ESPAÑOLES

SOBRE LA REVISTA

360. revista de altavelocidad pretende servir de foro de discusión serena y plural, a la vez que profundiza en todos los temas relacionados con la alta velocidad ferroviaria: planificación, efectos económicos y sociales, explotación, tecnología, etc.

El nombre "360.revista de alta velocidad" simboliza la voluntad de "ir más allá" en la aportación social de la alta velocidad (300 km/h es la velocidad máxima actual), y a la vez el deseo de ofrecer una visión panorámica y plural (de 360º de amplitud).

Se articula en tres partes: artículos propios; datos comentados sobre la alta velocidad; y revista de blogs y de prensa, etc., para dar cabida a las opiniones ajenas y ofrecer un termómetro del estado de opinión sobre la alta velocidad.

La revista asume que la velocidad no es un fin, como tampoco lo son las infraestructuras necesarias: el objetivo debe ser el incremento de la sostenibilidad del sistema de transporte y de la eficiencia de la movilidad.

Además se asume que en este campo no hay verdades absolutas ni de validez universal, sino que cada caso debe analizarse individualmente olvidando los apriorismos o ideas preconcebidas.

Los artículos son solicitados a los autores por el Editor (a iniciativa propia o propuesta del Consejo Editorial). Podrán ser publicados en español, inglés o portugués.

Los artículos expresan, exclusivamente, la opinión de sus autores.

Los temas concretos que serán abordados en la publicación; las normas de petición, envío y revisión de los artículos; y las normas de presentación de los mismos podrán ser consultadas en el sitio web de la revista.

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This Special Issue of the journal joints a set of selected papers presented in the International Congress on High Speed Rail that took place on 4-6 October 2017 at the University of Castilla La Mancha in Ciudad Real to commemorate the 25th anniversary of the Madrid Seville HSR corridor.

The congress plenary and parallel sessions were divided in three days: the first and the third ones in Ciudad Real and the second was held in Sevilla, moving the participants on board of an Special High Speed Train (Miguel de Cervantes) service between Ciudad Real and Sevilla. In particular, the commemorative video that was projected on board of the train can be seen following that link: https://goo.gl/KfH9ZW

Regarding to the objective of the Congress, it was thought to evaluate the usefulness of High-Seed Rail system under a quintuple perspective:

- Long-term implications
- Multidisciplinary scientific approach
- Transport relevance
- Territorial development
- Technology development and diffusion

The social cost and usefulness of the High Speed Rail system has been abundantly studied prior to and shortly after the introduction of this new transport mode. With this fact in mind, this Congress tried to focus on a long-term perspective on its costs and benefits and on a technology development and diffusion perspective. In fact, high speed rail systems have already been in operation for just over half a century in Japan and for 35 years in France. Thus, it was possible to debate its pros and cons considering an important time span.

Finally, this International Congress combined several High Speed Rail system point of view such as superstructure, infrastructure and rolling material optimization, economic, urban and territorial development, sustainability and energy savings, and safety.

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Impacts on mobility

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The demand in a railway corridor after the HSR

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Jaro, Lorenzo

ADIF Alta Velocidad[1]

Abstract

This paper analyses the changes in mobility and modal share in a railway corridor after the construction of a new high-speed line (HSL), during the last economic crisis.

The following chapters describe the new HSL Madrid-Levante, that connects Madrid with Valencia and Alicante, detailing the fieldwork carried out (before and after the HSL), and finally presents the most relevant results, mainly in relation to modal share.

The first results of the analysis carried out in Madrid-Galicia and Madrid-León / Asturias corridors are also presented.

From the results of these studies, we observe the great modal shift experienced in the relationships where a high-speed rail (HSR) is implemented, turning the railroad into a very important mode of transport, reaching between 25 and 35% of passengers. Airplane experiences a great fall in its demand, maintaining basically the connection traffic, whereas car, although it descends, continues being the dominant mode of transport.

Keywords: High-speed rail (HSR), high-speed line (HSL), demand, modal share, economic crisis.

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1. Introduction

In December 2010, the Madrid-Albacete / Valencia HSL was put into service, allowing a significant improvement in travel time between Madrid, Albacete, Valencia and Alicante, with the introduction of rail services with gauge change (Alvia services).

Subsequently, in June 2013 the HSL between Albacete and Alicante was completed, thus allowing the direct connection in HSR between Madrid and Alicante, also building a new station in Villena.

The following figure shows the Madrid-Levante High Speed Line, currently in service.

The improvement of travel times in rail has been very relevant, as we can be seen in the following figure:

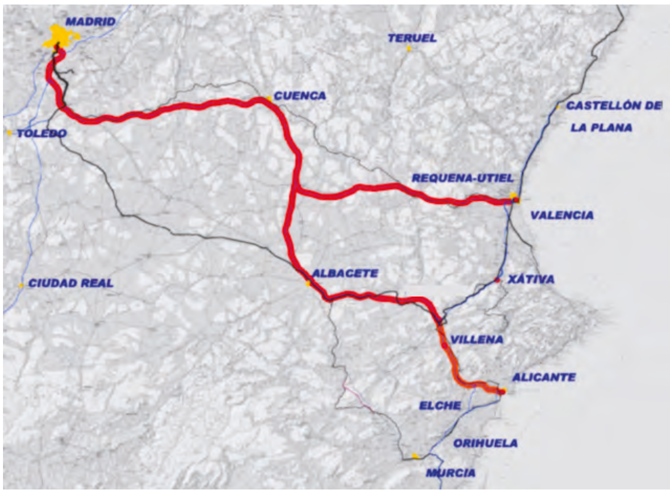


Figure 1. Madrid-Levante HSL.

In 2015 ADIF put into service two new sections of the HSL Madrid-Asturias (Valladolid-León) and Madrid-Galicia (Olmedo-Medina del Campo-Zamora), extending the Madrid-Valladolid HSL opened at the end of 2007.

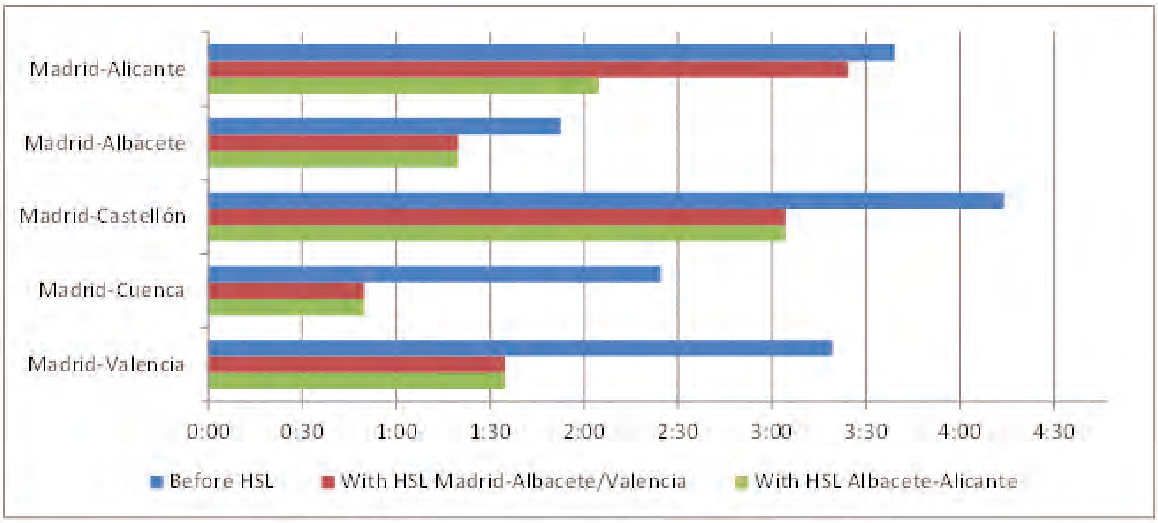


Figure 2. Rail travel times before and after HSR.

Figure 3. Madrid-Valladolid-León-Asturias HSL and Madrid-Zamora-Galicia HSL.

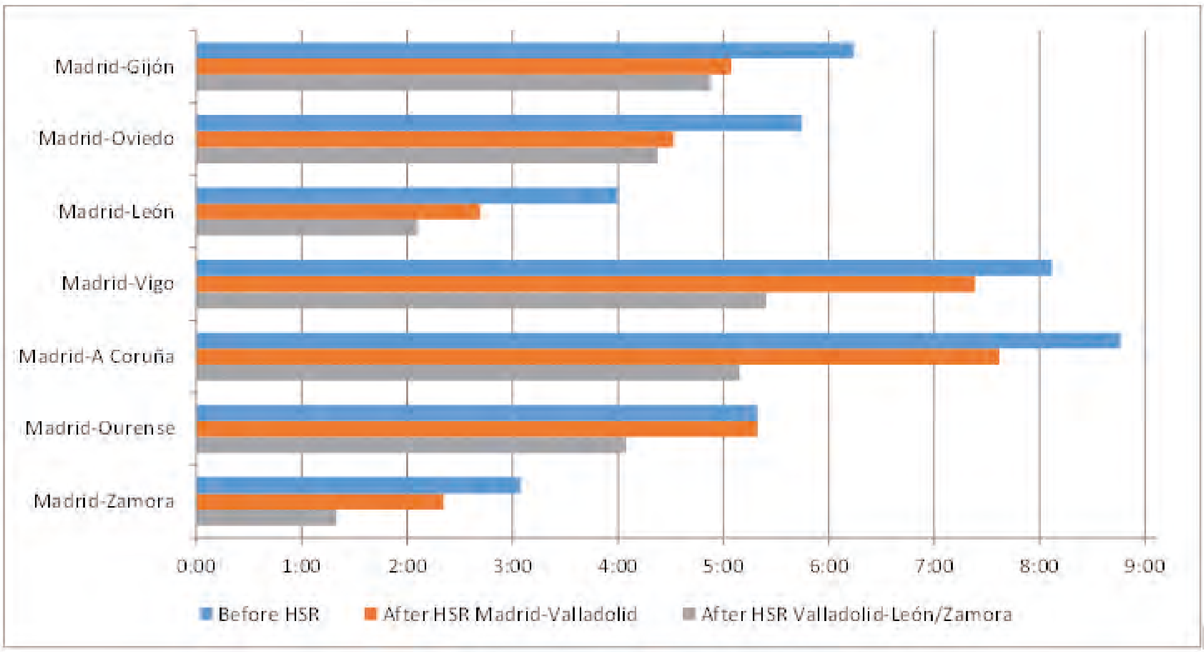
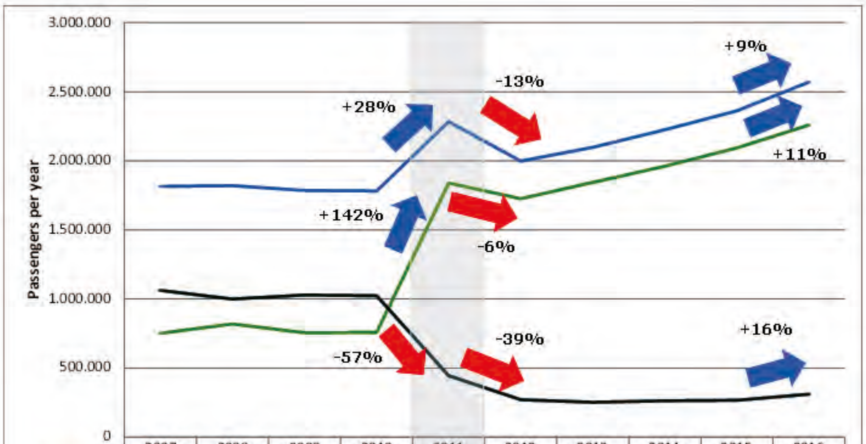


Figure 4. Rail travel times before and after HSR.

2. Effect on transport demand – airplane and rail

The new HSL Madrid-Valencia meant a large increase in the demand for rail passengers (+ 142%), between the cities of Madrid and Valencia connected in just 1 hour and 35 minutes, and a drastic fall of airplane demand during the first full year of operation (2011). However, the number of passengers of rail and airplane went down by 13%, recovering from 2013 as it's shown in the following figure.

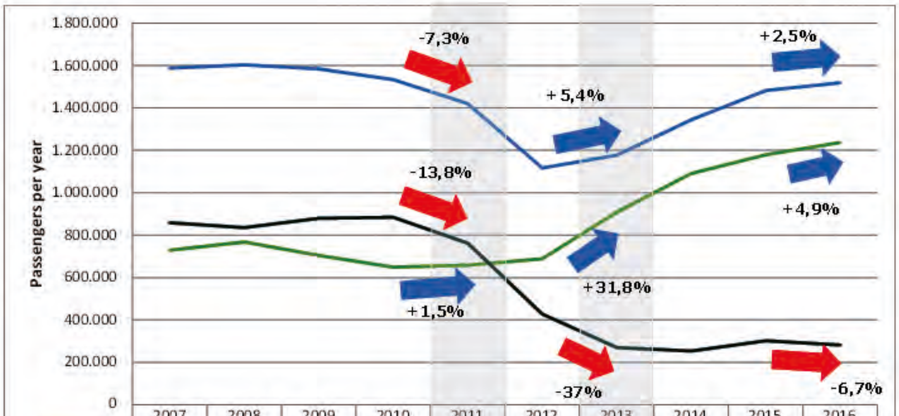


	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
HSR	751.739	819.999	756.284	758.610	1.838.544	1.725.701	1.844.436	1.960.521	2.093.837	2.259.185
Air	1.063.004	1.000.152	1.029.742	1.023.631	445.188	271.964	253.419	264.006	268.065	311.529
TOTAL	1.814.743	1.820.151	1.786.026	1.782.241	2.283.732	1.997.665	2.097.855	2.224.527	2.361.902	2.570.714

NOTE: HSR passengers between Madrid-Puerta de Atocha and Valencia Joaquín Sorolla HSR stations

Figure 5. Evolution of rail and air traffic between Madrid and Valencia. Source: ADIF AV.

In the case of Alicante, the evolution was different, initially, in 2011, rail demand barely increased although the Madrid-Albacete section was put into service, however the completion of the line (2013) increased rail demand significantly.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
HSR	729.249	767.893	703.973	648.945	658.531	688.712	907.862	1.090.871	1.179.227	1.236.630
Air	858.176	835.447	879.607	883.989	761.901	428.262	269.630	253.624	302.251	282.148
TOTAL	1.587.425	1.603.340	1.583.580	1.532.934	1.420.432	1.116.974	1.177.492	1.344.495	1.481.478	1.518.778

NOTE: HSR passengers between Madrid-Puerta de Atocha and Alicante HSR stations

Figure 6. Evolution of rail and air traffic between Madrid and Alicante. Source: ADIF AV.

3. Forecast and current demand - field work

In 2007, a detailed fieldwork was carried out throughout the Madrid-Levante corridor, consisting of surveys and counts in the different modes of transport, as well as the collection of statistical data to establish the main flows in the corridor.

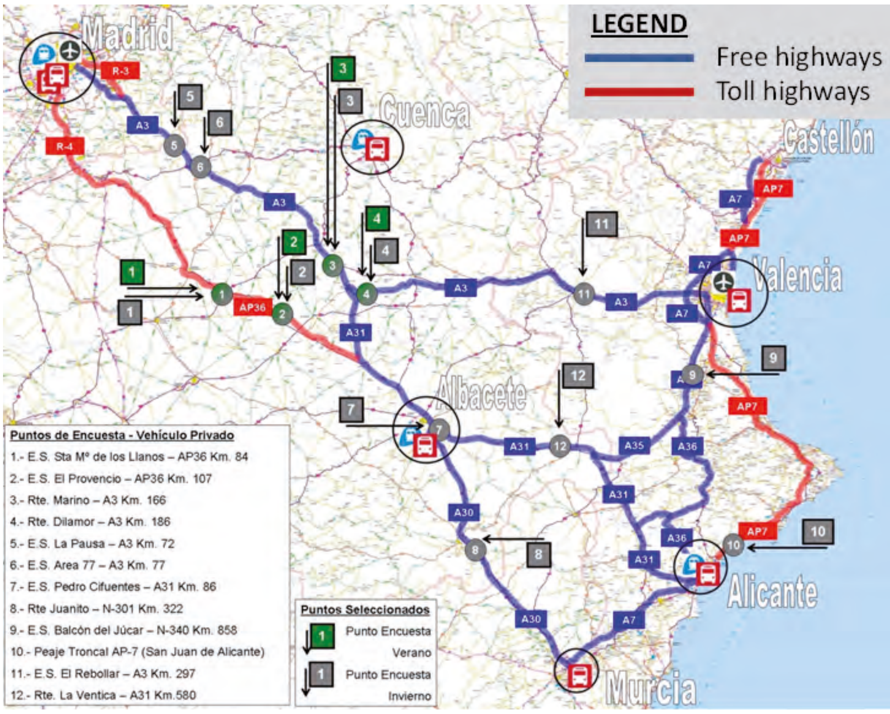


Figure 7. Surveys in corridor Madrid-Levante (2007).

Once the first phase of the line (Madrid-Albacete/Valencia) was put into service, ADIF decided to carry out several fieldwork campaigns to know the changes in the mobility between Madrid and Valencia, with the same methodology as in the previous studies in 2007. Later, in 2013 and 2014, the campaigns focused in the relationship Madrid-Alicante, with surveys and counts before and after the new HSL Albacete-Alicante.

The following table shows the date of these fieldworks.

<table>
<tr><th rowspan="2">Relation</th><th colspan="2">Campaigns</th></tr>
<tr><th>Winter</th><th>Summer</th></tr>
<tr><td rowspan="2">Madrid-Valencia</td><td>November 2011</td><td>July 2012</td></tr>
<tr><td>November 2013</td><td>July 2014</td></tr>
<tr><td rowspan="2">Madrid-Alicante</td><td colspan="2">April 2013</td></tr>
<tr><td>November 2013</td><td>July 2014</td></tr>
</table>

Table 1. Campaigns of field work carried out between Madrid, Valencia and Alicante

The same type of fieldwork was carried out by ADIF for the corridor Madrid-Galicia/Asturias, in 2008 a complete campaign of surveys was made to establish the real mobility in that moment, and recently (last year) this work was done over with the new sections of HSL Madrid-Galicia and Madrid/Asturias.

4. The evolution of global demand: the effect of economic crisis

In order to analyze the evolution of global demand in these corridors, and also to take into account the period of economic crisis, the observed demands of the following studies have been used:

- 1997: Informative study of the HSL Madrid-Castilla La Mancha-Comunidad Valenciana-Region of Murcia, carried out by Ministerio de Fomento in 1999.
- 2006: Demand study of Madrid-Levante HSL, carried out by ADIF in 2007-2008.
- 2007: Demand study of Madrid-Galicia/Asturias HSL, carried out by ADIF in 2008-2010.
- 2011/2013/2014: Demand study after opening the HSL Madrid-Levante, made by ADIF / ADIF AV in the period 2011-2015.

In the following graphic, we can see the GDP evolution hypothesis considered in ADIF demand studies in the period 2006-2008 and the real GDP variation. Foreseeing an economic downturn in 2008/2009, that is to say, if it were considered that there was an economic crisis, the real evolution of GDP has been very different, with a worsening of the crisis in 2009 much stronger than expected, 1% against the real of -3.6%, and a second period of decline in 2012-2013, totally unforeseen.

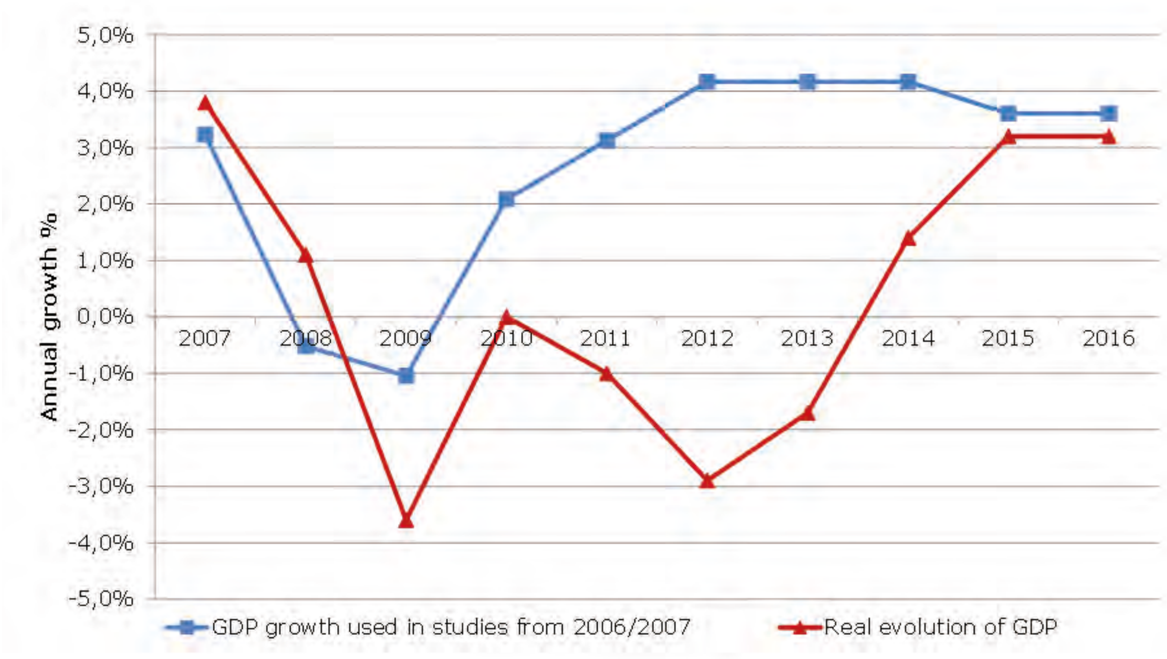


Figure 8. Evolution of GDP.

4.1 Madrid-Valencia

Comparing the evolution of the real demand in this relation in the years 1997, 2006, 2011 and 2013, it is observed that the demand in 2011 was in 2000 levels, that is to say, what is known in Economy as "lost decade". In the data obtained from 2013, there is already a recovery in demand, with an annual rate that is half of the pre-crisis period (2.1% versus 5.5%). The total mobility data is presented without considering the bus, due to the fact that in the various fieldworks it was not possible to obtain information from this mode of transport.

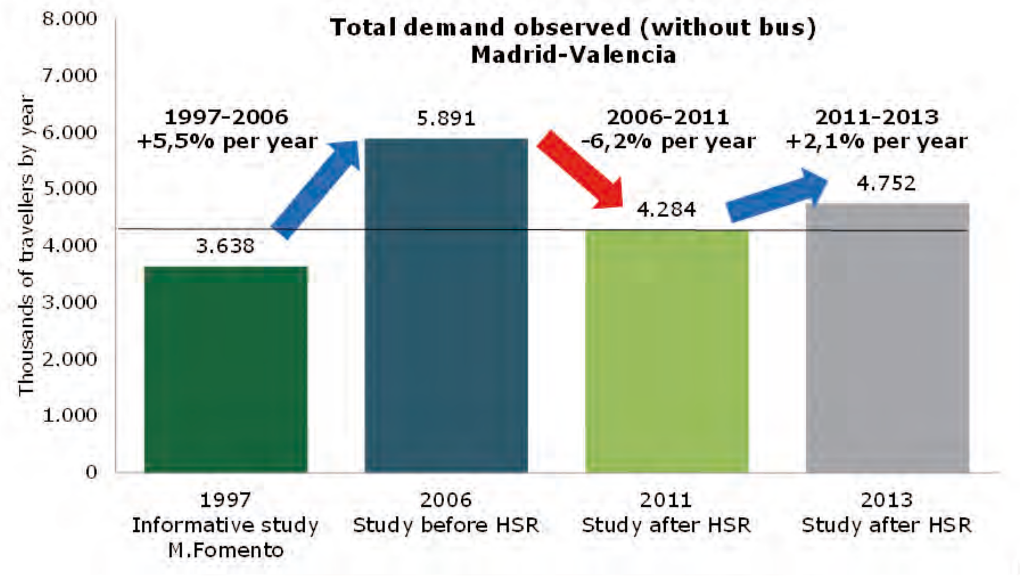


Figure 9. Evolution of annual demand between Madrid and Valencia.

4.2 Madrid-Alicante

In the case of the Madrid-Alicante, the growth between 1997 and 2006 was lower than in Valencia, although it grew significantly at a rate of 3% per year. The economic crisis of the period 2008-2013 has reduced the demand at a rate of 4.2% per year, observing, as in Valencia, a recovery from 2013 onwards, higher than the one experienced in Valencia and at a similar rate to the pre- -crisis period, growing 3.3% in the last year with data available.

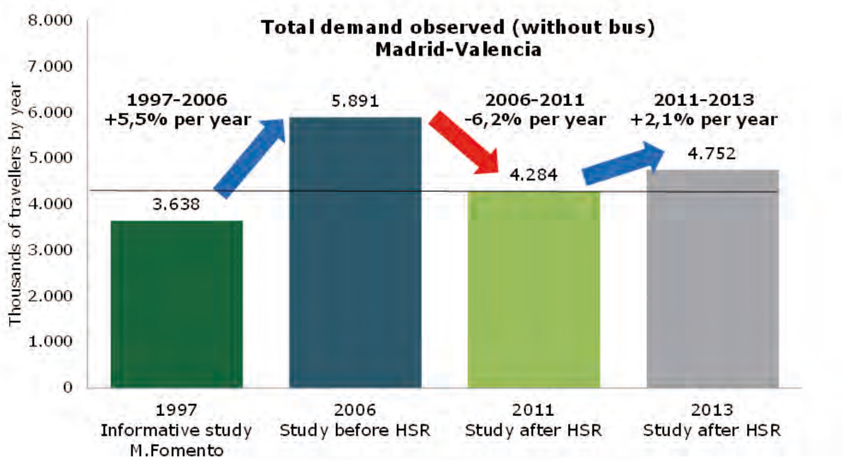


Figure 10. Evolution of annual demand between Madrid and Alicante.

4.3 Madrid-Galicia

Between Madrid and Galicia, the total number of passengers in all modes between 2007 and 2016 fell at a rate of 1,4% per year.

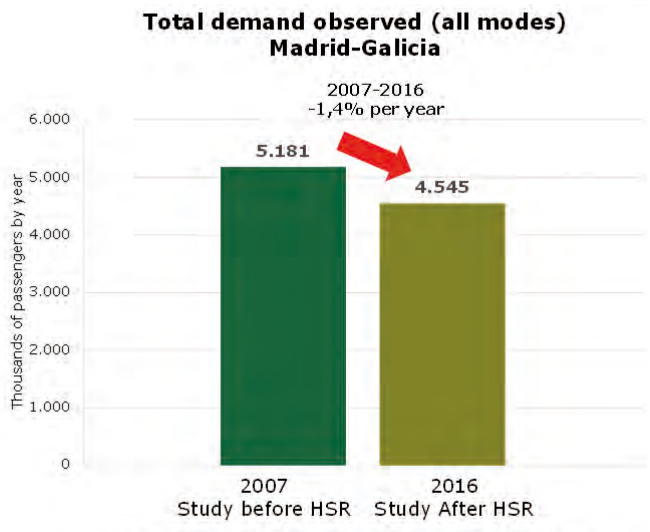


Figure 11. Evolution of annual demand between Madrid and Galicia.

4.4 Madrid-León

Between Madrid and León, the total number of passengers in all modes between 2007 and 2015 grew at a rate of 0,6% per year.

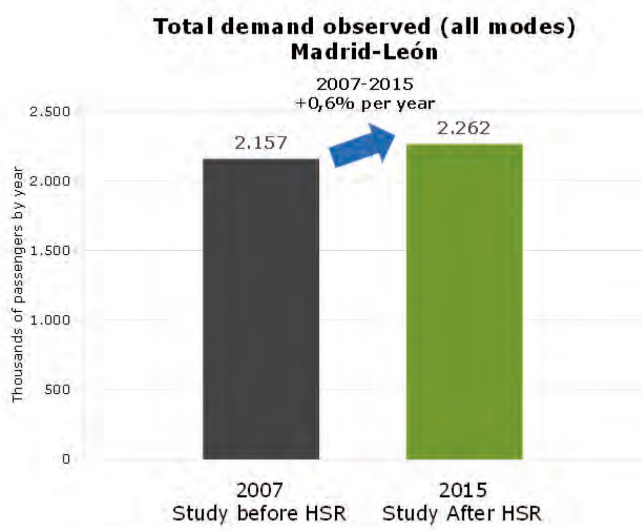


Figure 12. Evolution of annual demand between Madrid and León.

4.5 Madrid-Asturias

Between Madrid and Asturias, the total number of passengers in all modes between 2007 and 2016 fell at a rate of 1,2% per year.

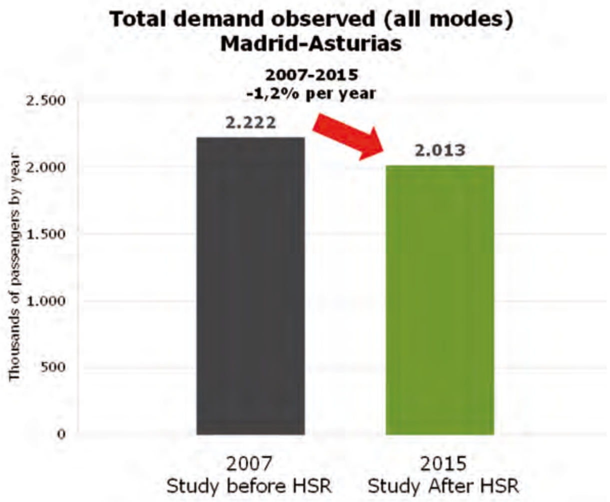


Figure 13. Evolution of annual demand between Madrid and Asturias.

5. Effect in modal share

5.1 Modal distribution: Madrid-Valencia

The new HSL has led to a considerable increase in the market share of the railway mode (from 11.4% to 34.8%). This increase is accompanied by a significant fall of car and airplane as

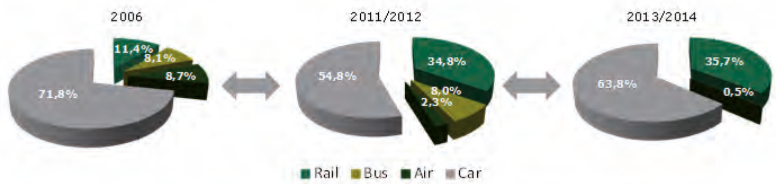


Figure 14. Comparison of modal shares in 2006, 2011 and 2013. Madrid-Valencia

expected in previous studies. The share of bus seems unaffected by the appearance of the HSR in 2011, although the difficulty of obtaining information does not allow for obtaining a clear conclusion about the real effects of HSR in this mode. In the campaign 2013/2014 it was not possible to carry out surveys to bus users.

5.2 Modal distribution: Madrid-Alicante

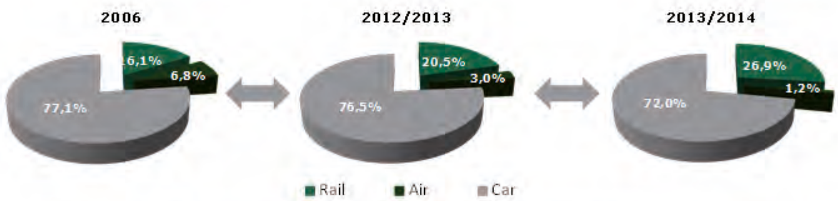


Figure 15. Modal share in 2006, 2012 and 2014. Madrid-Alicante

In the case of Madrid-Alicante relationship, there is a notable increase in modal share, but less than in Valencia, from 16% in 2006 to 27% in 2014 (with the HSL finalized). In this case the data are presented without bus, because it was not possible to obtain the demand in this transport mode.

5.3 Modal distribution: Madrid-Galicia

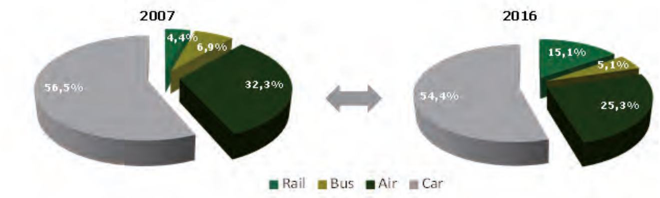


Figure 16. Modal share in 2007 and 2016. Madrid-Galicia

In this relationship, the HSR has not reached the percentage of the total demand as in Valencia and Alicante, logically because the HSL is not finished, but the rail modal distribution has increased significantly.

5.4 Modal distribution: Madrid-León

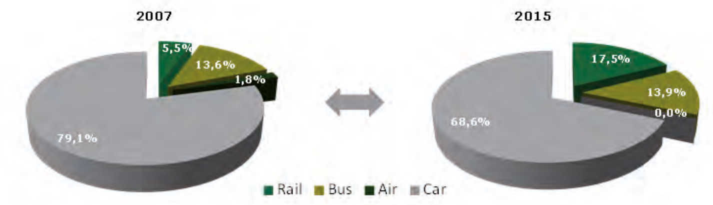


Figure 17. Modal share in 2007 and 2015. Madrid-León

In this relationship, the main effect is the disappearance of airplane.

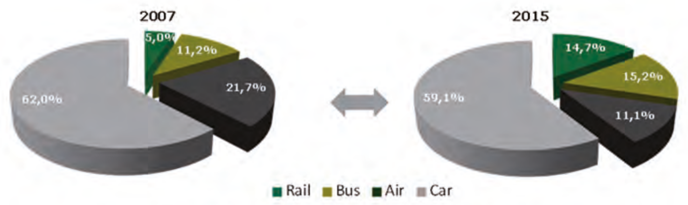


Figure 18. Modal share in 2007 and 2015. Madrid-Asturias

5.5 Modal distribution: Madrid-Asturias

6. Origin of HSR passengers

According to the data obtained in the surveys conducted between Madrid and Valencia, HSR captures the following percentage of the existing modes:

Car: 14%	Bus: 18%	Airplane: 73%	Conventional rail: 32%

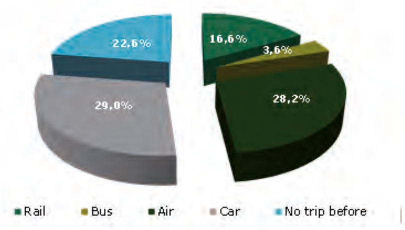


Figure 19. Origin of HSR frequent passengers in 2013/14. Madrid-Valencia.

The following graph shows the HSR frequent passengers' response on how they were doing the trip before the HSL was put into service, with a high percentage of "not doing this trip", with 22,6% of the trips, part of which they would be passengers generated.

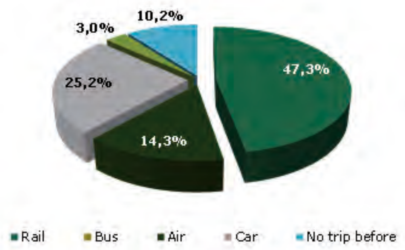


Figure 20. Origin of HSR frequent passengers. Madrid-Alicante.

In the case of Madrid-Alicante relationship, the percentage of frequent passengers who answered "did not make this trip" decreases to 10%, highlighting the origin of the railway mode with 47% of travel.

7. Comparison with forecasting

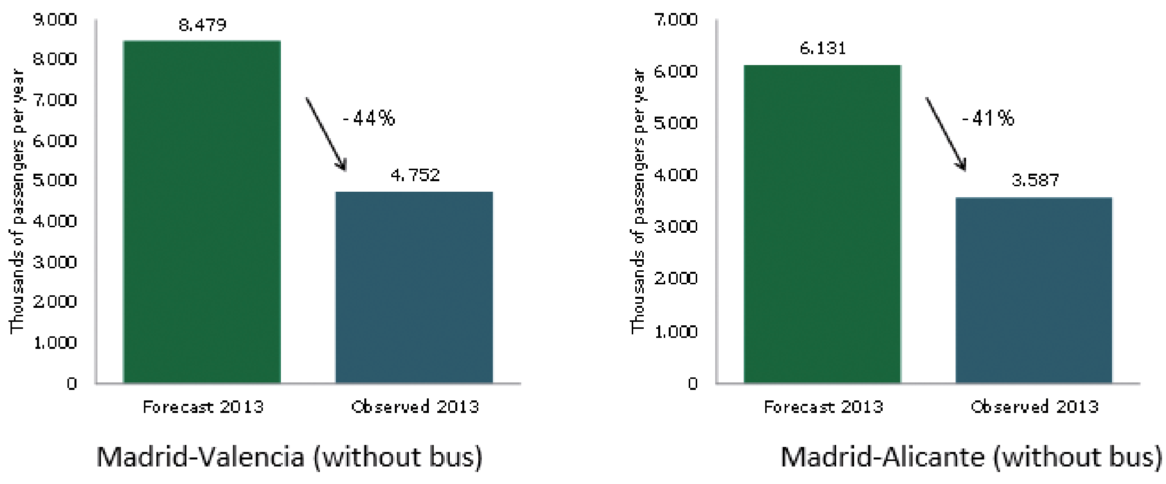


Figure 21. Comparison of forecast and observed data.

Figure 22. Comparison of forecast and observed data.

As it can be seen from the global data, the mobility observed in 2013 is much lower than in the forecasting study, before the high-speed line was put into service. In the study carried out in 2007-2008, models of growth of mobility were estimated from economic variables such as employment and GDP, which, as already mentioned, have had a much lower evolution.

The following subchapters show the comparison of modal distributions, where the models have been more realistic.

7.1 Madrid - Valencia

Although the current demand between Madrid and Valencia is 45% lower than estimated in the forecasting study, the modal distribution resembles what was predicted:

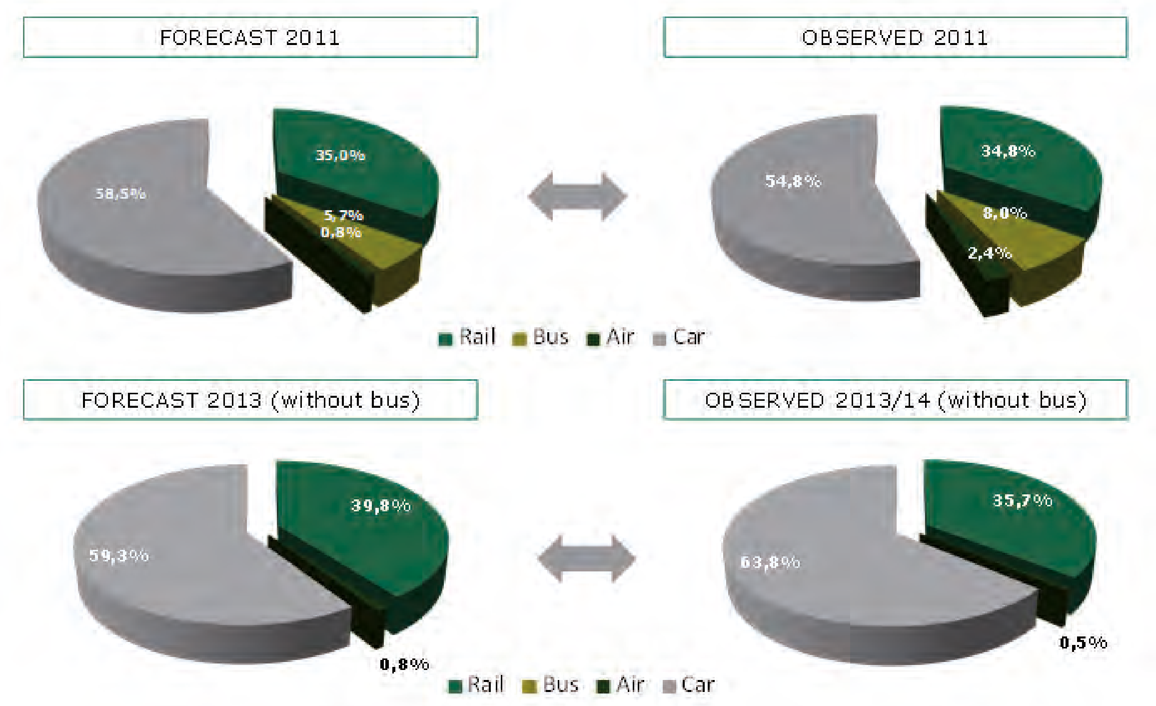


Figure 23. Comparison of expected and observed modal share. Madrid-Valencia.

7.2 Madrid - Alicante

Between Madrid and Alicante the modal share is lower than estimated, getting a worse fit than in the case of Valencia.

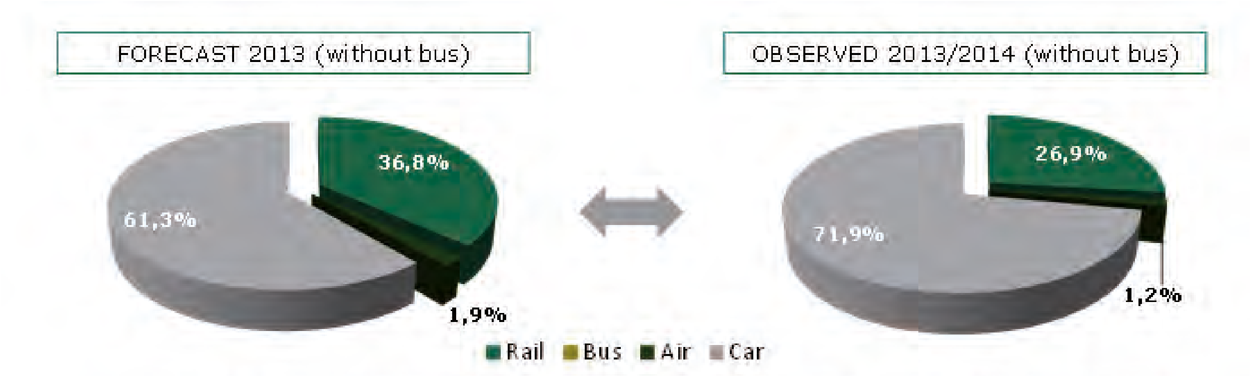


Figure 24. Comparison of expected and observed modal share. Madrid-Alicante.

7.3 Madrid - Galicia

In this case, the participation of rail is slightly higher than the forescast.

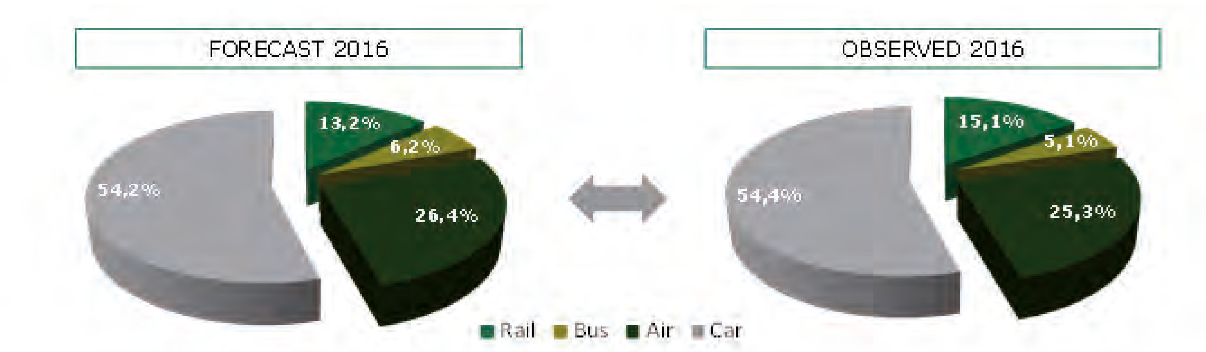


Figure 25. Comparison of expected and observed modal share. Madrid-Galicia.

7.4 Madrid - León

Between Madrid and León the participation of rail mode is practically the same as it was predicted.

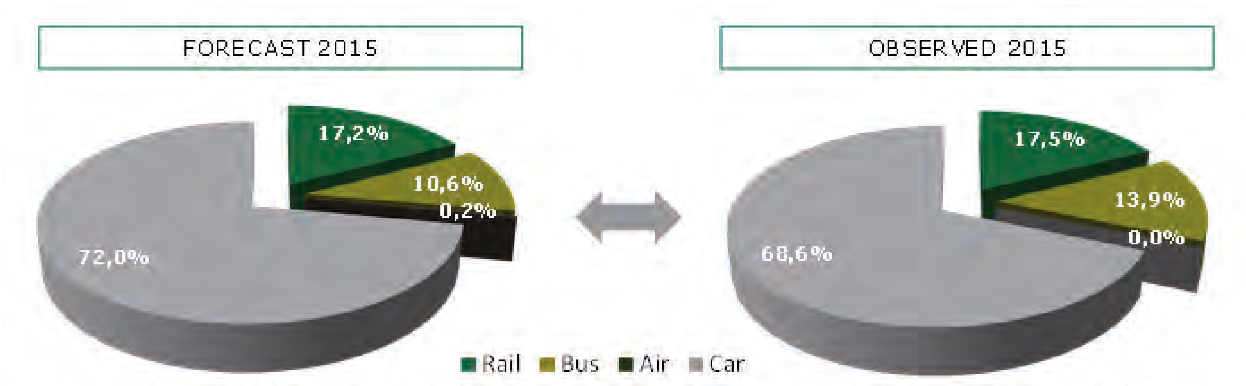


Figure 26. Comparison of expected and observed modal share. Madrid-León.

7.5 Madrid - Asturias

In this case, the participation of rail mode is lower than the forecasting, because the expected travel time is also slightly worst.

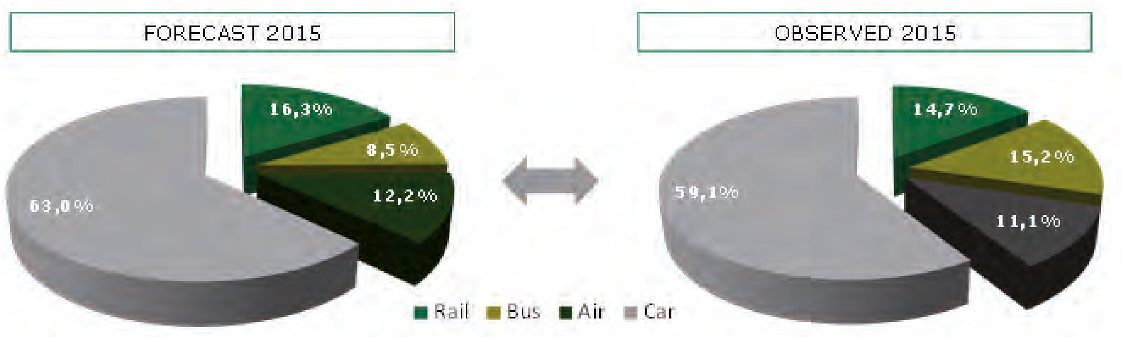


Figure 27. Comparison of expected and observed modal share. Madrid-Asturias.

8. Conclusions

The main conclusions drawn from these analysis are the following:

1. **A new HSL substantially modifies the modal split, observing that:**

    - The most affected mode is the airplane, whose participation in the demand decreases drastically, basically maintaining only connection traffic.
    - HSR reaches a participation between 25% and 35% of the trips.
    - Car is still the majority mode, with more than half of the trips.

2. **A great percentage of frequent passengers did not travel previously, 22,6% in Valencia and 10,2% in Alicante.**

3. **Regarding the economic crisis effect, we can observe:**

    - Total mobility was in 2011 at the level of the year 2000, what is known in economy as "lost decade".
    - As of 2013/2014 with the recovery of the economy, it is observed that mobility returns to positive growth rates.
    - Analysis of the evolution of demand before and during the crisis has seen a greater dynamism in Valencia, with strong growth both before the crisis (+ 5.5% per annum) and during the crisis (-6.2% annual).
    - In the case of Alicante, where this dynamism of mobility is lower, there is a greater recovery after the crisis than in Valencia (+ 3.3% vs. 2.1%).

4. **Studies of forecasting passenger demand between Madrid and Levante carried out before the new HSL estimated quite accurately the modal share with HSR, but due to the economic crisis the forecasts of global mobility have not been fulfilled.**

9. References

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- ADIF AV (2016-present): Demand Study of Madrid-Galicia/Asturias HSL.

Impacts on mobility

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Intermodal passenger transport in Spanish high-speed rail stations

Jaro, Lorenzo

Folgueira, César

ADIF Alta VelocidadI[1]

Abstract

This paper analyses the intermodality of different high-speed rail stations, establishing the mode of access and dispersion of travellers, and their complementarity with other modes of transport, with special attention to the rail-plane link in Madrid and Barcelona.

In order to carry out this analysis, we have studied the intermodality of travellers from the stations of Madrid Puerta de Atocha and Madrid-Chamartín, Barcelona Sants, Zaragoza Delicias, Málaga María Zambrano, Córdoba Central, Santiago de Compostela Alicante, Girona, Ourense and Jerez de la Frontera. The 9 first among the 15 with highest demand for AV (more than 1 million pax).

Keywords: intermodality, stations, high-speed rail, etc....

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1. The stations analysed within the high speed network

1.1 Introduction

With the objective of deepening aspects related to intermodality in different typologies of High Speed stations, where basically one can find a nearby bus station, but also to know how is affected intermodality by the typology of services offered or the size of Cities or even by its location within the city, a study has recently been launched in Adif Alta Velocidad in order to show some conclusions on this important issue in today's large transport nodes

1.2 Railway services of the study stations

The majority of the stations in the study move around 900 trains per week, with maximums of almost 1,700 in Madrid-Puerta de Atocha and minimum values in Orense (300) and Jerez (200). The following table shows the main characteristics of railway operation for the period 2014 -2015.

Table 1. Annual passengers and weekly trains by station

	Passengers (mill)	Week trains
Madrid-Pta de Atocha	18	1.670
Barcelona-Sants	10	950
Madrid-Chamartín AV	4,21	508
Madrid-Chamartín Conv	1,36	451
Madrid-Chamartín	5,57	959
Zaragoza AV	2,7	498
Zaragoza Regionales	0,54	341
Zaragoza-Delicias	3,24	839
Málaga AV	2,4	276
Málaga Conv	0,4	88
Málaga-M.Zambrano	2,8	364
Córdoba AV	2,24	611
Córdoba Conv.	0,98	284
Córdoba	3,22	895
Alicante AV	1,98	235
Alicante Conv	0,28	73
Alicante Terminal	2,26	308
Girona AV	0,90	203
Girona Conv.	2,00	379
Girona	2,9	582
Ourense AV	0,77	226
Ourense Conv	0,09	104
Ourense	0,86	330
Santiago de Compostela	1,97	NA
Jerez de la Frontera	0,59	213

With this first perspective of the weight of each one of the stations, the main results of the study are described below.

2. Accessibility to stations. Aggregate results

The first approximation to the results, shown in the next graph, clearly shows a different behaviour according to HS services or conventional services.

For Great cities:

- Madrid and Barcelona: great influence of public transport, Metro and Rail (> 35%)
- The previous ones, plus Zaragoza, Málaga and Alicante show car preponderance (> 58%), highlighting for HS services (≈ 25-35 % taxi)
- Ourense and Córdoba an intermediate situation, walking access is increasing but cars are the main mode > 50% (≈ 20-10% taxi)

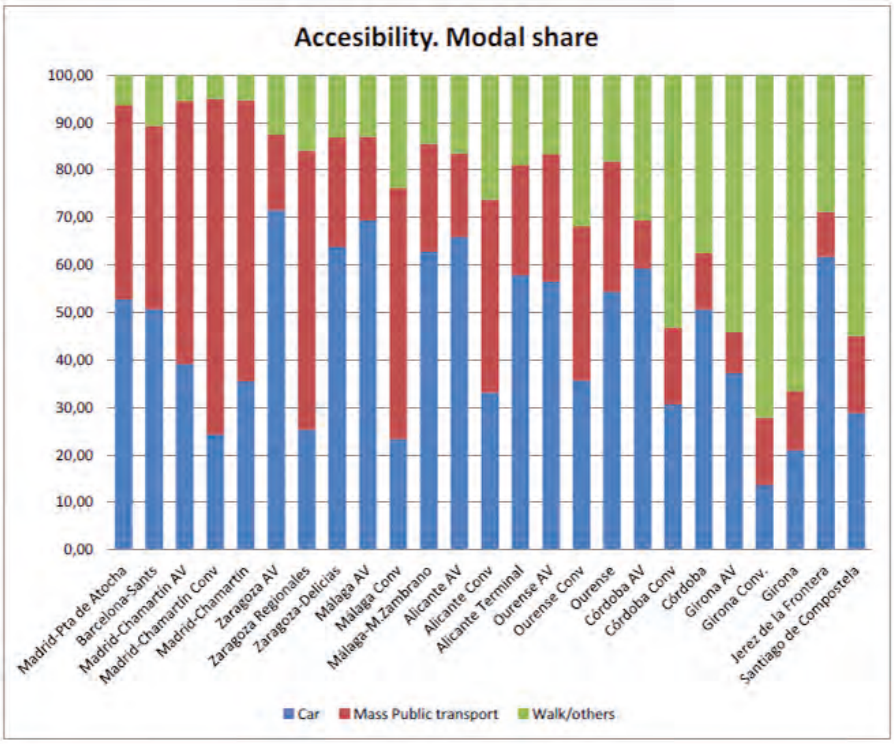

Figure 1. Accessibility to stations. Aggregate results

For Small cities, the results show a great influence of walking access (between 30 and 70%) depending on location

The greater the size of the city the less walking access is, being replaced by mass public transport. (Metro and Rail in Madrid and Barcelona, “Conventional” trains in Zaragoza and Córdoba, tram in Málaga and Alicante and urban bus in the rest).

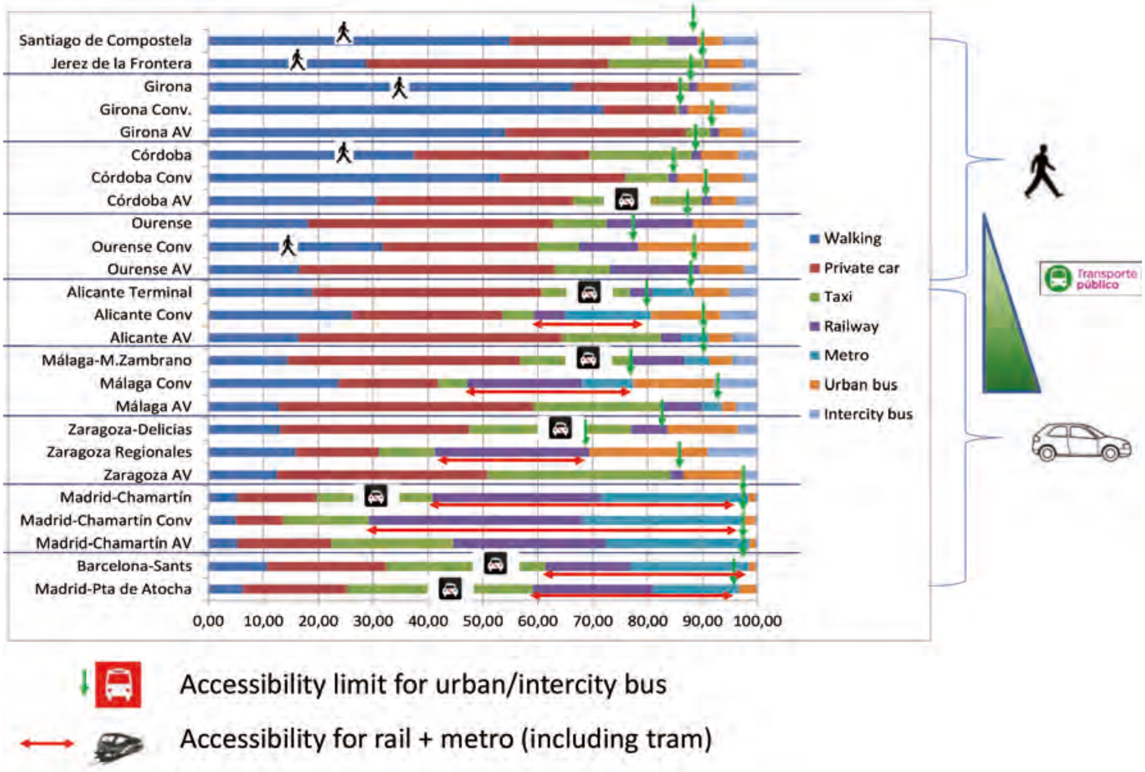

Figure 2. Accessibility to stations. Details

3. Car accessibility

The detailed analysis for "Car"(including taxi) show that this mode has the highest modal share, from 30% up to 70%, with "normal" values between 40-60%. (Fig. 3)

However, Taxi shows different behaviour depending on the size of the city. Except for Girona, it remains between 10-30% of "Car".

4. Bus accessibility

In relation to the bus, and as can be seen in the Figure 4, the results highlight the following:

- There is a low participation of the bus, especially intercity bus, as access / egress mode.
- In Madrid and Barcelona, as has already been mentioned, the main "public transports" are metro and train (> 35%), Bus remains under 3%.
- In medium cities, Urban bus modal share between 4-12%
- Intercity bus between 2,5-5%, only for passengers of conventional services in Zaragoza, it reaches 7%.

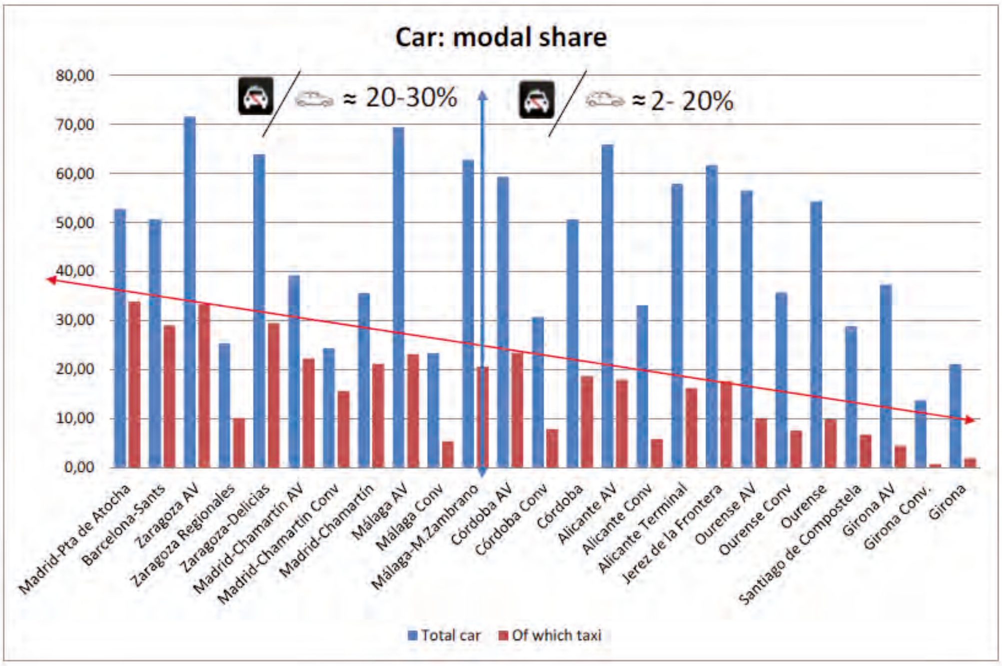

Figure 3 – Accessibility to stations. Car

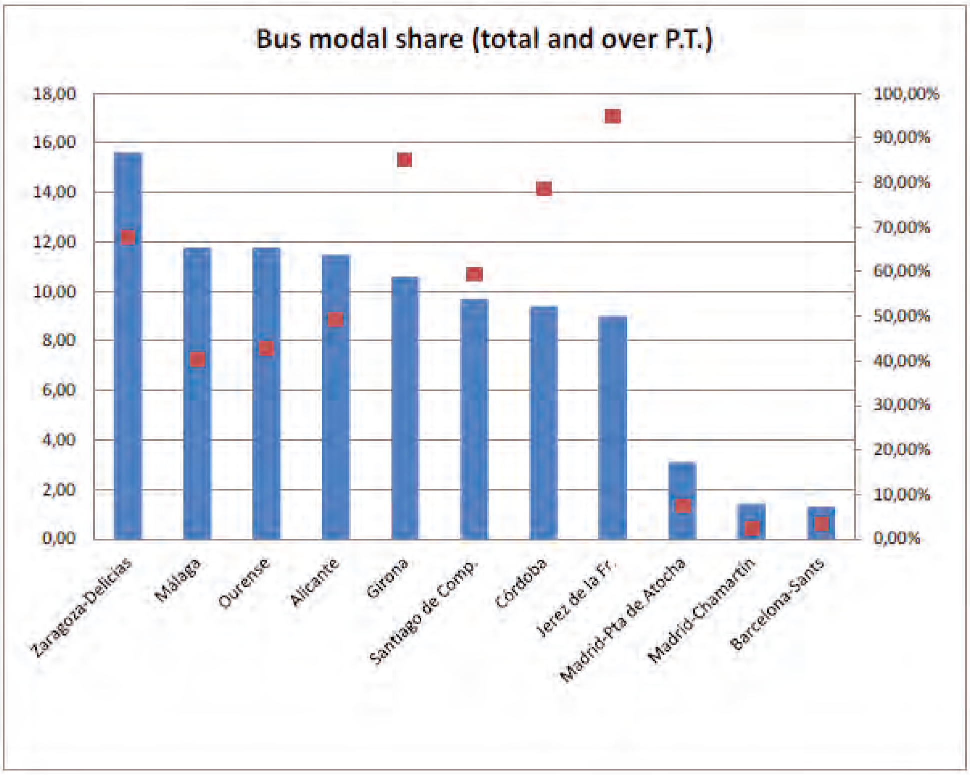

Figure 4. Bus modal share (total, left, over Public Transport, right)

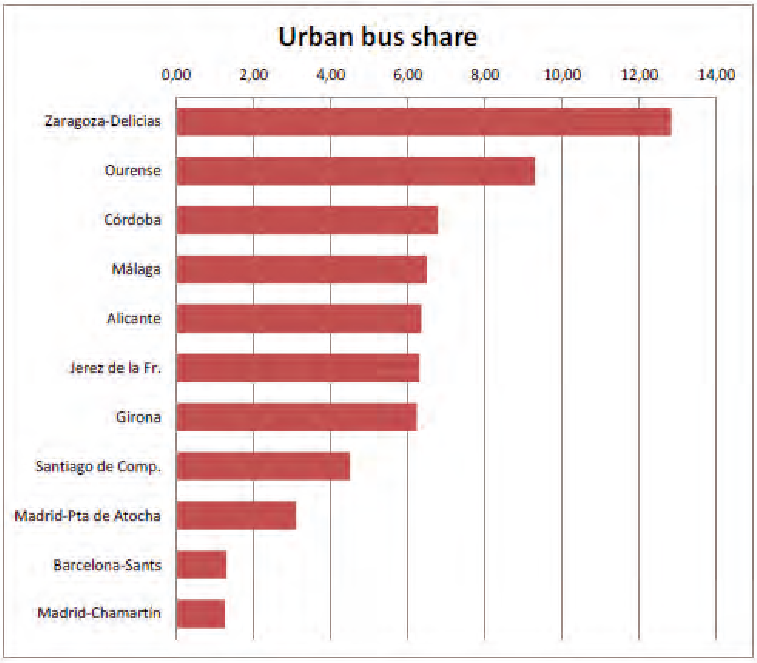

Figure 5 – Bus modal share. Urban

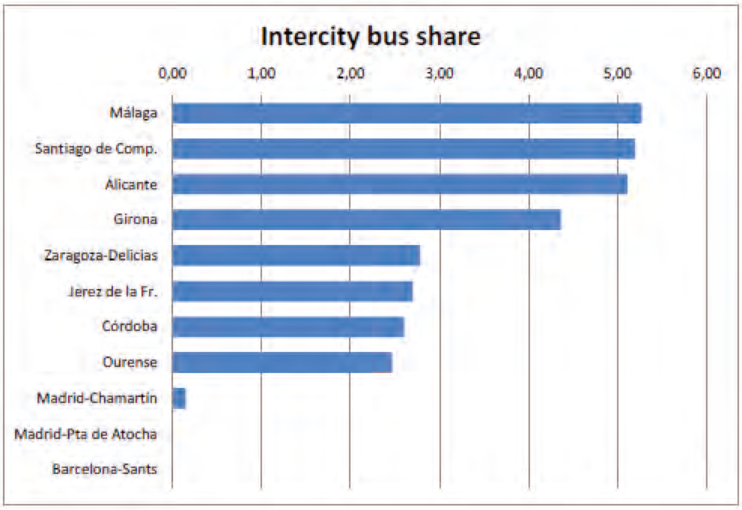

Figure 6 – Bus modal share. Intercity

5. Walking accessibility

Related with walking access, the main results are:

- For small cities, walking access lies between 30-60% of total passengers
- For medium/great cities this figures decrease up to 15-10%, except Madrid under 6%.

Figure 7. Walking Access. "Modal share"

6. Demand distribution. High speed details

As can be seen in figures 8 and 9:

- For Madrid and Barcelona, around 90% of passengers are coming/going to the cities and Metropolitan Areas, as well as Santiago de Compostela (¿Is this last city reflecting the feature of Capital City?)
- Córdoba and Zaragoza: the "unique" area is the city. More than 85% are coming from them.
- Alicante, Málaga and Girona: In these cities (50-70%), there are very important tourist areas generating between 25% - 40%
- Ourense reflecting the special population distribution in Galicia, including the connection with Lugo

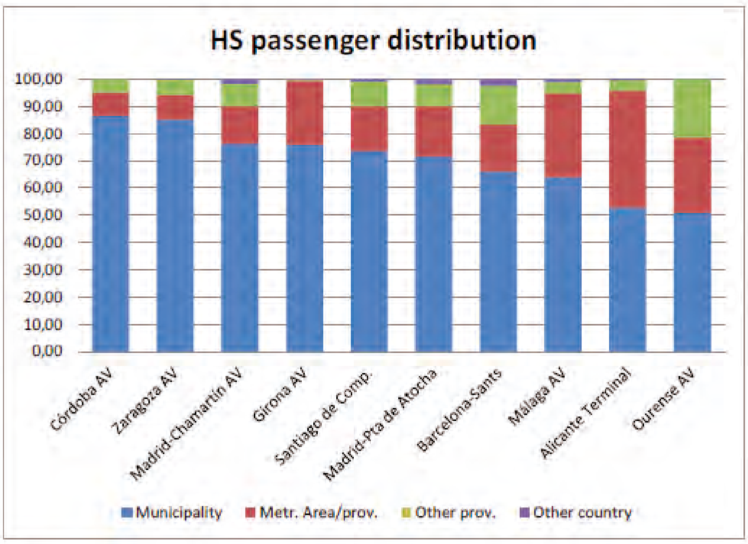

Figure 8. Distribution. Rating Criteria, Municipality

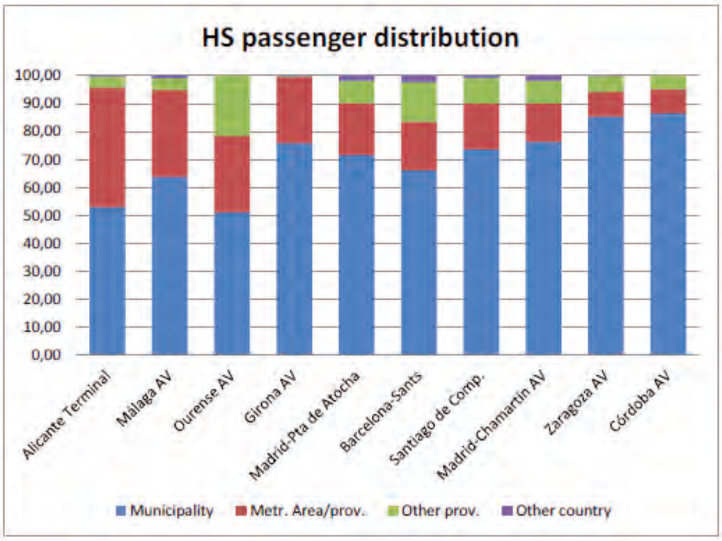

Figure 9. Distribution. Rating Criteria, Metropolitan Area/province

7. Demand purpose. High speed "vs" conventional services

Figures 10 and 11 show that:

- High Speed and Conventional Services are very different depending on purpose
- For HS, except for Galicia (Santiago and Ourense) where study purpose is important (15%), work purpose lies between 40-55%
- For Conventional services the main purpose is "study" between (20-45%)
- The cases of Jerez de la Frontera and Santiago de Compostela with different kind of services, show similar purpose distribution. This is the result of similar fares (reduced fares for HS services in Santiago)

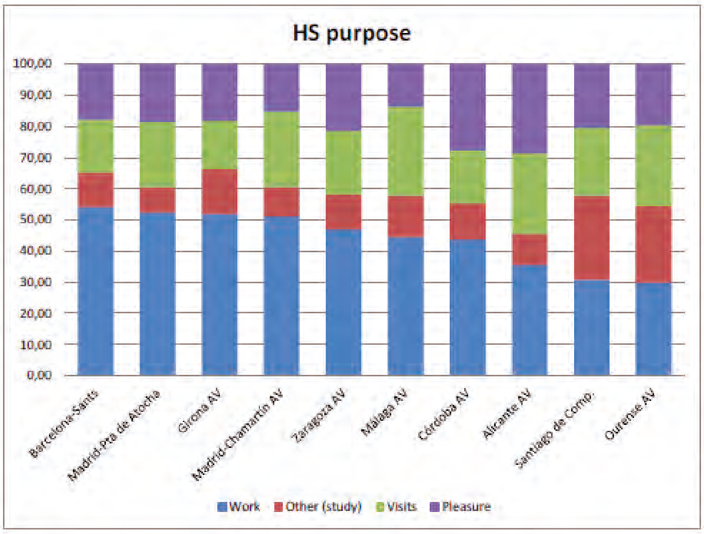

Figure 10. High Speed passengers Purpose. Per stations

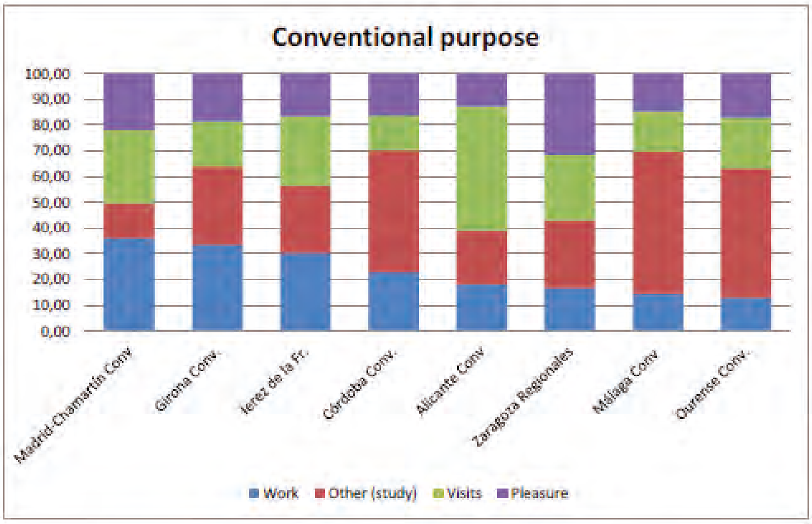

Figure 11. Conventional passengers Purpose. Per stations

8. Air/rail intermodality. The cases of Madrid and Barcelona

According to the results obtained in the survey:

For Madrid:

- 2,5% of the passengers leaving/arriving Puerta de Atocha (HS) went/came from Madrid-Airport (Barajas). That means about 450.000 passengers per year.
- 80% of these passengers had their O/D in foreign countries, the rest (20%) had it in Spain
- The main mode chosen to link airport and HS is train (40%), followed by taxi (33%)

Mode chosen FROM/TO the Airport TO/FROM Puerta de Atocha	%
Private car	6,8
Taxi	**33,1**
Metro	9,1
Urban Bus	10,5
Commuter railways	**40,3**
Renting car	0,3
Total	**100,0**

Table 2. Modal choice: Madrid Puerta Atocha – Madrid Airport link

- 2,9% of the passengers leaving/arriving Chamartín (HS) went/came from Madrid-Airport (Barajas). That means about 130.000 passengers per year.
- 61% of these passengers had their O/D in foreign countries, the rest (39%) had it in Spain
- The main mode chosen to link airport and HS is train (53%), followed by Metro(24%)

Mode chosen FROM/TO the Airport TO/FROM Chamartín	%
Private car	3,3
Taxi	18,8
Metro	**24,2**
Urban Bus	0,7
Commuter railways	**52,9**
Total	**100,0**

Table 3. Modal choice: Madrid Chamartín – Madrid Airport link

For Barcelona:

- 2,5% of the passengers leaving/arriving Sants Station (HS) went/came from Barcelona-Airport (El Prat). That means about 250.000 passengers per year.
- 86% of these passengers had their O/D in foreign countries, the rest (14%) had it in Spain
- The main mode chosen to link airport and HS is train (61,5%), followed by taxi (37%)

Mode chosen FROM/TO the Airport TO/FROM Puerta de Atocha	%
Private car	1,5
Taxi	**37,0**
Commuter railways	**61,5**
Total	**100,0**

Table 4. Modal choice: Barcelona Sants – Barcelona Airport link

9. Conclusions

The main conclusions of these studies are:

Car (including taxi) is the main mode of access, followed by public transport in great and medium cities or walk access in little cities.

For public transport, commuter **trains** and **metro** are the main options. Only **bus** (urban bus) is the selected choice when there is no other public alternative. Intercity bus is a low option as access/egress mode (3-5%).

For capital cities most of the passengers (85-90%) are going/coming from the very cities or their Metropolitan Area/province, whereas other capitals with important “tourist” destinations, show a lower value (50-70%).

Related with Air/HSR intermodality in Madrid and Barcelona, currently there is an important flow of passengers using both Terminals, rail and air, with estimations of 600 Madrid and 250 Barcelona (000 yearly pax)

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High-speed rail in developing countries and potential inequalities of use: the case of Morocco

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Abstract

The 21st century is characterized by the extension of the high-speed rail network in developing or emerging countries. While lines are already in operation in China and Turkey, others are under construction in Morocco and Iran, and projects exist in numerous other countries (Brazil, Malaysia, Egypt, etc.) in very different socio-economic contexts and characterized by significant inequalities. What are the effects of high-speed lines in these countries? By improving territories' accessibility, high-speed lines can foster population mobility and exchanges within a given country or between two or more countries in the case of international lines. But, especially in developing countries, one key issue is knowing for whom and for what use they are built. The aim of this article is to show that the creation of a high-speed line could reinforce the existing inequalities that are widespread in this type of country because the uses of such a line are spatially, economically and socially quite different. Our analysis will be illustrated by the case of Morocco.

Keywords: High-speed rail, inequalities, developing countries, Morocco

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1. Introduction

In January 2017, there were 37,343 km of high-speed lines (HSLs) in the world, with a further 15,884 km under construction; almost 36,000 km were planned worldwide for completion by 2050 (UIC, 2017). By favouring mobility, these lines are used to develop exchanges between cities and sometimes with other countries, in the case of transnational lines, and more broadly to foster economic development. But forecasts for high-speed rail projects tend to overestimate traffic levels and underestimate their financial cost (Bonnafous, 2014). Moreover, the potential indirect effects (or wider impacts) of high-speed rail (HSR) on the local economy are difficult to assess and not automatic (Bazin et al., 2006; Delaplace and Dobruszkes, 2013; Vickerman, 2015). There is no structuring effect of high-speed rail on local development (Offner, 1993 and more recently, in 2014, in the controversial debate in the French journal *L'Espace géographique*). But this is an issue that needs to be re-examined, as 21st-century rail has so far been characterized by network extensions in developing or emerging[1] countries (China, Turkey) and by projects in many others (India, Brazil, Morocco, Malaysia, Egypt, etc.). These high-speed lines take shape in very different socio-economic contexts from those of developed countries. Can the issue of potential increases in mobility be addressed in the same way in both sets of countries? In developing countries in particular, one key issue is knowing for whom and for what use these lines are built. Does everybody have access to high-speed rail in developing countries? Are its uses and clients the same as in developed countries? Do factors such as low income and greater inequalities, which characterize these developing countries, influence the way transport infrastructure is used? The aim of this article is to show that high-speed rail could induce more inequalities in terms of access and use in developing countries than in developed ones, not least because its uses differ spatially, economically and socially. This article suggests analysing a less-developed issue concerning the effects of high-speed rail, namely the issue of spatial, social and economic inequalities linked to high-speed lines. Section 2 will consider network extensions in developing countries that are characterized by great inequalities, while Section 3 will address the issue of high-speed rail effects on these inequalities. In Section 4, we will illustrate our analysis using a case study in Morocco that will be in operation by June 2018; and Section 5 contains some concluding remarks.

2. High-speed rail in developing countries

High-speed rail developed during the 20th century, first in Japan, from 1964, and then in European countries (France and Italy in 1981, Germany in 1988, Spain in 1992, Belgium in 1997, etc.), i.e. in developed countries that were designated as such[2]. But since the beginning of the 21st century, highspeed rail has spread to and/or is planned for emerging or developing countries, i.e. in countries characterized by greater inequalities.

2.1 The spread of HSR in the developing world

The first high-speed line in a developing country was launched in China in 2003. This line, some 405 km in length, links Qinhuangdao and Shenyang. Since 2003, the network in China has been expanding: in April 2017, a total of 23,914 km of high-speed lines were in operation in China (Table 1), which is more than the 22,551 km of existing lines in Europe.

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1 *In this article, we consider that this term encompasses all countries that are not considered to be developed. These might be emerging countries, lower-middle-income countries or upper-middle-income countries according to the classification of the World Bank.*

2 *Except Japan, which was considered an emerging country in 1964 when the first Shinkansen was introduced.*

Table 1. High speed lines in developing countries			
Country	Km of line		
	In operation	Under construction	Long term planning
China	23,914	10,730	1,525
India			4,630
Turkey	688	469	1,134
Morocco		183	480
Malaysia (to Singapore)			350
Egypt			1,210
Brazil			511
Russia			2,978
Kazakhstan			1,011
Iran		425	870
Thaïland			2,877
Mexico			210
Indonesia			712
South Africa			2,390
Vietnam			1,600
Total in developing countries	**24,602**	**11,807**	**22,506**
Total in the world	**37,964**	**14,973**	**35,640**

Source: based on data from UIC (July 2017)

After China, HSLs were inaugurated in Turkey in 2009, with the 232 km line between Ankara and Eskisehir. The network has subsequently been expanded towards Konya, as well as towards Istanbul.

In all, 469 km of lines are currently under construction. Iran and Morocco have also built lines, which will soon be operational. At the beginning of April 2017, there were more than 24,602 km of lines in operation in developing countries, representing 65% of the world total. Moreover, numerous developing countries are characterized by high-speed rail projects. Some 11,807 km of lines are under construction in developing countries, accounting for 79% of the worldwide total, and a further 22,506 km are currently in the planning stages, representing 63,1% of all planned lines worldwide. These lines are improving, or are set to improve, the accessibility of the cities served to varying degrees[3]. These lines and projects are or will be taking shape in very different socio-economic contexts characterized by significant inequalities.

2.2 Socio-economic contexts in developing countries characterized by significant inequalities

Developing countries are characterized by lower levels of income per capita (Table 2).

3 This improvement depends on numerous factors (Delaplace, 2017): speed, the existing service, the topography of territories crossed, geographical characteristics (Campos, Rus de, 2009), the degree of urbanization, etc., or the management of interchange, access and egress times in stations (Givoni and Banister, 2011).

Table 2. Gross domestic product (GDP) per capita (current and constant $), gross national income (GNI) per capita and Human Development Index (HDI) in developing countries with HSLs or HSR projects				
Country	**GDP per capita in current $ (2016)**	**GDP per capita (PPP constant $ of 2011) (2016)**	**Gross national income (GNI) per capita in $ PPP (2015)**	**GNI per capita rank minus HDI rank**
Countries with lower-middle income				
India	1,709	6,092	5,663	-4
Vietnam	2,185	5,955	10,053	18
Morocco	2,832	7,266	7,195	-4
Egypt	3,514	10,319	10,064	-7
Indonesia	3,570	10,764	10,053	-8
South Africa	5,273	12,260	12,087	-30
Countries with upper-middle income				
Thailand	5,907	15,681	14,519	-11
Iran	6,530*	16,010*	16,395	-2
Kazakhstan	7,510	23,419	22,093	-3
China	8,123	14,400	13,345	-7
Mexico	8,201	16,831	16,383	-9
Brazil	8,649	14,023	14,145	-19
Russia	8,748	24,026	23,286	1
Malaysia	9,502	25,660	24,620	-13
Turkey	10,787	23,679	18,705	-7

Source: based on data from the Human Development Report, 2016 (GNI per capita and HDI); OECD 2017 (GDP per capita in $ PPP); World Bank 2017 (current GDP per capita/inhab.).

* 2014 data

But they are also characterized by significant inequalities – although these vary from one country to another – especially in terms of education and health, as reflected by their Human Development Indices. With the exception of Russia and Vietnam, taking into account education and life expectancy induces a lower ranking for these countries compared with the ranking obtained by taking into account GNI per capita only[4].

Moreover, income inequalities are also higher than they are in developed countries: “Developing countries tend to exhibit wider within-country inequality relative to developed countries” (World Bank, 2016, p. 10). Indeed, as shown by Kuznets in 1955, during the take-off period, growth is highly unequal because only a small percentage of the population benefits from the growth of national income[5] induced by this industrialization.

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4 Luxembourg is the only developed country with a high-speed rail service characterized by such a low ranking.

5 Then, after a peak, inequalities diminish to form an inverted U. The existence of this inverted U-curve has been demonstrated econometrically very recently (Lessmann, 2014).

The value of their Inequality-Adjusted HDI (IHDI)[6], which is below the value of their HDI, shows the magnitude of these internal inequalities (Table 3).

In these countries, the Gini coefficient, which measures the deviation of the distribution of income among individuals or households within a country from a perfectly equal distribution, tends to be high or very high (Brazil, Mexico, South Africa), and in all cases[7] is greater than the Gini coefficients for developed countries with high-speed lines[8].

Moreover, in developing countries, income inequalities are linked to spatial inequalities that increase with growth and development. "Rapid economic growth is often associated with uneven regional and urban development" (Kim, 2009, p. 1).These spatial inequalities exist between regions, within regions, between cities and between cities and rural areas (Kim, 2009, Kanbur and Venables, 2005). In many countries, inequalities within regions seem to be as significant as inequalities between regions (Kim, 2009, p. 145).

Table 3. A selection of indices of internal inequalities in developing countries with operational or planned HSLs

Country	HDI	Inequality-adjusted HDI (IHDI)	Gini coefficient (Coefficient de Gini (revenu national brut par hab.)
Countries with lower-middle income			
India	0.624	0.454	35.2
Vietnam	0.683	0.562	37.6
Morocco	0.647	0.456	40.7
Egypt	0.691	0.491	N/K
Indonesia	0.689	0.563	39.5
South Africa	0.666	0.435	63.4
Countries with upper-middle income			
Thailand	0.740	0.586	37.9
Iran	0.774	0.518	37.4
Kazakhstan	0.794	0.714	26.3
China	0.738	N/K	42.2
Mexico	0.762	0.587	48.2
Brazil	0.754	0.561	51.5
Russia	0.804	0.725	41.6
Malaysia	0.789	N/K	46.3
Turkey	0.767	0.645	40.2
Developing countries	0.668	0.499	-
High HDI countries	0.892	0.793	-

Based on data from Human development report, 2016

6 The inequality-adjusted HDI (IHDI) value takes into account the inequalities in the three basic dimensions of human development, i.e. the way the country performs in terms of education, health and the distribution of GNI among the population. It reduces the HDI according the degree of inequality in the country in question.

7 Except Kazakhstan.

8 It is between 28 for the Netherlands and 35.9 for Spain.

There are also inequalities between the rural world and the urban world because, within a given country, wages in urban areas are higher than those that prevail in a rural environment. As underlined by Perroux (1955, p. 309) “growth doesn’t appear everywhere at the same time; rather, it appears in different areas or growth clusters with variable intensity”. For example, in China in 2006, the incomes of the urban population were on average 3.55 times higher than those of rural populations (Boquet, 2009) and this gap has grown as the country has developed (1.7 times in 1984, 2.3 in 1992, 2.8 in 2000, 3.2 in 2004). Similarly, in Morocco, while 19% of the Moroccan population lives below the national poverty line, 70% of these individuals live in rural areas (Boutayeb, 2006). So what is the impact of high-speed rail in the developing world, given the levels of economic, social and spatial inequalities that characterize it?

3. High-speed rail and the issue of inequalities in developing countries

Mobility has become necessary in developed countries. Since 1982 in France, the national law on domestic transport (known as LOTI, or Loi d’orientation des transports intérieurs) has institutionalized a right to transport, and mobility has become a right (Orfeuil, 2011, Urry, 2000, quoted by Cass et al., 2005). Indeed, this “rising value of contemporary societies is at the same time a factor in the reinforcement of social inequalities” (Bacqué and Fol, 2007; see also Cass, 2005 for the case of Great Britain), since without this right an individual cannot access a whole series of activities and, increasingly, employment (Orfeuil, 2004, Bacqué and Fol, 2007). The mobile processes and infrastructures of travel and transport can generate and reinforce social exclusion (Cass et al., 2005). While the issue of inequalities associated with transport and mobility is not new, it has to date mainly been addressed from the point of view of daily urban mobility. However, high-speed rail is also likely to reinforce inequalities. This is the case in developed countries, but more particularly in developing countries, in part because high-speed rail does not serve all areas within these countries, but also because it can lead to economic exclusion and exclusion in terms of access and use.

3.1 High-speed rail and inequalities: an analytical framework

People do not always have the opportunity, income and/or skills to be mobile. The literature defines social exclusion as the inability of individuals to access activities in which they need to participate (Kenyon et al., 2002, Preston and Rajé, 2007 and Church et al., 2000, for an analysis of social exclusion linked to transport, and Banister, 1994, on equity issues in transport). An improvement in the transport offer associated with a high-speed line can lead to inequalities and be spatially inequitable in the sense that not everyone has access to it.

The issue of inequalities associated with high-speed rail has recently been studied in developed countries. In the case of Spain, Monzon et al. (2013) show that extensions of high-speed rail in periurban areas have led to an increase in spatial imbalances and contribute to a more polarized spatial development. Bouf and Desmaris (2015) consider that high-speed rail lines are spatially unfair in France, first because they promote growth in an unfair way, secondly because the pricing system is unfair (ticket prices per kilometre vary according to the line and are not proportional to the distance travelled), and lastly because the way in which they are funded (amounts, types of contributors) vary significantly from one line to another. Kim and Sultana (2015) point out that in South Korea spatial equity was diminished when the network was extended in 2010/2011, as accessibility improvement was concentrated in cities located on the first high-speed corridor near the capital. Pagliara et al. (2016) show that in Italy people are very sensitive to the cost of accessing high-speed rail and the cost of high-speed train tickets. These costs have a strong impact on spatial equity.

In developing countries, this issue has been analysed by Shi and Zhou (2015) in China. They show that investments in high-speed lines have not significantly changed transport equity. While the accessibility of cities has been improved by high-speed services, the price of a ticket is unaffordable for a large part of the population.

In the literature, we can find three types of inequalities linked to high-speed rail:

- spatial inequalities linked to the fact that the infrastructure is not uniformly distributed in spatial terms;
- spatial inequalities related to differences in service between the territories served;
- economic inequalities linked to pricing.

3.2 Inequalities in access related to infrastructure and service

As Kim pointed out in 2009 (Kim, 2009, p. 137), “infrastructure investments that increase the mobility of goods, labour, and capital may have significant impacts on spatial inequality because of the self-forcing nature of increasing returns”. In both developed and developing countries, highspeed rail networks do not serve all cities and are generally concentrated on routes between the largest urban centres. Indeed, while in France many intermediate and even small towns are served by TGV (the French high-speed train), most often on a conventional line, in other countries such as Japan, where high-speed trains do not operate on the conventional network, fewer cities are served (see Campos and de Rus, 2009, for a presentation of the different types of networks). In China, the network serves the largest cities in the country, mainly on the east coast, except for the line linking Xuzhou to Lanzhou in the centre of the country . In Turkey, Ankara, Istanbul and Konya are among the seven largest cities in the country [9]. The other smaller cities served by high-speed rail are located on the Ankara–Istanbul line. Thus, the inequalities of access linked to the existence of a line are close to those existing in some developed countries.

Moreover, the level of the service (frequency, during the week, at weekends) is variable between cities. For example, the frequency is often correlated to the size of the urban areas in question. In 2010 in France, there were on average 3.3 direct round trips to Paris for cities with 20,000 to 100,000 inhabitants and 10 for cities with more than 200,000 inhabitants (Delaplace, 2012).

There are inequalities in the service provided. These inequalities depend on the size of the cities served. In China, given the large size of most cities, service inequalities are likely to be lower. The magnitude of improvements resulting from new high-speed services also depends on the existence and quality of conventional rail services in a given city (Delaplace, 2017, Garmendia et al., 2008). If the quality of the previous classic rail service was very low, the improvements linked to HSTs will appear to be more significant. In these circumstances, the increase in accessibility will represent only a marginal improvement. In developing countries, rail service is generally of lower quality or nonexistent. The inequalities of accessibility between territories served by high-speed rail and those that are not are thus much more significant.

This differentiated spatial impact of HSR may be linked to economic inequalities.

3.3 Access inequalities related to pricing and differentiated income

High-speed rail services can generate economic exclusion because of ticket prices. Indeed, these tickets are often more expensive than conventional train tickets. High-speed rail services are thus not merit goods accessible to all.

9 There is another line towards the north-western part of China linking Lanzhou and Urumqi, but its operating speed is below 250 km/h, the minimum for a rail line to be considered a high-speed line.

When prices are high, they are used more extensively by the socio-professional categories that have the highest income and are most mobile (senior managers, consultants, etc.). This was long the case in France (Klein and Claisse, 1997, Klein, 1998, Mannone, 1995), before the development of discounted fares ("Prem's" tickets and Ouigo services) (Delaplace and Dobruszkes, 2015). According to Szynkier (2012), more than 70% of TGV trips are made by the five wealthiest deciles (Szynkier, 2012). For example, a second-class ticket for a Paris–Marseille round trip in July 2017 can cost up to EUR 223 – that is, 13% of the net median per-capita wage in 2016. While the literature shows that daily mobility varies relatively little according to income level (Paulo, 2007), this is not the case for professional mobility or weekend mobility. Rates of weekend travel are two-thirds higher for the fifth quintile than for the first quintile. The distance travelled by the former group is also 2.4 times higher than for the latter. Rouquette shows that, in France, 58% of people belonging to the first decile of standard of living do not go on holiday, whereas this proportion drops to 15% for the tenth decile (Rouquette, 2001). Long-distance mobility (over 100 km) is even more highly correlated with income. Similarly, the modal shift from air to rail travel is a priority for high-income travellers. Income levels influence the potential for leisure mobility and long-distance mobility. Low-income populations might therefore be excluded from the possibility of using these high-speed rail services. For example, in France in 2013, national rail operator SNCF estimated the number of users who would not have travelled at all without the Ouigo offer (Delaplace and Dobruszkes, 2015) to be 25% of the total number of Ouigo users, reflecting a possible economic exclusion.

These income levels vary from country to country and, by definition, are lower in developing countries. In these countries, the level of exclusion can be significant if the cost of a ticket is high and income inequality higher. As highlighted by Shi and Zhou (2015), high-speed rail is inaccessible to a large part of the Chinese population in a country characterized by very high growth in income inequality: "The top 10% income share rose from 27% to 41% of national income between 1978 and 2015, while the bottom 50% share dropped from 27% to 15%" (Piketty et al., 2017). For example, a Beijing–Shanghai ticket was priced at about EUR 142 in July 2017, which represents about EUR 621 in purchasing-power parity (PPP). In these conditions – and, as some have argued, given public spending on HSR – taxpayers pay for the mobility of the richest (Delaplace and Dobruszkes, 2016). Nevertheless, the price of a high-speed train ticket is not always so high in developing countries. For example, in Turkey, the train fare is equivalent to the bus fare on the Ankara–Konya route and only slightly higher for the Ankara–Istanbul and Ankara–Eskisehir routes. It is even lower for the Eskisehir– Konya link (Celikkol-Kocak et al., 2017). For example, the price of a Konya–Istanbul ticket in PPP is just EUR 41.30. In the case of Morocco, if our calculations (see below) are correct, the cost of a Casablanca–Tangier ticket will be MAD 150 – or, in PPP[10], approximately EUR 45 – for 350 km[11].

The economic inequalities of access to high-speed rail are thus variable in developing countries. They depend on fare policy and income inequality: the greater the income inequality and the more selective the pricing policy, the greater the inequality of access.

But beyond these types of inequalities, there may also be inequalities in terms of possible uses. Indeed, the range of possibilities in terms of economic activity and mobility for the population is differentiated not just according to individuals' status but also to the society to which they belong.

3.4 Inequalities in terms of possible uses of high-speed rail

A high-speed line can be used for business trips, for tourist trips and sometimes for commuting. But it is only relevant for distances between 150 km and 800 km. Below 150 km it competes with car travel and beyond 800 km it competes with air travel (Klein, 1997, 1998, EC, 2010).

10 OECD (2017) Purchasing-Power Parity (PPP) (index). doi: 10.1787/c0bc06ba-fr (accessed July, 18 2017).

11 For comparison, a ticket for travel between Paris and Nancy (i.e. for an almost equal distance) can cost up to EUR 89.

High-speed rail transport therefore only concerns long-distance mobility. It should be noted that, at the international level, these mobilities in developing countries currently lag behind those in industrialized countries. According to Doyle and Nathan (2001), the richest 20% travel 3.5 times farther than the poorest 20%. On the other hand, while in Western societies one may consider that “individuals live in one place, work in another, and distract themselves in a third” (Paulo, 2007), it is in all probability less marked in developing countries. Mobilities are therefore linked to levels of development.

For example, tourism-related mobility depends on working time and holiday allowance, which varies between countries. A reduction in working time, as has been the case in France since the beginning of the 2000s, has increased the potential for mobility and has led to an increase in short-term tourist stays (notably city breaks) as a result of TGV services. The very idea of tourist mobility also differs between countries. In South Korea, due to the low annual holiday allowance (15 days), travel is most often devoted to family events. Consequently, mobility potential is more restricted for leisure and tourism. More generally in developing countries, tourism has long been either international or the preserve of a local minority. It grows among the middle classes only with increases in the standard of living (Cazes, 1983, quoted by Berriane, 1989), as evidenced by the current development of domestic tourism in China, estimated at 300 million tourists (Taunay, 2010). It is therefore initially the wealthiest populations who are able to travel for tourism purposes, and in particular long-distance tourism-related travel. But developing countries can also be countries that play host to international tourists. By reducing journey times, high-speed rail could expand the geographical market area of tourist destinations (Sands, 1993, Masson, Petiot, 2009, Urena et al., 2009, Wang et al., 2012, Chen, Haynes, 2014) that are connected to the network within these countries, and even in certain cases influence the destination choices of tourists (Delaplace et al., 2014, 2016, Pagliara, 2015, Saladie et al., 2016).While economic analysis considers that transport time is a cost that must be minimized, the value of travel time savings associated with a high-speed rail service depends, however, on the importance given to time, its valorization and possible alternatives, as evidenced by the study by Zhao et al. (2015): in China, some passengers prefer to take a night train rather than a high-speed train. This also depends on being in a position to arbitrate between several possible choices. Moreover, the use of high speed cannot be understood in a society in which time is not valorized. People do not value or devalue the future solely on the basis of their age, situation or position in society: “Conceptions of time depend on the rules of the social game; behind the exchange, there is communication of signs and symbols” (Hugon, 1991, p. 343). Thus, behaviours and uses are determined by values and rules, which delineate the rules of the game and shape the preferences of agents (Windrum and Garcia Goni, 2008). These rules, these values, and these institutions (North, 1991) are different from one space to another, and from one society to another. The actions of agents are embedded in tissues of institutions that are likely to be different since these agents are located in specific societies. “What is necessary for full ‘social’ inclusion varies as the means and modes of mobility change and as the potential for ‘access’ develops with the emergence of new technologies such as charter flights, high-speed trains, budget air travel, SUVs, mobile phones, networked computers and so on. These developments transform what is ‘necessary’ for full social inclusion” (Cass et al., 2005, p. 542).

The set of possible choices for each individual as well as the set of uses he or she envisages are partly determined by location (Delaplace, 2017). High-speed rail is essentially a sign of modernity, and moving frequently over long distances is sometimes a sign of distinction. There is thus a symbolic dimension of the use of high speed that is likely to reinforce existing inequalities.

In addition, individuals do not always have the competencies to identify transport options and produce their own itineraries.

3.5 Inequalities in terms of competencies required to use high-speed rail

As Orfeuil pointed out (2010, 7), “mobility is also a matter of competence”. In both developed and developing countries, there may be a form of exclusion linked to the inability to construct a travel itinerary. Because of a very simplified world representation, it may be difficult for certain population categories to identify journey break points, etc. Others may not be able to build complex routes involving transfers between stations. Similarly, populations without bank accounts and/or internet access or who do not have a smartphone cannot buy tickets remotely. Indeed, like any new object, high-speed rail must be appropriated and domesticated (Haddon, 2011) in order to be used (Akrich, 1990). The ability to plan a journey to discover a museum, city, region or country depends on the competencies of individuals. The cultural resources (or cultural capital – Bourdieu, 1979) available to them determine their ability to envisage a given destination and a particular journey. This capacity or “capability”, to use Sen’s terminology can be analysed as the possibility for each individual to choose the type of life he or she wishes, “the various combinations of functionings (beings and doings)” (Sen, 1989, p. 44) that the person can achieve, and consequently the associated form of mobility or immobility. However, this capacity is linked to one’s level of education, which in developing countries is on average lower than in the so-called developed countries, as shown by the inequality-adjusted education index (Table 4).

Table 4. Index of Inequality-adjusted education in developing countries with operational or planned HSLs

Country	HDI	Inequality-adjusted education (%)	Inequality-adjusted education index (value)
Pays à revenu intermédiaire de la tranche inférieure			
India	0.624	39,4	0, 324
Vietnam	0.683	17,6	0, 508
Morocco	0.647	45,8	0, 273
Egypt	0.691	35,0	0, 390
Indonesia	0.689	20,8	0, 492
South Africa	0.666	13,8	0, 608
Pays à revenu intermédiaire de la tranche supérieure			
Thailand	0.740	16,1	0, 538
Iran	0.774	37,3	0, 441
Kazakhstan	0.794	5,9	0, 758
China	0.738	Nc	Nc
Mexico	0.762	19,7	0, 525
Brazil	0.754	22,6	0, 527
Russia	0.804	2,2	0, 798
Malaysia	0.789	Nc	Nc
Turkey	0.767	14,2	0, 574
Developing countries	0.668	31	0,391
High countries	0.892	7,2	0, 797

Based on data from Human development report, 2016

From this point of view, and to paraphrase Myrdal (1957), there may be circular and cumulative causality in terms of inequality in developing countries. High-speed rail might increase the already significant inequalities in these countries.

The question is now to identify the effects of high-speed rail on inequalities in Morocco.

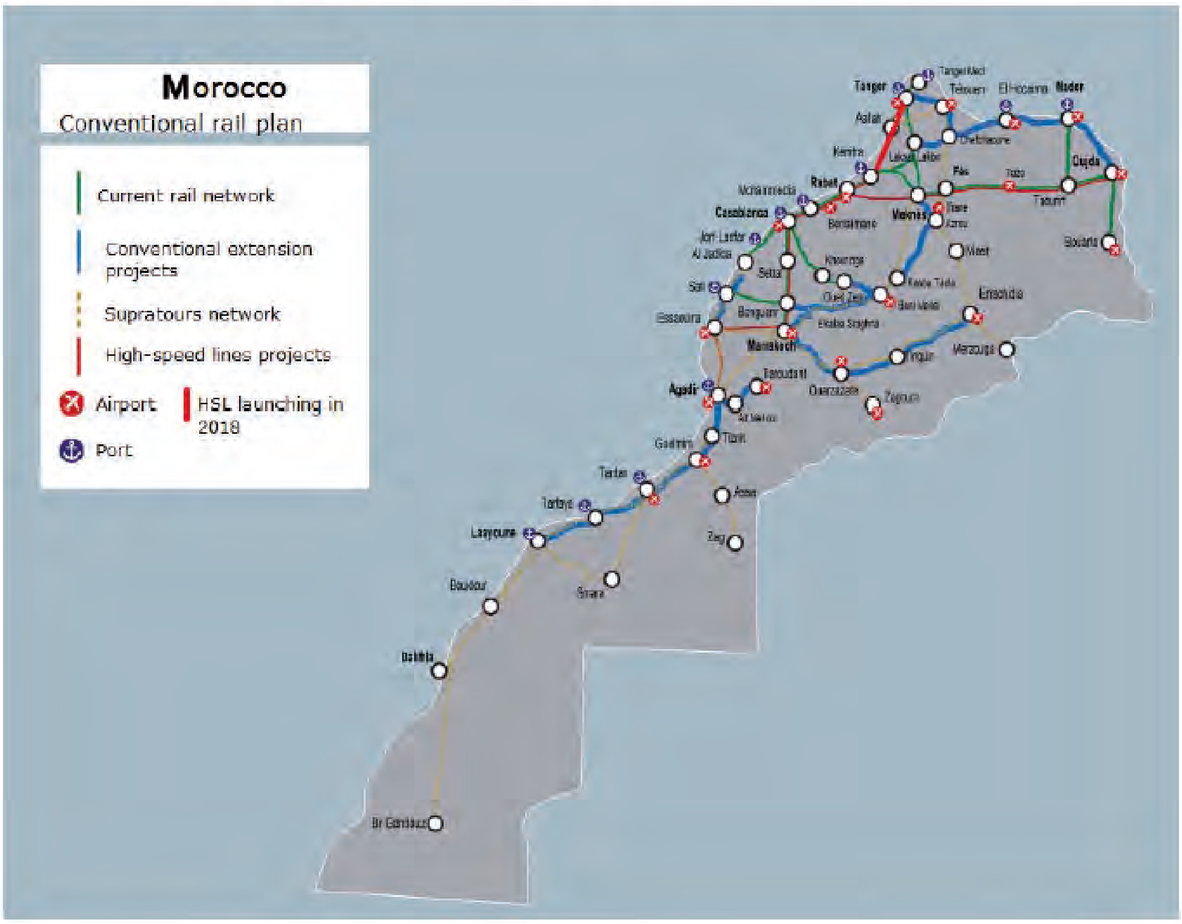
4. High-speed rail in Morocco and the issue of access inequalities

A national master plan for high-speed lines in Morocco was drawn up in 2005. The construction of 1,500 km of lines is expected by 2035 along two axes: the Atlantic axis and the Maghreb axis [12]. This plan could reinforce the already significant inequalities in access to rail transport. Other possible inequalities are associated with income levels and uses of rail transport.

4.1 The national master plan for high-speed lines and the public transport network in Morocco

The west and north of Morocco are equipped with a railway network serving both travellers and freight (shown in green on Map 1).

Map 1. High-speed lines and the wider public transport network in Morocco



Source: modified from Ipemed, 2014, p. 81.

12 *This second axis, planned for the very long term, might enable services from Rabat to the eastern part of Morocco, and in particular Meknes and Fez, then Taza, Taourirt and Oujda, and then Algeria and Tunisia.*

Inherited from the colonial era, the rail network has been modernized since the 1980s[13] and new sections have been built. The investment budget devoted to rail transport more than doubled between 2008–2011 and 2012–2015, from MAD 13.2 billion to MAD 30.8 billion. Morocco has begun major renovations of several stations (Hakimi, 2017).

Following network modernization, passenger rail traffic growth – and thus growth of mobility – was very strong, increasing from 14.7 million passengers in 2002 to 18.5 million in 2004, 31 million in 2010, 34 million in 2011 and 40 million in 2015. It is in this context of traffic growth in western and northern Morocco that the first section of the high-speed rail line along the Atlantic axis was built. It is 200 km long and connects Tangier to Kenitra (Map 1)[14] without any intermediate stations[15]. It is the first high-speed line in Africa. Trains will start operating in June 2018. Beyond Kenitra, the trains will continue on conventional lines at 160 km/h, or on some sections 220 km/h, in order to reach Rabat (the political capital of Morocco) and then Casablanca (the country's economic centre). Subsequently, the line is due to be extended to Settat, Benguerir, and then Marrakesh (480 km), and in the longer term from Marrakesh to Essaouira[16] and Agadir.

These lines are supposed to enable increased mobility. The Moroccan National Railways Office (ONCF) estimates that the total number of passengers on its routes in 2035 will be 133 million compared with 52 million without the high-speed line. High-speed rail will thus contribute to the development of rail traffic and consequently to exchanges between the cities served. The ONCF has announced that the number of travellers is set to double (from 3 million to 6 million per year) on the Tangier–Casablanca[17] route. Of these, 4 million (66%) would come from the usual demand for rail (including induced traffic estimated at 12%), while the other 2 million would be new customers (34%) switching from road-based transport. This corresponds to a modal shift from road to rail (all modes of individual or public transport) as well as to air travel (2%) (ONCF, 2015). This growth in passenger numbers resulting from such modal shifts – as well as partly from growth in overall mobility – is very strong; however, it will also be accompanied by significant inequalities in access.

4.2 A significant improvement in accessibility associated with inequalities in access

Given the relatively outdated state of existing rail transport, the Tangier–Kenitra high-speed line will allow for a considerable reduction in journey times, although these reductions will vary according to the city, since some will be served in part by high-speed trains running on conventional tracks. The Moroccan TGV is an adaptation of the French TGV[18]. They have been adapted to conditions in Morocco, particularly in terms of outdoor temperatures and the effects of sand. The 12 duplex trains that have been purchased can circulate at an operating speed of 320 km/h (the equivalent of the East European HSL). Journey times will be cut by 76% between Tangier and Kenitra (entirely on HSLs), a reduction much higher than that made possible by the commissioning of HSLs in countries such as France[19]. They will decrease by 57% between

13 Between 2005 and 2009, the Casablanca–Fez, Casablanca–Kenitra, Casablanca–El Jadida and Fez–Sidi-Kacem lines, which were previously single-track, have been split. New tracks linking Tangier to the Tanger Med passenger and cargo port and Taourirt to Nador have been built (AT, 2011).

14 Intermediate city located at 50 km north of the capital.

15 The station planned for Larache, 90 km to the south of Tanger, has been temporarily abandoned. Land reserves have nevertheless been preserved for a possible station.

16 This project seems to have been modified in 2017. The new project doesn't serve Essaouira and instead provides a direct link from Marrakesh to Agadir. See: https://www.tgvmaroc.ma/projet/.

17 See: https://www.tgvmaroc.ma/projet/retombees/.

18 The trains are built by Alstom, the company which builds the French TGV (source: Alstom Transport (AT), June 2011).

19 For comparison, the East European high-speed line cut journey times by 44% from Paris to Nancy and by 50% from Paris to Reims.

Tangier and Rabat, and by 51% between Tangier and Casablanca; in both cases, trains coming from Kenitra will run on conventional lines (Table 5).

Table 5. Time savings in June 2018

Origin-Destination	Time savings (%)	Origin-Destination	Time savings (%)
Tangier-Kenitra	47 min instead of 3 h 15 (-76%)	Tangier-Fez	3 h instead of 5 h (-40%)
Tangier-Rabat	1 h 20 instead of 3 h 45 (-57%)	Tangier-Meknes	2 h 30 instead of 4 h 30 (-41%)
Tangier-Casablanca	2 h 10 instead of 4 h 45 (-51%)	Tangier-Marrakesh	4 h 30 instead of 8 h (-44%)

Source: based on ONCF data. 0

Moreover, with the interconnection made possible in Kenitra, the high-speed train will bring Tangier significantly closer to other Moroccan cities like Fez, Meknes and Marrakesh. Although the latter are currently well served in terms of frequency (two trains per hour between the cities of Fez and Meknes on the one hand and Kenitra on the other), journey times are currently very long. Highspeed rail will significantly reduce these times, as Fez will be connected to Tangier in less than 3 hours, compared to 5 hours today (a 40% reduction in travel time); and Meknes will be connected to Tangier in 2½ hours, compared to 4¼ hours on average today (a decrease of 41%).
Similarly, with the doubling and upgrading of the Casablanca-Marrakesh line, Marrakesh is expected to be at 4½ hours from Tangier in June 2018, compared with 8 hours at present – a decrease of 44%. Lastly, in Tangier, a connection will exist with El Jadida, a tourist town on the Atlantic Ocean, with Tangier airport, and with the port dedicated to passenger transport (at Tanger Med).

Beyond travel times, improvements in accessibility depend on the service frequency.

Each of the 12 duplex trains can carry up to 533 passengers and consists of 8 carriages (two first-class carriages, one buffet car and five second-class carriages). The 10 trains in circulation (2 will be kept in reserve) will allow for a maximum of 40 rotations per day. The frequency between Tangier and Kenitra and then Rabat and Casablanca will make possible a frequency of one train per hour[20] (probably a little more during peak hours) from 6 a.m. to 9 p.m. (compared with 5.30 a.m. to 1.30 p.m. today with conventional trains). Although the timetable is not currently known, it will be primarily intended to facilitate business mobility between the cities served.
Improving accessibility will thus be extremely important for the cities that are on the network (Tangier and Kenitra), and very important for those connected to the network but served on a conventional line (Rabat, Casablanca, Fez and Marrakesh).

The overall population concerned by this line and its services can be estimated. If we consider only the cities served by high-speed lines and population centres near these cities served by conventional lines, just over 6.2 million inhabitants of Moroccan cities – out of a national population of 33 million – will benefit from this service[21].

20 Source: http://www.usinenouvelle.com/article/quand-l-oncf-fait-la-promo-en-video-du-train-a-grandevitesse-marocain.N341962/.
21 Source: http://rgph2014.hcp.ma/Repartition-geographique-de-la-population-d-apres-les-donnees-du-Recensement-General-de-la-Population-et-de-l-Habitat-de_a380.html/
22 As with other indicators in developing countries, population data must be treated with caution, as accurate data collection is often difficult to achieve.(tabla 6)

Table 6. Population[22] growth in Moroccan cities served by high-speed trains		
City	Population	Average annual rate of population growth, 2004–2014 (%)
Tangier	947,952	3.26
Kenitra	423,890	N/K
Rabat	577,827	-0.79
Salé	890,4	1.59
Casablanca	3,359,818	1.03

Source: based on data from HCP 2014.

The inhabitants of Fez (1,112,072 inhabitants), Meknes (632,079 inhabitants) and Marrakesh (928,850 inhabitants) – a total of 2,673,000 residents – will also benefit from a significant reduction in journey times to Tangier, but with an interchange at Kenitra.

However, a large part of Morocco is not only excluded from high-speed rail access but also excluded from the conventional rail network (see Map 1 above). Those areas of Morocco to the east and south of Marrakesh (which represent half of the country's geographical area) are served by the Supratours bus network (shown in orange on Map 1). The populations of the Moroccan regions of GuelmimEs Semara (501,921 inhabitants), Laâyoune-Boujdour-Sakia El Hamra (301,744 inhabitants), Oued EdDahab-Lagouira (142,955 inhabitants) (i.e. 2,097,629 inhabitants in total) and those in the south-east of Meknes-Tafilalet (2,316,865 inhabitants) are not served by either the conventional or the highspeed rail network.

The cities that are served, by contrast, are among the most dynamic cities in Morocco.

4.3 A first section of HSL that could reinforce existing dynamics

As indicated by the ONCF, the first section of high-speed line should enable "the rapprochement, synergy and integration of the two most dynamic regions of the Moroccan economy: the Casablanca-Rabat-Kenitra historic core, and the emerging business leisure and tourism centre in the northern region". It is expected that "there will be significant benefits in terms of [...] the country's international and regional reputation and its image and attractiveness within the tourism and business sectors (investors, business community, etc.)" (ONCF, p. 3).

High-speed rail will benefit Tanger Med, which is one of the largest intermodal platforms on the Mediterranean coast and the largest container port in Africa (World Bank, 2015. For example, the HCP report (2016) points out that the regions of Casablanca-Settat and Rabat-Salé-Kenitra made the largest contributions to national GDP in 2014, with Rabat-Salé-Kenitra generating 32% of GDP and Casablanca-Settat 16.3%. The Tangier-Tetouan-Al Hoceima region arrives in third position with 9.4% of GDP. These three regions are thus characterized by GDP growth rates well above the national average (2.9%), with 7.1% for the Rabat-Salé-Kenitra region, 5.3% for the Casablanca-Settat region and 4% for Tangier-Tetouan-Al Hoceima (HCP, 2016).

As in many countries, high-speed rail service serves the most populous cities – and also the richest ones – so as to generate sufficient demand.

The question is now to identify how high-speed rail is integrated into Moroccan society, in terms of income and uses.

4.4 Limited access inequalities in terms of fares

According to the ONCF, the Moroccan HSR project has been designed differently from other similar projects developed elsewhere – especially in Europe, where high-speed trains compete with air travel. It is expected that HSR will be used by a large majority of Moroccans and not just the wealthiest sections of the population (ONCF, p. 18). If this turns out to be the case, Moroccan high speed-rail services could be compared to Turkish HSR, which offers relatively cheap fares (cf. above) and directly competes with bus services. In Morocco, "pricing will be incentive-based and competitive, in harmony with the purchasing power of conventional train users" (ONCF, p. 18), in accordance with the King's wishes that the service be designed for the greatest possible number of people. The inequalities of access in terms of pricing should therefore be relatively low.

However, the exact fare structure and prices are not yet known, as of August 2017.

But we can estimate the prices. According to the journal *Jeune Afrique*[23] and the ONCF, the price increase should be very low. Casablanca–Tangier ticket prices should only increase by MAD 17 (EUR 1.50), that is to say an increase of 12.9%, and should cost just under MAD 150[24], or about EUR 45 in PPP, for 350 km. This would be only MAD 4 more than the bus ride[25].

Assuming that the 12.9% increase will apply to all journeys[26], the price of a journey from Tangier to Kenitra would be MAD 100.80 (MAD 90 currently + MAD 10.80), or about EUR 30.10 in PPP, while a ticket for Marrakesh to Tangier would cost MAD 243.80 (216 + 27.80), compared with MAD 235 for the same journey by bus, which corresponds to a little more than EUR 73 in PPP.

If our estimates are correct, it is clear that pricing will be low and likely to be set at a level close to current ticket prices for bus travel. Moreover, unlike Turkey, where prices are fixed, pricing will be based on a yield-management system. This means it will be possible to buy tickets at prices close to the cost of classic tickets for certain timetable slots, thus encouraging use by more diversified populations.

The next question, however, is to know what these prices represent in Morocco – in other words, what is the purchasing power of the Moroccan currency?

Morocco is characterized by a relatively low level of development. With $7,266 of GDP per capita (current international PPP $ from 2011; cf. Table 2 above) in 2014, it is among the lower-middleincome countries according to the World Bank. In terms of the Human Development Index (HDI), Morocco's score of 0.647 in 2015 placed it in 123rd position out of 188 countries, although this ranking has been constantly increasing since 1980.

In 2015, the non-agricultural minimum wage was MAD 2,570 per hour (or EUR 240 per month).

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23 See: http://www.jeuneafrique.com/30394/economie/le-tgv-tanger-casablanca-en-sept-points/.

24 It should be borne in mind, however, that ticket prices did increase in early 2016 as a result of a rise in the VAT rate from 14% to 20%. Source: http://telquel.ma/2016/01/05/decouvrez-les-nouveaux-tarifsloncf_1476364/.

25 Our calculation, based on Supratours data; source: http://www.supratours.ma/.

26 This will not necessarily be the case, as certain journeys or sections of journeys will be made by HST but on conventional lines; any price increases that are implemented for such journeys are therefore likely to be limited.

The average wage in the private sector varies between MAD 4,811 (EUR 442), for the 3 million employees affiliated to the National Social-Security Fund (CNSS), and MAD 11,205.60 for the 580,000 employees affiliated to the Moroccan Interprofessional Pension Fund (CIMR), for a total employed labour force of 11.5 million. However, just over 87% of workers affiliated with the CNSS receive less than MAD 6,000 per month, and 43.4% receive a sum equal to or lower than the minimum wage.

Finally, the inactive population amounts to just over 22 million and the unemployment rate stands at 16.4%.

With this in mind, a Casablanca–Tangier high-speed rail ticket would represent a little more than 5.8% (MAD 150 / MAD 2,579) of the minimum wage[27]. It should therefore be noted that prices represent a relatively small percentage of income.

Of course, not all Moroccans are salaried, and some earn less than the minimum wage. Moreover, Morocco is characterized by significant inequalities that are likely to lead to inequalities in HSR use.

4.5 Potential inequalities deriving from possible uses linked to gender inequalities

While high-speed rail is used for long-distance mobility associated with professional travel or commuting (see above), we have little data on these mobilities in Morocco[28].

These being the case, professional mobility or long-distance commuting are often linked to income and/or a high level of education. Furthermore, Morocco is characterized by an average duration of schooling for the population aged over 25 that is not just very low (5 years) but also much lower than other countries in the same category (for which the average is 6.6 years), and even less that the average duration in sub-Saharan Africa (5.4 years). In addition, educational inequalities are very marked. For example, Morocco's inequality-adjusted education index (0.273; see Table 4 above) is much lower than the other countries in its category[29]. Moreover, it is also characterized by a GenderRelated Development Index (GDI) of 0.826, which is at a lower level than other countries in the same region, such as Algeria or Tunisia, or than countries in the same category (lower-middle-income countries). This GDI value signifies that the level of human development of Moroccan women is only 82.6% of that of men, compared with an average of 87.1% for countries with average human development and 84.9% for countries with weak human development; this rate is lower than that of sub-Saharan African countries. And it is once again educational inequalities that are at stake: the average duration of schooling for women over 25 is just 3.8 years, compared with 6.4 for men.

In this domain, too, Morocco is characterized by results equivalent to those of the least developed countries in the world. As noted in the UNDP Africa report, "gender disparities are particularly acute in Egypt, Morocco and Mauritania" (UNDP, 2016, p. 174). An analysis of the different elements of gender inequality in Morocco shows that women's incomes are 30% lower than those of men, as is the case everywhere in North Africa. Morocco is also characterized by

27 For comparison, a normal Paris–Strasbourg ticket costs between EUR 107 and EUR 149 in second class – that is, between 9.3% and 13% of the net minimum wage (EUR 1,149 per month).

28 Except for trips outside Morocco (whether migratory or tourism-related), but these are not of interest for this analysis.

29 The index for Morocco is on a par with some of the countries with the lowest human development indices on the planet (Haiti, Togo, etc.).

a lower number of women than men with a secondary-level education (7 women for every 10 men among the population aged 25 and over), and only 11.7% of members of parliament are women. In addition, the percentage of companies headed by women is extremely low (less than 5%), the lowest in Africa after Sudan. Lastly, the unemployment rate for women is 29.6%, compared with 12.4% for men.

Accordingly, the types of inequalities that HSR services could reinforce, in terms of gender, are likely to be inequalities of professional mobility: the population likely to use HSR will probably be more male than female.

But high-speed rail services can also be used for tourism-related mobility.

Morocco's "Prospective Maroc 2030" long-term perspectives initiative (HCP, 2007) and "Vision 2020" tourism development strategy aim to continue to make tourism one of the motors of the economic, social and cultural development of Morocco (SMIT, 2011). Indeed, Morocco recorded 9.3 million tourist arrivals at its border posts in 2013, rising to 10.4 million in 2014 and 10.2 million in 2015. From this point of view, HSR services could be used by foreign tourists for certain journeys within Morocco, in particular between Tangier and Marrakesh[30]. However, given the existing competition with airlines from the main countries of origin of tourists visiting Morocco, this use seems unlikely.

But HSR services could also be used for domestic tourism, which has long been ignored, even if certain authors, such as Mohamed Berriane, stressed how important this was as early as 1989. "With an average departure rate of over 30%, Moroccan urban dwellers account for between 18% and 20% of overnight hotel stays (depending on the year), with some also choosing to lodge with local residents" (Berriane, 1989, p. 10). The Moroccan administration wishes to develop this type of tourism with the aim of tripling the number of domestic travellers. In 2015, the domestic tourist market has continued to grow, as has been the case since 2010. Overnight stays in hotels grew by 11% to represent 32% of the total, a larger percentage than those of the French market (20%). It is thus not just the wealthiest Moroccan categories, but also those within the middle classes who are able to benefit from tourism activities, that are liable to travel by high-speed train.

In such cases, the organization of connections and intermodality in order to access or exit from stations when travelling to or from the seaside destinations of M'Diq, Tetouan, Fnideq and Cabo Negro on the Mediterranean coast, or Larache[31] on the Atlantic coast near Tangier, or the resorts of Mehdia or Salé close to Kenitra will therefore be of central importance. Indeed, for tourism-related trips, links between HSR stations and final destinations must be designed so that the time saved by high-speed rail is not lost in reaching the station or the final destination.

5. Conclusion

In this article, we have highlighted the fact that there are many high-speed rail projects under way in developing countries. We subsequently showed how these countries' socio-economic contexts, marked by significant inequalities, could influence the use of HSR. We put forward the hypothesis that the innovations in terms of service improvement represented by high-speed rail – which are considerable in Morocco – could actually reinforce these inequalities insofar as infrastructure and services are differentiated in spatial terms; however, we also pointed out that these inequalities could be spatial, economic, social and use-related. In

30 *High-speed rail is used by tourist foreigners in China, for example (Chen and Haynes, 2014).*

31 *Where land reserves have been made for a planned high-speed rail station (cf. above).*

the case of Morocco, considerable spatial inequalities already existed, in particular because the conventional railway network is old and very unequally distributed in spatial terms. Consequently, with the arrival of high-speed rail, accessibility inequalities between different Moroccan cities will become much greater. On the other hand, if our estimates are correct, inequalities in terms of pricing may well be relatively low for people who are in employment. But economic, social and educational inequalities could combine with gender inequalities to make use of high-speed rail highly unequal.

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Airline and railway disintegration in China: the case of Shanghai Hongqiao Integrated Transport Hub

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Abstract

In China, the need to integrate the air and rail networks has been identified and dozens of transport hubs that include air and HSR links have been built or are planned. In this research, which is complementary to Chen and Lin, the level and potential for air–rail integration at Shanghai Hongqiao Integrated Transport Hub is examined and analyzed. The results show that despite the excellent infrastructure the actual level of integration is low, while the potential benefits from such integration could be very large. It seems that in China the main barrier for air–rail integration is institutional and stems from the institutional (and cultural) division between air and rail transport and from the importance placed on promoting competition almost at any cost – both of these barriers can be said to be 'imported' to China from (especially) the U.S. and Europe. But with the infrastructure for air–rail integration in place, the potential to realize such an integration is far greater. A move away from the uni-modal governance and planning of transport can open the door not only to air–rail integration but to the creation of a truly integrated transport system in China.

Keywords: air–rail integration; Highspeed rail; Hub and spoke; airlines; integrated Transport Hub; shanghai Hongqiao; railway station; rail planning

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1. Introduction

Despite its potential benefits, the idea of air-rail integration (**Givoni 2007a**; **Givoni and Banister 2006**) is not gaining ground, even at times when congestion at airports increases. It is not that policy makers are blind to the idea. The EU, in its 2011 Transport White Paper, declares 10 goals one of which (Target 6) is 'By 2050, connect all core network airports to the rail network, preferably high-speed' (**EC 2011, 9**). Calls for integration are heard elsewhere as well. Yet, despite integrated transport in general, and air- rail integration more specifically, being a formal policy objective there is not much evidence of it. More common is for the disintegration of modes to prevail, especially between air and rail transport with London Heathrow airport being a prime example. **Givoni and Rietveld (2008)** and later **Givoni (2015)** try to provide some explanations for this lack of air–rail integration. While the roots of the problem are traced back to the institutional division between the air and rail industries and between air and rail policy making, the practical and most tangible obstacle for air and rail integration is a lack of infrastructure to support it – i.e. high-quality rail station at the airport.

This obstacle has been realized in China and led to the construction of many Integrated Transport Hubs, primarily as part of the construction of the high-speed rail (HSR) network and stations (**Hickman *et al.* 2015**). Many of these integrated hubs include an airport adjacent to HSR station, offering the infrastructure for air-rail integration. A prime example of the newly built integrated hubs is 'Shanghai Hongqiao Integrated Transport Hub' that includes Shanghai Hongqiao Airport (one of two major airports in the city) and Shanghai Hongqiao Railway Station (one of three major stations in the city) alongside a large metro and bus stations (see more details below and in **Chen and Lin 2016**). At least from an infrastructural perspective, Hongqiao hub provides the conditions to become a blueprint for air–rail integration. Examining to what extent this is the case in practice is the main objective of this paper. Overall, and unlike **Chen and Lin (2016)** who see the Hongqiao hub as a case of air–rail integration and through their analysis suggests way to further improve it, the analysis here shows that Shanghai Hongqiao Integrated Transport Hub is more a case of airline and railway disintegration and in this context aims to provide an analysis of the potential for such integration and what might stands in its way.

To achieve its aim and objective, the paper first reintroduces the model of airline and railway integration and briefly discusses the emergence of the Integrated Hub concept in China (The Integrated hub model) before providing a detailed description of Hongqiao hub from supply and demand perspectives (Shanghai Hongqiao Integrated Transport Hub). Current and future air–rail integration at the hub are then examined (current and future air–rail integration) followed by the assessment of the potential for air and rail integration (assessing the potential for airrail integration). The paper ends by providing key policy conclusions for the promotion of air-rail integration and the challenges in overcoming current air–rail disintegration (Conclusions and discussion). The analysis relies on a range of sources and primarily Hongqiao Hub plans alongside airline and railways schedules.

2. The Integrated hub model

2.1 The concept of the Integrated hub

As illustrated in Figure 1, in an airline's Hub and Spoke (H&S) network, which was adopted by many of the major airlines after the deregulation of the U.S. air passenger market in 1978, two types of network models can be distinguished: (1) the Hinterland model: short-haul flights feed traffic into long-haul flights; and (2) the Hourglass model: short-haul services are replaced by the more profitable long-haul flights (**Doganis and Dennis 1989** in **Button and Stough 2000**).

A third model that is offered is the Integrated hub model: short-haul services are provided by the airlines using the railways (rather than aircraft) to feed traffic into the airlines' long-haul services (**Givoni and Banister 2006; Givoni 2007a, 2007b**).

In the Integrated hub model, rail services may be provided to those destinations which are currently served by aircraft, and in this case, mode substitution takes place. Rail services may also be to destinations that are not currently served by aircraft and by that expand the airline's network, creating a win–win situation for both railway and airline industries. Mode substitution can potentially also provide significant environmental benefits, especially air and noise pollution around airports, although the environmental impacts of air transport could worsen if runway capacity freed through mode substitution is taken up by new (longer routes) air services (**Givoni 2007b**). Albalate, Bel, and Fageda (2015) demonstrate for three European countries that the introduction of HSR services on routes where air services were in operation, does not necessarily lead to reduction in flight frequency, even if the number of seat supplied is lower.

The success of airline and railway integration requires a close cooperation and collaboration between the airline and railway operator. According to **Givoni and Banister (2006)**, the commercial agreement between the airline and railway operator can take different forms, similar to cooperation agreements airlines sign between them (e.g. code-share agreements). There is no reason for code-share agreements, whereby one airline operates the flight, but many can offer it to their passengers, to not include rail service providers (**Chiambaretto and Decker 2012**). In Europe, Lufthansa operates rail services as part of its network on several routes, such as Frankfurt–Stuttgart and Frankfurt–Cologne. The rail service is actually operated by Deutsche Bahn (DB) but carries a Lufthansa code. Another example of commercial agreements between airlines is the formation of airline alliances. Unfortunately, the railways have largely remained outside of these agreements (**Givoni 2015**).

A prerequisite for airline and railway integration is the colocation of a railway station at the airport. The most favorable situation is to directly integrate railway stations into the main passenger terminal(s) of airports, which will create a seamless intermodal transfer. Amsterdam Schiphol airport is such a good example. In addition, the railway station needs to be a through station (providing a high-frequency service to many destinations) rather than an end of the line station. For more discussion on airline and railway integration see Givoni and **Banister (2006), Givoni (2007a, 2007b)** and **Givoni and Rietveld (2008)**.

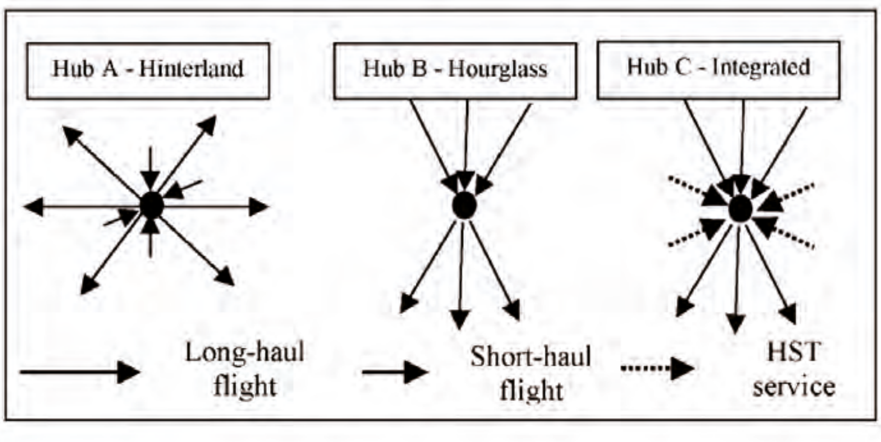

Figure 1. The Integrated Hub model of H&S operation (Source: Givoni 2015).

Note: HST – High-Speed Train.

2.2 The emergence of the Integrated hub in China

China is experiencing rapid economic growth and fast expansion of transport infrastructure in recent years. For example, in China, the number of civil airports increased from 94 in 1990 to 175 in 2010 and is expected to reach 244 in 2020 (**Fu, Anming, and Zheng 2012**). At the same time, China is fast developing its HSR network largely to accommodate the increase in demand for rail transport, i.e., for capacity reasons (ibid.; **Chen 2012**), similar to what was the case in Japan and France, albeit at a much larger scale. The intermediate and long-term plans for the HSR network were first published in 2004 and later updated in 2008 by the then Ministry of Railways, subject to approval by the State Council (**Chen 2012**). By the end of 2015, the total operating length of China's HSR network had reached 190000 km[1]. The network model of HSR in China is that of a 'comprehensive national' and its backbone consists of four east-west and four north-south lines (ibid.). By 2020, the Chinese HSR network is expected to link all provincial cities and cities with a population of over half a million (**Chen 2012**). These figures have already made China the largest HSR network in the world and an almost ideal case for airline and railway integration, considering also the regulatory environment that might be more open for cooperation between the modes (see below).

Moreover, in the development of HSR in China, strategic consideration was given to the location of the stations, with respect to which cities are served (which is obvious) and the function of each station as a hub in the HSR network. As **Hickman et al. (2015)** illustrate (Figure 2, 180), the network consists of several tiers of 'hub' stations, or 'multimodal interchange hubs,' which range from superlarge to large and medium hubs – those which offer interchange with multiple transport modes, and more modest small and basic hubs. The position of a station in the hub hierarchy is determined by the operational volume of the station. Hickman et al. (2015) note that the Chinese rail hubs often have very large, airport-style, multilevel buildings (see also Chen, Hickman, and Saxena 2014). In this context, the need to integrate the air and rail networks has been identified and more than 32 Chinese airports are planning HSR links and turning the airports into transport hubs (**Fu, Anming, and Zheng 2012**). According to **Givoni and Banister (2007)**, for an airport to be suitable for air-rail integration, it would be better to have the railway station situated at the airport and the station should offer a high-frequency service (not necessarily HSR service) to many destinations, as noted above.

Rail services in China are categorized according to the types of service offered (**see Appendix A**). This categorization lends itself for the consideration of air–rail relationship. Train services of types G and D – the fastest services – are those where HSR is most likely to successfully compete with aircraft services. On train services of types C, Z, T, K and S – where routes tend to be relatively short (and speed varies but, with the exception of C trains, is lower than 200 km/h) – rail is more suitable to complement aircraft services. Considering the Integrated Hub model (Figure 1), rail services G and D can substitute current aircraft services, while rail services C, Z, T and K can complement current aircraft services.

3. Shanghai Hongqiao Integrated Transport Hub

Shanghai Hongqiao Integrated Transport Hub best illustrates the concept of the Integrated Hub in China and it can be used as a case study to analyze air–rail integration as in **Chen and Lin (2016)**, or as a case study of air-rail disintegration as done in this paper. This section first describes the physical characteristics of the hub and the supply of services, it then examines the demand for services at the hub before describing the regulatory framework within which the hub is operated. The data used and described below are similar to that used by **Chen and Lin (2016)** in their analysis.

3.1 The supply side

Following the development of Puxi (traditional city centre) and Pudong (east to the traditional city centre) areas, the next logical step for Shanghai's development was to create a new growth pole and a subcentre to the west. At the heart of this development is the Shanghai Hongqiao Integrated Transport Hub ('Hongqiao Hub' for short) which is expected to support and facilitate the economic development in the Hongqiao Business District (see **Chen and Lin (2016)**).

The Hongqiao hub includes an airport, railway station, metro station, coach/bus station all under one roof and including good access to the motorway network. At present, it is the only such hub in China that has both an airport and a railway at the same place (500 m apart) and where transfer by walking is possible (in about 10 min.[2]) While the airport, railway and coach stations support intercity travel, the metro and bus stations focus on urban, intracity transport and serve largely as access/egress routes to the integrated hub.

Figure 2. Destinations with direct air service to Hongqiao hub.

Before the opening of Pudong International Airport (which is serving mainly international flights and is now the third-largest airport in China) in 1999, Hongqiao Airport used to be the principal airport in Shanghai. Since 1999, however, Hongqiao airport has primarily served domestic flights. As part of the development of the hub, a second runway and a new terminal (Terminal 2) opened in 2010 to allow maximum capacity to reach 40 million passengers per year. In 2010, the airport served over 31.2 million passengers (on average 85,000 passengers per day), primarily through Terminal 2 (about 90%), making it the fourth-busiest airport in terms of total passenger traffic in China[3]. By 2013, the airport handled over 35.5 million passengers (5.3% growth) and was ranked 36th in the world by passengers, behind Pudong airport that was ranked 21st in the world (total demand over 47 million passengers[4]). The airport served 64 Chinese cities in 344 daily flights in 2013. The main destinations served were Beijing (41 daily departures), Shenzhen (32), Guangzhou (30), and Xiamen (23). Another 36 destinations in China were served with over five daily flights (Kunming, Qingdao, Nanjing, Changsha and Tianjin all had between 13 and 11 daily departures) and 19 destinations in China were served by less than four daily flights. The airport also serves international and regional services, from Terminal 1, but they are relatively limited and include Tokyo, Seoul, Hong Kong, Taipei (4 daily departures to each destination) and Macau (3 daily departures). Connection between Terminal 1 on one side of the airport and Terminal 2 and the adjacent rail station on the other side of the airport is through the Metro and a shuttle bus. The two dominant airlines at Hongqiao Airport are China Eastern Airlines, for which the airport is a hub (offering 105 departing flights) and Shanghai Airlines (65), followed by Juneyao Airlines (35), Spring Airlines (34), China Southern Airlines (28), Air China Limited (22) and Xiamen Airlines (17). Sixteen more airlines offer service from the airport with as many as 12 airlines offering only one departure per day.

Figure 3. Destinations with direct rail service to Hongqiao hub.

Opened in 2010 as well, and located 500 m west to Terminal 2, Hongqiao Railway Station has a design capacity of 52.72 million passengers per year planned for 2020. It is one of the largest rail terminals in China and is one of the three main railway stations in Shanghai – the others being Shanghai and Shanghai South Railway Stations. The station includes a floor area of about 1.3

million m², 16 platforms, and 30 tracks. It is planned to cater in the future for Maglev services but these are yet to be finally decided on. The station only provides HSR services (train types G – 65% of the services and D – 35% of the services – see Appendix A) on the Beijing–Shanghai Passenger Dedicated Line (PDL), Shanghai–Hangzhou Intercity HSR Line and Shanghai–Nanjing Intercity HSR Line, all three opened in 2010–2011. The 143 services departing from the station (in 2013) served 28 cities the main ones being: Beijing (South) served by 32 daily services; Nanjing, Ningbo (East) and Hangzhou by about 16 daily services and Hankou by 12 daily services. Twenty-three destinations were served by less than 10 daily trains, many by one or two only.

The Coach station at the hub provides inter-city bus services from/to Shanghai, mainly to Jiangsu Province – located at the core of the Yangtze River Delta (YRD) Megaregion (204 coach services per day) and Zhejiang Province (74 coach services per day). Hongqiao hub is also well connected with the Motorway network.

Hongqiao hub is planned to be well integrated with the city's transport network. Five different metro lines are planned to pass through the airport, with Metro Line 2 (connects Hongqiao and Pudong airports) and Metro Line 10 (has a stop at the railway station, Terminal 2 and Terminal 1) already in operation. Metro Lines 5, 17 and the Qingpu Express are under construction. The hub also serves a wide range of local bus routes.

Overall, Shanghai Hongqiao Integrated Transport Hub offers excellent air, rail and road infrastructure and is well connected. It is a major node on all of these respective networks. It thus certainly has the conditions to be a truly Integrated Hub.

3.2 The demand side

According to Shanghai Hongqiao's Central Business District Governing Board, on average 684,300 passengers used the various transport facilities at the Hub every day in 2013[5] (see Table 1 for details). This daily demand split was 50.6% for urban transport and 56.5% for intercity long-distance travel. The majority of long-distance passengers used the rail station (28.7%), while only 13.9% passengers used the airport. The daily demand is forecast to grow to 693,600 in 2020, with most of the increase expected in the demand for rail travel (the railway station is expected to cater for 45.5% of the demand[6]). The demand for Coach services will increase almost threefold but will continue to serve a relatively minor share of the hub's passengers. The airport is also expected to grow, but by only 15% and in 2020 is expected to serve 109,400 passengers per day, equivalent to about 40 million passengers per year, just over 11% of the Hub's daily demand. By 2020, most of the passengers using the hub, almost 60%, will be intercity long-distance travelers. With respect to intracity travel, the metro is the main access/egress mode to the hub. Shanghai Hongqiao Integrated Transport Hub is still a relatively new transport facility that is rapidly growing, the demand for its services is focused around the long distance travel modes, rail and air, with the rest of the demand for various modes is mainly to access/egress the railway and airport services[7].

Table 1. Demand and mode Share at Hongqiao Hub, 2013 and 2020.

Mode	2013*		2020**	
	Average daily passengers	%	Average daily passengers	%
Railway station (external)	196,100	28.7	438,200	45.5
Airport (external)	95,000	13.9	109,400	11.4
Coach bus (external)	6,200	0.9	23,000	2.4
Metro, bus, taxi, and other vehicles (internal)	386,800	56.5	393,000	40.8
Total	684,300	100	963,600	100

*Shanghai Hongqiao Central Business District Governing Board's Website, http://www.shhqcbd.gov.cn/html/shhq/shhq_2013/2014-01-13/Detail_6403.htm;
**Shanghai Comprehensive Transportation Institute.

A survey of the airport's passengers conducted by Huang, Yang, and Gu (2011) found that 30% were local residents in Shanghai, while 70% were from outside the city, most of them are residents in the YRD region. In terms of trip purpose, 48% of passengers were tourists, 19% travel for private business purposes, 12% for public business purposes and 10% travelled to visit relatives (11% travelled for other purposes). A different and not comparable, unpublished survey of railway station users conducted in February 2012 by Tongji University planning graduate students among 1834 passengers shows that 70% of rail passengers were from Shanghai and 30% from other cities. The main trip purpose among rail passengers was business travel (45%). The most popular mode of transport to get the railway station was the Metro (61%) followed by taxi (15%), bus (8%) and private car (8%). Less than 5% of the rail passengers surveyed were transfer passengers from the airport.

Although the surveys of the airport and railway station passengers are not comparable, they nevertheless shed some light on the different characteristics of passengers using each of the modes. In general, it appears that the rail station primarily serves Shanghai, while the airport has a much wider catchment area than Shanghai only. In both facilities, it appears that business travel makes up close to half of the demand. Although not the largest rail or airport in Shanghai, the combined demand for transport services in the Hongqiao integrated hub makes it the largest transport facility in the city.

3.3 The regulatory framework of China's transportation system

At the central government level, the Ministry of Transport (MOT) of China is an agency responsible for railway, road, air and water transportation regulations and is a member of the State Council of China. Until March 2013, the Ministry of Railways was in charge of the railways, not the MOT, and its duties were taken up by the MOT (safety and regulation), State Railways Administration (inspection and monitoring) and China Railway Corporation (construction, operation, and management). The State Railways Administration has several main functions including the formulation of laws, regulations and provisions for the supervision and administration of the railways. As the owner of China's railroad tracks, stations, and rolling stocks, China Railway Corporation is the national railway operator that operates both passenger (including HSR) and freight rail services. Within China Railway Corporation, the Transport Bureau is specifically responsible for developing the HSR network and determining the station locations, subject to approval from the State Railways Administration.

The Civil Aviation Administration of China (CAAC) is the regulatory agency under the MOT that oversees civil aviation and responsible for air transport safety. In 1987, the CAAC's airline operations were split into six separate airlines each named after the geographic region where their headquarters and main operation were located. These airlines (Tier-1) were: Air China; China Southwest Airlines; China Eastern Airlines; China Northwest Airlines;China Southern Airlines; and China Northern Airlines[8]. In addition to the above largest state-owned airlines, there are also other medium-sized airlines (Tier-2) subsidized by local governments and other funding partners including: Shenzhen Airlines (Major Parent Company: Air China), Xiamen Airlines (Major Parent Company: China Southern Airlines), Shanghai Airlines (Major Parent Company: China Eastern Airlines), Shangdong Airlines (Major Parent Company: Air China). Examples of fully privately owned airlines (Tier-3) include Hainan Airlines, Spring Airlines, Juneyao Airlines, Okay Airlines, and others.

In China, airports are typically owned and operated by the airport authorities of local governments. Local planning departments and transportation departments will determine the ground access to the airports, in conjunction with the airport authorities.

From a regulatory perspective, Shanghai Hongqiao Integrated Transport Hub consists largely of two components: the railway station and the 'international airport' (although most of the flights are domestic). The railway station is under the direct jurisdiction of Shanghai Railway Bureau, which is one of 18 railway bureaus administered by China Railway Corporation, while the airport is currently administered by Shanghai Airport Authority (SAA), which is the state-owned enterprise directly under the jurisdiction of Shanghai Municipal Government. SAA is the regulatory body that is also responsible for Shanghai Pudong International Airport. The regulatory link between the SAA (operating the airports) and the CAAC (regulating air transport) is through the airlines using Shanghai's airports. The main operators within Hongqiao hub are all profit maximization entities. In summary, while the railways are the only mode of transport in China that is centrally planned, the airports are usually locally planned.

4. Current and future air-rail integration

The close proximity of a major airport and a railway station provides for an almost ideal starting point for air-rail integration. At present, however, this integration is relatively limited as appears from the survey of railway passengers reported above. Nevertheless, some form of integration does exist. Three airlines have signed agreements with Shanghai Railway Bureau to provide integrated air–rail services in the YRD area: China Eastern (largest airline at the hub by daily departures), Spring Airlines (4th largest) and Air China (6th largest) and the profile of destinations they serve by rail is shown in Table 2. The rail services offered by airlines are designated a flight number but otherwise are not different from nonairline rail services. The frequency of air–rail services varies and in somecases considered to be in a trial period. Overall, the existing frequency of air–rail integration services is relatively limited in scope and is confined to nearby cities in the YRD region. A round of interviews[9] suggested that also in the eyes of local experts and policy makers, the level of air–rail integration, despite the progress being made, is low (compared by the interviewees to that at Frankfurt airport for example). At Hongqiao hub, luggage cannot be seamlessly transferred from the rail station to airport, it must be checked in twice. Another form of integration that currently exists allows passengers to check in for their flight at Kunshan bus station, about 45 kms from the airport and then be transported by bus to either Hongqiao or Pudong airports, a form of road–air integration.

Given that the Integrated Hub concept in China is still relatively new, a long-term view of air-rail integration is required. Such a view is provided by a forecast of the daily number of passengers transferring between the different modes at the hub in 2020 (Table 3). Considering an average estimate of the range provided in each cell of Table 3, it is clear that in 2020 the transfer of passengers within the integrated hub is expected to be between the long (air and rail) and the short distance (urban) modes of transport. The transfer of passengers from aircraft torail (HSR and Intercity) is expected to be 6000 daily passengers, about 11% of the airport passengers. Another 3100 daily passengers are expecting to transfer from the aircraft to the Maglev rail services (if they will be built), the majority (2500 passengers) to the planned interairport Maglev service, thus transfer from air to air using a Maglev ground transportation service.

Table 2. profile of rail services provided by airlines at Hongqiao hub.

Airline	China eastern	Spring airlines	Air China	Distance from Shanghai (km)
Daily flights	105	34	22	
Rail destinations	8	13	9	
Cities served by the airline 'rail' service	suzhou Wuxi Changzhou	suzhou Wuxi Changzhou	suzhou Wuxi Changzhou	84 126 165
	ningbo	ningbo	ningbo	314
	Jiaxing	Jiaxing	Jiaxing	84
	Zhenjiang	Zhenjiang		237
		Hangzhou	Hangzhou	159
	Kunshan		Kunshan	50
		Yiwu	Yiwu	304
	Tongxiang	Tongxiang		112
		Hefei		468
		shaoxing		202
		nanjing		311
		Danyang		210
			Taizhou	466

The main onwards mode for airport passengers other than to the local, urban public transport services (63%) is the private car (road network, 14%). Seventy-six percent of daily HSR passengers in 2020 are forecast to transfer to the local public transport services, while only 2% are expected to transfer from the 'HSR' to the 'Intercity rail' services, from long to short distance HSR routes[10]. Although the expected level of air-rail integration at the hub in 2020 will not be small, the picture that emerges from the forecast is that the hub is largely serving to connect Shanghai's local transport network with the long-distance, intercity transport network. Air-rail integration as a strategically planned interface between the two of the main long-distance transport networks in China is not really considered. The rapid development of the Chinese transport network as well as fast changes in other sectors means the forecast in Table 3 is likely not up to date anymore. However, it still shows the level of air-rail integration expected at the time which illustrates the planning 'mind set' of those responsible for the hub's future development.

Table 3. Year 2020 projected daily intermodal transfers at the Hongqiao Hub.

Mode or service	HSR	Intercity rail	Aircraft	Inter-airport (Maglev)	Shanghai- Hangzhou (Maglev)	Express bus	Car	Urban public transport
Hsr		1000-2000	2000-3000	7000-8000	1000-2000	500-1000	6000-7000	65,000-66,000
intercity rail	1000-2000		3000-4000	7000-8000	400-1000	500-1000	1000-2000	68,000-69,000
aircraft	2000-3000	3000-4000		2000-3000	400-1000	3000-4000	7000-8000	34,000-35,000
interairport (Maglev)	7000-8000	7000-8000	2000-3000		0	1000-2000	0	0
shanghai-Hangzhou (Maglev)	1000-2000	400-1000	400-1000	0		1000-2000	1000-2000	24,000-25,000
express bus	500-1000	500-1000	3000-4000	1000-2000	1000-2000		0	3000-4000
express highway	6000-7000	1000-2000	7000-8000	0	1000-2000	0		0
Urban public transport	65,000-66,000	68,000-69,000	34,000-35,000	0	24,000-25,000	3000-4000	0	

note: The total forecast demand by node (summing a row or a column) is not equal to that shown in Table 1 since the two represents different forecasts done at different times.

Source: Li and Zhu 2008.

Table 4. Comparison of routes on which the modes compete.

Origin	Airline frequency	Rail frequency	Air linehaul time (min)	Train linehaul time (min)	Air fare in CNY	Train fare in CNY
Beijing	41	34	150	336	336	553
Changsha	11	2	105	402	220	468.5
Fuzhou	8	7	80	377	188	261.5
Jinan	2	1	85	236	200	398.5
Longyan	1	1	85	570	250	373.5
nanchang	4	3	85	376	260	237
Qingdao	13	4	80	398	227	518
Tianjin	11	2	115	303	300	513.5
Wenzhou	3	7	65	212	230	226
Wuhan	7	15	90	301	336	302.5
Xiamen	23	7	80	513	200	328
Yichang	1	2	90	496	540	348.5
Zhengzhou	8	3	80	410	227	236.5

Note: For door-to-door travel time it is assumed that access and waiting time is 100 min for a flight and 60 min for an Hsr travel.

5. Assessing the potential for air-rail integration

Figures 2 and 3 show the cities from which there is a direct air service and rail service to Hongqiao airport and rail station, respectively. The maps also include a 900 km radius line around Hongqiao hub to depict the distance where the two modes are considered to still be in direct competition. Somewhat surprisingly, there are many more direct flights than rail service to the hub (not necessarily to Shanghai, since many rail services terminate at the other main railway stations). There is a clear duplication of air and rail services to the hub from several cities (see below) and, given rail connectivity to cities that offer HSR service to the hub, large potential for substitution by rail of some of the flight services, especially given the low frequency of service by some airlines (see below). Altogether, there are 61 destinations within 900 km radius that are served directly form the hub by air services and 26 such destinations served by rail.

A more detailed analysis of the routes served by air and rail to Hongqiao hub reveals 13 routes in which services are offered by both modes (competition routes – see Table 4) and additional 56 routes where the service is only offered by one of the modes (complementary routes, excluding international destinations).

With respect to fares, and in general, on the routes where the modes compete flights services are cheaper (Table 4)[11].Out of 13 routes, on eight routes the flights were considerably cheaper (more than 50 Yuan and up to about 300 Yuan), on four routes the fares were comparable and only on the route from Yichang using HSR was considerably cheaper, by almost 200 Yuan from flying. In terms of service frequency, the differences between the modes are relatively small and the choice between high (over 10) medium (between 5 and 10) and low (under 5) daily service frequency is very similar for aircraft and rail services. With the exception of one route, the airlines in general offer higher level of services. With respect to time, and restricting the comparison to in-vehicle time (as opposed to door-to-door travel time) aircraft services are of course considerably faster, with only on two routes (Jinan and Wenzhou) the difference is less than 3 h. Assuming a check-in time of two hours for flights and only 30 min for rail in China, flights are still faster by a margin on all routes (Table 4). Thus, travelling by HSR might be competitive to the flight in terms of travel time only if the railway station is located in the city centre while the airport considerably far from the centre. In addition to travel time, comfort factors should also be considered in the comparison between air and rail and the advantage here is clearly with travelling by HSR, which provides the conditions to use travel time for work, rest, etc.

Table 5. potential runway capacity to be released at Hongqiao airport following mode substitution.

Runway utilization at Hongqiao Airport (Average daily in 2013) Total daily: ATM: 332; Seats: 48767					Runway utilization			
					Route level		Cumulative	
Destina-tion	Distance	ATM	Seats	Aircraft	ATM (%)	Seats (%)	ATM (%)	Seats (%)
nanjing	273	12	444	37	3.6	0.9	3.6	0.9
Tunxi	374	1	162	162	0.3	0.3	3.9	1.2
Wenzhou*	418	3	474	158	0.9	1.0	4.8	2.2
Chizhou	447	1	158	158	0.3	0.3	5.1	2.5
Huai'an	450	1	37	37	0.3	0.1	5.4	2.6
Lianyungang	468	2	324	162	0.6	0.7	6.0	3.3
Wuyishan	532	1	158	158	0.3	0.3	6.3	3.6
Linyi	541	2	324	162	0.6	0.7	6.9	4.3
Xuzhou	554	1	158	158	0.3	0.3	7.2	4.6
anqing	555	1	21	21	0.3	0.0	7.5	4.6
Jingdezhen	589	1	158	158	0.3	0.3	7.8	4.9
Fuyang	606	1	162	162	0.3	0.3	8.1	5.3
nanchang*	632	4	632	158	1.2	1.3	9.3	6.6
Wuhan*	676	6	894	149	1.8	1.8	11.1	8.4
Fuzhou*	678	9	1458	162	2.7	3.0	13.8	11.4
Qingdao	693	13	2054	158	3.9	4.2	17.8	15.6
Jining	715	1	162	162	0.3	0.3	18.1	15.9
Jinjiang	763	5	810	162	1.5	1.7	19.6	17.6
Longyan*	784	1	158	158	0.3	0.3	19.9	17.9
Yichun	805	1	162	162	0.3	0.3	20.2	18.2
Xiamen*	827	22	3564	162	6.6	7.3	26.8	25.5
Ji'an	833	1	162	162	0.3	0.3	27.1	25.9
Yantai	846	7	1134	162	2.1	2.3	29.2	28.2
Jinan*	852	3	486	162	0.9	1.0	30.1	29.2
Ganzhou	854	1	158	158	0.3	0.3	30.4	29.5
Zhengzhou*	858	9	1458	162	2.7	3.0	33.1	32.5
Jinggangshan	860	1	180	180	0.3	0.4	33.4	32.9
Total/ave.		111	16052	145	33.4	32.9		

*Note: Distance in km; aTM = air Traffic Movements (take-off only); aircraft = average aircraft size. ave. = average, Bold cities – destinations within the YrD area. *– routes where there is currently a Hsr service.*

From destinations where there is either a HSR or a flight service to the hub (56 in total), the level of service is relatively low with often only one or two daily services. On only three routes, where a HSR service is offered but not a flight service, the frequency of service is very high[12] and stands at between 19 and 25 services per day. In terms of air service frequency, out of 43 routes where there is a flight service but no HSR, on only 12 routes the frequency of service can be considered high, and very high (over 10 per day) on two routes. It appears that the majority of destinations on which the two modes do not compete there is a relatively low demand for services to Hongqiao hub (this does not necessarily mean low demand for services to Shanghai). Such routes, however, might offer more potential for integration between the modes (see below).

Another way to consider air–rail integration or the lack of it at Hongqiao hub, is to consider the potential to free runway capacity (as in **Givoni and Banister 2006**) through mode substitution. There are 27 destinations within 900 km radius of Hongqiao Airport that are served by flights but could potentially be served by rail only (Table 5). These destinations currently take up about third of the runway capacity (in terms of Air Traffic Movements (ATM) and seat capacity). Looking only at those routes where currently there is already a HSR service, eight routes (marked by * in Table 5) they take up 17 and 19% of the airport's ATM and seat capacity, respectively, and, with the exception of Xiamen, Fuzhou and Zhengzhou, offer relatively low or modest frequency. The remaining 19 routes, where there is currently no HSR service, take up 16 and 14% of the airport's ATM and seat capacity, respectively, and in general offer low level of service (on 15 routes there are only one or two daily services). It is clear from Table 5 that the aircraft operated by the airlines from Hongqiao airport are single-aisle (narrow body) aircraft, many of them small aircraft within this category. This has implications of the use of runway capacity.

6. Conclusions and discussion

The need to and benefits from integrating the different elements of the transport system are well recognized (**Givoni and Banister 2010**) but nevertheless are seldom fully internalized by policy makers. This is often apparent in the disintegrated planning of the air and rail networks, even at the age of the HSR, which is recognized on many routes as a potential substitute to the aircraft. Current HSR plans in the US as in California's HSR13 and the UK as in HS214 are two very illustrative examples. China is very different in this respect. China seems to be the first country to internalize the need for integrated infrastructure, including the infrastructure for air-rail integration, when planning and developing its HSR network. The evidence from Shanghai Hongqiao Integrated Transport Hub suggests, however, that this is not sufficient for airline and railway integration at the operational level, to materialize.

What seem then to stand in the way for a full, beneficial airline and railway integration are institutional barriers. At the national level, the airline and railway industries are regulated by different government entities with distinct regulations, revenue sources, cost expenditures, and operating procedures. The airline industry is more decentralized, operating more like an oligopoly, with several airlines competing against each other, while the airports are locally owned and managed. In contrast, the railway industry is a full monopoly. Along several medium-range corridors (e.g. 300–500 km, and in some cases, up to 900 km as indicated in Table 5), the two industries directly compete for the same customers. Each industry has its own self-interests, lacking a revenue/cost sharing mechanism.

Despite the concept of the 'integrated hub' being an important element in the development of the Chinese HSR, it is still a 'railway' (State Railways Administration) and not a multimode (Ministry of Transport) planning initiative. Furthermore, with the operators of rail and aircraft services in China being profit maximizers, the focus on competition might make them blind for the full potential of integration. This 'blindness' seems to be present also within the regulatory bodies governing transport in China and air transport especially. The limited evidence for air– rail integration that does exist (Table 2 and see Chen and Lin 2016) reinforces that potential for such integration exists. When China 'discovered' and adopted the idea of HSR around 2004, it also imported the idea of HSR as a competitor to the aircraft and thus the airlines. By that, China locked itself into an inefficient use of these, largely complementary, long-distance modes of transport, even to the point of destructive competition between the modes (more so for the airlines – Fu, Anming, and Zheng 2012) and inefficient use of airports' and stations' capacity.

From a technological perspective, the difference between the modes should be apparent and assessed from the distance and demand perspectives. In terms of distance, aircraft is a long-range long-haul mode of transport, while HSR is short-range long-haul mode of transport. There is an overlap in this respect between the modes on routes of about 400–1000 km. Within this range, aircraft are suited to cater for relatively low demand routes while rail, HSR in particular, for high-demand (dense) routes. This functional consideration of air and rail transport advocates for a geographical division (of routes) between the modes. In turn, it lends itself for a very different organization of China's air and rail services, domestically and internationally, where routes of over 1000 km are mainly served by aircraft and shorter routes predominantly by rail. Under 1000 km, dense routes should be operated by HSR, while very thin routes by aircraft[15]. In that range, conventional rail services should serve routes with 'medium' demand.

In a hypothetical reorganization of air and rail transport in Shanghai, with a focus on air-rail integration, the role of Hongqiao and Pudong airports will change. Hongqiao, since it has excellent HSR connectivity, will become the international gateway to Shanghai and the YRD region and will offer a seamless transfer between a range of international (air) destinations and domestic (rail) destinations – becoming the first truly 'integrated hub' as depicted in Figure 1. For the same reason, Hongqiao airport should become a transfer point between domestic long-haul (aircraft) and short-haul (HSR) routes. Pudong airport, under this new organization of services will become a pure origin-destination airport for those wishing to travel to/from Shanghai and not beyond. The relatively high demand for travel foreseen between the airports (Table 3), currently served by a metro[16], and the consideration of an expensive Maglev line for that is evident for the inefficiency of the current functional roles of the airports. If HSR is supposed to accelerate the regional economic integration in China (**Zhang and Nie 2010** in **Chen 2012**) organizing in this way the functions of the two airports should be conductive. Furthermore, it will allow Shanghai to develop a true hub airport, using the Integrated Hub model (Figure 1). **Fu, Anming, and Zheng (2012)** argue that for the Chinese aviation industry there are multiple benefits from transforming the airlines' network to hub and spoke networks.

Extending further the hypothetical re-organization of Shanghai's Hongqiao hub and adhering to the Integrated (air-rail) Hub model, suggests that Hongqiao railway station should also serve conventional railway services to further maximize the inland reach, or catchment area, of the airport/hub. As **Givoni and Dobruszkes (2013)** show, most of the demand for HSR seems to originate from the slower, conventional railway. A truly Integrated Transport Hub should connect all transport networks and offer a seamless transfer between all these respective networks. It is such an integrated transport hub that should be the backbone of China's transportation network with such a hub in each of the mega-city regions, and where rail and HSR services mainly complement and not compete with the aircraft.

The above suggestion does not mean the end to competition in the Chinese airline industry. Rather, it suggests, as alluded to by **Perl and Goetz (2015)** and **Fu, Anming, and Zheng (2012)**, a reorientation of China's airlines away from domestic services and more towards international services. In the competition with foreign airlines, an adoption of the air-rail integration model should give Chinese carriers a significant competitive advantage, largely by substantially increasing the number of domestic destinations served by Chinese airlines (using rail services).

Even if the wheel cannot be turned back, the potential for air and rail integration at Shanghai's Hongqiao hub can still be realized, at least partly. Considering future demand for services to/from Hongqiao, the potential for air-rail integration is still large and thus the potential for much more efficient utilization of Hongqiao's facilities in the face of future growth in demand. This will require a move away from the uni-modal nature of governing and planning transport, which is currently the dominant approach worldwide. Given China's political nature, it is expected that a move away from such unimodal approach will be easier to adopt. With the infrastructure for air–rail integration in China very much in place, especially in Shanghai, the potential for air–rail integration can be more easily realized and in turn can act as a catalyst for the creation of a truly integrated transport system.

Latest planning announcements in China suggest the idea of air–rail integration as part of the future development of HSR still has merit and that it might have been recognized. According to the medium- and long-term railway network plan, which was approved during the State Council executive meeting on June, 2016, the HSR network should be extended to include eight vertical and eight horizontal lines that will link many large- and medium-sized cities of 1–4 h apart[17]. This can substantially increase the scope for HSR services to complement air services at air-rail hubs. In the Shanghai area, according to the Shanghai-Nantong Intercity Railway Phase II Plan, the Pudong Airport will be directly connected to the HSR network via a new HSR station at the airport. The plans also include a direct rail line connecting Pudong and Hongqiao Airports[18]. This suggests the importance of connecting the main international airport to the rail network has been recognized, but not yet the benefits of fully adopting the integrated hub model at Hongqiao.

7. Notes

1. See http://baike.baidu.com/view/3119844.htm (last accessed on 6/7/2016).
2. A random test by one of the authors revealed that it is possible to walk from the airport to the railway station without using any other modes of transportation, in about 10 min.
3. https://en.wikipedia.org/wiki/List_of_the_busiest_ airports_in_China#cite_note-1.
4. Based on ACI data, published on Wikipedia (https:// en.wikipedia.org/wiki/List_of_the_world%27s_ busiest_airports_by_passenger_traffic – accessed 18 October 2015).
5. Passengers who, for example, used the metro to get to the airport are counted twice: first arrival from Metro, followed by second departure from airport.
6. The forecast assumes the construction of interairport (Hongqiao–Pudong) and Shanghai-Hangzhou Maglev project, which to date has not been approved.
7. See Li 2014 and Qian et al. 2014 for the mode split on access journey to other large airports in China.
8. China Northern Airlines, China Southwest Airlines and China Northwest Airlines were integrated into China Southern Airlines, Air China, and China Eastern Airlines, respectively, in 2002 as part of the CAAC reorganization strategy.
9. The interviewees included: An Urban Planning Professor of Tongji University; the Deputy Director of Shanghai Comprehensive Transportation Planning Institute; and the Planning Manager of Hongqiao Airport. The interviews were conducted in the Summer of 2014.

10. In Table 3, the term 'HSR' refers to the so-called passenger dedicated HSR long lines passing through the study area (e.g. Beijing–Shanghai high-speed railway). The term 'Intercity Rail' refers to those HSR short lines running between cities within the study area (e.g. Shanghai-Nanjing intercity high-speed railway, Shanghai-Hangzhou intercity high-speed railway). Technologically, they are both HSR lines carrying train types G and D.
11. For air services, the cheapest economy fare and, for rail, the fare for the fastest service were assumed. While rail schedules and fares are relatively constant across days (as there is only one service supplier), air flight schedules and fares fluctuate over time due to the existence of competition between multiple airlines and travel agencies. This means that rail fares might be more attractive, especially closer to the day of departure. Data used here represent the average.
12. For air transport, five daily services or higher is considered to be high-frequency service.
13. The new line is planned with a station at San Francisco International airport at one end of the line, but without connection to Los Angeles International airport on the other end.
14. HS2, or high-speed 2, is the HSR line planned from London to the North, Birmingham in stage 1 and later Manchester and Leeds in Stage 2. Heathrow airport is not planned as a station on the line, but a branch line connection is planned as part of Stage 2. The connection of HS2 with HS1, will allow HSR services from Britain to Europe, Paris and Brussels especially.
15. It is evident in Tables 4 and 5 that currently there are many 'thin' (with very low frequency of service) routes served by both air and HSR services, often in competition between the modes.
16. At present, the interairport link between Hongqiao and Pudong Airports (separated by Huangpu River) is very poor, taking one hour or longer. Metro Line 2 that connects the airports is very crowded since it serves and traverses the urban CBD area. At present, the planned Maglev service between the airports has been suspended.
17. Source: http://english.gov.cn/policies/policy_watch/2016/06/30/content_281475383269632.htm. (last accessed on 2/8/16).
18. Source: http://news.takungpao.com/mainland/focus/ 2016-02/3282727.html. (last accessed on 2/8/16).

8. Disclosure statement

No potential conflict of interest was reported by the authors.

9. Acknowledgment

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11. Appendix A.Types of trains services operating in China

Train type and specifications	Main characteristics
G – High-speed electric multiple units (eMU) train	The fastest, long distance train in China, with top speed of up to 300 km/h. [since the Wenzhou collision accident on July 23 2011, the government has ordered the maximum operating speed to be cut to 300 km/h, from 350 km/h. This speed policy is being reevaluated by China railway Corporation (source: http://www.singpao.com/xw/nd/201510/ t20151016_575726.html)].
– electric multiple units (eMU)	Called Hexiehao (Harmony) or bullet trains in Chinese. Designed for top speed of 250 km/h. Have been widely used for serving fast and frequent services between the main cities, such as Beijing–shanghai, shanghai–suzhou and shenzhen–Guangzhou.
– intercity eMU	same as train G with top speed of up to 300 km/h, but runs on shorter distance routes, largely between two nearby cities. For example, the 120-km Beijing–Tianjin intercity railway.
Z – Direct express	With top speed of 160 km/h, this train is also used for long-distance travel. in general, run directly to the destination city or with limited number of stops on the way.
T – express	This train type has limited number of stops on routes mainly in the major cities. The highest speed is 140 km/h.
K – Fast	This train type has a top speed of 120 km/h and has more stops than the T type.
s – suburban	This train type has a top speed of 100 km/h, it travels on relatively short routes, and is largely used for travel (commuting) between the city center and the suburbs.
– Temporary	This series is in operation only during the peak travel time, such as in the Chinese spring Festival and the national Holiday. These services will not be listed in the official schedule. These trains are often subject to delays. its top speed is 100 km/h.
Y – Tourist	This train type largely serves tourist destinations such as popular tourist cities. For example, there are Y-trains departing between Beijing and Qinhuangdao. its top speed is 120 km/h.

Source:

China railway Corporation. 2014. The notice on printing and issuing new Train services, no. 308. accessed December 4, 2015 from: http://bbs.railcn.net/ thread-1499931-1-1.html.

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The rail traveller, pedestrian or customer? Passenger flow and retail: critical boundary objects in HS Station development

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Abstract

Passenger flow has become the new central paradigm for the design and management of high speed stations (Pitsiava-Latinopoulou M. Iordanopoulos P., 2012). The articles explains how and why railway operators conceptualize crowd versus flow concepts and produce streaming techniques that seek fluidity as well as retail value creation. To begin with, a legal-economic analysis replacing the introduction of competition into the rail system and the space pricing methods for commercial leases are provised. Then, developing the notions of flow fertilisation and commercial layout, the author explains the links between flow management techniques and retail intensification, thanks to a 2010-2017 evolution map of Paris Gare du Nord. This leads to a more generic discussion establishing the role of services in pedestrian versus consumer behaviour and micromobility patterns in main railway hubs.

Keywords: regional efficiency, country comparison, high-speed rail.

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1. Introduction

Facilitating mobility within stations entails releasing space to give pedestrians greater freedom of movement. At the same time, commercial station development is causing an expansion in retail spaces, prompting two trends: reduction in the space dedicated to pedestrian movement, reduction in the speed of pedestrian movement (as a result of window-shopping). Mobility and retail development are therefore inherently contradictory realities, as it may seem (Peters D., 2009, Cidell J., Pryterch D, 2015). However, Gares&Connexions, the entity that runs France's stations on behalf of SNCF, claims not only that commercial development and free flowing movement within stations are perfectly compatible, but that they are interdependent. The operator claims that a good pedestrian flow model ultimately makes stations commercially profitable, and conversely, that good retail spaces impact favourably movement. A rise in user numbers creates greater consumer demand, with the result that people spend more in stations (Steinmann L. 2015). Because of this greater commercial intensity, the operator is able to raise the prices of its commercial leases, and therefore obtain an increase in certain kinds of revenue (so-called deregulated revenue). This increased funding opens up possibilities of two types. Either the station operator limits the level of regulated revenues that the rail companies pay to use a station (this may gradually reduce ticket prices, thereby increasing the modal share of rail and therefore footfall within stations). Or the station operator can use this income to expand and modernise the station and thereby improve the conditions of movement (Picard Rachel, 2013).

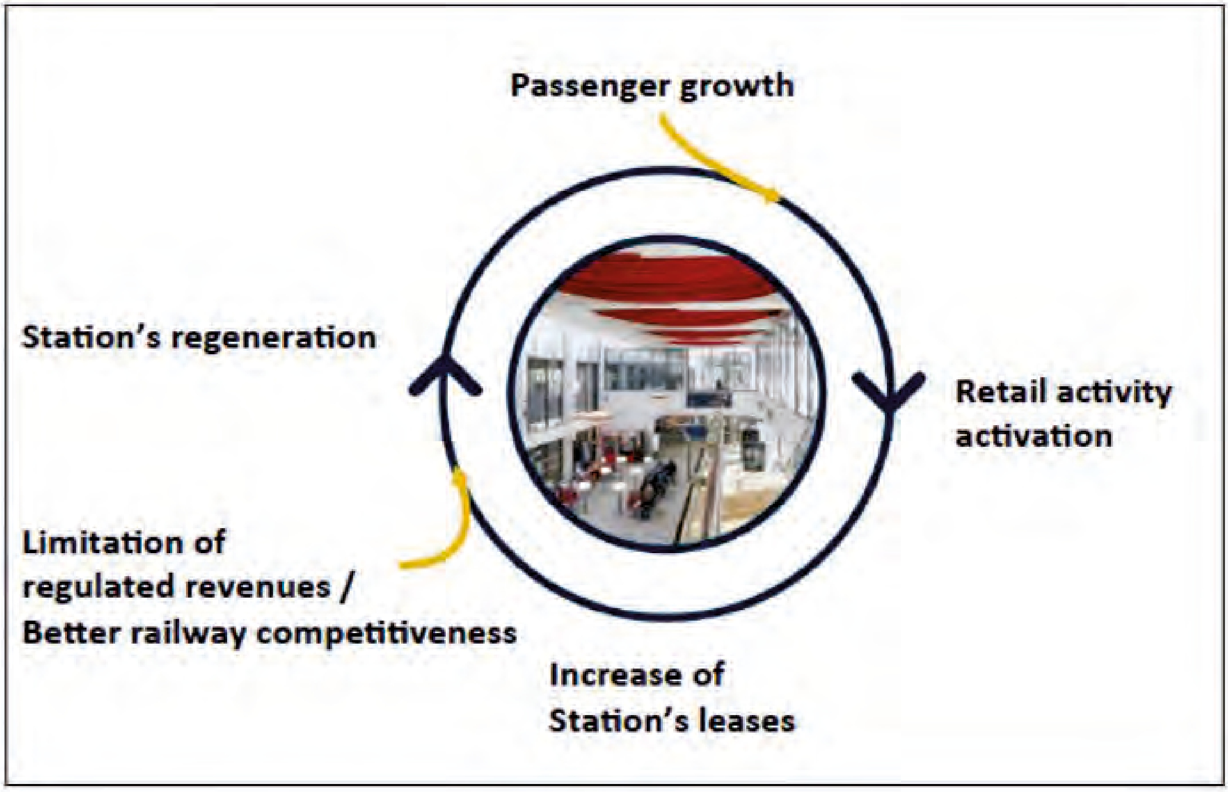


Figure 1. Passenger growth and retail development interdependance

The aim of this article is to deconstruct this circular reasoning (figure 1), by observing the limitations of its real-world implementation. Employing the notions of resizing, pedestrian flow management, intensification of the commercial value of space and the "nudging" of traveller behaviour, we explore the spatial principles of railway station retail development. A first part theoretical approach of the definitions of crowd and flow management in railway stations is presented. Then, we will detail the physical changes the transformations occurred in Gare du Nord between 2010 and 2017, before (part 3) describing more generally the use of retail development as a technique of flow management in railway hubs.

2. Traffic streaming and commerciality in France's big stations:

2.1 The normative framework redefines the station operator's role

Stations and the entities that operate them have undergone major institutional changes in the last 20 years, in response to a European directive requiring the unbundling of infrastructure operation from train operation (Riot E. 2014). Across Europe, station management is gradually taken out of the hands of the historic national rail operators, and station operators must adopt a position of neutrality towards the different rail operators that use their stations. In France, the station operator is still entirely state-owned, but it prepares itself for this opening of the market. Two third of its financiation comes fees paid by the regulated sector (for train access to stations and for the use of station premises: ticket offices, technical premises…), and one third of its income is earned from the leasing of retail space. This means that making stations both attractive for train operators and profitable for retailers are two pillars of a station development strategy.

Figure 2.A Gares & Connexions facts sheet and institutional transformation

Gares & Connexions : railway asset manager
- employs 3700 peoples (SNCF 125 000) - manages 4000 stations - welcomes 10 million visitors per day - manages 2 millions square meters of railway public domain
Gares & Connexions : 2016 main results
- total activity : 1,2 billions € - total fees earned from railway operators and retail: 590 millions € (48 % of total activity) - 210 millions € invested in station regeneration projects
Gares & Connexions 2016 retail activity (deregulated revenues)
- leasing 180 000 square meters in retail - earning 190 millions € in commercial fees

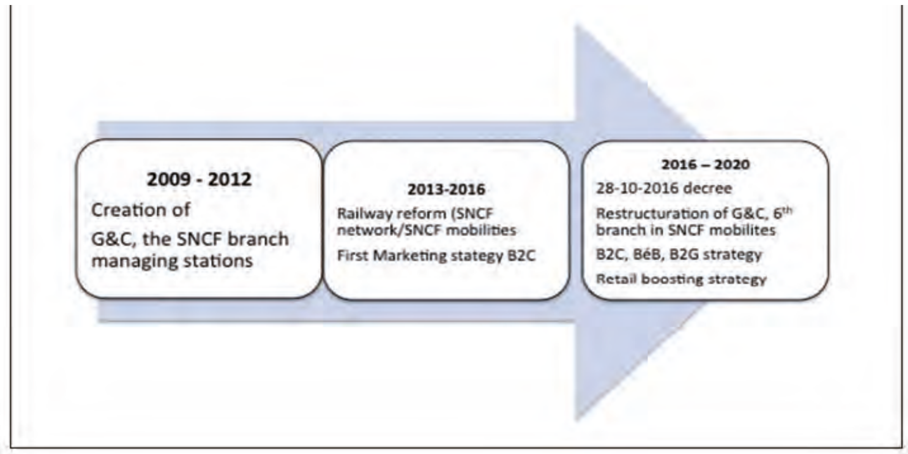


Figure 2.B. Gares & Connexion institutionnal and industrial transformation: progressive automomy from SNCF, anticipating neutrality to any railway operator

2.2 The art of converting a crowd into a stream

Following the legal and institutional changes, the station operator now works with a series of “customers”: partnerships with rail companies, financial and real estate entities, commercial developers (B2B); station users (B2C); other public institutions (B2G). Flows represent a central topic in the negotiations conducted with all three clienteles (Bertolini L, Spit T, 1998). The volume and sociodemographic characteristics of these flows are essential parameters in the profitability of B2B operations. Smooth flows within stations generate customer satisfaction, which is central to a good B2C relationship. Social acceptance of changes to the station, the quality of its integration into the urban environment, its role as an attractive presence in a neighbourhood, are key to good B2G relations (Mulders-Kusumols C, 2005). In social sciences, therefore, flow represents a “boundary object” (Trompette, P. Vinck, D. 2009., Pucci P. 2011), in other words a point of convergence between institutions with different or diverging interests, as well as an object that forms the basis for the construction of a series of political and financial arrangements. In this sense, flow is a construction, it is not just something that is quantified, but something that is produced. Organising a human multitude into a flow consists in a series of actions that are both material and immaterial. Materially, it entails transforming a formless crowd into a series of pedestrian streams in order to achieve performance objectives (relating to movement, commerce and security). In immaterial terms, it entails a series of operations to translate mathematical scales into economic scales. Traffic streaming is both a method and an essential goal of the ongoing changes to stations. It consists in constructing the optimum conditions for passenger navigation around stations, which themselves are envisaged as assemblies of spaces and temporalities with the capacity to fertilise – and maximise – the commercial potential.

The transformation of crowd into flows signifies a profound shift both in social representations and in operational techniques. This change is not historical, yet railway companies try to manage and control crowds and produce flows since a long time and had established a doctrine: different arrival and departure halls, separate areas for freight and passenger traffic, waiting areas and waiting rooms allocated to specific categories of passengers, shopping galleries, and catering areas on the upper floor (Ribeill G., 1996). Nonetheless, the fear of the crowd is still resurging as a threat, while flow appears to be the basis for the development of an economic sector, railway travel retail. The balance between crowd (universe of the street) and flow (vocabulary of networks) entails a series of symbolical and managerial changes.

The crowd evokes both social risk (riots) and the mob, and therefore congestion. Flow relates to technologies, conveying an image of order and discipline. A crowd is made up of an approximate number of individuals, whereas flow is measurable (Fruin JJ. 1971). Each product of a disaggregation of the flow, that is to say the pedestrian can receive a message and become manageable. Shaping a flow signifies therefore the conversion of a mass of travellers into atomic units possessing each particular temporal and spatial attributes. Station flow management, hence, is a field of engineering is anchored in traffic management techniques drawn from road engineering. Today, station flow management, as a combination of scientific knowledge and empirical know-how is being integrated into a new field based on two metrics.

In geography, a metric is more than a measurement of distance, it is a way of determining relations of magnitude and of ordering space and time. The station organization during the peak hours and the evaluation of time passed into the station (the “allowance time” i.e. the time passengers allow before the scheduled departure time of their train, Gasnier A, 2007) are key informations to calculate the station’s optimum volume and planification. It results of a mathematical equation, including the number of users present at a given moment (the rush-hour), the duration of their presence in the station and the walking speed of each pedestrian. Then, once each of these pedestrians has the capacity to react to informational stimuli, the station operator is in a position to manage the station around flows, by means of audible or digital messages relating to both planned and unplanned events (ticket sales, train departures, etc.).

2.3 Flow management, condition and result of railway station commercial intensification

The French station operator explains the professional shift towards flow-based management by the very sharp growth in station use, presenting this both as a proven fact, an unavoidable process that demands heavy investment in expansion, and at the same time as a strategic objective in the construction of the previously mentioned virtuous circle. True, the rise in the number of rail travellers is an observable reality, even if a certain ambiguity remains in the projections for station occupancy. The rail company produces traffic projections and the station operator produces wish figures for growth in station “users” (travellers + friends and family of travellers + 20% local community). Every presentation of a station upgrade project starts with a reminder of this very high growth level, in the same time generating a sense of anxiety (the danger of the crowd envisioned as mob, factor of congestion), and legitimating the implementation of the streaming model justifying retail growth.

Article R 145-6 of France's Commercial Law defines the commerciality of a station as “the extent to which it enables tradespeople who do business there to make profit as a result of the qualities of the place alone, regardless of the abilities of the store operators”. The potential commerciality of a store depends mainly on its location and relative position to pedestrian traffic (Dang Vu H., Jeanneau H., 2008). An improvement in these criteria can justify an increase in the value of the lease, and therefore an increase in rents and fees. With the setting up of the subsidiary Retail&Co in 2016, the French station operator approached railway station retail with the intention of maximising the rental value by combining growth in the numbers of station spaces with growth in overall station commerciality. For the 400 French stations containing at least one retail outlet (out of the 4000 across the country), the operator has announced growth targets of 50% in retail area (300,000 square metres by 2025) and of 100% in fees from the deregulated sector in less than 10 years (Ropert P, 2015). The intensification plan is very evident. The station operator’s objective is to take advantage of a travel retail sector in which it is still a minority player (around 30% of market share, compared with the airport sector players, which have carved out 50% of the potential market). What is at stake here is nothing less than a transformation of the fundation of railway activity. By applying new flow streaming principles to station spaces, the company is no more as manager of a major asset burden (2 billion square metres) but a firm specialisd in harvesting pedestrians and generating profits from their movement (Baron N., Roseau N., 2016).

3. Intensification of traffic flows and commercial potential in Gare du Nord

3.1 Gare du Nord : socio-spatial assessment

Gare du Nord is a transport hub that offers a wide variety of lines and rail provision: regional trains, high-speed trains, intercity and interregional trains, regional express network (RER) and metro. The station's most recent aboveground architectural changes coincided with the arrival of high-speed rail in the 1990s: TGV to Lille in 1991, Eurostar service for the link with England in 1994, then Thalys in 1996 to cities in Belgium, Germany and the Netherlands. In the early 2000's, further redevelopment was carried out on the western part of the station, its facade and basement, in order to facilitate the connection with the RER and the Metro, with the inauguration of a shopping street at basement level (level -1), and a big transfer lounge in the sub-basement (Level -2). This reinforced the vertical structure of the station into four levels open to passengers, two (first floor and sub-basement) accessible following ticketing controls, the other two (surface and level -1) free access. Gare du Nord is mainly a commuting station, (75% day dwellers) many of them moving between different types of rail service. As a result, there is intense vertical and horizontal movement between the four levels, particularly at rush hour, although not creating a universal mix. On the contrary, the occupancy and movement regimes in the station's different levels are socially very distinct: the top level, set aside for the cross-channel train, is occupied by international customers, with large spending capacity, whereas the two underground levels are used by regional commuters from the northern suburbs, the poorest in Ile-de-France. The surface hall distributing passengers west to east towards the Thalys, TGV, Intercity and TER regional express trains is, technically therefore used by the widest range of customers (leisure, business, commuters, locals), whether boarding at this level or passing through to move to another level.

Figure 3. The vertical structure of Paris Gare du Nord. View of the concourse (level 0), mix of retail facilites and passenger stair to Eurostar boarding in foreground. In the bakcground, main information pannel, removed in 2015.

Flow data at Gare du Nord are tremendous: at any given moment during rush hour, the number of people within the station is around 20,000, which every day generates some 650 to 700,000 pedestrian movements or, in round figures, annual footfall of some 200 million people. Traffic surveys forecast a 26.7% increase in passenger traffic by 2020 (up to a capacity of 25,100 travellers per day) resulting from the introduction of new and larger rolling stock. The current 750-seat TGV Eurostar is to be replaced by a 900-seat model, while the regional trains are shifting from a capacity of 570 passengers to double decker vehicles with capacity of up to 1500 people. This increase in flows will affect the sections of the cross-platform differently: on the western side, an additional 20% passengers will be disgorged from Eurostar and Thalys, whereas at the eastern end, TER is likely to handle a further 34% traffic.

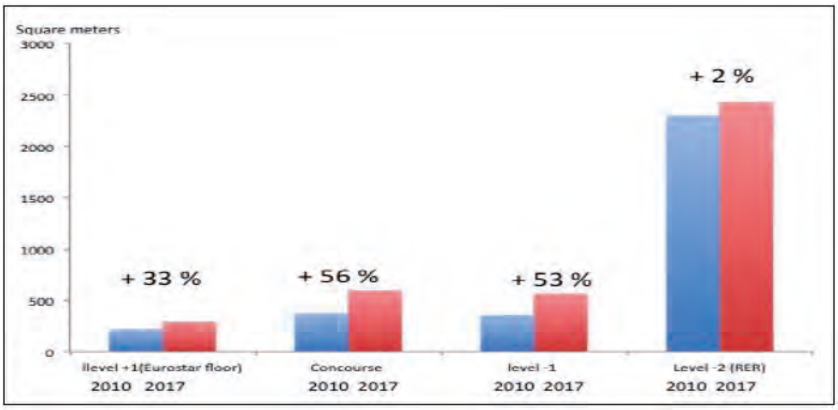
Figure 4 : Paris Gare du Nord facts

Building
- Date of construction (Hittorff Architect 1889 then 1900) - Façade (and concourse) length : 180 meters - Total surface: 80.000 m2 - Retail: 110 Stores (2015)

Frequentation
- 2012: 19.800 passengers at peak hour (Commuters 75 %) - 2020: 25.100 passengers at peak hour (+26,7 %) - First european station : 700.000 passengers a day / 200 millions a year

It seams clear that store distribution and commercial profitability at Gare du Nord reflects of station's flow segmentation. The current flows account for the presence of 110 retail outlets in the station, generating €16 million in annual revenues (excluding parking and advertising). The retail areas are very unevenly distributed across the different levels, but the contrast between the profitability of the levels and store types is even greater. The huge transfer lounge in the subbasement was redesigned some 10 years ago and provides 2400 square metres of retail space, with around forty outlets, laid out like a mall with lines of shops clustered in blocks of two or three. There is no major plan to change the commercial dynamic in this zone, apart from the ongoing replacement of the brands as leases come to an end. For this reason, we will not focus on this level, nor on the basement level above, which is laid out on a street model with ground-level shops, though there are here ambitious plans for this space (a 53% increase in retail space, but no changes in articulation between flow and commerciality). Our interest focuses now in the surface concourse and the Eurostar zone (level +1) living respectively 56% and 33% increase in retail surface, and demonstrating the reciprocial optimization of flow management and commercial optimisation techniques.

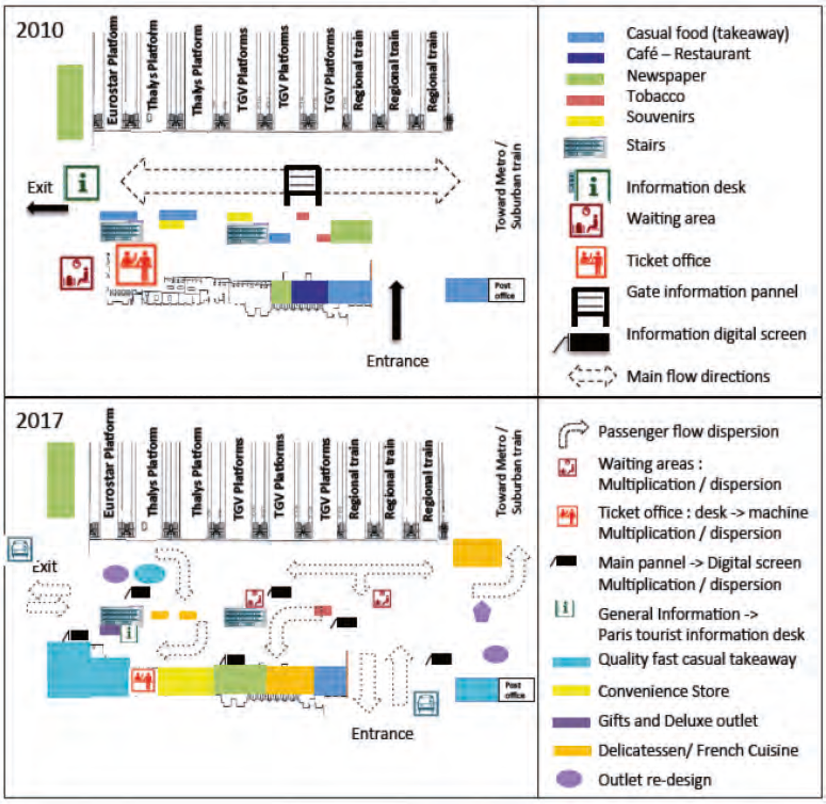
Figure 5. Retail surface extension in the 2010's at Paris Gare du Nord



3.2 Before - After comparison of concourse and eurostar level

The changes made to the layout of these two levels between 2010 and 2017 show the application of flow streaming principles. This station is, in fact, a shallow building with severe architectural constraints: the concourse has a depth of no more than 30 metres between the shops against the facade and the platforms (Clozier R., 1942). In 2010 it has two entries (heritage of arrivals and departures doors), 4 escalators connecting it to the floor below, and services and shops supply: fast food, newspapers, tobacconist, sweets and souvenir shop. In addition, under the first floor mezzanine, there was a waiting room in the eastern corner, ticket counters along the facade, along with a line of ticket machines and another row of food outlets (snacks and sandwiches). In all, the cross-platform contained 7 brands with 12 sales outlets, dominated by the Relay brand (with 55% of the surface area), the rest being mediocre quality food outlets.

Figure 6.A 6.B Retail relocation and flow optimization transformation : Concourse

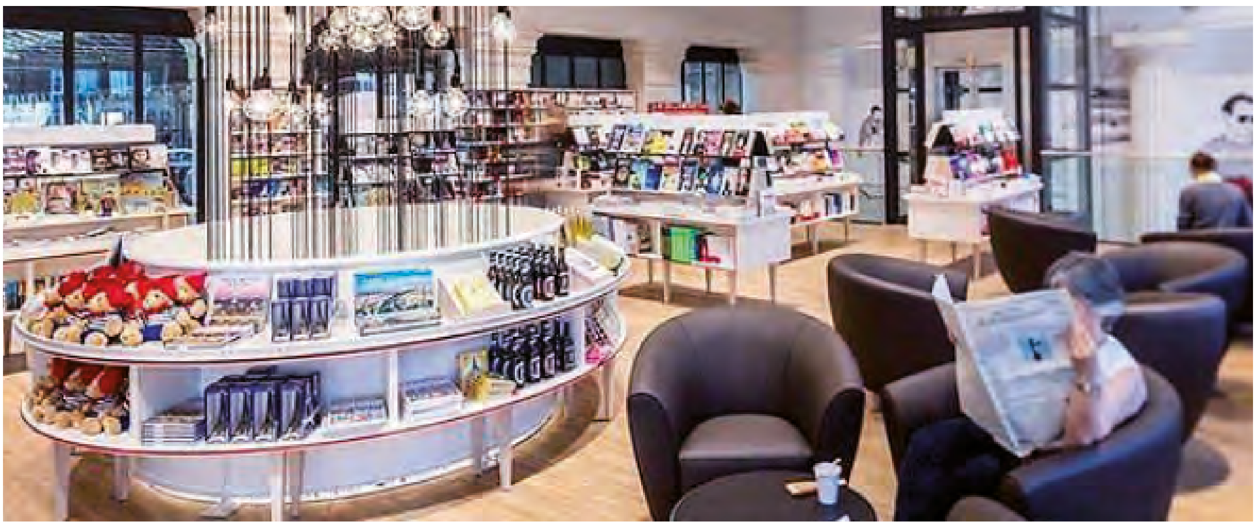


The Eurostar floor was organized very differently for legal reasons. At the top of the escalator was the Schengen border post, with customs and police inspection points, then a long, narrow shopping alley with 7 sales outlets, leading on to waiting and ticket inspection zones and a final waiting room. Despite the very tight spatial constraints of this system of alleyways, allowance time here was very long and the shops so scarce that, despite their ordinariness (fast food, newspapers), they were quite remarkably profitable, notably in terms of returns per square metre.

Above long bibliographical capitalization on commerce strategy at Gare du nord (Perier M., 2003 and Oki-Debayles K., 2008,) personal observation and 2010 and 2013, and then in 2015 and 2017 gives noticeable modification both in traffic flow organisation and retail outlet location (figure 6). We clearly understand that two previous problems with pedestrian mobility have been partly solved. First, permanent crowding – not under, but in front of and behind the central noticeboard – hampered flows onto or off the escalators, creating a shearing effect (movement of people blocked by a fixed and compact crowd) at rush hours. Second, the general congestion of the zone and the immobility of passengers around the noticeboard restricted the profitability of the shops located against the wall, which were also disadvantaged by their distance (approximately 20 m) from the most attractive part of the hall and by the lack of light (because of their position under the mezzanine).

In 2017, following changes have been made. First, the central noticeboard has disappeared and been replaced by a profusion of digital monitors scattered everywhere. This reorganisation was done to disperse travellers and keep them moving throughout the whole space of the station, in order to avoid the shearing effect in the central zone. Second, the row of ticket offices has almost disappeared, since most tickets are now bought at machines or online. This has released space for movement and shops. The latter are no longer contained in small kiosks but in larger "shells", alternating with information points and short-wait micro-lounges (a quiet zone to the west is still set aside for longer waiting times). Better lighting and plexiglass walls generate transparency. The result, therefore, bigger place, denser space obtained by more partitioning. Shops have undergone four types of transformation: relocation and enlargement, diversification and renovation of the retail range (Briard C., 2015, Bertrand P. 2015). The dominance of the Relay brand has not been affected, this chain has opened a specially designed “concept store” offering not only books and newspapers, but also fine food (Fauchon), a café, a reading lounge. As a sort of station in the station, Relay combines the functions of waiting-room, information desk and travel retail store (Briard C.,2016).

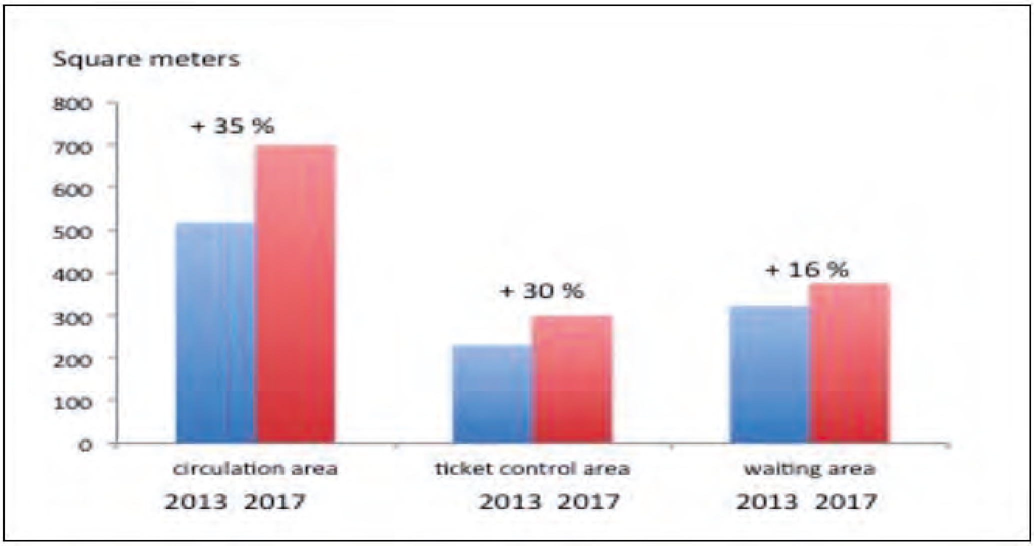
Figure 7. Relay “concept store” design: the convergence of information, consumption and waiting functions appart from the main stations spaces.



What is observed in 2017 is the result of a gradual renewal of leases made by Retail&Co conducted with a commercial strategy : moving the fast food offering upmarket and increasing the diversity of eating options. The concourse hosts several 'lab' stores testing out experimental products (highquality pastry) and formats (cafes on wheels, pop-up shops, show-rooms). The longitudinal distribution of the brands along the concourse reflects the application of a differential in commerciality and the adaptation to the different types of travellers. In the east of the hall, near the street entrance, a post office, a tobacconist and an affordable food outlet enable morning commuters, who have the shortest allowance time (often less than 10 minutes), to do routine shopping without wasting time (coffee, water, newspaper). For TGV customers, who board in the middle of the cross-platform, the allowance time goes from 15 minutes in the case of frequent business travellers to 30 or even 45 minutes for leisure passengers. Ad, in 2017, these travellers are exposed to a wider range of options : apart from routine shopping, they may succumb to impulse buying (gift, chocolate, cakes), and even if they resist, if they are themselves commuters (which they often are), they will be exposed to the same brands on their return in the evening and may perhaps be prompted to make a more considered purchase. Finally, the area closest to the Eurostar and Thalys boarding point, to the west, shows a particular concentration of "chic" new brands (special teas, french cuisine) taking advantage of maximum proximity to international customers (for another approach in Brussels Stations, see Ingelgem G., 2015).

3.3 Eurostar floor Level +1: integrating movement and consumption logics to maximize spatial profitbility

Figure 8 Enlargement and redistibution of surfaces at Level + 1



The changes identifiable on the concourse as well as in the upper level are taking place through the renegotiation of B to B contractual conditions, which produce both higher revenues for Gares&Connexions and a new spatial experience for travellers. With a small increase in the surface area accessible to the public (achieved by reducing the space allocated to the customs offices and the police, who are shifted upstairs, without public access), pedestrian space has been increased by a third and waiting areas by 86%. Here, passengers are obliged to wait for long time : they must pass the police checkpoint, then the boarding. Flow congestion has been reduced through the installation of more gateways and more technology (passport recognition and face recognition). Consequently, the long passageway has been converted to a free strolling area, where people can freely shop. The highly profitable corridor of shops remain mostly, but its continuity is broken up by mini confortable lounges and a shallow counter with barstool type chairs, where travellers can lean to enjoy the view below. Then there is a second retail module leading to a large and luxurious lounge (for the importance of waiting areas Van Hagen M., 2011). This 2010-2017 comparison leads us to recontextualize and discuss, as in Pitsiava-Latinopoulou M. Iordanopoulos P., 2012, the place of design in connecting flow management and commercial development.

4. Eye and foot, shops and surfaces, movement and value creation

4.1 Beyond station commodification

The interplay between flow reorganisation and retail space rearrangement in Gare du Nord shows how railway institutions (Gares&Connexions and its subsidiaries, Retail&Co for retail space management, AREP for arrangement and design) are introducing flow management as a way to maintain movement and produce value. The guiding principles of the changes observed since 2010 are inspired by a fast-growing science of mobility, driven by transnational trends that draw on airport development principles and on railway architecture and design. These chages show us very materially the railway adaptation to a new legal and institutional environment. Here in the Gare du Nord, disadvantaged as it is compared with its counterpart, Saint-Pancras Station in London, the station operator has taken every opportunity to enhance its image and is preparing, in the near future, to offer SNCF and its competitors equal excellence in the range of B2B and B2C services. The hypothesis we have now demonstrated of the interdependence between processes intended both to make spaces of movement more efficient and retail outlets more profitable, now raises further critical questions on the new nature of station's spatiality and commerciality.

Our analysis shows that flow management, generates additional consumption, in other words greater profitability, not only because of the increase in passenger numbers or retail spaces, but through the intensification of commerciality produced by spatial rearrangements. The increase in the average sales transaction and in purchase frequency, the diversity of consumption modes (routine or impulse buying, automatic or considered purchase) reflect parallel nudging processes of movement activation and behaviour modification among clients. In order to gain further understanding of the determinants of these events (choice of movement and impulse to buy), we now need to go beyond a rationalistic conception of commerce and beyond a mere mechanistic approach to flow, by debunking two illusions.

The first illusion entertained by station traffic engineers is that the traveller’s allowance time can be divided up in the same way as Euclidean space, that one can identify a time of arrival at the station, then a time of information searching, then a time of access to the platform and waiting. This division is the only way to individualise an allowance time that is itself divided into two parts, the first under conditions of stress (when the traveller’s movement is determined by the need to identify the right platform and check the departure time), the second without stress and allocated to other activities (waiting or shopping), hence waiting rooms and stores. The central component of traffic streaming, the nudge, seeks to use aural, visual or digital messages to modulate the decisions of pedestrians, to encourage without forcing, influence without pushing, and gently to prompt individuals, through the appeal of brands, or gregarian attitude, to move in the right directions at the right time. However, this mathematical partitioning fails to take account of the reality of the traveller’s experience, in other words to the chaos of sensations, emotions and states of mind in which they are immersed from their arrival in the station (Löfgren O., 2008), with the result that time as they experience it is not clock time, divisible into sequences, but subjective in its extent and duration.

The second illusion is one held by observers of the changes in the stations, who mock the corporate rhetoric around customer focus and question the real utility of station retail in terms of the assumed needs of travellers. Are all these gift shops and fine food outlets really necessary? This debate on the commodification of stations has prompted comparative research on stations and airports and on the connection between public and private in the management of potentially useful transport spaces. However, for our purposes, it would seem more useful to go beyond the simple measurement of commercial provision, and to explore the paradigm shift whereby the pedestrian is more and more - at the same time - reacting as a customer.

4.2 Harmonizing visual consumption and movement patterns

Any science of station flows and more generally of pedestrian mobility in dense conditions must firstly take into account the conditions of spatial visuality and visibility, and secondly the different perceptual regimes of users (Brighenti A. 2010). This new episteme establishes the station not only as a space of flows, but first of all as a space of looking, defining the user not as a pedestrian but as an observer (moving observer/observing mover). The pedestrian's behaviour therefore arises from the succession of planes of view presented as he moves, in the same time he moves, which at each moment defines the field of visibility and therefore the range of actions open to him.

And precisely, the before and after studies 2010 - 2017 conducted in Gare du Nord confirm that the rearrangement of the flows and retail spaces has brought about a enormous change in the conditions of visibility. In a way, stations are designed for nearsighted people, in another way for longsighted or vista lovers. The cross-platform, initially structured by large clusters (waiting at the back, shopping at the side, departure board in the middle) has been fragmented. Because of the proliferation of retail outlets, commercial intensification has infiltrated throughout the station (including moving and waiting areas). Already saturated with sensory and visual stimuli, the station space – a space both fragmented and filled – nudges the customer through a series of enticements, prompting two major forms of mobility. Within a visual field of some 10 to 20 metres, the customer perceives – simultaneously – a short empty space to move through, a first mass of informational signals (signs, platform number) and commercial messages (shopwindow, brand, billboard…). The act of buying no longer entails a break or a detour, but has arguably become a simple gesture one can do without stopping the movement logic. Moving customers navigate or drift, from one spot to another, in zigzags, from one local sphere to another contiguous zone (from the screen to the shop, then to the ticket punching machine, then to the train).

The second flow paradigm lies in the construction of a new optical relationship between movement in the station and retail function. The installation of a two-level starred restaurant on the crossplatform, the vertical extension of the Relay outlet, and the reorganisation of the Eurostar mezzanine, all these examples proof that the provision a panoptic view of the flow is a station design trend. In any of these three stores, the pedestrian can appreciate the long view, the wide spectrum, the aerial perspective, a "stationscape" which is a source of visual or sensory enjoyment that itself creates commercial value. Thus, the place with the best view of the station is no longer the station master's office, but Eurostar floor or deluxe restaurant, that are the station's smartest retail outlet. From here, the user is no more a pedestrian (he feels aristocratically detached from the dangerous crouwd or from the coercitive flow. Thus, the traveller unconsciously consents to buy an expensive sandwich in an outlet, topologically perched above the fray, and the price includes the enjoyment of the show laid out before him as he eats.

Figure 9: Retail verticalisation, flow visual consumption as part of retail value (a: from above, B; from inside) NB authors photography

4.3 Trademarks as landmarks: spatial thresholds and punctuations within the station space

This in-depth study of the spatial changes at Gare du Nord has more to add to our understanding of the connection between traffic management laws and retail layout marketing techniques. First, a reminder: retail outlets in stations have always played a role in spatial orientation. However, in the context of enhanced commercial density and traffic intensity, this role becomes even more essential. Today, one can no longer arrange to meet under the main information board, since it has gone, or under a digital screen, since there are dozens of them. So retail brands play an even more fundamental role than in the past. Their features (position, orientation, height, colour) punctuate perception of the station space.

An examination of social networks shows that young people arranging to meet at Gare du Nord do not choose the rail company's information kiosks as their rendezvous point, but the favorite outlet. As a static landmark that stands out in the human flood, a trademark is as effective a way as an information screen to negotiate the movement through space, to construct access strategies around obstacles. The more the station space fills up with discontinuities, the more layered and fragmented it is, the more the passages through it must be both marked and softened. Retail spaces act not only as waymarks for the different spaces, but become pivot points and thresholds in their own right. So shop windows disappear, partitions become transparent, retail kiosks become rotundas or acquire wheels, operating as junctions between between passport control and ticket inspection in the Eurostar mezzanine), or between concourse and departure platform.

5. Conclusion

Even before the transfiguration scheduled for 2025 by the architect Wilmotte (Wilmotte et al 2016) which will give it a new bridge and dozens of additional retail outlets, Gare du Nord shows how a process of flow engineering and the strategic management of commercial leases can combine to transform the conditions of movement and consumption in stations. We have seen how, in a classic space-time metric used by traffic mannagement ingineers, the pedestrian is conceptualised as a rational individual who seeks to optimise his movement. In this view, a retail outlet is only seen as an embellishment that contributes to customer satisfaction, but alos as an encumbrance. Following this research, however, we can see that there is a much richer connection between movement and commerciality in a station, and that the retail outlet is a key to the flow management process. For an even closer analysis, this research would need to integrate more field research (and more stations analyses) andcould focus on two areas. One would entail mapping the role of shops from and within the pedestrian's visual cone in order to achieve a finer measurement of the value added (or subtracted) through the incorporation of the logic of flows into commercial production. The other research direction would be to develop a cognitive approach to movement in stations in order to better understand how the pedestrian drifts in radar mode within this fragmented density, this material and sensory labyrinth, from one attractor to another, between positive and negative stimuli and excitements and, also, with the help of digital devices (Vincent S., Ravalet E. et Kaufman V., 2015).

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South Madrid and High Speed. An example of symbiosis

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ADIF[1]

Abstract

The process of transformation of Madrid-Puerta de Atocha station runs parallel with the evolution of the urban space around. Railway was early implemented in an area outside the city wall that had been the object of important urban projects in the 18th and 19th century.

Throughout the 20th century, Atocha area concentrated a significant number of public buildings, cultural and teaching facilities, presided by the General Hospital and its ancillarybuildings.

A project by Alberto del Palacio provided in 1892 the iron canopy, whose tympanum has beenthe iconic image of the station since.

After decades of dereliction of the area and serious threats to heritage buildings on the mid 20th century, a new sensitivity towards industrial architecture appeared on the 70's. This fact helped to preserve the historic station and made it the terminal for the new HS line Madrid –Seville.

The improvement of the commuter network in the 80's and the implementation of the new High Speed line in 1992 meant a revolutionary change into citizens' perception of railway and a key dynamic factor on railway renewal on the 21st century. Atocha is nowadays the undisputed top railway passengers' hub in the country.

A parallel process of urban renovation and cultural concern triggered the implementation ofcultural facilities such as the Prado Museum enlargement, the appearance of new ones, such as the Thyssen-Bornemisza and Reina Sofia Art Center, and the successive creation of other complementary ones that turned the area into the Golden Triangle of Art, one of the highest concentration of world-class art galleries on Earth. Private investments have taken advantage of the situation and enhanced retail and accommodation sectors. Atocha has obviously benefited from the quality improvement of its surroundings.

In summary: HS success relies not only on its obvious technical and operational advantages, but also on the boundary conditions of its main destination.

Keywords: high-speed railway, urban development, intermodality, Atocha, Golden Triangle.

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1. Introduction

These pages are dedicated to explain the evolution of an urban space originally located out of the city walls, how it acquired a central position when railway was implemented and the way that it has increased its symbolic and cultural character in parallel with the development of the High Speed railway, highlighting the multiple ways in which the two processes are connected.

In order to avoid repetition of long names, a few acronyms are used. A list at the end of the article, before the bibliographical references, clarifies the issue.

Some urban references have been simplified. The author has chosen the terms 'Atocha Station', instead of the official denomination 'Madrid-Puerta de Atocha station' and 'Atocha square' in reference to the urban space that no one but the official maps name 'Glorieta del Emperador Carlos V'. The two main parts of the station are simply named 'Commuter station' and 'HS station' or 'HS terminal'

2. Railway and the City

Railway appeared in the mid 19th century as a revolutionary mode of transport that changed dramatically the way people and freight moved. Up to this moment, travel times had not substantially improved since the moment when Romans established a road network that covered the whole empire.

Railway stations were originally implemented outside the urban walls. Describing the station as the city gate is even a cliché, but in fact a deeply based one, as in the first decades of railway development thousands of new station buildings were located exactly in front of the physical gates of city walls.

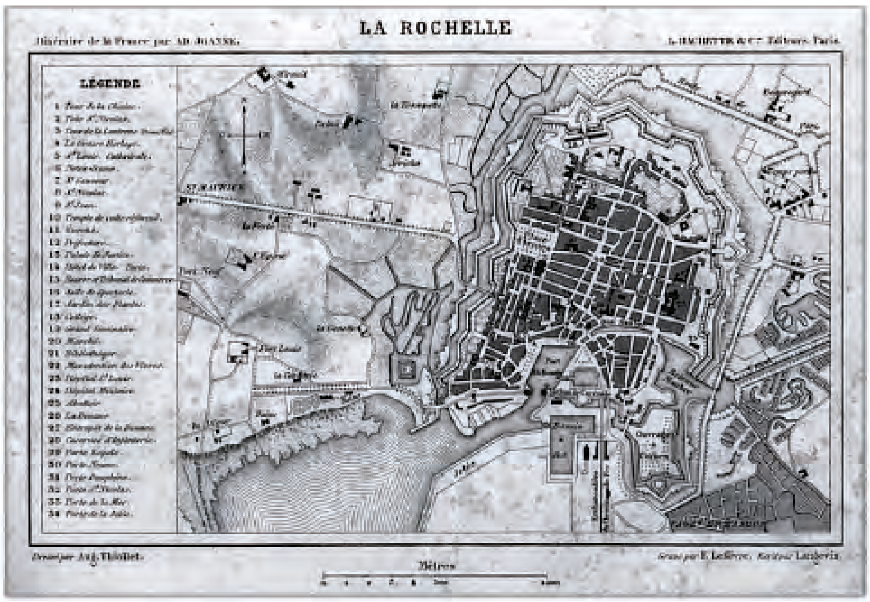


Figure 1: Station located by the city walls. La Rochelle in 1862. Itinéraire de Poitiers à la Rochelle, à Rochefort et à Royan. Source : Wikipedia.

When railway became the undisputed mass transport mode, the image of the station was the first impression of the place for the newcomer. This fact has remained unchanged. Railway operators and infrastructure managers know that stations represent a substantial part of passengers' experience, even if they take a tiny part of travel time.

Their locations turned central due to cities' growth, in many cases fostered by railway itself. In these almost two centuries past, cities and railway have had a parallel development, although their relationship has been somehow asymmetric, as railway's demanding geometry established tough conditions. The flexible tissue of the city had to adapt to the rigid lines of tracks. Costly civil works frequently raised barriers and segregated neighbourhoods.

On the other hand, railway injected plenty of energy on cities' activity, fed their growth and ordered their surrounding territories.

Madrid and the area around Atocha station are a good example of these permanent dynamics.

3. Atocha urban area: origins and evolution

3.1 Outside the city walls

Prior to railway implementation, Atocha was an external urban area. Since the arrival of the Royal Court to Madrid in 1561, the city exceeded its medieval walls and was successively encircled by other enclosures with no military purpose, but only for taxation. The latter was built in 1625. One of its openings was the so-called Atocha gate, located in a spot close to the current roundabout and the fountain in front of the station.

Figure 2: Atocha gate and the Artichoke Fountain in 1840. Source: Wikipedia.

The gate stood at the edge of a leisure zone, the Prado (meadow), a promenade that provided shadow, water and fresh air to Madrid citizens in summer hot season.

Outside the Atocha gate started the road to Valencia, a very important connection with the closest harbour. It was also the way to Vallecas, a small town that supplied flour and bread for the court. In the near vicinity stood the sanctuary of Atocha, a very popular place of worship patronized by the monarchy which gave its name to the area.

3.2 The Age of Enlightenment

During the reign of Fernando VI, around 1750, a network of tree-lined avenues, the so-called Baroque Fork (Tridente Barroco), was designed and built by Joseph Salcedo, a military engineer. The pattern of roads organized all the territory between the south wall and the river with no purpose of fostering the enlargement of the city, constrained by the taxing walls.

Figure 3: Paseo de las Delicias in 1770 by José Bayeu.

Source: Museo del Prado.

Figure 4: The Baroque Fork designed by Joseph Salcedo.

Source: http://www.madrid.org/cartografia/planea/cartografia/html/web/index.htm

The Prado, that was inside the walls, kept its leisure character, receiving an increasing number of visitors. It was divided into three parts: the northern section named Prado de Recoletos, the central part called Prado Viejo or de San Jerónimo and the southern section or Prado de Atocha, now the eastern limit of the old station, totalling some 2 km.

In the corner of calle Atocha, a hospital was built in 1603 under the initiative of King Phillip II, with the purpose of unifying many private and underfunded assistance foundations. In the 18th century, the new enlightened mentality of King Charles III government fostered the ambitious project of a modern building, following the example of the Albergo dei Poveri, sponsored by the same king during his reign in Naples. The project by royal architects José de Hermosilla and Francesco Sabatini occupied an area substantially more extended than the previous building.

By the death of King Charles in 1788 the works remained unfinished. Only the west courtyard and the north wing were built and operating. In 1832 the building was complemented by the Royal College of Surgery in a neighbouring plot.

Figure 5: General Hospital section Source: www.museoreinasofia.es

Figure 6: General Hospital North wing, now Royal School of Music. Source: Luis Garcia in Wikipedia .

In 1763, José de Hermosilla, also under the patronage of King Charles government, designed an essentially enlightened project: an urban promenade along the Prado, surrounded by buildings with a cultural and scientific use: the Royal Botanical Garden, more extended than now, linked to the Natural History Cabinet, now Museo del Prado.

Figure 7: Paseo del Prado watercolour by Isidro González Velázquez. Source: BNE

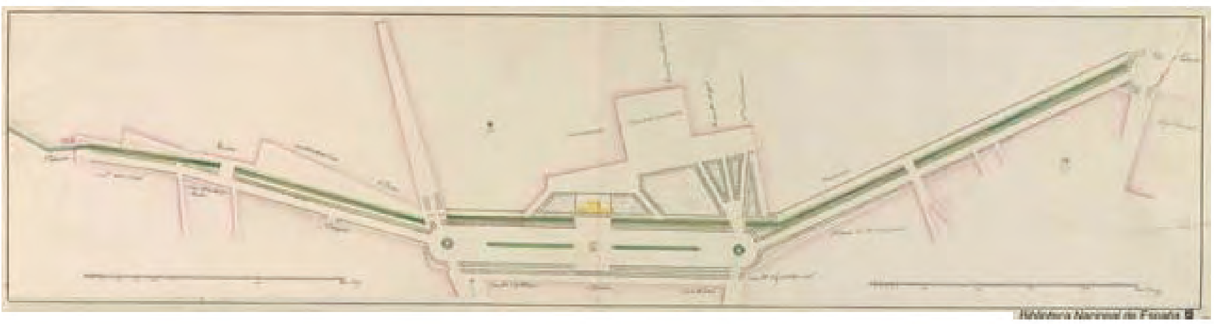


Figure 8: Paseo del Prado Project by José de Hermosilla. Source: BNE

The Royal Observatory was established in a nearby hill, beside the grounds of the Retiro Royal Gardens. All three works were projected by Juan de Villanueva, the best known Spanish neoclassical architect.

The design was completed with fountains representing Cybeles (Earth), Neptune (Sea) and Apollon (Sun) and other minor sculptures.

All three remain in place and make the place one of the most beautiful avenues in Madrid and one of the best examples of enlightened urban design. The Artichoke fountain was set at the edge of the promenade, in the square besides the gate were the Prado de Atocha began. Now a bronze reproduction occupies its place.

Figure 9: Royal Observatory, by Juan de Villanueva

Source: http://www.historialia.com/

Figure 10: Royal Cabinet of Science, by Juan de Villanueva

Source: http://www.historialia.com/

Figure 11: Royal Botanical Gardens, by Juan de Villanueva. Painting by Luis Paret.

Source: Museo del Prado

The area where the station stays remained outside the city walls up to their disappearance in 1868. Prior to this date many changes had taken place.

4. 'A deadly beast arrives, flashing fire and smoke'. Railway in the 19th century

4.1 Early railway development

A hollow area south of Atocha gate, the bed of a modest brook, was chosen to start the second railway line in the country, from Madrid to Aranjuez, in 1851. The line was the first section of the railway to Alicante, intended to connect Madrid with the coast, completed in 1856. A modest building called Embarcadero was the first terminal station. Twenty years after its opening, Atocha was the central terminal of the company MZA, whose lines connected the most important cities in the south and east of the country.

Figure 12: Embarcadero Station in Atocha. Madrid Aranjuez line opening in 1851. Source: FFE

4.2 Station enlargements

The first station soon proved insufficient for the increased services. A new building, designed by Victor Lenoir in 1863 was set in front of the old station to house MZA offices. In 1880, a railway by-pass connected Atocha with the Norte station, the head of MZA competitor Compañía del Norte. This new link totally changed the character of the south part of the town, which turned into an industrial area. This character remained unchanged until the second half of the 20th century.

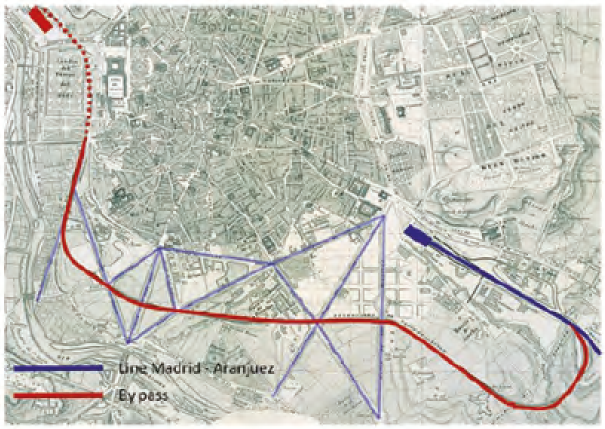


Figure 13: By-pass line between Atocha and Norte stations. Source: Ferropedia

A new building designed by engineer Alberto del Palacio substituted in 1892 the old 'Embarcadero'. The shape of its canopy turned into an urban landmark for 100 years and is still the most identifiable element of the station nowadays.

Figure 14: Atocha station projected by Alberto del Palacio. Source: Via Libre

5. Urban development in the 19th Century

5.1 Breaking the limits

On 1860 Carlos María de Castro projected the Madrid urban enlargement plan that bears his name. The plan forecast the city growth on the north, west and south. The whole Atocha area was redesigned, although the existing railway obliged to adapt the regular pattern of the plan to the existing railway facilities and respected too the layout of the baroque avenues from 1750. The demolition of the 1625 wall by the revolution called 'La Gloriosa (The Glorious)' accelerated the process.

5.2 New neighbours in town

In these new grounds, redesigned by the square pattern of Castro's plan, other relevant buildings dedicated to culture and politics were added:

- In 1875, Dr. Pedro González Velasco founded the Anatomic museum, nowadays National Anthropology Museum.
- In 1897, the Ministry of Fomento (Agriculture, Industry and Public Works), designed by architect Ricardo Velázquez Bosco, was built on the grounds of the Royal Botanical Garden. The same building currently houses the Ministry of Environment.
- In 1899, the Pantheon of Illustrious Men was partially established on the grounds of the former Dominican convent of Atocha. Due to the lack of funds, only the courtyard and the campanile were built.

Figure 15: Carlos M. de Castro enlargement plan and public buildings implemented.

Source: www.madrid.es and Juan Ayrault

Figures 16 – 17 – 18: Ministry of 'Fomento' –Anatomic Museum –Pantheon of Illustrious Men
Sources: https://artedemadrid.wordpress.com/2011/11/14/el-palacio-de-fomento/
http://www.historiadelamedicina.org/Instrumentos/instrumento_157.html
http://urbanity.cc

6. Railway in the 20th century.

6.1 Madrid Railway Access Plan

The new station by Alberto del Palacio soon exhausted capacity. Several plans were designed like the one in 1924 to enlarge the terminal, but were never carried out.

Madrid metropolitan area grew up to

900.000 inhabitants on the early thirties. Railway accesses were congested and connections between southern and northern stations slow and inconvenient: the by-pass line between Atocha and Norte (now Príncipe Pio) was only used for freight.

After several unsuccessful plans, the Republican Government (1931-1939) promoted a new Madrid Railway Access Plan in 1933. Its main objectives were the construction of a new station in the north, a tunnel linking Atocha with the new northern terminal and a by-pass line on the northeast, connecting lines from Barcelona and Irún (Atlantic French border). The works were initiated but soon interrupted by the Civil War (1936-1939).

Figure 19: Madrid Railway Access Plan.

Source: https://informetfm.wordpress.com & JAY

6.2 Post war crisis and recovery in the 60's

War damages and harsh economical conditions after the war led to private railway companies' limited usefulness or even to bankruptcy. In 1941 the Government merged most of them in the national network 'Renfe'. The top priority was then rebuilding infrastructures damaged by the war, but aside from this it was a time of scarce investment, so the network remained basically like in the 19th century. Nevertheless, economical recovery from 1960 favoured the finishing of works started by the republican plan: the first North-South tunnel link opened in 1967; a new provisory north terminal in Chamartín opened in 1968. The current building was inaugurated in 1975. North-western, southern and eastern lines in Madrid region were finally connected. Nevertheless, the boundary conditions had substantially changed when the new infrastructure was open: Madrid area had more than tripled its population; road and aerial transportation had multiplied in a proportion that no one could have imagined in 1933.

Figure 20 and 21: 'Apeadero' station in Atocha and Chamartín station.Source: Adif

6.3 Railway challenges in an evolving scenario

The democracy arrived (1977) with the railway system in a very bad mood, unable to compete with road and aerial transportation.

Consequently, long distance services stagnated. Instead, commuter services demand increased significantly in a network with scarce capacity to withstand more pressure.

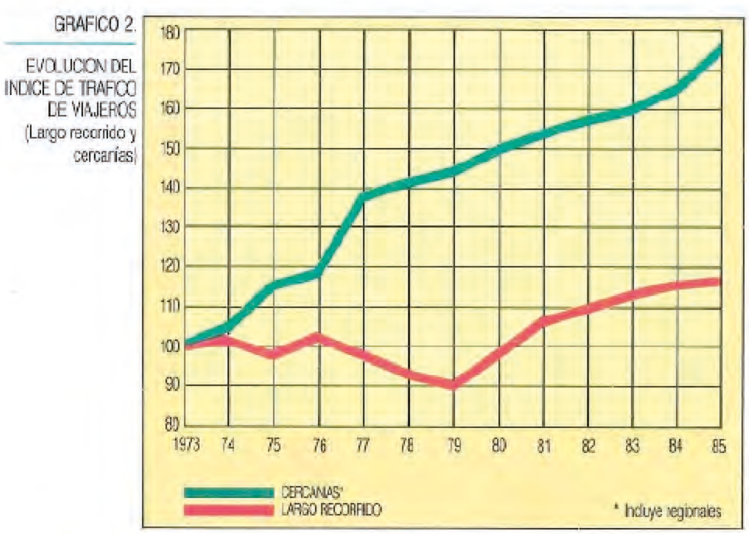


Table 1: Passenger traffic evolution 1973-1985. Source: PTF 1987

Several plans followed with the intention of closing a substantial part of the network. In order to start a way to solve structural shortages, Renfe signed in 1979 the first Programme-Contract with the Government. The latter would provide economical resources; Renfe compromised with renovation and services improvement. A new Programme-Contract was signed in 1984 with the final aim of making railway profitable. In 1985, 901 km of highly loss-making lines were closed all over the country, many of them in scarcely populated areas.

6.4 Urban growth and transport crisis

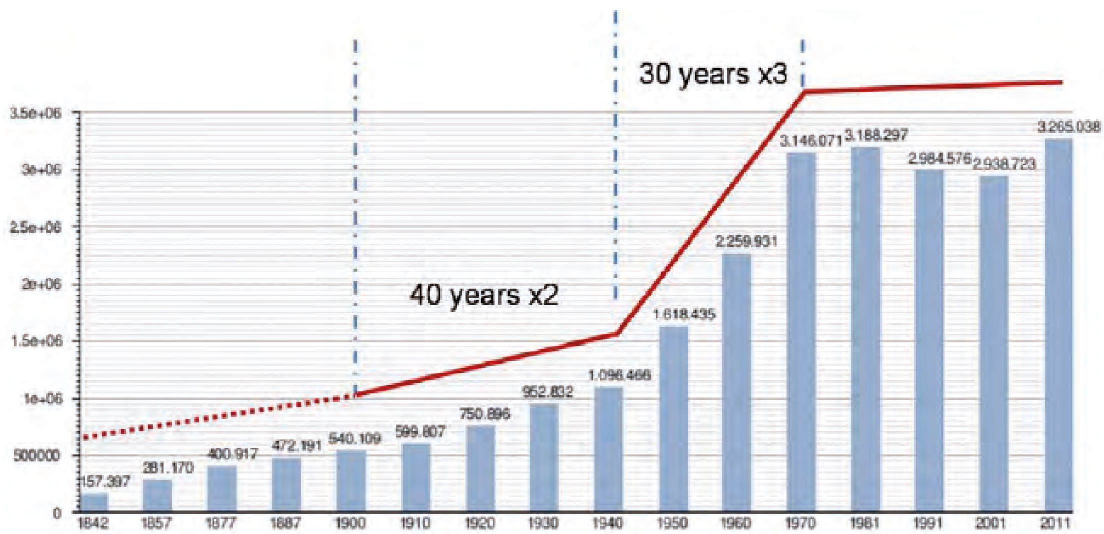


Table 2: Madrid city population growth 1842-2011. Source: Wikipedia and Juan Ayrault

In the period 1940-1970 Madrid tripled its population. Since then, figures remained stable but the metropolitan area increased significantly, particularly in the south-western metropolitan area supplied with commuter lines acceding to Atocha. Transport demand congested the access roads and commuter turnout soared. Economical recovery on the mid 80's increased the trend. The situation reached moments of severe tension: the railway network was close to collapse. Riots provoked by angry users took place in April 1986 in Atocha Station.

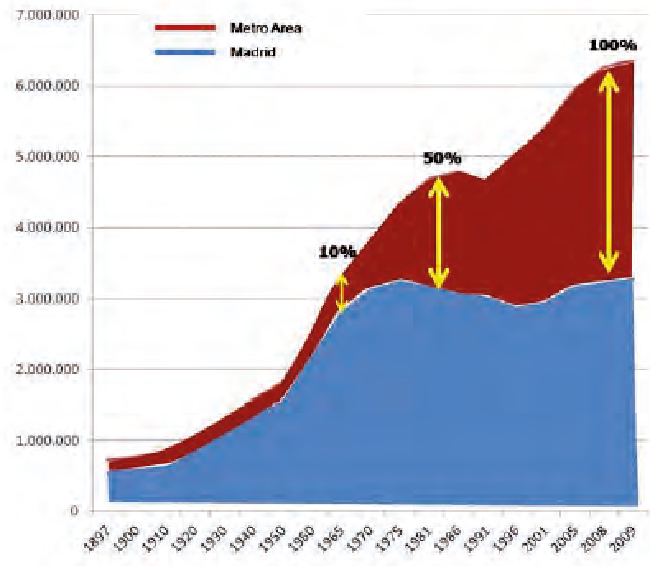


Table 3: Madrid Metro Area population growth 1897-2009. Source: Wikipedia and Juan Ayrault

6.5 The birth of new commuter networks: Cercanías

As a reply to urban transportation challenges, the first socialist government in the democracy implemented several measures in order to improve the commuter railway network in major Spanish urban areas. In respect to Madrid metro area, all the services were studied as a whole and rescheduled with periodic timetables. New stretches were projected to connect lines that were not integrated in the network. Atocha was decided to be the linking point of all the lines, due to the fact that most of the lines already started there or were accessible through the tunnel to Chamartín.

Figure 22: Commuter (Cercanías) network in 1989 + projected extensions.

Figure 23: Cercanias network in 2007. Source: Adif and Juan Ayrault files.

In 1988, the new commuter station projected in 1983 opened with 10 tracks, connected to the 1967 tunnel. Two years later, in 1990, a second tunnel linked Atocha with the south-western line to Móstoles, until then isolated from the network. In 1996 a new line following the old bypass between Atocha and Principe Pío (Pasillo Verde) was open. The process went on and in 2007 a new tunnel N-S was open with a new station in Sol, acceding la Puerta del Sol, the symbolic core of the city. This new tunnel permitted to connect with the north two lines that firstly ended at Atocha. The whole network functioned as an integrated system.

6.6 Rail Trasport plan - New access to Andalusia.

In respect to long distance routes, railway in Spain faced a big challenge: survival face to the harsh competition with road an aerial transport. Long distance passenger services experienced poor results on the 70's and the situation was worsening as far as road infrastructure improved. In 1987 a Railway Transportation Plan was approved by the Government. Several proposals stood out: A triangle line

Madrid-BarcelonaValencia-Alicante with standards of 200 kph, a new connection between Vitoria and Bilbao to avoid the extremely complicated Orduña pass, a new access to Andalusia and other lines improvement with standards from 160 to 200 kph.

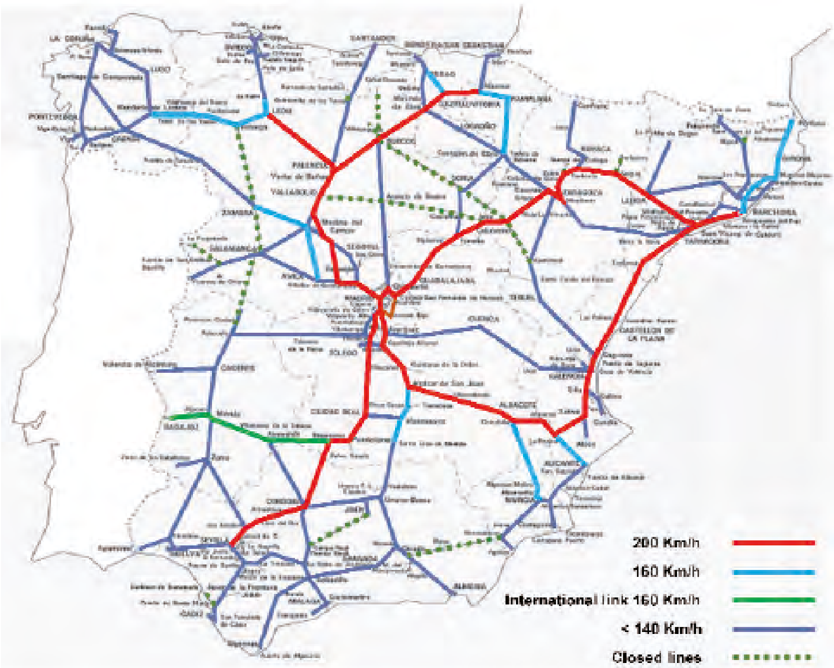


Figure 24: PTF plan (1986) and line standards.

Source: PTF http://www.vialibre-ffe.com/noticias.asp?not=5154 and Juan Ayrault

Access to Andalusia was one of the most problematic existing connections due to the slow passage through Despeñaperros mountain pass, very difficult to solve technically. Consequently, a new line was proposed 60 km westwards, connecting the old line Madrid-Ciudad Real-Puertollano with Córdoba through the mountain range of Sierra Morena. In 1988 a dramatic decision with important consequences was made: all new HS lines will be built with the standard gauge (1435 mm), instead the Iberian gauge (1668 mm).

Figure 25: New Raiway Access to Andalusia (NAFA).

Source: Ferropedia and Juan Ayrault

7. Madrid Atocha's surroundings. Urban development in the mid 20th century

The history of HS in Spain and more precisely in Madrid and Atocha station would not be completed without the record of the urban evolution on the mid 20th century. Some of the most critical decisions regarding railway were taken in close connection with the urban dynamics that took place along the 20th century. Because of that, it is indispensable to look back and watch carefully what was happening to the society and the city of Madrid on those critical years, particularly from the post-war period to the 80's.

7.1 New (sour) wine into old wineskins

Railway evolved due to social demands and political decision. Regarding the area subject to this study, the setting of the new HS line and particularly the decision of implementing the terminal station of a brand-new HS line in an old refurbished and enlarged building cannot be separated from the process performed on-site.

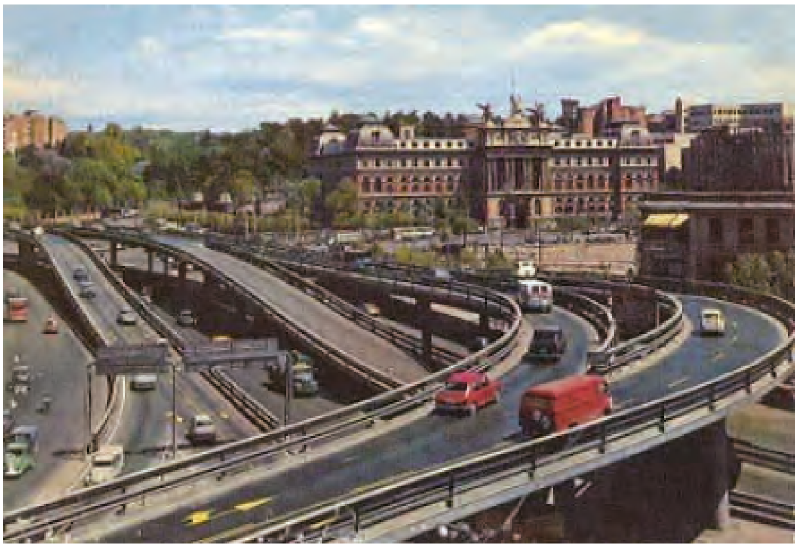


Figure 26: Atocha road bridge: the 'Scalextric' . Source: http://danceandcars.blogspot.com.es/2010/04/scalextric-de-atocha.html

After the civil war, the urban area surrounding Atocha station faced a long process of dereliction that reached the decade of 1980. Madrid population and motoring development soared from the early 60's. New problems with urban traffic were faced by local powers with aggressive policies of urban highways. One of the most harmful examples was the road bridge built in Atocha square that totally changed the character of the place in 1968. This new infrastructure, far from solving traffic conditions, provoked the worsening of traffic jams and a dramatic rise of pollution. Hotels located in the area were particularly affected due to the plummeting air quality and noisy environment. Hotel Mediodia, opened in 1914, languished with its main façade leaning on the noisy and polluting bridge. Hotel Nacional, a 1926 beautiful Secession work by Modesto López Otero, closed its doors at the late 70's. Atocha area accommodation standards fell to a lower standard.

The effect was so harmful that as early as 1975 the City council started considering the demolition of the bridge, built only seven years before. It would last in place only nine years more.

7.2 Heritage threatened. The age of scorn

On the other hand, a notorious increase of urban property prices led to real estate speculation and consequently a permanent threat for heritage buildings. In 1965 the old General Hospital finished its function. Years later, its proprietor, Madrid Provincial Government, had plans to demolish it and raise an 18 stories building. In January 1969, a report by Fernando Chueca, from the Royal History Academy, brought about its inclusion as a historical monument and consequently saved the building.

Figure 27. General Hospital
Source: Artehistoria.com

Figure 28. Madrid Atocha canopy.
Source: FFE.

Figure 29. Palacio de Medinaceli, one among the many palaces demolished in La Castellana.
Source: urbancidades.wordpress.com

Figure 30. Palacio de Villahermosa, now ThyssenBornemisza Museum.
Source: artedemadrid.wordpress.com

In 1976, Renfe presented a plan to displace Atocha station, demolish the old building and build a supermarket. The proposal raised a lot of controversy. A campaign against Renfe project cancelled the company's plan, but still in 1978 press articles begged for the station not to be demolished.

In the early 70's, the neighbouring Royal Botanical Garden was almost abandoned, even though it still maintained part of its initial scientific task. Its original buildings had been altered by unfortunate interventions. Surprisingly, the worst threats came even from culture officials, as a project of a museum dedicated to Goya could have seriously damaged the place. Fortunately the project was discarded after receiving numerous criticisms.

The palace of Marquis of Villahermosa, now the venue of Thyssen-Bornemisza museum avoided nearly demolition, but lost all its 18th century magnificent interior decoration in 1973. The Lopez-Quesada bank commissioned a project that preserved only its façades to install the bank headquarters.

In fact, heritage destruction was generalized at that time. 19th century architecture was generally disregarded as 'bourgeois' and 'decadent'. Madrid experienced discouraging examples of losses such as the Cebada market, built in 1880, the Grasset workshops by Demetrio Ribes and plenty of private aristocratic palaces in the Castellana avenue. This phenomenon was not exclusively Spanish. Along the 50's, 60's and 70's, masterworks such as the Penn station in New York City, Euston station in London, Les Halles in Paris or Victor Horta's buildings in Brussels were pitiless demolished, in many cases to make room for buildings of an uttermost mediocrity. The latter was one of the numerous actions that coined – quite unfairly, though- the infamous verb 'brusselization' as a synonym of speculative, disrespectful and careless urban development.

Figures 31-32 Euston Station, demolished in 1961-1962. Les Halles, Paris, demolished in 1971. Source: Wikipedia.

Figure 33. Maison du people, Brussels, by Victor Horta, demolished in 1965. Source http://www.ianthearchitect.org

Figure 34. Penn Station. New York City, demolished in 1963. Source: Wikipedia

Figure 35: Antonio López 1960 Painting 'Atocha. Source: www.diariolibre.com

In summary: some of the best achievements of the Enlightenment and the industrial architecture of the 19th century were not only deteriorated but also seriously threatened.

A token of how undervalued was the area on the mid 20th century is a picture of 1960 by Antonio López. A couple of lovers in the middle of a desolate square describe the state of dereliction of Atocha area. The road bridge built eight years later worsened the scenario.

The first Madrid catalogue of heritage-listed buildings in 1974 settled the first conditions for heritage preservation. The arrival of democracy and a growing public concern for cultural values implemented new conditions that favoured from the early 80's the use and refurbishment of historic buildings. The process was sustained, supported by adequate political decisions.

7.3 Madrid Urban Planning and Atocha complex project

In a process parallel to the railway improvement plans, the socialist City council elected in 1979 promoted an urban plan that settled different principles. A book published in 1982 set the main lines of the new municipal policy.

The General Plan was approved in 1985. Some of its basic principles such as heritage recovery and urban public transport improvement had direct consequences for the station and its surroundings.

Figure 36: Madrid General Plan 1985

Source: https://arquites.wordpress.com/2013/01/01/plangeneral-de-madrid-de-1985/

A commission appointed by the ministry of Public Works designed a proposal in close cooperation with the city council that included urban regulations and the essential characteristics of railway infrastructure. The special plan for the area was finished on December 1983. In April 1984, an agreement among the Ministry of Transport, the City Council, the Regional Government and Renfe was signed.

The architecture was not detailed on the planning regulations. Therefore, five teams were selected in order to design a new railway complex that should include a commuter station with ten tracks, connected with the existing tunnel, a High Speed terminal with 15 tracks, an access bridge to both, an urban bus terminal and a new metro station at the existing line 1. Out of these five, Moneo proposal was chosen on September 1984.

The whole area reshaping was parallel with the building of the station. The infamous 'scalextric' disappeared, traffic lanes were redesigned, a bronze reproduction of the 18th century Artichoke fountain occupied the place of the original, now shown in the Retiro Park. The renovation of the area was radical but at the same time respectful with the site's history.

7.4 A new station for a brand-new line

In 1992 the new High Speed terminal was opened. A concrete, glass and steel new canopy sheltered 15 tracks, initially seven with standard gauge for HS services and eight with Iberian gauge for other regional or LD services. It was the edge of the first Spanish HS line, from Madrid to Seville. A new era on Spanish railway had begun. The old terminal by Alberto del Palacio was refurbished and integrated in the new complex. The old canopy sheltered a tropical garden, which was not part of the original architectural project, but a proposal from the city council with unexpected consequences.

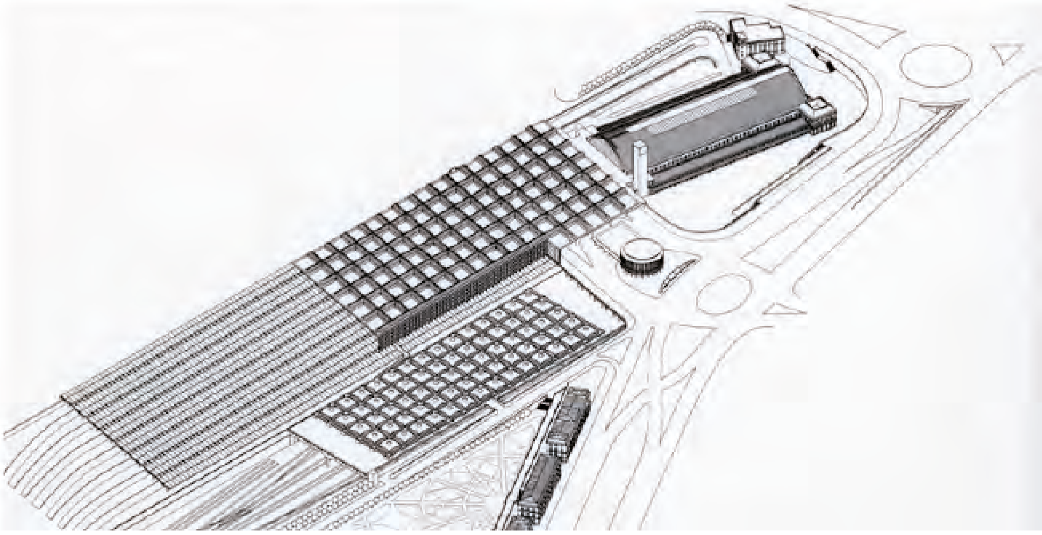


Figure 37: Rafael Moneo awarded project for Atocha station

Source: http://madrid2008-09.blogspot.com.es/2009/06/apuntes-miercoles-20-de-mayo.html

Figure 38: Atocha station complex

Source: Adif

7.5 New cultural facilities

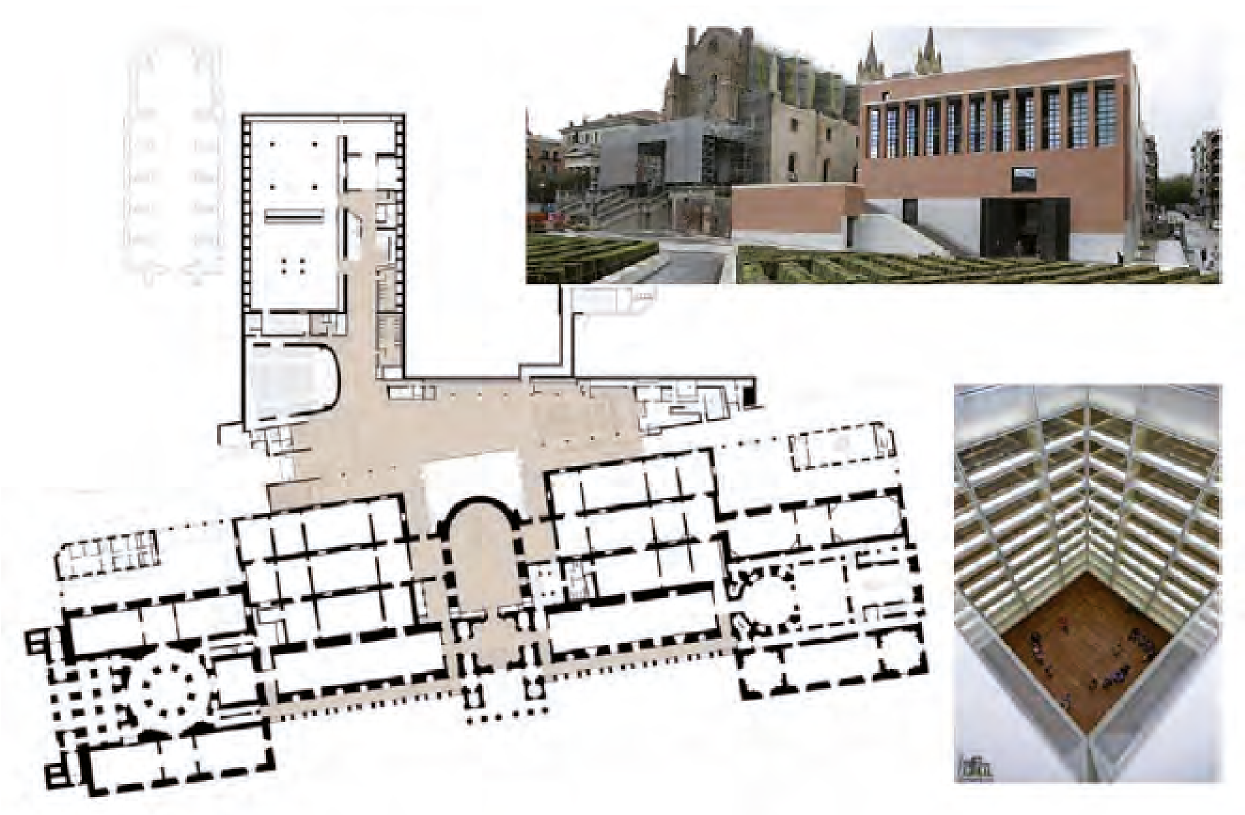
In a generation term, a new sensitivity toward the heritage and the commitment of cultural officials appeared and fostered relevant projects involving the refurbishment of old facilities.

Apart the Prado, the very jewel of the crown, periodically subject to renovations along its history, the first significant renovation of the area came on the late 70's. The Royal Botanical Garden was refurbished in from 1977 to 1981, funded by the Ministry of Culture. Senseless projects were fortunately forgotten. The architectural part was designed by Antonio Fernández Alba, who made an exemplary recovery of the most refined neoclassical architecture: the original 18th century buildings were renovated, eliminating inappropriate additions. The project restored the 18th century gardening plan and recuperated the most relevant vegetation elements as well. In 1993, a new glasshouse was built according to a project by Ángel Fernández Alba, Soledad del Pino and José Manuel de la Puente.

Figure 39: Royal Botanical Garden.

Source: http://www.secretosdemadrid.es

The Prado museum was the object of an international contest won by Rafael Moneo. The building grew underground and added a new pavilion around the ruins of the old cloister of San Jerónimo monastery, enlarging the surface dedicated to temporary exhibitions, workshops and ancillary services, thus liberating surface in the old Villanueva building for the permanent collection exhibition.



Figures 40-41-42: Prado museum enlargement by Rafael Moneo.

Source: www.museodelprado.es

The same Ministry promoted the transformation of the former General Hospital into the Reina Sofia Art Centre, with an exemplary project by Antonio Fernández Alba. Now it is the most visited museum in Madrid, housing the symbolic Guernica by Pablo Picasso and an excellent collection of Spanish 20th century painting.

Figure 43: Centro de Arte Reina Sofia.Refurbished courtyard and garden.

Source: www.museoreinasofia.es

Figure 44: Centro de Arte Reina Sofia. Lift towers by Vázquez de Castro and Iñiguez de Onzoño.

Source: www.museoreinasofia.es

In 1992 three communication glass towers by José Luis Íñiguez de Onzoño and Antonio Vázquez de Castro were located in west and north façades.

Figure 45: Centro de Arte Reina Sofia. Enlargement by Jean Nouvel. Source: www.museoreinasofia.es

Figure 46: Thyssen Bornemisza museum. Source: www.esmadrid.com

In 2006 an enlargement designed by Jean Nouvel doubled the exhibition surface

permitting to reshape the best collection of Spanish modern art.

Up North, by the Neptune fountain, the new Thyssen-Bornemisza Museum opened in 1992 in an old palace to exhibit one of the most impressive private art collections: the one purchased by the Spanish Government to Baron Thyssen-Bornemisza.

The building had been acquired by the State after

the bankruptcy of its former proprietor, the Banca López Quesada.

Paseo del Prado by Alvaro Siza. In 2002 the City Council approved a new plan for the axis Recoletos-Prado, won by Portuguese architect Alvaro Siza Vieira in an international contest. The plan was partially implemented near Atocha area, although the bulk of the project remains still pending, due to disagreements between the City Council and the Regional Government

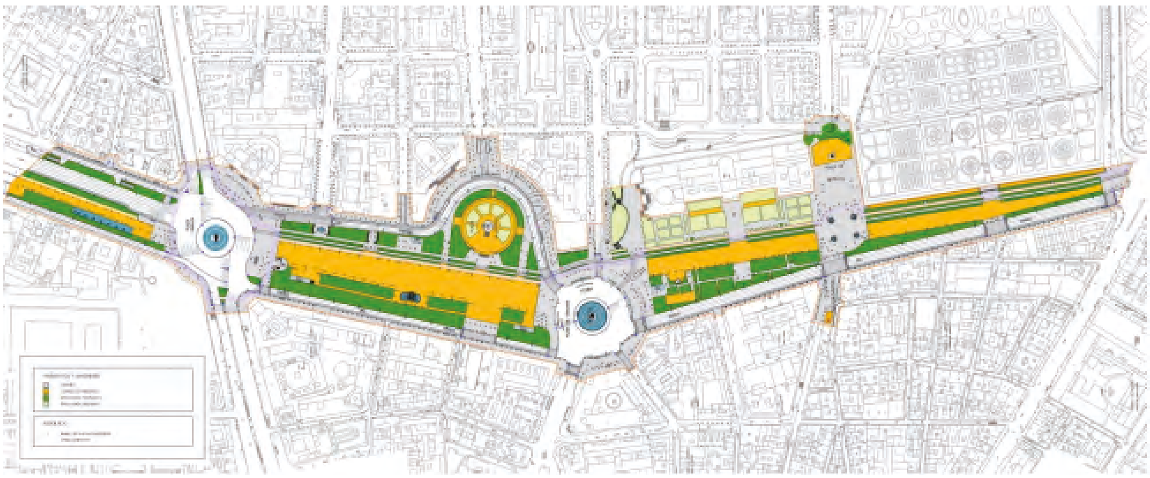


Figure 47: Recoletos-Prado axis by Alvaro Siza & J. M. Hernández de León. Source: http://es.globedia.com

When the three star museums –Reina Sofia, Prado and Thyssen- were established, the area began to be known as Paseo del Arte (Art Promenade) or Golden Triangle of Art. The three world-class art galleries were complemented by other cultural landmarks that shaped one of the biggest concentrations of artworks in the world.

Caixaforum, an exhibition centre sponsored by the third Spanish bank opened in 2008 in an old powerhouse.

The exciting project by Herzog & De Meuron, an old brick industrial vessel lifted in the air by powerful pillars, was complemented by the amazing Vertical Garden created by French artist Patrick Blanc, located in the front square, where an old petrol station once stood.

Besides Caixaforum, an innovation space sponsored by the City Council occupies the old Belgian Sawmill (serrería belga). Medialab started in 2013 in the old industrial facility renovated with a project by María Langarita and Víctor Navarro.

Other secondary buildings survived dereliction too and complemented the others: Renfe and Adif preserved their French-like office buildings in Av. Ciudad de Barcelona, including the old MZA office building by Victor Lenoir.

Not far, the Italian-style campanile of the Pantheon watched its serial neighbours.

Figure 48: Caixaforum and vertical garden.
Source: Wikipedia

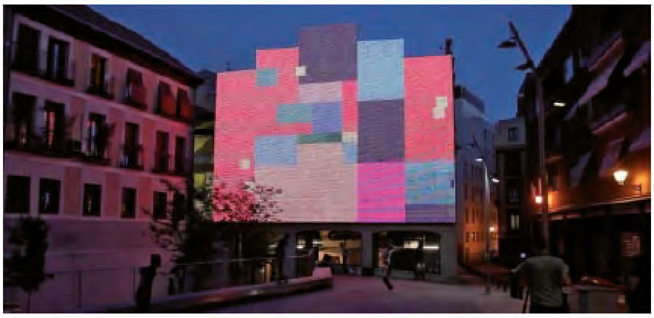


Figure 49: Medialab.
Source: Madrid.es

Figure 50: Old MZA offices and Pantheon's campanile.
Source: Juan Ayrault

7.5 Beyond the Golden Triangle

The influence of the Golden Triangle went much beyond the 'noble' Prado Avenue. A secondary axis took progressively shape along the formerly industrial Ronda de Atocha. Some prestigious institutions were housed in refurbished industrial or office buildings.

Circo Price occupied the former PACISA cookies factory. It was the first building dedicated to circus shows after the disappearance of the former Price circus in 1970.

Figures 51-52-53: La Casa Encendida, Circo Price, Tabacalera.

Source: www.wwwlacasaencendida.es - diario.madrid.es – www.elpais.com

A private savings bank sponsored the culture centre La Casa Encendida in a former banking office.

Nearby, since 2003 the self-managed Tabacalera culture centre runs in an old tobacco factory, a magnificent example of 18th century industrial building.

7.6 Accomodation

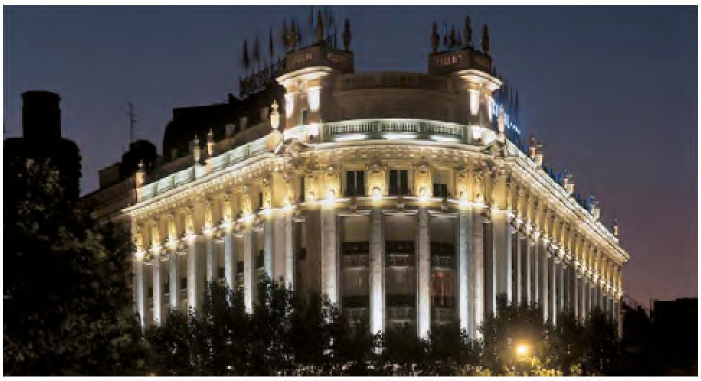


Figure 54: Hotel Nacional.

Source: https://www.booking.com/hotel/es/nhnacional.es.html

The effect of Atocha area urban renovation on accommodation facilities was revolutionary. One of the oldest hotels in town, the Mediodía, the worst affected by the building of the road bridge a few meters far from its balconies, caught its breath again and was refurbished. Hotel Nacional, closed since the late 70's, was renovated and reopened almost twenty years later, in 1995, stimulated by the opening of the HS line.

Newspapers mentioned that the refurbishment addressed to 'clients from Seville', with no prospect of the much further horizon that HS would bring to Madrid transportation. Other hotels followed: Rafael Atocha in 1998 and AC Atocha in 2009 were set on the western side (calle Méndez Alvaro), a former industrial area under renovation. Hotel Paseo del Arte in Atocha Street, besides the Nacional, took its name in 2003 from the new brand of the area.

NH Atocha opened in the eastern side, near the Ministry of Environment. Besides, Only You Hotel Atocha occupied as recently as 2016 an old apartment building.

Summarizing, in the term of these past twenty-five years, all accommodation facilities in the immediate vicinity of Atocha station have been renovated and new establishments triple the original figure of rooms offered.

Table 4: Renovated and new hotels in Atocha Area in the period 1992-2017

Renovations since 1992	Opening	Renov.	Rooms	New openings after	Opening	Rooms
1992						
Mediodía	1914	cont.	167	AC Atocha	2009	161
Mora	1950?	cont.	55	NH Atocha	1994	68
Nacional *	1926	1995	206	Only You Atocha	2016	204
Sleep'n	1956	2016	80	Paseo del Arte	2003	260
				Rafael Atocha	1998	245
Total			**508**	**Total**		**938**

** Closed from 1978 to 1995*

Source: Data collected by the author

8. Madrid-Puerta de Atocha 25 years later

8.1 HS first impact

The implementation of a HS line drew a lot of scepticism. As late as 1991 the press complained about the decision of building the line with standard gauge and forecast a failure in passenger numbers and an unnecessary excess of capacity. Figures were not very ambitious: Madrid Seville line began with twelve services a day, six on each direction, and a forecast of 3.900 passengers a day.

In spite of gloomy predictions, the 'AVE' made a big impact on public opinion. Passengers demand exceeded the most optimistic predictions and the services soared accordingly. After ten years of operation the turnout had more than tripled. A new mezzanine was built in 2002 in order to separate passenger flows. In 2010 arrival flows were displaced southwards to a new pedestrian bridge, which was the first element of a new arrivals terminal, still to be completed.

8.2 A country's hub

In these past 25 years, Atocha station has experienced a dramatic rise in passengers' number, from an early figure of 1,9M HS travellers a year in 1993, the first whole year to be operational, to the current 19M in 2016. That means exactly tenfold.

Figure 55: HS trains in Atocha. Source: Juan Ayrault

Initially the principal traffic was from Madrid to Seville, although other destinations benefited partially of the new track with the help of variable gauge systems (Málaga, Huelva, Cádiz). The rise was sustained during the first ten years, reaching 6,5M passengers in 2002, more than three times the figures of 1993. The further increase was parallel to the opening of new lines:

Table 5: HS passengers 1992-2016. Major increases highlighted in yellow.

Line/Service	Year	Passengers	Annual incr.
Madrid - Sevilla	1992*	1.300.000	
	1993**	1.875.000	100,00%
	2001	6.331.980	111,07%
	2002	6.529.491	3,12%
Madrid - Lleida/Huesca	2003	6.883.294	5,42%
	2004	8.222.611	19,46%
Madrid - Toledo	2005	9.071.790	10,33%
	2006	11.096.960	22,32%
Madrid - Málaga	2007	12.112.542	9,15%
Madrid – Barcelona	2008	14.582.292	20,39%
	2009	14.039.340	-3,72%
Madrid – Valencia	2010	12.959.169	-7,69%
	2011	15.679.224	20,99%
	2012	15.038.075	-4,09%
Madrid - Figueres/Alicante	2013	16.390.132	8,99%
	2014	17.960.251	9,58%
Madrid - Cádiz	2015	18.773.832	4,53%
	2016	19.502.257	3,88%

** April to December **First entire year* *Source: Adif*

Openings of new lines had substantial effect on passengers' turnout. The relation between the start of lines to Barcelona, Málaga and Valencia and double digit rises must be noticed.

This success in terms of passenger figures must not be understood only as a consequence of High Speed itself. Atocha was conceived as an intermodal hub into which customers could easily connect with commuter lines, metro and buses. According to Renfe data, in 2016 at least 2,2M customers purchased HS + commuter combined tickets.

Atocha has the undisputed top position as the most frequented commuter station in the country. It supplies also a noticeable amount of medium distance services. The whole provides a unique interchange point where HS passengers have endless possibilities of continuing their way.

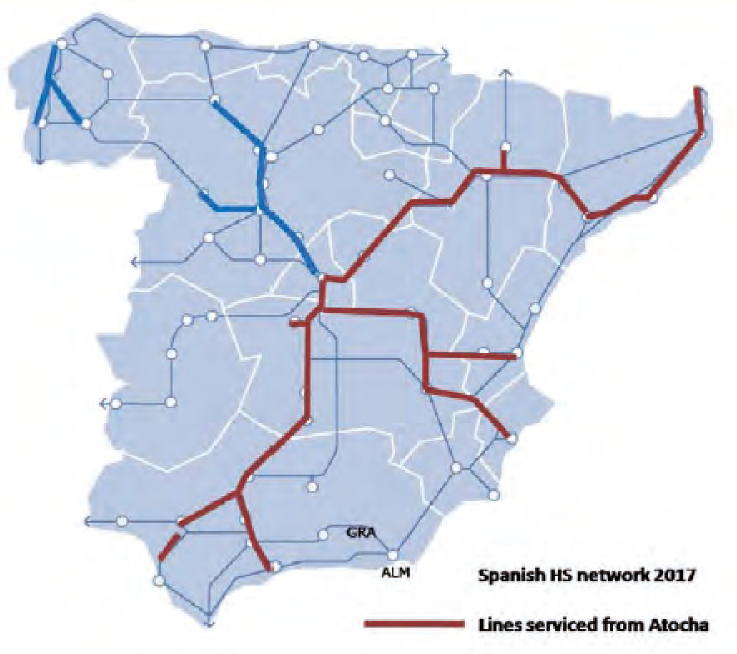


Figure 56: HS network serviced from Atocha. Source: Adif and Juan Ayrault

In spite of Atocha's success, tensions never disappeared. Scarcity of parking spaces provoked complaints from customers that could hardly park their vehicles before taking their trains. In 2007, during the mandate of Alberto R. Gallardón, the City Council proposed the transfer to the HS terminal to a building 4 km southwards, on the grounds of the Abroñigal freight station. Adif and the Ministry never accepted this proposal, defending that Atocha's location favoured intermodality much more than the suggested one that, in any case, was only more accessible for private cars. Even this point was uncertain, as Abroñigal station stays in a section of the first road ring (M-30) particularly exposed to traffic jams.

8.3 A complex system

Atocha works as a complex piece of architecture and engineering, an addition of particular elements closely linked that work as a whole. Commuter and HS stations, located in different levels, as well as ancillary facilities, retail venues and leisure areas complement each other as part of the passenger experience.

Figure 57: Commuter station dome, arrivals terminal and vaulted car park. Source: Adif.

A brick dome appears on the surface to call the presence of the underground commuter station, located on the east side.

It is the linking point of all local lines. Its position favours the immediate connection with metro line 1, one of the busiest in the extended Madrid metro network.

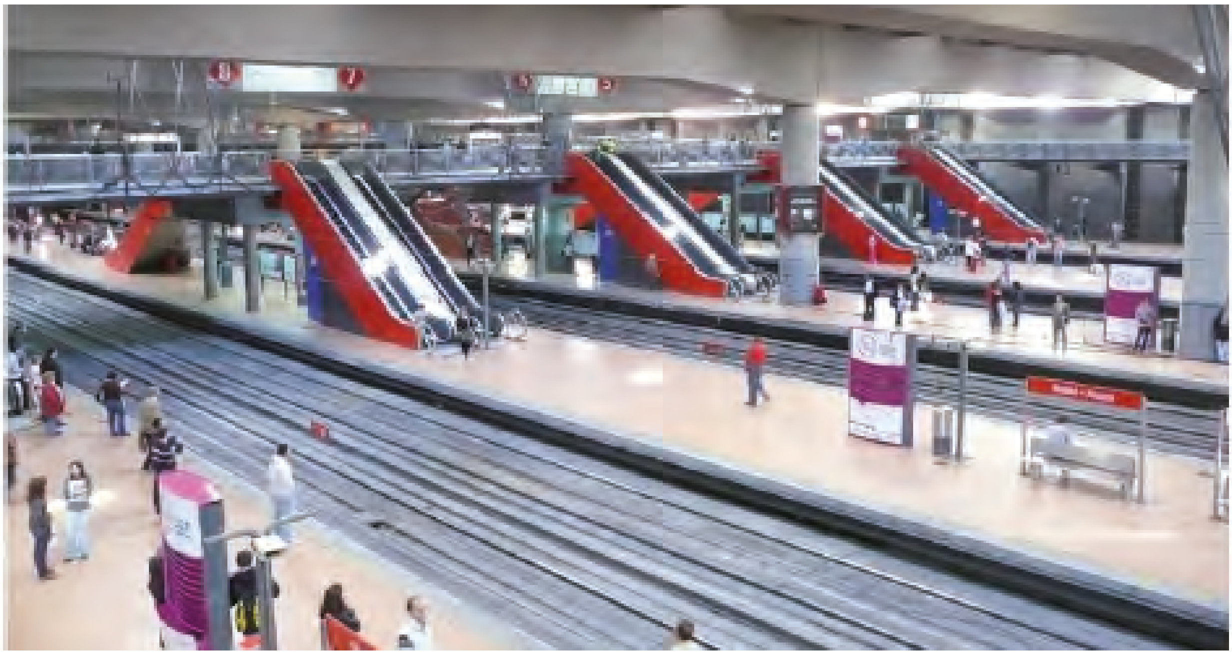


Figure 58: Commuter station. Source: Adif

Before the opening of the 2nd N-S tunnel in 2007, Atocha CS reached 500.000 passengers per day, although the opening of the tunnel reduced this figures in favour of other new stations like Sol.

Prior of the tunnel opening, most of the travellers coming from the south had to transfer to the only passing-by line, on platforms 1 and 2, which had severe capacity problems at the rush hours.

Besides, at the HS terminal, fifteen tracks and their corresponding platforms are sheltered by a magnificent concrete, steel and glass canopy, the so-called hypostyle room.

Figure 59: High Speed terminal canopy.
Source: Adif

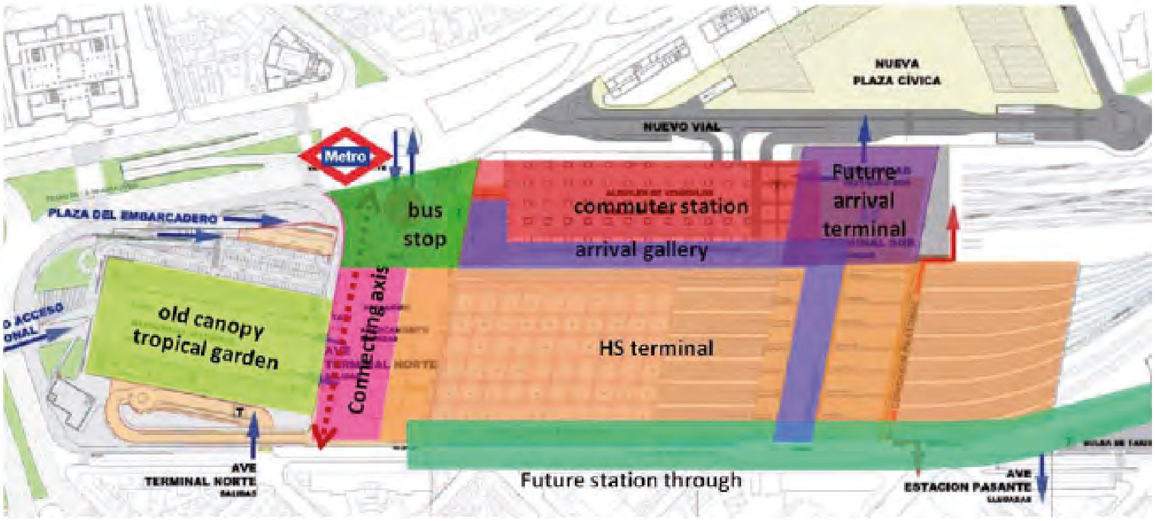


Figure 60: Atocha complex plan: Three main pieces and a connecting link. Source: Adif – Juan Ayrault

Both terminals are connected by a transversal pedestrian axis that works as an urban passage. More than 60.000 non-passengers a day go through it. The barrier effect usually caused by railway infrastructure is broken, as that corridor is the principal access from the western neighbourhoods to the metro station, located in the eastern side. A 'waiting bridge' on the southern section of the platforms, is prepared to connect the western side with the future arrivals terminal.

The old canopy by Alberto del Palacio houses railway operator's facilities, as well as retail and food venues, but most of all the iconic tropical garden that all the visitors highlight as spectacular and unique, sometimes with the disappointment of station operator that must face the costly maintenance of the garden.

With the exception of the crisis period between 2008 and 2012, Atocha continues its steady growth, facing day by day new challenges. The major one is the continuity of HS services. In 2017-2018 a HS tunnel is about to open to link northern and south-eastern HS networks, currently isolated from each other. It will be the third North-South tunnel. A future HS station through is projected on its western side, under tracks 14 and 15 and Méndez Alvaro street.

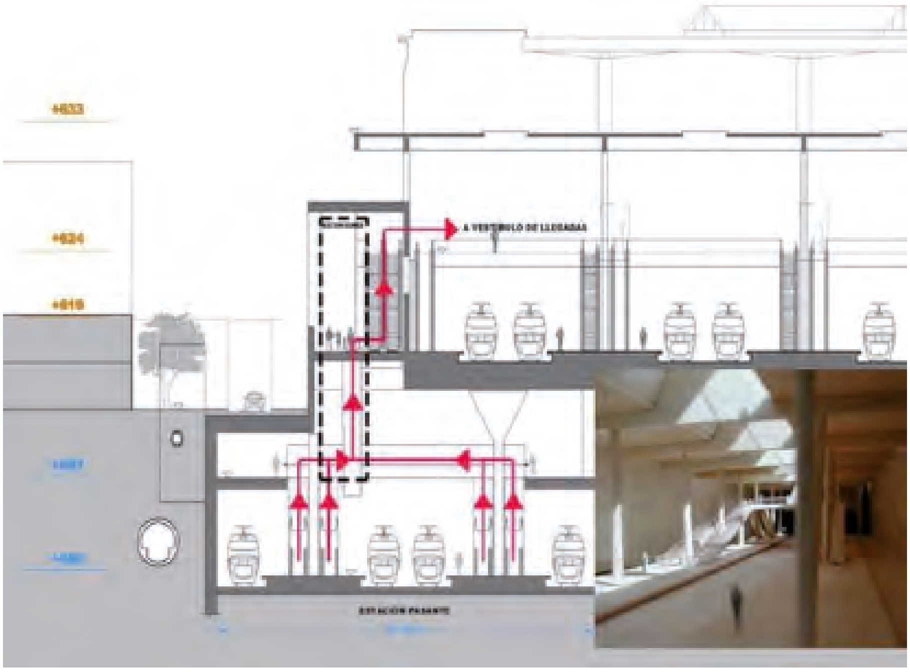


Figure 61: Future station through. Cross-section. Source: Adif.

8.4 More than just a station – Beyond efficiency, technology and engineering

The importance of stations on passenger experience was mentioned at the beginning of this paper and takes part of its final conclusions. It is a fact that, beyond functionality and technology, the place where the travel starts and ends has an effect than leans more on psychology than on pure 'rational' concepts. It is certain that passengers appreciate the efficiency of a HS service, value the time spared, compare the fares with other transport modes, take advantage of services offered...

But their experiences do not end there. Feelings driven by colours and smells, images seen or remembered, memories of other places visited, of sad farewells, of friendly encounters... A station is a complex space where people meet and divert, where many things could happen and, more than everything, where the adventure of travel starts or finishes. Do not forget that the train itself is a strange transport mode where human relations can happen, more than in any other one. In fact, trains are moving spaces where the comedy of life continues at stage and, surprisingly, moves. I consciously avoid to mention how many stories have been written about events happened on a train and a station. This is another story...

Figure 62: Stazione Termini – Vittorio de Sica. Source: Pinterest .

A travel to and from Atocha cannot be understood without the passenger impression on his or her arrival/departure: journey, way in, waiting time, arrangements, shopping, departure...

From Atocha windows, strange artefacts can be seen: a columned building crowned with winged horses, a neoclassic temple on top of a hill, an odd campanile escaped from Tuscany emerging behind a row of French-like buildings with slate roofs and Parisian mansards, aligned like a train, an endless horizon of working class blocks...

Inside the buildings, walls of smooth orange-red bricks bring echoes from Amsterdam or London; a huge iron vault shelters an unexpected tropical garden surrounded by a thin mist, strange creature grown in a dry and continental city with harsh winters.

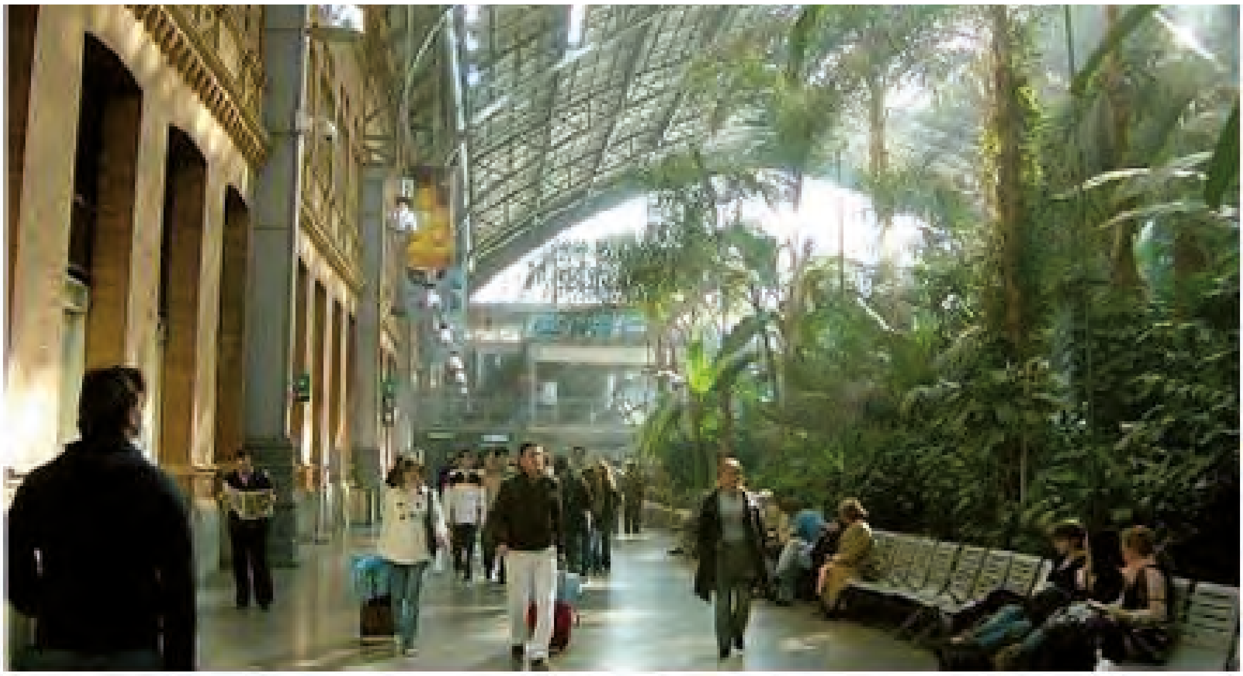


Figure 60: Tropical garden. Source: Adif.

Atocha regularly appears in the international press as one of the most spectacular stations in the world. It is curious that the feature that draws more attention once and again is the tropical garden, an element that was not part of the original refurbishment project.

16

Travel

Terminal

スペイン・マドリード

旅人癒やす300種類の植物

Figure 64:
Article about Atocha station in Asahi Shinbun, November 2016. Source:
http://globe.asahi.com/station/2016110400014.html

Tobias Buck, correspondent in Madrid for Financial Times, qualifies Atocha as 'splendid' in a recent article in which he summarizes the best of his Madrid experiences after four and a half years in office.

Another article in Asahi Shinbun, one of the most read newspapers in the world, highlighted in November 2016 the condition of Atocha as the city gate and its proximity to the top class museums.

Lisa Abend, correspondent in Spain for NY Times for many years, described her first impression of the station when she arrived as a 19 years old student, and how years later the whole building was wholly transformed and provided her very different sensations, and how little by little it became a familiar space. She wrote it in an emotional article on the occasion of the savage terrorist attack of March 4th 2004.

Unfortunately, some memories refer to that terrible attack, that thirteen years later still bring some madrileños to tears. However, they evoke too the wave of sympathy and solidarity that we experienced and shared in those dreadful days.

Summarizing: Atocha is everything but a neutral space. It is certainly an efficient building that provides top class services to customers: hurried business persons, commuters, easy-going tourists, etc, but it is also a place for memories, for meetings, for dreams...

9. Conclusions

The area around Atocha gate experienced constant urban renovation projects in the 17th and 18th centuries.

Its role as a key communication spot was enhanced with the implementation of railway in the mid 19th century, when the area incorporated other industrial, political and cultural facilities.

In 1892 Alberto del Palacio constructed the building that lasted for a century as an iconic image.

In the mid 20th century, both the urban surroundings and the railway terminal endured a process of dereliction and were severely threatened by wrong transport policies, speculation and disregard for their architectural values.

Planners' reflections in the early 80's recovered the appreciation for city centres. These new principles resulted in a positive assessment of Atocha's central position in town. New policies recovered the character of the area with a notorious respect for its past and a fresh vision of its future.

The renovation of Atocha station was possible due to a new sensitivity toward 19th century iron and industrial architecture and a general major concern for heritage.

Close cooperation between local and national authorities transformed dramatically the surroundings of Madrid Atocha turning it into the Golden Triangle of Art, a world class cultural hub that draws millions of visitors per year. These transformations attracted new services such as accommodation, art galleries and new housing provided by the private sector.

HS arrival 25 years ago to Madrid-Puerta de Atocha was a disruptive event that turned upside down railway perception by Spanish society. Atocha station as a major railway hub combines HS regional and long distance services will the whole commuter network and other modes. This fact has been crucial for its success.

But HS railway and the city nourish each other. A renovated urban space plus a world-class station are a good recipe for success. This success is not only linked to the efficiency of the HS line and the quality of the railway service, but to the image provided by a brand new terminal that integrates the best of the old, urban and culturally rich architecture with the functionalities of a modern terminal, and its character as an open gate to an open, vibrant and welcoming city called Madrid, my beloved hometown.

Portosin (Galicia). September 2017.

10. Acronyms

• ADIF	• Administrador de Infraestructuras Ferroviarias
• APA	• American Psychological Association
• BNE	• Biblioteca Nacional de España
• CARS	• Centro de Arte Reina Sofía
• COAM	• Colegio Oficial de Arquitectos de Madrid
• EP	• El País
• ETSAM	• Escuela Técnica de Arquitectura de Madrid

• FFE	• Fundación de los Ferrocarriles Españoles
• FT	• Financial Times
• HS	• High Speed
• NYT	• New York Times
• PTF	• Plan de Transporte Ferroviario
• RENFE	• Spanish Railway Operator
• RJB	• Real Jardín Botánico
• UPM	• Universidad Politécnica de Madrid

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11.7 Pictures

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- Figure 4: www.madrid.org + Juan Ayrault
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- Figure 6: Luis García - Wikipedia
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Sine amicitia, vita esse nullam

Urban Impacts

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Central versus Peripheral High-Speed Rail Stations: Opportunities For Companies to Relocate? The cases of Reims Central Station and Champagne-Ardenne Station

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Abstract

High-speed rail (HSR) can serve cities in two main ways: first and foremost via city-centre stations, but increasingly also via peripheral stations. By analysing the case of Reims, this article aims to identify the reasons that lead firms to locate around each type of station. Two surveys conducted in 2014 and 2015 enable us to show that HSR not only structures urban space but also segments it by function. While office availability is a very important consideration in the choice of location for both types of areas, other location factors including HSR are type-specific. Moreover, the types of companies in each kind of area are not the same. While local companies are present in both cases, the central station in Reims plays host to more external creations whereas the peripheral station is favoured for more external relocations. The companies present also differ in terms of their activities. Around the central station, there is a predominance of financial and insurance activities, while in Bezannes – the location of Champagne-Ardenne TGV station, on the southern outskirts of the city – there is a strong specialization in offices for industry-related activities.

Keywords: High-Speed rail, central and peripheral rail station, location choice

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1. Introduction

A number of authors have explained that the effects of high-speed rail (HSR) services on local economic development are heterogeneous (Sands, 1993, Delaplace, 2012, Loukaitou-Sideris *et al.*, 2013, Vickerman, 2015) and the reasons for this numerous. This is particularly the case for the establishment of businesses around stations (Mannone, 1995, Fachinetti-Mannone, 2009, Bazin *et al.*, 2009, and Beckerich *et al.*, 2016, Willigers and van Wee, 2011). The aim of this paper is to investigate one reason for this heterogeneity, namely station location, which varies not just by country (Givoni, 2006; Urena *et al.*, 2009) but also by city. Sometimes, HSTs arrive at central rail stations (historic stations in most cases, although some are more recent). In other cases, new stations are specially built for HSR service, outside the city, directly on the high-speed line (HSL). These are known as peripheral, or city-edge, railway stations[1].

In the first case, urban-renewal operations can be implemented in order to transform the station district into a central business district, sometimes also incorporating residential real estate. Peripheral stations, on the other hand, tend to give rise to new business parks, as well as residential real estate in some cases. In France, however, business parks around peripheral stations do not always fulfil their objectives (FacchinettiMannone 2009): “while intermediate stations have been provided on most routes, there has been little identifiable local economic development associated with many of these stations” (Vickerman, 2015, p. 157). In Spain, as in France, projects around central stations have tended to be more successful (Bellet *et al.*, 2012, Mohino *et al.*, 2014, Bazin *et al.*, 2009, Beckerich *et al.*, 2016). However, analyses conducted to date have been carried out either at central stations or at peripheral stations – but not both simultaneously – and in different contexts. In addition, few studies have analysed the location choice of companies in station districts. Lastly, the respective advantages associated with a location close to a central station or a location in proximity to a peripheral station served by high-speed rail in the same urban area have not yet been jointly analysed. The aim of this paper is to analyse the case of Reims, a city located 150 km to the east of Paris, which since 2007 has been served by the East European High-Speed Line, which calls at both the central station in Reims and Champagne-Ardenne TGV station, an interchange station directly connected to the rest of the high-speed network. In both cases, real-estate operations have taken place, but on different timescales. In order to analyse companies’ location choices, two surveys were conducted, the first around the central station and the second around Champagne-Ardenne station. This analysis allows us to eliminate the existing bias linked to comparisons between different cities.

The paper is organized as follows: Section 2 presents the literature concerning HSR services and firms’ location choices around central and peripheral stations, as well as the literature concerning HSR services and business real estate. Accessibility improvements in Reims and local policies surrounding both of the city’s high-speed rail stations will be analysed in Section 3. Section 4, devoted to the presentation of both surveys, shows that high-speed rail not only structures the urban space but also segments it by function; and Section 5 contains some concluding remarks.

2. Location choice near a central or a peripheral high-speed rail station

The literature identifies a number of effects of HSR on firms’ location choices and behaviour (Table 1). But while the logic that governs technical choices of station location (Auphan 2002) and the territorialization of different types of stations have been analysed (Fachinetti-Mannone, 2016, Fachinetti-Mannone and Richer 2011), the respective benefits of centrality or peripherality have not been investigated simultaneously, only separately. Moreover, the location choices of

1 Mannone (2016) identifies six types of HSR stations in France and Spain: central stations (old or new); pericentral stations, in urban spaces but not in the city centre; urban-fringe stations, located at the limits of the city; periurban stations, located on the periphery of the city in a rural environment; and bi-urban stations, located far away from a city but serving several urban centres; see also Bellet et al., 2012.

companies in both types of areas, and the trade-off between centrality and peripherality in a given city, have not been analysed to date.

2.1 High-speed rail service, location choices and the behaviour of companies

HSR is expected to attract firms, especially in domains related to metropolitan activities such as business consultancy and research and development (R&D) (Agences d'urbanisme du Grand Est, 2005, ISIS, 2004, TE & MS, 2007, Kamel and Matthewman, 2008, Kantor, 2008, Lee, 2007, Sands, 1993, Urena *et al.*, 2009, Vickerman, 1991). It will induce the relocation of certainly activities (typically office-based) in cities that are served by HSR, particularly in major cities (RFF, 2010, Garmendia *et al.*, 2008, Rietveld *et al.*, 2001, Sands, 1993) or in large intermediate cities (Urena *et al.*, 2009); however, there is no global *ex-post* evidence for this (Lee, 2007, Bazin *et al.*, 2013, Beckerich *et al.*, 2016) (see Table 1).

The effects depend on different characteristics, including the types of firms, stations, and HST services concerned, as well as connections to the rest of the railway network.

Some authors consider that HSR plays a role in the attractiveness of locations due to improved accessibility and an "image effect" (Willigers, 2008, Willigers and van Wee, 2011) – but the accessibility effect depends on the type of HST service (Willigers, 2008, Willigers and van Wee, 2011).

Table 1. Different effects of HSR on firms' behaviour, competitiveness and location

Types of effects	Authors
Increase in business real-estate prices	Kamel and Matthewman 2008; Kantor, 2008,; SEEDA, 2008
Development of office real estate	Bazin et al. 2009; Kamel and Matthewman 2008; Sands, 1993; SEEDA, 2008
Development of commercial real estate	Haynes, 1997; SEEDA, 2008
Increase in the attractiveness of territories	Lee, 2007; Mannone 1995; Vickerman and Ulied 2006; Agences d'urbanisme du Grand Est, 2005; ISIS, 2004
Increase in the attractiveness of large intermediate cities	Urena et al., 2009
Little impact on attractiveness for firms	RFF, 2010; Mannone, 1995; Bazin et al. 2009; Haynes, 1997
Attractiveness depending on the type of HSR service and the type of firm	Willigers, 2008; Willigers and van Wee, 2011
Attractiveness depending on the type of station	Mannone, 2009, 2013; Willigers, 2008; Vickerman,2015
Location of business consultancy activities and more broadly metropolitan activities	Agences d'urbanisme du Grand Est, 2005; ISIS, 2004; TE & MS, 2007; Kamel and Matthewman, 2008; Kantor, 2008; Lee, 2007; Sands, 1993; Urena et al., 2009; Vickerman, 1991; Willigers, 2011
Development of business parks	Preston, 2009 ; Agences d'urbanisme du Grand Est, 2005
Relocation of local firms	Willigers, 2008; Bazin et al., 2009; Beckerich et al., 2016
Relocation of some activities (offices, financial, etc.) to cities served by HSR, particularly larger cities	Rietveld et al., 2001, Garmendia et al., 2008; Sands, 1993; Preston, 2009; GLA, 2008; Bertolini and Spit, 1998; Murakami and Cervero, 2012
Failure of some business parks	Facchinetti-Mannone, 2009, 2010; Sands, 1993; Troin, 2008
Development of urban projects and additional investments	Kamel and Matthewman 2008
Increase in the office occupancy rate	Kamel and Matthewman 2008
Increase in productivity and competitiveness	Vickerman and Ulied 2006; Preston, 2009; INSEE, 2017; Martin, 1997
Widening of the market area	Preston, 2009; Ollivro, 1997
Enlarging the labour market, especially for highly qualified employees	Preston, 2009; Cheng, 2009; Kamel and Matthewman, 2008; Haynes 1997

Source: authors' own work.

There is an attractiveness effect at the intraregional level for firms already located in the same city or region before the arrival of HSR, but this effect doesn't exist at the interregional level (Willigers, 2008). For other authors, HSR brings no major changes in terms of attractiveness for businesses (RFF, 2010, Mannone, 1995, Bazin et al., 2009), while for others still HSR is rarely, in itself, a location factor (Mannone, 1997; Sands, 1993; Kamel and Matthewman, 2008; Haynes, 1997): "The majority of offices that choose a high-speed train station site, would also have chosen this location in a situation without high-speed trains" (Willigers, 2008, 262).

Others consider that the effect of HSR depends on the type of station, with comparisons made between peripheral and central stations (Mannone, 2009) or between central and intermediate stations (Vickerman, 2015), for example. With regard to intermediate stations, "there has been little identifiable local economic development associated with many of these stations" (Vickerman, 2015, p. 157).

Moreover, among peripheral stations, there is a heterogeneity due to valorization policies (Mannone, 2010, 2013; Bellet, 2016).

In reference to the case of Amsterdam, Willigers (2008) points out that a central location tends to be favoured by companies whose employees frequently require access to international destinations because central stations offer better international connexions.

Peripheral locations are favoured by service-sector firms oriented towards the national market because accessibility is better. Finally, Willigers and van Wee point out that, in the case of Netherlands, it depends on the kind of HSR services: while "international HST services can have a considerable impact on the attractiveness of an office location […], domestic HST services are less important for location choices, because of the small domestic distances" (Willigers and van Wee, 2011, p. 9).

2.2 Developments around central and peripheral HSR stations: a review

From an empirical point of view, the location of firms around central stations sometimes takes time, and the firms present are not always those that one might expect (firms in highly qualified sectors). Ultimately, though, firms do move in to occupy the business real-estate programmes induced by the arrival of HSR.

In Spain, Bellet et al. (2012) show that HSR services favour urban renewal around central stations. In London, the Eurostar service at St Pancras has been considered a key factor in encouraging the location of financial companies in the King's Cross–St Pancras district (GLA, 2008, Bertolini and Spit, 1998, Murakami and Cervero, 2012). Similarly, in France, HSR has induced urban renewal and associated dynamics around central stations, and their districts seem to be successful, even if in some cases location decisions have been postponed by economic crisis. This was the case for the Novaxis business district in Le Mans in 1993, for example, but not in Reims, where available offices have been sold very quickly following their construction (Bazin *et al.,* 2009; Beckerich *et al.,* 2016). Around peripheral stations, the literature shows that business parks developed to coincide with the arrival of HSR were not successful, even when local stakeholders had keenly anticipated the arrival, as shown by Fachinetti-Mannone (1997, 2010). In Vendôme, in the middle of the 1980s, a ZAD2 of 140 hectares was designed to play host to a technological park, with serviced development plots made available according to demand. The aim was to create 1,000 jobs (Bellanger, 1991). In 2004, nearly 15 years after the inauguration of the Atlantic HSL ("LGV Atlantique" in French), only 16 companies had located on this site near Vendôme TGV station (occupying just a little more than 8 hectares). In 2010, this number had risen to 22, covering a mere 6.6% of the total surface area of the business park (Fachinetti-Mannone, 2010).

2 ZAD: a zone d'aménagement différé, or deferred-development area, i.e. a planned development area where the public authorities have compulsory-purchase powers.

Similarly, in Mâcon, the 55-hectare business park developed[3] to attract company head offices and government offices (Ellenberg, 2011), was still not fully occupied over 20 years after the arrival of HSR. In 1997, there were just two companies (Mannone, 1997). In 2010 – nearly 30 years later – 45 firms were located there; the business units are nearly all full but the office buildings created in the mid-1990s are not. In Montchanin–Le Creusot, the Coriolis business park was not a success. Only four companies, corresponding to 147 jobs, were located there 10 years after the area was developed (Mannone, 1997). In 2010, there were 24 companies and 252 jobs (Fachinetti-Mannone, 2010). In Valence, six years after the first companies moved in, the occupancy rate in the area is only 10%. The tertiary park works well, but there are only five companies on the 45ᵉ Parallel business park (Fachinetti-Mannone, 2010).

Comparing ex-metropolitan stations, that is to say stations located in the periphery of London, Paris and Madrid, Mohino *et al.* (2014) show that a moderate distance from the metropolitan core (20– 35 km) combined with efficient transport connections to central areas increases the potential for creating new centralities in the metropolitan area when they are linked to major infrastructure. This is the case for stations at Marne-la-Vallée Chessy and Charles de Gaulle airport in Paris, and for Stratford International station (near the Olympic Park site) in London. By contrast, office relocation is more difficult when stations are much more than 50 km from the city centre.

Central stations thus seem to be characterized by greater dynamism than peripheral stations; the question now is to identify the reasons why the districts around these stations attract companies with relative ease while those around peripheral stations are less attractive.

2.3 High-speed rail service and location choice around central or peripheral stations: theoretical background

Several theoretical arguments can be put forward to explain the location of companies around central or peripheral stations.

First, economic base theory (Hoyt, 1954) points out that business services depend on an industrial base and that their location requires proximity with industrial users. Market proximity will be favoured by the improved accessibility brought by HSR. HSR allows firms to minimize distancerelated obstacles and visit their clients located in connected cities. Indeed, in compliance with gravity models, distance is thought to have an effect on the intensity of exchanges: by reducing the time taken to cover the distance between the cities served, HSR services may enable service-sector companies to develop these exchanges and even broaden their market area (Ollivro, 1997, Preston, 2009, Willigers *et al.*, 2011). In other words, "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). Consequently, HSR could benefit the service industries (Bonnafous, 1987; Preston, 2009, Albalate, Bel, 2012). Activities requiring plenty of travel could take advantage of HSR (Ollivro, 1997). Such is the case for firms with a national or even international market (Pol, 2003) (e.g. design and engineering consultancies, advertising agencies, marketing consultancies), but less so for those who have a mainly local or regional market (e.g. accountancy firms, legal firms, human-resources consultancies). HSTs could therefore play a more significant role for firms with a customer base outside their region (Bricout, 1996, Willigers, 2011) or, in the case of France, those that implement a strategy of expansion beyond the Parisian market (Buisson, 1986).

Second, since time is money, HSR services can reduce general transport costs. The increase in accessibility may result in an increase in productivity and competitiveness (Preston, 2009, Vickerman and Ulied, 2006, Martin, 1997, INSEE, 2017). Improved connectivity may be transformed into increased competitiveness for firms located in cities connected to the HSR

3 *Initially, in 1982, the business park covered 5 hectares; it was expanded to 55 hectares in 1993.*

network (Martin, 1997). Nevertheless, according to Crozet, the positive impacts of accessibility gains on productivity are conditional (Crozet, 2015). In such cases, the station with the better accessibility will be preferred. But, as quoted by Banister and Givoni (2011), journey time by high-speed train is not the only transport time to take into account. Access and egress times – the amount of time it takes to get to and from stations – could also reduce the time savings generated by HSR.

Third, establishing a firm in the district around an HSR station may facilitate access to larger pools of skilled labour insofar as HSR services make it possible to bring cities closer together in terms of the time taken to cover the distance between them. In cases like these, the labour force living in such cities would find it easier to come and work for firms located in the station districts of cities served by HSR. In this way, HSR would enlarge the labour market (Preston, 2009, Cheng, 2009, Kamel and Matthewman, 2008) and improve the mobilization of highly skilled labour (Haynes 1997). In this case, it is again the issue of access to different transport modes, including conventional rail transport (Willigers, 2011), that is crucial, whether the station is central or peripheral.

Fourth, while the function of the stations is to be rail hubs or more generally transport hubs, they are also increasingly public spaces (Bertolini and Spit, 1998). By generating urban renewal and refurbishment operations around stations (Terrin, 2011, Pol, 2008, Bazin *et al.*, 2009 & 2010, Yin *et al.*, 2014), high-speed rail services reinforce the role of the station as a public space (De Jong, 2009, Mannone, 1997), a veritable urban hub (Bourdin, 2011) characterized by different types of flows, in particular flows of people. Establishing a firm in a station district may ensure proximity for customers passing through the station. In this case, it is the proximity to end customers who use rail transport – though not necessarily HSR transport – that would explain the location of tertiary and commercial activities around central stations. But peripheral stations could also generate new urban centrality in dynamic ways, in particular when they are characterized by residential real-estate programmes. Lastly, the choice to locate in a peripheral area or a central area depends on the cost and the value of each location for a given firm. Within a given city, the cost of a location depends on business realestate prices; indeed, real estate is the second-largest expense after labour within most organizations (Ward, 2016). But as regards the price of residential real estate (Beckerich, 2001), and as shown by the hedonic pricing method (Lancaster, 1966; Rosen, 1974, Nappi-Choulet *et al.*, 2007), the value of an area first depends on the amenities it provides. And these amenities are linked in turn to accessibility and more generally to different public policies with respect to education, employment, and so forth. Amenities are more plentiful in the city centre (Crouzet, 2003) because centrality offers more externalities in terms of transport and information than peripherality (Crouzet, 2003). Consequently, the price of business real estate is higher in the city centre than in the periphery. A firm looking for a location thus has to arbitrate between land and real-estate costs and centrality.

In cases where sensitivity to land and real-estate prices is high and large plots of land or offices are required for the company's activity, a peripheral location may be favoured. However, from a dynamic perspective, such location choices could lead to tertiary companies also seeking to locate around peripheral stations, resulting ultimately in price increases (see also Willigers, 2011).

To conclude, location choice can be linked to the type and level of accessibility of each type of station, to the type of customer proximity sought (customers passing through the station or clients located in other cities served by HSR), to the need for access to a large pool of qualified labour, to the existence of local clients, to the existence of other companies, and to the cost of real estate.

3. The HSR service in both stations in Reims and changes to accessibility

The East-European High-Speed Line, which began operating in June 2007, modified the accessibility of the cities it served. The urban area of Reims is served by two stations: the historic station, located in the Clairmarais district in the centre of Reims, and the new Champagne-Ardenne TGV station in Bezannes, a village located 7 km to the south-west, beyond the urbanized fringes of Reims (figure 1).

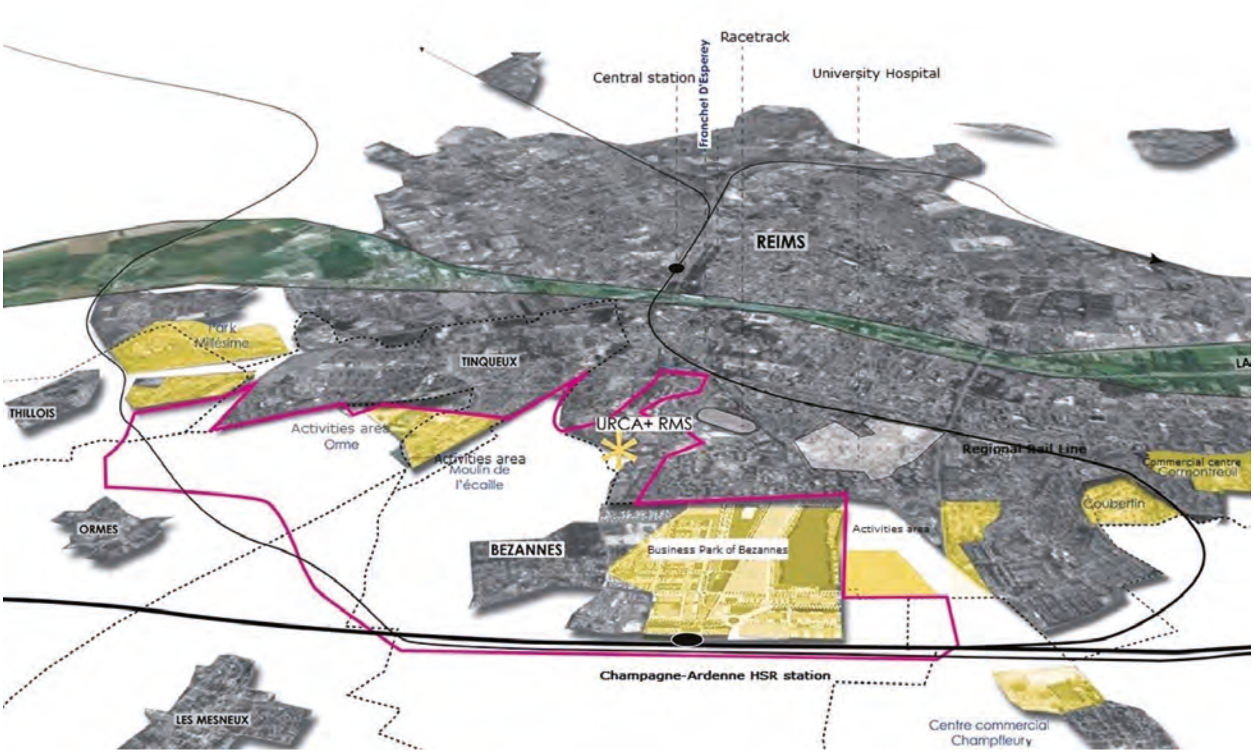

Figure 1. The two stations in Reims

Source: http://www.saisonmenu-architectes.com/projets/reims-pole-urbain-de-l-innovation/, modified by the authors.

Accessibility was improved by HSR at both stations, but in different ways. Similarly, although business premises were built around both of these stations, the circumstances and realization of these projects were different.

3.1 The accessibility's modifications in both stations

The central station in Reims is 45 minutes from Paris by HST, with eight round trips per day (Table 2). However, this new HSR service has led to the discontinuation of conventional rail services between Reims and –Paris[4].

4 The launch of the HSR service has also led to increases in regular and season ticket prices. For example, when the HSR began operating, the price of a one-way trip from Reims to Paris was EUR 38.00 in rush hour and EUR

In addition to HSTs, this central station is still served by conventional trains and regional express trains (TERs), as well as the city tram network, which has been in operation since 2011, four years after the arrival of the HSR service.

Champagne-Ardenne station is 40 minutes from Paris by HST, with six round trips per day. It also offers links to other French destinations on the high-speed network (Table 2), including Paris Charles de Gaulle airport, and, to a more limited extent, international connections (Brussels and Luxembourg).

Table 2. Modification of journey times from both Reims stations to major cities in France since 2007[5]

	Before 10 June 2007	After 10 June 2007	Time saved
Paris Gare de l'Est (from Reims central)	**1 h 35 min**	**45 min**	**50 min**
Paris Gare de l'Est (from Champagne-Ardenne, the peripheral station)	Not served	40 min	New service
Meuse TGV station	Not served	30 min	New service
Lorraine TGV station	Not served	40 min	New service
Metz	3 h 10 min (direct)	47 min	2 h 23 min
Strasbourg	30 min + change in Épernay (15 min) + 2 h 30 min = 3 h 15 min	1 h 55 min, reduced to 1 h 17 min since July 2016	1 h 20 min, increased to 1 h 55 min since July 2016
Marne-la-Vallée Chessy	Not served	30 min	New service
Paris Charles de Gaulle airport	Not served	30 min	New service
Lille	1 h 35 min + transfer in Paris (45 min) + 1 h 05 min = 3 h 25 min	1 h 25 min	2 h 00 min
Nantes	1 h 35 min + transfer in Paris (45 min) + 2 h 15 min = 4 h 35 min	3 h 15 min	1 h 20 min
Rennes	1 h 35 min + transfer in Paris (45 min) + 2 h 05 min = 4 h 25 min	3 h 15 min reduced to 2 h 46 min since july 2017	1 h 10 min increased to 1 h 39 min since July 2017
Bordeaux	1 h 35 min + transfer in Paris (45 min)+ 3 h 15 min = 5 h 30 min	4 h 25 4h 8 min reduced to min since july 2017	1 h 10 min to 1 h 27 min since July 2017
Luxembourg	Not directly served	1 h 31 min	New service
Brussels	Not directly served	2 h 14 min	New service

Source: authors' own work, adapted from SNCF data.

5 *Champagne-Ardenne station is also served by some regional express trains.*

This station has become the western gateway to the new Grand Est region (created in January 2016), with Strasbourg, the regional capital, 1 hour and 17 minutes away by HST. Since July 2017, Champagne-Ardenne station has also been served by Ouigo trains (the French low-cost HSR service) to and from Strasbourg, Marne-la-Vallée and Paris Charles de Gaulle airport.[6] In addition, it is served by regional express trains: the former Champagne-Ardenne region and the French state financed a line connecting both stations, enabling TERs that previously terminated at the central station to continue to Champagne-Ardenne station. The station is also served by urban trams and buses, financed by the intermunicipal structure covering Greater Reims.

Both stations benefit from good service levels, but Champagne-Ardenne station has the advantage of being directly linked to Paris Charles de Gaulle airport, a number of large French cities, and to a lesser extent Paris and the other towns and cities in the former Champagne-Ardenne region.

Companies wishing to locate in Reims now have the option of choosing between the city's central and peripheral stations, but this was not always the case, as premises were not available around both stations at the same time.

3.2 The projects and the realizations around both stations

The central station is located in the Clairmarais district, which developed during the second half of the 19th century with the onset of industrialization. At the beginning of the 1990s, the district was still marked by the vestiges of this industrialization and became the object of urban-renewal operations. From the mid-1990s, the public authorities wanted to create a business district here (Bazin *et al.*, 2009, Beckerich *et al.*, 2016) and the arrival of the East European HSL in 2007 led the various public and private stakeholders (Reims City Council, SNCF (the French national rail operator) and RFF (its sister organization responsible for managing the national rail infrastructure)[7], banks, property developers) to think about how to transform the district. For the city of Reims, this arrival was also an opportunity to remodel one of the city's principal gateways: its railway station. The aim was to transform this district into a tertiary pole with some 70,000 m² of office space while respecting the urban mix (economic activity and housing) required by the Urban Renewal and Solidarity Law (*Loi SRU*) of 2000. SNCF freed up land and created a new station entrance accessible from Clairmarais by means of an underground passage, the city centre being on the other side of the station. This new business district was thus connected to the city centre via the station. Its forecourt was redeveloped in order to allow a better connection to Place d'Erlon, the square at the commercial heart of the city.

In 2005, an office complex, an apartment hotel, a residential building, and further office and housing were delivered. In 2007, a mixed complex comprising offices, business premises and housing was finalized. In 2008, the second phase of 10,000 m² of office space and a budget hotel is delivered (Figure 2). In 2009, a multi-storey car park was built. In 2011 and 2012, various new constructions were completed in the streets farthest from the station: another office building in 2011, followed by business premises, housing and a student residence in 2012. In 2015, a residential complex containing social and private housing was developed; and in 2017, two new business complexes should be delivered. Reims City Council, which was the main stakeholder in this project, was backed by local developers. In all, more than 70,000 m² of offices and 500 housing units have been built.

6 However, Ouigo HSTs will not serve Bordeaux, Nantes or Rennes. For these destinations, a change will be necessary at Marne-la-Vallée Chessy station, but timely interconnections are not guaranteed.

7 Since 2015, SNCF Réseau.

Figure 2. Real-estate operations in the Clairmarais district

The case of Champagne-Ardenne station is different in many respects. First of all, the station is located in a rural environment without any buildings (Figure 3), close to the historic village of Bezannes (1,286 inhabitants in 2006) located to the south-west of Reims.

Figure 3. Champagne-Ardenne station, in a rural environment
Source: the authors

Bezannes is not (yet) part of the Reims built-up area, although the new business park has helped to close the gap somewhat. Nevertheless, Bezannes has always participated in the intermunicipal structures covering Reims and its suburbs, from the District of Reims created in 1964 to the Urban Community of Greater Reims (Communauté Urbaine du Grand Reims) that came into being on 1 January 2017. Moreover, although the mayor of Bezannes was initially against the location of an HSR station within the village boundaries, a compromise was found with the intermunicipal structure in the form of a 172-hectare ZAD (deferred-development area) (Figure 4). As with the area around the central station, the aim here was to promote a mix of functions, with a third of the area dedicated to housing, a third to offices, businesses and services, and the final third given over to green spaces. The laying of the foundation stone took place on 1 February 2006. However, the area's development has been very slow: the first business premises were only built in 2010, followed in 2011 by a hotel and a head office (for the Frey group, with 2,321 m² of floor space), and in 2012 by two office buildings and the head office of an architecture firm.

The following year, 2013, saw significant developments (a 59-unit residential complex, a second hotel, a new office block, and the arrival of the luxury-goods firm Cartier International). In 2014, a new medical services complex and, in 2015, two new office and business complexes were built. In 2016, five new projects were initiated (including housing projects, a head office or one of France's largest sugar manufacturers and the first phase of a private hospital with the construction of a 112bed nursing home).

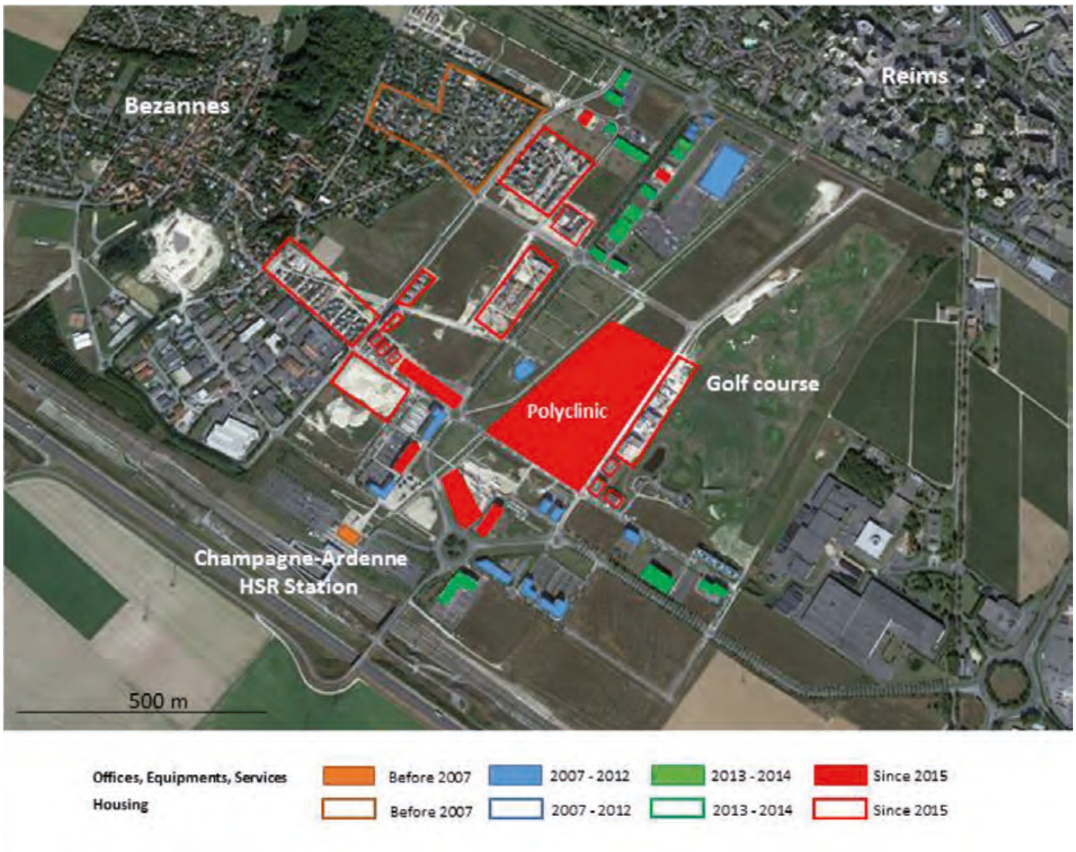

Figure 4. The Champagne-Ardenne Station business park

So far, 2017 has been marked by the construction of seven new projects: a senior-living complex comprising 124 apartments, a development of 69 collective housing units, a development of 41 new houses, and 3 office developments. Several firms and local authorities joined forces to create a co-working space of 7,000 m² dedicated to start-ups, which should be operational in 2017. Lastly, in 2018, a further development of 32 housing units are set to be built, along with the head office of Rédeim, a Reims-based property developer, and three housing developments by social landlord Plurial Novilia.

In parallel, cycle and pedestrian paths have been realized. In all, according to the mayor of Bezannes, some 300,000 m² of office space – more than four times the amount in Clairmarais – and 8,000 jobs should be created.

So, while housing, offices and businesses around the central station were all built at the same time – and in some cases even before the arrival of the HSL – around the peripheral station it has been necessary to wait, respectively, four and six years for business premises and housing to appear.

Finally, around this peripheral station, office rents range from EUR 135 to EUR 165 per square metre, with larger surface areas available (from 400 to 4,700 m²), whereas around the central station the equivalent rents are between EUR 160 and EUR 180 per square metre for smaller surfaces, ranging from 120 to 790 m².

4. The location of businesses around the two stations: the results of a comparative analysis

To understand why an individual firm chooses to locate where it does requires specific surveys, as statistical data alone only provides a snapshot of the situation at a given moment in time, and does not provide any information concerning the micro-economic behaviour of businesses. Consequently, two surveys were conducted using a questionnaire administered either by phone or face to face with firms located in each district. The first survey conducted in 2014 aimed to identify the types of businesses located around the central station (in the Clairmarais district), their location factors, the impact of the HST on their choice of location, and their use of the HST. In all, 42 firms agreed to participate, out of the 100 firms operating in the district as of late 2014 (42%).

The second survey was conducted using the same methodology, but for firms located in the new area around Champagne-Ardenne TGV (Bezannes) station in 2015. Of 65 firms, 26 agreed to participate (39%). Both of these surveys provide valuable information, even if the response rate was not particularly high.

4.1 Activity sectors and differentiated dynamics of location

In the Clairmarais district, there is a predominance of financial and insurance activities (38.10%), scientific and technical activities (23.81%), and public administration and educational activities (16.67%), reflecting a strong specialization in services, including personal services (see Table 3).

In Bezannes, the structure of firms is completely different, with a strong specialization in offices for industry-related activities (food products, electricity, mining, etc.; 24%). Indeed, the area is characterized by a significant presence of local industrial headquarters, as well as scientific and technical activities (16%), administrative and support services (16%), and accommodation and catering activities (16%). Unlike Clairmarais, which is close to the city centre, there are no restaurants for employees. Similarly, while there were already numerous hotels in the city centre close to Clairmarais, none existed in Bezannes. Finally, Bezannes is also characterized by the presence of information- and communication-related activities (8%).

Table 3. Comparison of business sectors in each area[8] and in Reims as a whole

Business sectors	Reims (2012)	Clairmarais (2014)	Bezannes (2015)
Hotels and restaurants	5.76%	16,00%	2.38%
Construction	9.36%	4.00%	0.00%
Financial and insurance activities	6.10%	8.00%	38,10%
Information and communication	2.86%	8.00%	4.76%
Manufacture of electrical, computer and electronic equipment; Manufacture of machinery	0.35%	8.00%*	0.00%
Manufacture of food products, beverages and tobacco products	1.69%	4.00%*	0.00%
Manufacture of transport equipment	0.04%	0.00%	0.00%
Mining and quarrying; energy, water supply, sewerage, waste management and remediation activities	0.95%	4.00%*	0.00%
Other manufacturing	3.01%	8.00%*	0.00%
Other service activities	7.56%	4.00%	0.00%
Professional, scientific, technical, administrative and support service activities	15.89%	16,00%	23,81%
Public administration and defence, education, human health and social work activities	14.97%	8.00%	16.67%
Real estate activities	5.09%	0.00%	2.38%
Total	**100%**	**100%**	**100%**
Transportation and storage	2.72%	4.00%	4.76%
Wholesale and retail trade; repair of motor vehicles and motorcycles	23,63%	8.00%	7.14%
Total	**100%**	**100%**	**100%**

** forms part of the 24% of industry-related activities. Source: authors' own work, surveys and INSEE data.*

8 For all business sectors and both areas, the null hypothesis H0 (that there is no difference between the distribution) must be rejected. The calculated p-value with Fisher's exact test (0.004) is less than the level of confidence a = 0.05; the alternative hypothesis H1 (that there is a difference between the distributions) can be accepted.

If we compare the business activities present in Reims (dominated by commercial and repair activities; 23.63%), each of the two areas studied is quite highly specialized: in service-sector activities in Clairmarais, and in industry-related administrative activities in Bezannes.

The types of firms are also somewhat different: firms tend to be smaller in Clairmarais than in Bezannes (Table 4). With this in mind, business sector (services) and company size are factors likely to explain a greater frequency of use of the HST (see below).

Furthermore, analysis of the dates of implementation shows differentiated dynamics.

Table 4. Size of firms in each district

Size	Bezannes	Clairmarais
Small and medium-sized businesses	20.00%	11.76%
Very small businesses	80,00%	88.24%
Total	100.00%	100.00%

Source: authors' own work.

In late 2009, in Bezannes, 53% of the total floor area of the mixed development zone (in French, ZAC, or *zone d'aménagement concerté*) intended for business use remained unoccupied, and there were not many new constructions (see above).

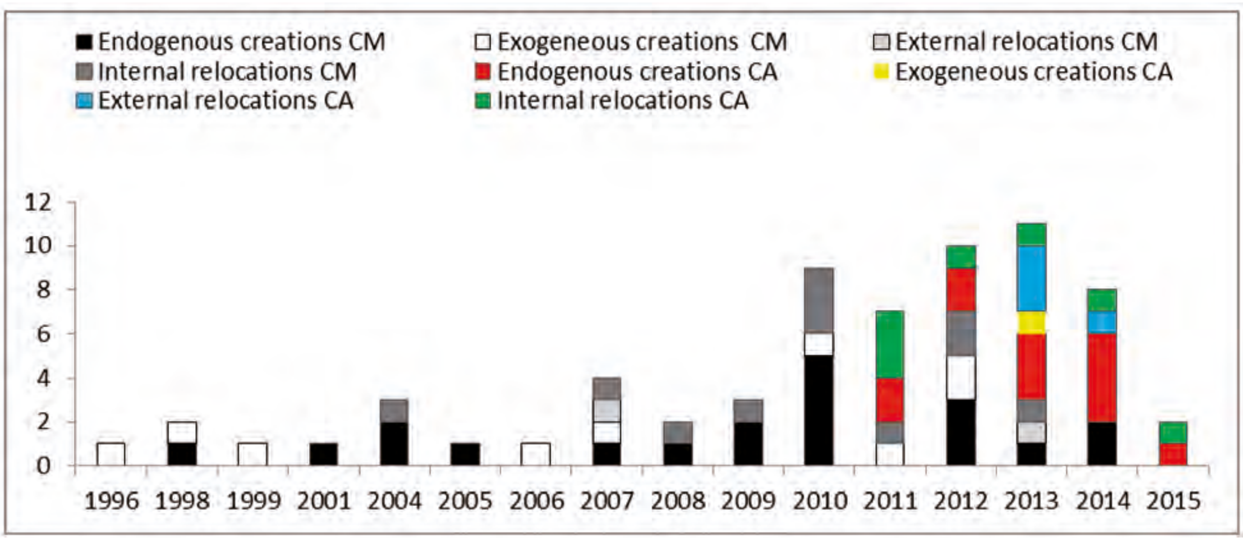

Figure 5. The dates and types of locations in each district

Source: authors' own work.

The economic context hampered its development[9], as well as the creation of other business parks in the metropolitan area. Development accelerated in 2013 and 2014 (see Figure 5) with endogenous creations (i.e. business creations originating from within the local area) representing 50% of company locations.

9 *Archaeological excavations also delayed operations.*

Internal relocations (i.e. from within the Reims area) mostly took place a few years earlier, in 2011, and subsequently tailed off. The total proportion of company establishments of internal origin is close to 80%.

In the Clairmarais district, the setting-up of firms occurred in several waves, in 2004, 2007 and 2010, as soon as business real estate became available. The role of real-estate developers was therefore particularly important. However, they exhibited different behaviours around each of the two stations. While developers maintained their construction projects around the central station, some of them postponed projects around the peripheral station amid the economic crisis. For example, the Mazars group, which had bought land in Bezannes with the aim of building offices just before the arrival of the HSR, sold off this land quickly from 2008 onwards.

Centrality therefore probably played an insurance role for real-estate developers, and particularly for local developers, which helped in turn to reassure external developers; however, by definition, this insurance effect of centrality did not benefit the peripheral station.

In the new development area in Bezannes, the settlement of outside firms – “exogenous creations” – has always been very rare. Only one exogenous creation set up in Bezannes in 2013 (corresponding to 4.17% of all firms in the area). Since that date, growth in the number of external relocations (16.67%) has been increasing. External locations as a whole represent more than 20% of firms in Bezannes.

If we compare company locations of internal and external origin in both areas, the proportion of outside firms is approximately a quarter in Bezannes, compared with a little over a third in Clairmarais. It is therefore fair to say that both areas mainly attract local firms.

However, the nature of the businesses coming to Reims from outside the city is completely different in each area. While Clairmarais attracts mostly exogenous creations (21.43%), this proportion falls to 4.17% in Bezannes. Conversely, exogenous relocations are quite rare in Clairmarais (4.76%) but are more frequent in Bezannes (16.67%). Indeed, firms with large office spaces are mainly concerned by exogenous relocations. Their activities require large offices, of which Bezannes has a plentiful supply. Furthermore, office rents and real-estate prices are more attractive in Bezannes than in Clairmarais (see above). Exogenous creations – generally smaller firms – typically seek to benefit from the centrality and image of Clairmarais. Therefore, they tend to choose locations around the central station.

4.2 The location factors self-reported by firms

The location factors self-reported by the firms surveyed are analysed first overall, and then hierarchically, initially by order of citation and lastly by business type.

First, in both areas, the number-one factor cited was office availability (14.93% for Bezannes – at the same level as accessibility and the district’s image – and 20.23% for Clairmarais). Other factors then differed (Table 5).

In Bezannes, the next most important factors are the proximity of clients (11.94%) and car parking (10.45%); by contrast, HSR is only cited by 5.97% of firms. In Clairmarais, the image of the neighbourhood, the proximity of clients and the presence of HSR were all cited by 10.71% of firms.

Table 5. Location factors self-reported by firms[10]

Location factor	Bezannes	Clairmarais
Office availability	14.93%	20.23%
Image of the district	14.93%	10.71%
Proximity of clients	11.94%	10.71%
HSR	5.97%	11.90%
Proximity of the city centre		8.33%
Proximity to highways	1.49	5.95%
Rail station		5.95%
Rent costs	2.99%	5.95%
Accessibility	14.93%	4.76%
Car parking	10.45%	3.57%
Public transport	1.49%	3.57%
Proximity of services		2.38%
Lack of competition	2.99%	
Employment area		1.19%
Image of Reims	2.99%	1.19%
Proximity to home	2.99%	1.19%
Proximity of head offices		1.19%
Business takeover		1.19%
Available land	1.49%	
Location	2.99%	
Proximity of Reims	1.49%	
Company strategy	2.99%	
Visibility	2.99%	
Total	**100.00%**	**100.00%**

Source: authors' own work.

In both cases, it is also the image associated with a neighbourhood located near to HSR that firms are looking for. Free car parking is also sought-after in Bezannes. In Clairmarais, all previously free parking became paid parking after the launch of the HSR service.

HSR is not very important for businesses in Bezannes (5.97%) while it is more so for those in Clairmarais (11.90%)[11]. In both cases, rent costs are not a major factor in location choice; however, it is more important in Clairmarais than in Bezannes.

During both surveys, firms could rank the top three factors that contributed to their choice of location in the area in question. The analysis of this hierarchy of location factors paints a different picture (Table 6) from the overall view outlined above.

10 For all factors and both areas, the null hypothesis H_0 (that there is no difference between the distribution) must be rejected. The calculated p-value with Fisher's exact test (0.001) is less than the level of confidence a =

11 This was not the case in 2007 (cf. Bazin et al., 2009).

Table 6. Hierarchy of location factors self-reported by firms[12]

Location factor	1st factor		2d factor		3rd factor	
Frequency (%)	**Bezannes**	**Clairmarais**	**Bezannes**	**Bezannes**	**Clairmarais**	**Bezannes**
Lack of competition	4.00%				5.26%	
Accessibility	24,00%		17.39%	10.71%		5.26%
Public transport			4.35%	7.14%		
Proximity to highways		6.06%	4.35%	3.57%		10.53%
Employment area				3.57%		
Proximity of city-centre		6.06%		14,29%		5.26%
Available land	4.00%					
Rail station		6.06%		7.14%		5.26%
Image of Reims	4.00%	3.03%	4.35%			
Image of the district	8.00%	9,09%	8.70%	17.86%	31,58%	5.26%
Location	4.00%		4.35%			
Office availability	4.00%	15.15%	26.09%	21.43%	15.79%	21.05%
Rent costs		9,09%	4.35%	3.57%	5.26%	5.26%
Car parking	12.00%		8.70%	3.57%	10.53%	10.53%
Proximity of clients	12.00%	21.21%	4.35%		21.05%	10.53%
Proximity of services		6.06%				
Proximity to home			4.35%	3.57%	5.26%	
Proximity of Reims					5.26%	
Proximity of head offices		3.03%				
Business takeover		3.03%				
Company strategy	4.00%		4.35%			
HSR	12.00%	12,12%	4.35%	3.57%		21.05%
Visibility	8.00%					
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Source: authors' own work.

In Bezannes, the analysis of prime location factors cited by stakeholders shows the importance of accessibility (24%), HSR (12%), car parking (12%), and the proximity of clients (12%). In Clairmarais, proximity of clients (21.21%) is the number-one factor cited, followed by office availability (15.15%) and finally the presence of HSR (12%).

The role of HSR, as a location factor, is different in each area. In Clairmarais, HSR is an additional factor (it is rarely cited as the number-one location factor), while it is almost always reported as the primary location factor in Bezannes.

Cross-referencing the number-one location factor and the type of company location is also interesting (Table 7).

12 For the first factor and both areas, the null hypothesis H_0 (that there is no difference between the distribution) must be rejected. The calculated p-value with Fisher's exact test (0.003) is less than the level of confidence a = 0.05; the alternative hypothesis H_1 (that there is a difference between the distributions) can be accepted.
For the second factor and both areas, the null hypothesis H_0 (that there is no difference between the distribution) can be accepted. The calculated p-value with Fisher's exact test (0.598) is greater than the level of confidence a = 0.05.
For the third factor and both areas, the null hypothesis H_0 (that there is no difference between the distribution) can be accepted. The calculated p-value with Fisher's exact test (0.097) is greater than the level of confidence a = 0.05.

Table 7. Number-one location factor self-reported by firms, by type of location

Location factor	Bezannes					Clairmarais					
Frequency (%)	Endogenous creation	Exogenous creation	External relocation	Internal relocation	Total Bezannes	Endogenous creation	Exogenous creation	External relocation	Internal relocation	Total Clair-marais	Overall total
Lack of competition	7.69%				4.00%						1.72%
Accessibility	30.77%	100.00%		14.29%	24.00%						10.34%
Proximity to highways						11.76%				6.06%	3.45%
Proximity of citycentre						5.88%		50.00%		6.06%	3.45%
Available land			25.00%		4.00%						1.72%
Rail station						5.88%			10.00%	6.06%	3.45%
Image of Reims	7.69%				4.00%	5.88%				3.03%	3.45%
Image of the district	7.69%			14.29%	8.00%	11.76%	25.00%			9.09%	8.62%
Location	7.69%				4.00%						1.72%
Office availability				14.29%	4.00%	11.76%			30.00%	15.15%	10.34%
Rent costs							25.00%		20.00%	9.09%	5.17%
Car parking			25.00%	28.57%	12.00%						5.17%
Proximity of clients	23.08%				12.00%	17.65%		50.00%	30.00%	21.21%	17.24%
Proximity of services						5.88%	25.00%			6.06%	3.45%
Proximity of head offices									10.00%	3.03%	1.72%
Business takeover						5.88%				3.03%	1.72%
Company strategy	7.69%				4.00%						1.72%
HSR			25.00%	28.57%	12.00%	17.65%	25.00%			12.12%	12.07%
Visibility	7.69%		25.00%		8.00%						3.45%
Total	**100 %**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: authors' own work.

In Bezannes, in the case of exogenous relocations, firms are seeking available land, car parking, HSR, and visibility (25% for each). In the case of exogenous creations, accessibility is always sought-after. Stakeholders are looking for traditional location factors (land, accessibility, etc.), and HSR is one key element of accessibility among others.

Local firms (whether creations or relocations) report much more heterogeneous factors. New firms are looking for accessibility (30.8%) and proximity to clients (23.1%); 28.6% of firms (internal relocations) are looking for free car parking[13] and the HSR service. Some local firms therefore seem to use the HSR service in their work-related travel. Before the availability of HSR, employees and managers would travel to Paris by car.

In Clairmarais, the opposite was recorded. HSR is especially important for endogenous creations (17.65%, on an equal footing with proximity to clients) and exogenous creations (25%, on an

13 *Many firms that are themselves located around the central station are moving out to areas around the peripheral station, where parking is free.*

equal footing with rent costs, proximity of services and the image of the district). In the case of the one external relocation, the firm is especially interested in the proximity of the city centre and the proximity of clients (50% each). In the case of the single exogenous creation, the firm sought to benefit from the image of the district, low rent costs, proximity of services and the HSR (25%). For local firms located in Clairmarais and Bezannes, the location factors are more heterogeneous, with priority given to the proximity of clients (17.6% for Clairmarais and 30% for Bezannes) and the availability of offices for relocations. By contrast, outside firms that do not know the area well reported just a few key factors such as available land, combined with car parking and accessibility, including HSR. In both areas, local firms are characterized by the importance of proximity to clients. With particular regard to HSR, firms in Bezannes (whether internal or external relocations) appreciate a factor such as HSR accessibility (even if this isn't the only factor that counts), while in Clairmarais only new firms (endogenous or exogenous creations, i.e. small businesses) mentioned it.

4.3 High-speed rail use

In Clairmarais, firms declared more often that they used the HSR service than firms in Bezannes. However, this HSR use varies according to the type of business in question. In Bezannes, the one newly created firm (i.e. an exogenous creation) and 71.4% of internal relocations (7 firms) declared that they use the HSR service (Table 8).

Table 8. Use of HSR and type of firm

	Bezannes			Clairmarais		
	No	Yes	Total	No	Yes	Total
Endogenous creation	53.85%	46.15%	13	35.00%	65.00%	20
Exogenous creation	0.00%	100.00%	1	44.44%	55.56%	9
Relocation	50.00%	50.00%	4	0.00%	100.00%	2
Internal relocation	28.57%	71.43%	7	27.27%	72.73%	11
Total	**44.00%**	**56.00%**	**25**	**33.33%**	**66.67%**	**42**
Type	No	Yes	**Total**	No	Yes	**Total**

Source: authors' own work.

In Clairmarais, all external relocations (2 firms) use it, as do 72.73% of internal relocations (11 firms). In each area, the frequency of use of HSR for work-related travel is different (table 9). In Bezannes, the HSR service is used by most firms several times per month.

Table 9. Frequency of work-related travel by HSR by job type[14]

	Bezannes				Clairmarais			
Frequency of work-related travel	Director	Manager	Employée	Total	Director	Manager	Employée	Total
1 to 5 times per week	2	2	2	**6**	10	2	5	**17**
1 to 5 times per month	6	4	5	**15**	4	2	2	**8**
Less than once per month	4	1	3	**8**	4	0	7	**11**
Total	**12**	**7**	**10**	**29**	**18**	**4**	**14**	**36**

Source: authors' own work.

This frequency of use is relatively equally split between directors, managers and employees. In Clairmarais, the use of HSR is more common (one or more times a week in general) and is most frequent for directors of smaller firms in the tertiary sector. In Bezannes, personnel working in construction, manufacturing and extractive industries, and information and communication activities are the most frequent users of the HSR service.

5. Conclusion

The case of Reims allows us to revisit the issue of firms' location choices with regard to HSR stations, by analysing two types of station: a peripheral station and a central station. Both of these stations have been served by HSR services for the same amount of time, since 2007, but the respective changes in accessibility have varied. The central station is the station with the best accessibility to Paris by HST and to the other towns in the former Champagne-Ardenne region. While ChampagneArdenne station is less well served by trains to and from Paris, the station has the advantage of being directly connected to the high-speed rail network.

The arrival of HSR is the main reason for the creation of a business district and business parks in Reims. It triggered the freeing-up of land around the central station, where offices have now been built. The arrival of HSR also led to the creation of the deferred-development area in Bezannes, close to Champagne-Ardenne station. In both cases, it was local companies that first chose to locate there. These "early adopters" had an insurance effect, encouraging companies from outside Reims to move in, but outside firms remain a minority.

14 For the frequency of work-related travel for all jobs and both areas, the null hypothesis H0 (that there is no difference between the distribution) must be rejected. The calculated p-value with Fisher's exact test (0.028) is less than the level of confidence a = 0.05; the alternative hypothesis H1 (that there is a difference between the distributions) can be accepted.
For the frequency of work-related travel for directors and both areas, the null hypothesis H0 (that there is no difference between the distribution) can be accepted. The calculated p-value with Fisher's exact test (0.112) is greater than the level of confidence a = 0.05. For the frequency of work-related travel for managers and both areas, the null hypothesis H0 (that there is no difference between the distribution) can be accepted. The calculated p-value with Fisher's exact test (1) is greater than the level of confidence a = 0.05. For the frequency of work-related travel for employees and both areas, the null hypothesis H0 (that there is no difference between the distribution) can be accepted. The calculated p-value with Fisher's exact test (0.234) is greater than the level of confidence a = 0.05.

Nevertheless, despite these similarities, each station is characterized by different dynamics. Around the central station, buildings were renovated or constructed ahead of the arrival of HSR, and company locations in the area were not halted by the economic crisis. By contrast, the crisis did have an impact on the development of the business parks around Champagne-Ardenne station, delaying their realization until 2015. Moreover, the companies in each area tend to be from different business sectors. Lastly, the location factors for firms in each area are similar but not identical by any means. Around both stations, office availability and the image of the district are the main location factors, but subsequent factors vary: the presence of HSR is a more important location factor in Clairmarais, but one that appears some way down the list in the location-factor hierarchy. By contrast, it was more often cited as the number-one location factor by firms located near the peripheral ChampagneArdenne station. Furthermore, it doesn't play the same role in each area: while HSR is one element of more general accessibility considerations in Bezannes, it is more important and used more in Clairmarais, where rail services to and from Paris play a more essential role.

In this way, by inducing a dynamic of business-district or business-park creation, HSR structures the urban space and segments it by function, with service-sector activities in the city centre and industry- and sales-related administrative activities on the outskirts, where firms can find large offices and good accessibility without the high costs of city-centre locations in terms of car parking and office rents.

To conclude, in the case of Reims, while location choice is partly linked to the type and level of accessibility provided by HSR in each type of station, it also depends on the types of firms in question, and in particular whether they are new or existing companies. For newly created outside firms, the most important location factors are office space, access to Paris, and lower rents than in Paris. For relocations within Reims, office availability and the proximity of clients passing through the station are most important in the case of the central station. Surprisingly, both surveys revealed that access of a large pool of qualified jobs in the Paris region was not an important factor for firms choosing to locate in Reims. It confirms that the economic climate is very important for business parks around peripheral stations but not for business districts around central stations, as centrality seems to be an insurance factor.

With an increase in the number of services to and from Paris – combined with existing services to Marne-la-Vallée Chessy and the fact that the future Grand Paris Express network will link the east of the Paris region with the north and south without having to pass through central Paris – the accessibility of Champagne-Ardenne station could be highly improved.

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Which way to the city centre? Pedestrian itineraries between High Speed Rail stations and historic centres. Assessing urban quality and tourist behaviour through GPS tracks in Toledo.

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Abstract

In heritage cities close to big metropolitan areas as Toledo, declared Unesco World Heritage, High Speed Rail has become the favourite access mode for single-day tourists visiting the city. The access from the station to the historic centre becomes a relevant subject to study, as tourists can choose between different transport modes: walking, buses, tourist buses and taxi. Walking should be encouraged because it is more sustainable and tourists' experience starts just in the rail station. In the case of Toledo, two pedestrian itineraries have been assessed, considering the quality of public space, the wide of footpaths, the continuity, etc. In addition, the use of these itineraries for reaching the city centre and tourists' behaviour when walking around the historic city have been also analysed using GPS tracks shared in social networks such as Wikiloc. This is a powerful tool to understand the points of interests of the city, the density of use of the different streets and the use of different access to the walled city.

Keywords: High Speed Rail, tourism, urban quality, pedestrian behavior, GPS.

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1. Introduction

As any other transport mean, High Speed Rail (HSR) is used by tourists when it is the most convenient mode in terms of travel time and costs, and when the timetables fit properly to their needs. HSR mainly allows connections between city centers, being useful for urban cultural tourism and business tourism (Coronado, et al., 2013). It also provides shorter travel times than the car or the bus, making same-day tourism trips more attractive in longer distances (Moyano, et al., 2016).

Once the tourist has arrived at the station, he/she must access the historic city center where the monuments and tourism amenities are usually located. The natural itinerary is walking along the "Station Street", a street created in the 19th century in order to connect the railway station to the consolidated city (Santos, 2007). These station streets took the form of tree planted, wide and straight avenues that were flanked by important buildings such as banks, hotels, or family palaces, etc. At the same time, these buildings were attracted by the relevance of the railway at the time (Calvo, 1998) and today are part of the city's visitor experience. In this way, the urban visit starts already at the station gate, or even inside the station, in the cases where the architecture is singular or interesting.

Back in the 19th century, when the city was not too relevant or there were other limitations (i.e. topography, rivers, high land prices, etc.), stations were located at peripheral locations within a variable distance to the city center. Usually, around the station, a neighborhood has grown, more or less independent from the city's historic core. In some cases where the distance between the station and the city was not too long, the city growth has made the location of these peripheral stations become similar to the initial edge locations. In these cases, the connection between the city and the station is not so straight and wide, as it was achieved by old conventional roads turned into regular streets by city growth. This is the case of the station in Toledo, located at the other side of the Tagus River, which has been reused by the HSR (Figure 1). In this case, the pedestrian access to this peripheral HSR station is still possible, but some tourists use taxis or specific buses that takes them right to the city center. Pedestrians have different itineraries to access the city center: a shorter one, the historic pedestrian path, and a longer one, used by cars and public transport.

Figure 1. Toledo in 19th century (left) and today (right). The station was located at the other side of the river Tagus.

Mapa Topográfico Nacional.

The aim of the article is to identify which of these itineraries is more used by tourists, and to assess its physical characteristics linked with its walkability in order to check whether they are relevant in terms of the path's election. The GPS tracks shared by tourists in social networks like wikiloc have been used to identify which are the tourist itineraries throughout the city. Then, the walkability of itineraries has been assessed and compared.

The pedestrian paths in these small and medium cities with edge HSR stations are a key factor for both tourists arriving to the city and residents commuting (or just travelling) by HSR. An adequate, readable and comfortable itinerary will enhance the experience of the former and will promote a sustainable transport mode for the latter. In many cases, the huge investments of HSR construction are not accompanied by small expenditures in urban space enhancements in order to provide a comfortable pedestrian access.

2. Background

2.1 HSR stations and tourist itineraries

One of the main issues on HSR is the way in which cities are served by stations (Garmendia, et al., 2012). As Bertolini and Split (1998) identified, train stations perform a twofold role. First, from the transport approach, stations can be considered as nodal points, where the resulting level of HSR service is of great importance. Second, from the urban approach, stations constitute a landmark in the city. In the case of HSR, stations are often the pretext for ambitious urban (renewal) projects and developments. The role of the historic train stations as "gate of the city", which had been overshadowed by the expansion of freeways and airports, is strengthened by HSR stations (Mannone, 1997).

In order to assess both the impact of a HSR station and the strategies developed by cities to make the most of the new infrastructure, literature on HSR stations establishes different typologies of HSR stations (Troin, 1995; Bellet et al., 2012). These classifications consider different criteria: if the station is new or an adaptation to HSR; the location of the station in relation to the city; and the relevance of the station as a transportation node. However, the key factor that has an influence on the urban development of the city is the location of the station (Ureña, et al., 2012).

When analyzing small and medium cities, Menéndez et al. (2002) consider three types of stations: central, city-edge, and peripheral. Given their weaker position, edge or peripheral settings are more common, making urban projects more difficult to succeed, especially in peripheral settings (Auphan, 1992; Troin, 1995). Literature on the latter has focused mainly on the tertiary or residential developments around HSR stations (Ribalaygua, 2005) and, taking into account their isolated situation, on the connection of these stations to the city center and to the historic train stations. This is the case of France, where new peripheral stations are built for long distance HSR services, and old conventional stations maintain regional and some of the HSR services (Facchinetti-Mannone & Richer, 2011). Finally, edge settings take advantage of the lesser dense urban fabric of the city outskirts, which allows for urban development projects around the station although the urban pattern continuity between the station and city is guaranteed.

HSR intermodal opportunities have been studied from three different scales. From a national and regional scale, the opportunities of HSR/conventional rail and HSR/air connections have been assessed (Chapelon & Bozzani, 2003; López-Pita & Robusté, 2004; Givoni, 2006). From a local scale, the literature has focused on the station-city connections. When the station is central, the connection between the station and the transit network is a principal issue (Peters, 2010), while in the peripheral ones specific shuttle services are necessary to assure the connection (Facchinetti-Mannone & Richer, 2011; Menéndez, et al, 2006). In addition, the station design as an intermodal node is also a relevant issue. The location of the platforms, park&ride spaces, parking, bus stops, etc. are key elements on the internal efficiency of the building (Tapiador et al., 2009; Menéndez et al., 2002). Although there are specific case studies which provide modal share data of access to and from the station (Menéndez, et al., 2002), there are no studies about the quality of the pedestrian link from the station to the city center.

Although there are no systematic studies about the effects of HSR on tourism (Coronado, et al., 2012), scholars coincide on the positive impacts of HSR effects on local tourism (Bazin, et al., 2011; Masson & Petiot, 2009; Van den Berg & Pol, 1998). The possibilities of urban tourism also depend on the local strategies which aim to take advantage of the new accessibility provided by HSR and the centrality generated by the station, including planning, management and promotional strategies (Ribalaygua, 2005; Bellet, et al., 2012). Planning strategies are related to the integration of the station and the coordination between the HSR project and the city/ regional planning. Management strategies aim to make the most of the station's vocation for centrality either as a modal exchange centre or as a developer of the surrounding land. Finally, promotional measures have focused on urban marketing campaigns, trying to recruit economic activity, building amenities and service facilities for congresses and meetings, and linking the image of the city to the modernity associated to HSR.

In fact, cities try to make the most of the HSR station, linking it to concepts such as centrality and/or modernity, but often, when a tourist arrives to the station finds it hard to get to the city center, especially if it is a novel destination and the station is not central. No strategies or policies have been found to make comfortable and legible itineraries between the HSR station and the city center, with walkable and pleasant promenades for city-edge stations.

2.2 Locating tourists using GPS

Assessing tourists' behavior in cities is not an easy task. While it is easy, or at least possible, to have accurate data about the temporal distribution and number of visitors to some cultural amenities like museums and other monuments where it is necessary to buy a ticket to enter, it is not so easy to know their physical distribution or which itineraries they use around the city in both open spaces and in the street network. Tourists blend with city inhabitants and it is not always easy to differentiate them when using cameras or street counting/audits (Ruiz-Apilanez et al., 2015).

GPS are a powerful tool to analyze this behavior as it is possible to register the location of the tourist at every moment. However, there are some restrictions. First, GPS data loggers have a limit in the duration of their batteries, so the visits must not be too long. An interesting alternative is to use smartphones' GPS, but in this case it is necessary to previously contact the users whose behavior is going to be analyzed so they download the Apps to register the tracks, and this is nearly impossible with tourists (Marmolejo & Chaves Custodio, 2016). Second, it is also necessary to have access to the tourist twice in order to give him/her the GPS device and to reclaim it at the end of the day. GPS have been used with cruise visitors taking one-day visits to cities (Ferrante, et al., 2016) that are identified when exiting and returning to the ship, or parks visitors (Santos, et al., 2016) that can be provided with the GPS device at the entry of the amenity (Beecoa, et al., 2014) (Zheng, et al., 2017). Third, the number of tracks that can be registered is limited by the number of GPS devices available, but on the other hand, the amount of information that each track provide is large. The tracks can be mapped depending of the objective of the study, but data usually include density of visitors, time-space distributions, speeds, stopping points, entering and exiting, gates, etc. It is also possible to elaborate statistical analysis of the tourists' behavior: total distance walked, duration of the visit, number of points of interest visited, etc. To overcome this difficulty, shared tracks in social network sites like Endomondo, Strava, MapMyRide, Runtastic, Sports-or wikiloc can be used (Mínguez García, et al., 2015) (B. & Nogueira Mendes, 2016), but only in very popular cities or destinations that will assure a large number of tracks.

2.3 Assessing urban design and walkability

In the mid-20th century the ideas of the Modernism entered in crisis and new ideas began to emerge claiming the recovery of a public space of quality based on the traditional city (Jacobs, 1961). In the 70s, these ideas were consolidated going beyond a mere critique of the functionalist city. The design and maintenance of a good quality public space is synonymous with 'making city' (Gehl, 1987) and that the correct design of the urban environment is a necessary condition for the happening of activities. Specifically focused on the streets, Allan Jacobs identified a number of key factors that make a street, a 'great street' (Jacobs, 1993). These factors go from the physical configuration of public spaces (sidewalks, trees, etc.), to the configuration and use of private spaces (facades, shops, accesses, etc.), and to other more generic aspects such as the urban morphology or the location of the street in the city, to even intangibles like the "magic" of the street. If the works of Jacobs and Gehl, among others, were focused primarily on the use of public spaces, more recent studies have focused on the "walkability". The quality of public space is a key element of the "walkability" concept which has been worked from the health sciences perspective, since walking is considered as part of the "active living" (Ewing et al., 2006; Freeman et al., 2012), and from the transport and sustainability perspective, since "walking" is the quintessential sustainable transport mode.

The concept of pedestrian Level Of Service (LOS), introduced by Fruin (1971) in the 70s, initially considered just the capacity of sidewalks, but has recently been expanded to include aspects such as the perceived quality of the urban environment (definition of the street, transparency, obstacles and barriers, etc.) in relation to the movement of pedestrians (Jaskiewicz, 2000; Tan, et al., 2007), or even the analysis of the influence of the characteristics of the built environment on the willingness of citizens to walk or riding a bike (Cervero, et al., 2009).

The evaluation of the quality of a route is done by analyzing a number of factors, generally qualitatively, and establishing a set of values and obtaining a final grade (level of service) that allows comparison with other spaces (Clemente, et al., 2005; Gandolfi, 2010). Determining which factors are most influential in the perception of quality from the point of view of the pedestrian, and its weight in the final grade, is usually done through surveys. These sometimes are of a general nature and are intended for residents of a city and focused on the factors that matters the most to pedestrians (Borst, et al., 2008; Kelly, et al., 2011), and sometimes these surveys are performed in areas of interest in situ, asking the reason for choosing a particular route (Weinstein, et al., 2008).

3. Object and Methodology

The aims of the paper are (1) to assess the tourists' behavior in the public spaces during their visit to the historic center of Toledo, which is a walled city that can only be entered through a reduced number of gates, and (2) to assess the different itineraries used when walking between the edge-HSR station and the historic city center. The ideal scenario would be a direct and legible path between the station and the city center in which the station would be the beginning of the tourist experience. However, this is not the case in Toledo due to peripheral location of the 19th century station that has been refurbished to be used by High Speed Trains. The station was originally located in a peripheral setting due to the proximity of the Tagus River, and the different bridges crossing the river have created different available itineraries that can be used by the tourists that must find their way to the city center overcoming several difficulties such as lack of orientation, narrow footpaths, inconvenient street crossings, unpleasant environment, etc. which introduce some friction in this transport link.

The behavior of tourists entering the city center has been analyzed using wikiloc tracks shared online by tourists. Wikiloc is a social network where users share tracks of their trips in the countryside and in the cities. In June 2017, there were 302 results when searching walking tracks across the city of Toledo. All tracks were checked one by one rejecting those that were too short (shorter than 1 km) or too long (longer that 10 km), as many of these were tracks following rural trails outside of the city. Some tracks were rejected as they were not passing through the historic city center, but the modern neighborhoods of Toledo. Also, some tracks uploaded several times by users were only considered once. Other tracks were not used as they belong to other cities but had Toledo as a keyword (i.e. some tracks in Madrid passing through the Toledo Street). After filtering all the tracks, only 90 were selected for the research.

Subsequently, all tracks were imported to a GIS program. As wikiloc filters tracks eliminating errors like reducing the number of points, it was not necessary to make corrections in the tracks. When a track is imported to GIS, the program finds a list of points that must be converted into lines to be able to make density measurements, counting how many lines pass through the cells of a grid (Zheng, et al., 2017). As GPS precision varies between 5 and 10 meters, several grid sizes were checked, finally adopting a grid of 40 x 40 meters.

In order to assess the pedestrians' paths between the HSR station and the historic city core, two itineraries have been identified from the results of GPS tracks analysis. The origin of the itinerary is obviously the HSR station, and the end was located in the different historic gates where the tourist enters the walled city.

The itineraries are then divided into sections (links) and nodes. The nodes are the street crossings and other points susceptible to introduce discontinuities to the itinerary (i.e. detours, disorientation, etc.), and the sections are the homogeneous stretches between the nodes which usually correspond to street blocks. Sections and nodes have been separately assessed.

For each node, three main data have been collected: legibility, level of detour, and accessibility. Concerning legibility, the follow through in a node can be legible, not legible, or not legible but solved with tourist indications. The level of detour (D) is calculated as the increase of length in the itinerary imposed by a street traffic crossing or any other obstacle. Lastly, the point will be accessible is the width is enough and the curb is adapted.

For the sections, several indicators have been used to quantify the quality of the footpath, the internal band and the external band, all of them in a scale ranging from 0 to 5. The footpath width will have the maximum value (5) when the width is over 5 meters, while it would be zero if there is no footpath at all. The footpath maintenance was assessed in a qualitative way. The quality of the internal band has a value of 5 in parks, squares, and high quality residential blocks with commercial activities in the ground floor, 4 in residential blocks with commercial ground floor, 3 in blocks with only commercial uses or only residential blocks, 2 in blocks with single family houses or public facilities, and 1 for industrial activities or parking lots, and 0 in empty plots. Transparency is measured considering the density of entries, windows and other openings in the buildings in the block. Similarly, the permeability is measured as the density of entries in the block.

The quality of the external band is also assessed in a qualitative way, with a value of 5 for parks, squares or pedestrian streets, 4 for green spaces which separate pedestrians from traffic, 3 for slow traffic streets with parking places or any kind of protection band, 2 for fast traffic streets with parking places or any kind of protection band, 1 for slow traffic streets without protection band, and 0 for fast traffic streets without protection band. Finally, the presence of street trees (T) is also measured, using the distance between trees, with a value of 5 when trees are closer than 7 meters, 1 when the distance is longer that 21 meters, and 0 if there are no trees at all.

Each indicator has been schematically outlined ranging from 0 to 5 following the same criteria, producing three possible assessments: red (poor), yellow (adequate) and green (good-excellent). The different itineraries are compared among them by means of an aggregate star graphic. However, the itinerary may vary a lot along sections, and the aggregate measures of the itinerary may not be really useful, as excellent resulting sections may cover up the poor ones. Also, no aggregate measures for each section have been assigned, since this aggregation would say nothing about how to address the deficiencies (Jaskiewicz, 2000).

4. Results

Using all the GPS tracks, a map of points' density in the historic center of Toledo can be drawn (Figure 2). This map represents how many registered points are found in each 10 x 10 m cell. In other words, it represents the density of tourists' presence considering how long they stay at a point. If a tourist stays longer in an area, his/her track will have more points registered at that point. In this sense, although wikiloc filters excessive data, this result is not too accurate. However, as it would be expected, hot spots appear at the entries to the monuments, squares were tourists sit, and queuing areas.

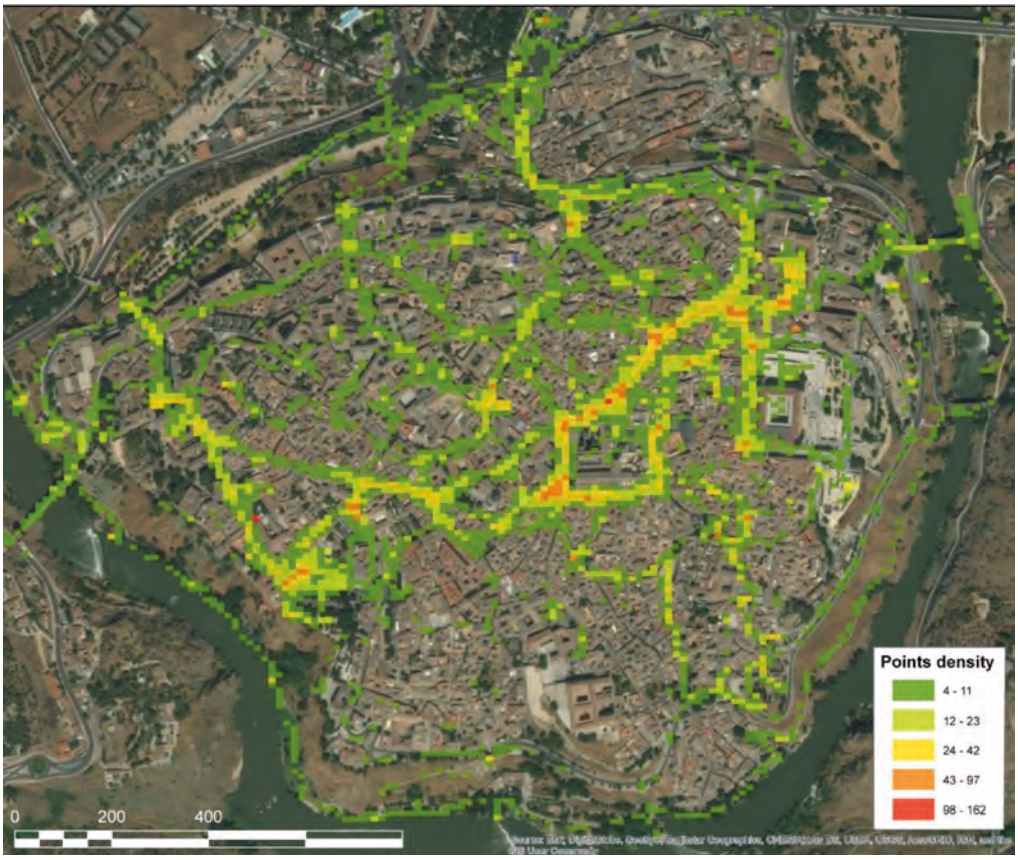

Figure 2: *Point density tracks in a 10 m x 10 m grid. Source: Own elaboration*

The use of a 10 m x 10 m gid introduces some errors as the precision of the domestic GPS is not so high. For this reason, a new map is drawn representing the density of GPS tracks shared trough wikiloc (Figure 3), meaning the percentage of the 90 tracks passing at least once through each of the 40 m x 40 m grid. This map shows how most of the tourist itineraries pass through the 'Comercio' street that links Zocodover plaza with the cathedral (red area in the map). It is also clear how most of the itineraries are concentrated in the north of the city, which was the richest part in the past and, therefore, is where most of the palaces and churches are located. On the contrary, the south part of the city is much less visited. This area corresponds with the historically poorest neighborhoods, and therefore, today, there are less points of interest for the tourist visit.

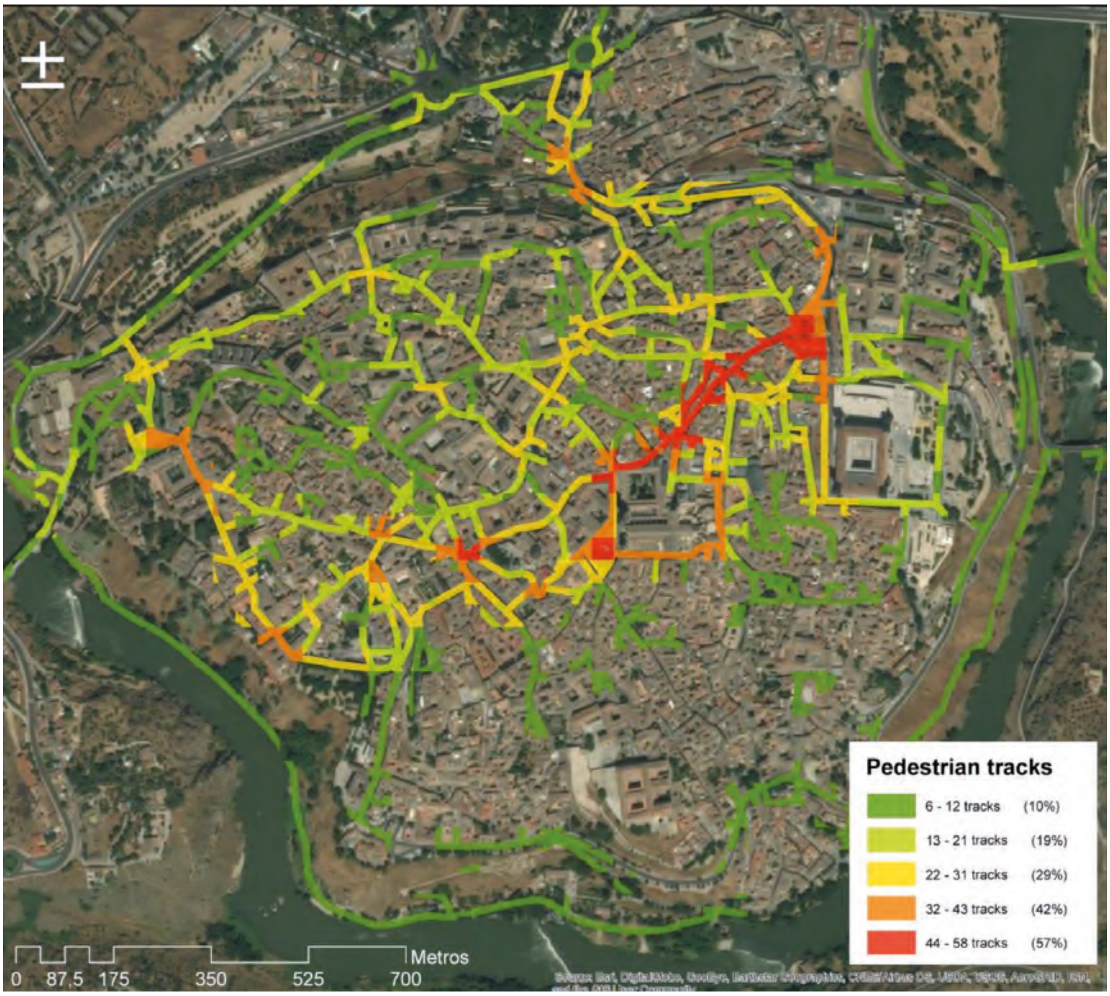

Figure 3. Percentage of all the tracks passing through a 40 m x 40 m grid.

Source: Own elaboration.

It is also possible to identify the use of the different gates of the city. Although the closer one to the station is using the Alcántara Bridge, most of the tourist enters the historic city using the Bisagra gate that corresponds with the road entering from Madrid in the north. This route takes a longer path to access Zocodover plaza, but it is the one used by cars and buses, and therefore, the one that is sign posted. Both routes from the station have been assessed in order to understand why this is happening.

The HSR station in Toledo reuses the historic station located at the other side of the Tagus River, between the flood plain and a residential neighborhood. Historically, the connection of the station to the city center was made through the Alcántara Bridge, to the south of the city, where the river narrowed. Later, with the expansion of roadways, a new bridge was built which connected the peripheral neighborhoods at the other side of the Tagus River (and the station) with the north access to the historic city, the Bisagra Gate, which is the main access to Toledo from Madrid. Today, the historic itinerary to the station through the Alcántara Bridge has been overshadowed by the new bridge connection and the arterial street tangential to the station. Therefore, there are two possible itineraries from the HSR station to the city center. The southern itinerary is the shortest (700m) but it is not very evident unless you are familiar with the city; and the northern itinerary, which is longer (1200m) but might be more straight or evident for foreigners, following the road traffic signs (Figure 5).

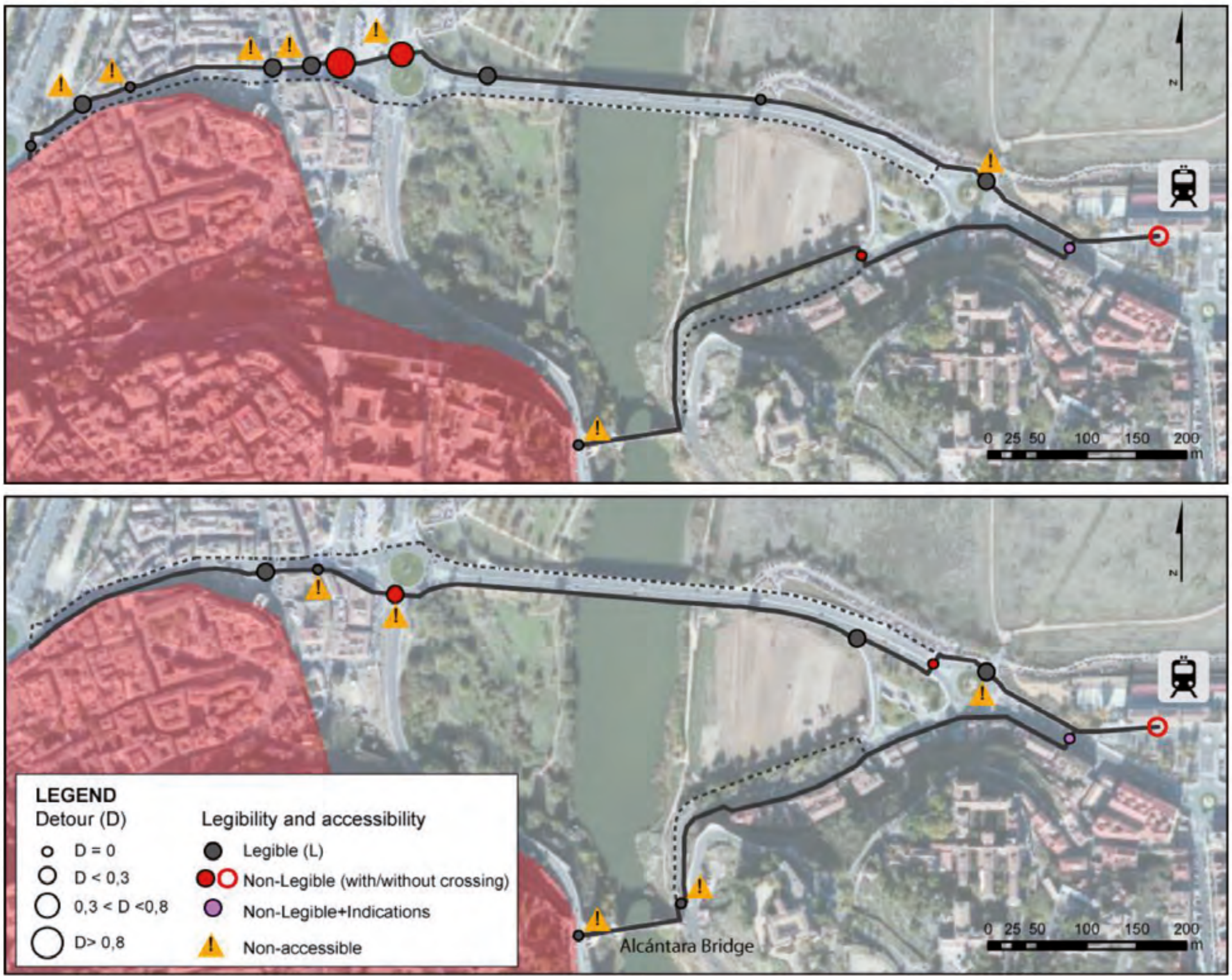

Figure 5: *Toledo: the two itineraries from the HSR station to the city centre.*

Source: Own elaboration

The connection of the station with the city center has never been considered from a pedestrian friendly perspective in spite of the short distance between them, due to the presence of the river and the topography, which constitute a powerful psychological barrier. Even more, the city offers a specific direct and non-stop bus service for tourists between the HSR station and the city center with timetables coordinated with the HSR services. In 2007, before this specific tourist bus was implemented, Guirao (2008), through an onboard survey, identified that more than 40% of tourists from HSR walked from the station to the city center, 20% were users of the city bus and a high percentage had no previous information on how to get to the city center.

Both itineraries begin along the tangential main road and cross different unplanned urban fabrics, at the periphery of the city, making their way to the city walls. In both cases, the two sides of the itineraries have been analyzed.

Southern Itinerary

Both sides finish once the Alcántara Bridge is crossed and they also share the first 200 m because of the roundabout and street crossings configuration. Both sides must cross the road to the station at the same point, where tourist can find a small sign on the wall (Figure 6), telling them to follow this historic itinerary. However, this indication is less visible than the road traffic signs and touristic signs in the northern itinerary.

Figure 6. Pedestrians must cross at this point to follow the historic itinerary, only sign posted with a very small sign on the wall of the building across the road.

Both sides present very different characteristics in the intermediate part of the itinerary and must cross the road just once, either at the beginning of the river embankment or just before the Alcántara Bridge.

In relation to the external band, both itineraries present problems in the last 80 m before arriving to the Alcántara Bridge, because pedestrians must walk along narrow footpaths without physical segregation from the traffic (Figure 7). The south side runs along a service lane with a mixture of old and recent residential developments with uninteresting commercial properties. On the contrary, and in spite of the narrow footpath on the north side (2 m which come to have 1.20 m in the narrower section), the existence of a promenade with a view to the river banks and the city of Toledo on this side is an asset. The tree planted promenade provides a quality external band and the view to the river banks and the city of Toledo in the background grades high the internal band (Figure 7). However, in the only street crossing to the north side there are no tourist indications.

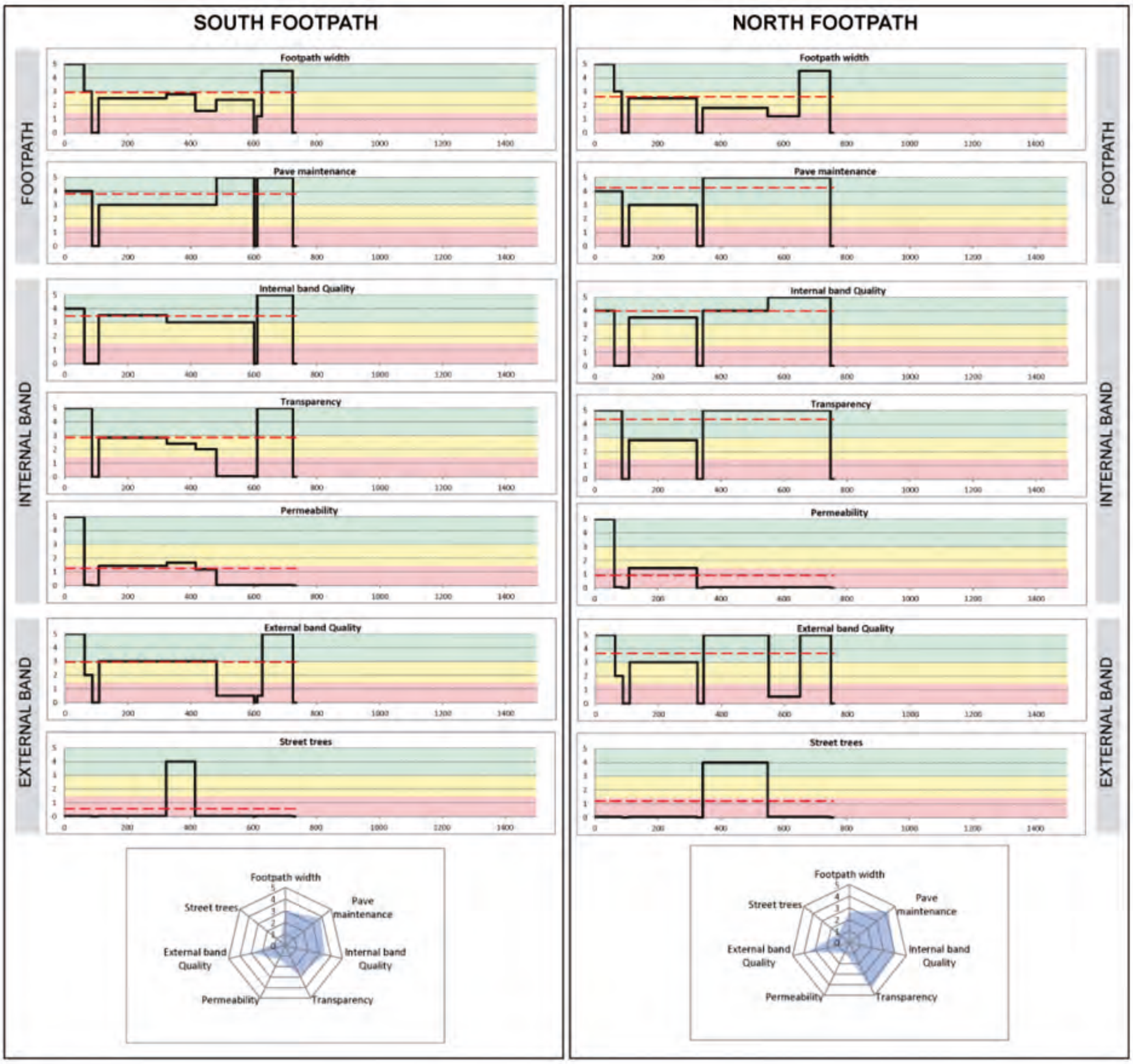

Figure 7: *Longitudinal characteristics of the southern itinerary.*

Source: Own elaboration

Northern Itinerary

This itinerary is more legible than the south one, due to the relevance of the arterial street and the traffic indications. The itinerary is not pedestrian friendly because of the adjacent fast traffic and the narrow footpaths (Figure 8). Both sides have continuity and accessibility difficulties after crossing the bridge, but these are even worst in the north one (Figure 8). In addition, in the south side the views to the river and the historic city are not disturbed by the presence of traffic. However, as in the Alcántara Bridge itinerary, there are no tourist signs indicating this option.

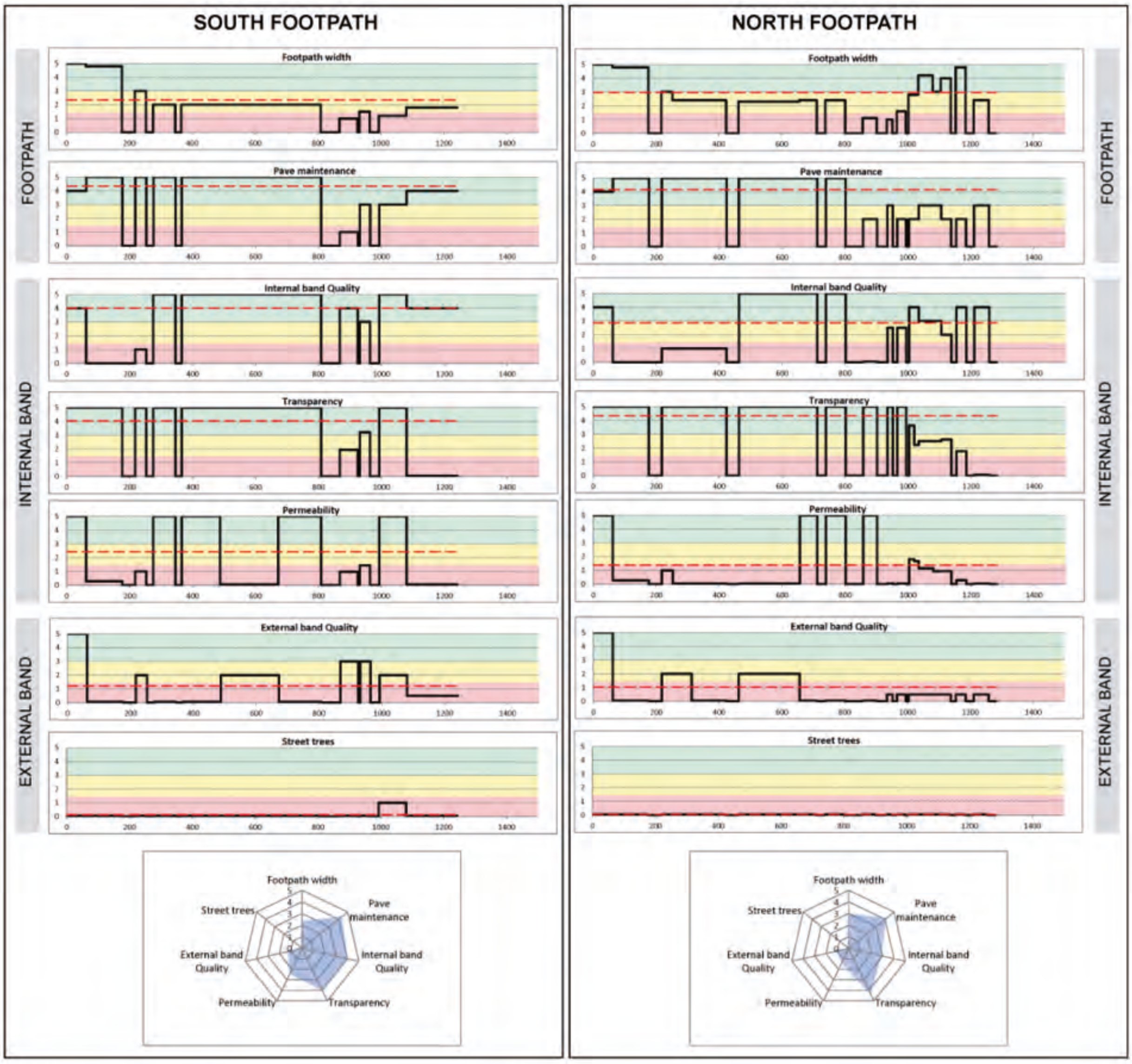

Figure 8: Longitudinal characteristics of the northern itinerary.

Source: Own elaboration

Toledo could have a short and pedestrian friendly access to the city center, following the Alcántara Bridge itinerary, but it seems that the city prefers to provide a comfortable bus connection, maybe trying to ease the ascent to the historic city.

5. Conclusions

In historic cities with large tourist areas it is hard to know where the tourists go and which streets do they follow. The use of GPS tracks may be a helpful tool, but it is difficult to obtain the tracks, as GPS data loggers must be provided to and collected from the visitors. The use of social networks sites as wikiloc, where the users share their tracks, may help in this task. However, the amount of information is reduced as it is impossible to know precisely enough when the route was made and by who. Yet, it is good enough to obtain density maps that show an average of the tourists' spatial distribution. When the number of access points is reduced, as it happens in Toledo, it is also possible to understand the use of these gates. In this case, we detected an unpredicted use of the longest itinerary to access the city from the HSR station.

The analysis of the itineraries showed the relevance of the legibility and signing. Also, the shortest itinerary has been made by linking different preexistent itineraries, usually with illegible changes of direction. These preexistent itineraries also respond to different periods and origins, and therefore present different characteristics not only in relation to the private space (urban morphology, building heights, setbacks, etc.), but also in relation to the public realm (footpath width, paving, street trees, etc.). On the contrary, the road access has a more uniform cross section.

The article conclusions help in designing measures to improve the quality of the itinerary and enhance the tourist experience. In small cities, HSR stations settings have sometimes followed the pattern of the 19th century stations in the surroundings of the consolidated city, in what could be called an edge location. However, while historic train stations shaped the urban structure with the “Station Street”, perpendicular to the tracks and leading directly to the city center, the edge HSR stations have usually been organized based on a tangential connection, parallel to the tracks, and conceived for road traffic.

Cities are concerned with getting a HSR station which always offers a good traffic access. However, it is not so frequent to provide an adequate pedestrian path, in spite of the walkable distance of edge stations to the city center. Considering the investment of cities in HSR accommodation and promotion campaigns, to adequately signpost and adjust footpaths for a comfortable and pleasant walk would be a low-cost measure to enhance the tourist experience.

Central rail stations are important transport nodes but also relevant places in the city, because they have been able to shape the urban pattern around them. On the contrary, edge HSR stations are also important transport nodes but their role as singular places in the city is limited by the bad quality of their pedestrian access. These edge HSR stations have become a hidden city gate and the station-city pedestrian connection has become the missing link in the intermodal transport chain.

6. Aknowledgements

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Processes, urban impact and evaluation of the high-speed rail in the city of Zaragoza, Spain

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Abstract

The city of Zaragoza experienced during the last decade the major urban transformation of its history. Two events made it possible, acting like "leverage effect" through strategic urban projects: the arrival of the high-speed rail in the year 2003 and the celebration of the International Exhibition in 2008. These two events, closely linked, allowed finishing a lot of former urban needs in strategical locations.

The rail infrastructure was a widely debated topic during the development of the General Master Plan, since 1997 to the definitive approval in 2001. This process proved an unexpected public participation, changing the location of the rail station and covering the rail lines.

For the development of the new rail infrastructures and the urban projects relate, in March 2002 was signed an Agreement by the Ministry of Public Works, the Regional Government and the City Council of Zaragoza to create a public company that became the responsible for the management of the urban transformation, that is still working.

The election of Zaragoza as the host city for the Expo 2008 in December 2004 boosted the execution of many infrastructural works and urban projects. But after the event, the real estate and economic crisis impeded the implementation of the post-Expo projects creating a great paralysis that has not been unblocked until today.

The paper analyzes the processes, the management and design of the strategic urban project since the beginning of the twenty-first century, the role of different stakeholders in the process, the urban impact of the built works and the decisions after the real estate crisis in 2008. In the end, it evaluates the limited resilience of the city facing this new scenario and the lack of leadership and capacity to find a way to continue the unfinished projects.

Keywords: *Strategic urban projects, Zaragoza, digital mile, high-speed rail*

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1. Introduction

The city of Zaragoza, in Spain, experienced during the first decade of the 21st century the greatest urban transformation of its history. Two events made it possible, acting as "leverage effect" through strategic urban projects: the arrival of the high-speed rail in the year 2003 and the celebration of the International Exhibition about Water and Sustainable Development, in the year 2008.

Fig 2. Delicias Intermodal Station and the Expo 2008 site by night. Source: ZAV

Zaragoza is the fifth biggest city of Spain with an estimated population of 661.108 inhabitants in the year 2016 (1), behind Madrid, Barcelona, Valencia and Seville. It is located in the northwest part of the country, in the river Ebro valley, with a similar distance from Madrid, Barcelona, Valencia and Bilbao. It is at the halfway point between Madrid and Barcelona – 312 km to Madrid and 306 km to Barcelona-, thus becoming the main stop between the two cities.

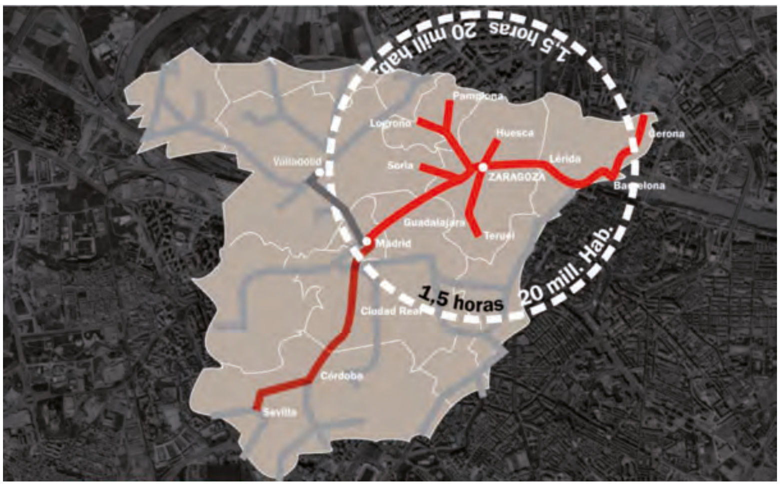


Fig 2. Location of Zaragoza and time distances on High-speed train. Source: ZAV

2. The arrival of HSR seen as an opportunity for the city

In the mid-nineties the city looked enviously how other Spanish cities celebrated great events involving major urban transformations. Barcelona hosted the Olympic Games in 1992 achieving a renowned urban renewal and Seville hosted the World Exhibition in the same year. The Expo in Seville did not imply as ambitious urban renewal as the one in Barcelona, but served to improve the infrastructural level of the city. In October 1993 construction works also had started in Bilbao on Guggenheim Museum, finishing in October 1997 (2).

In this context, the arrival of the high-speed train generated in Zaragoza a new level of expectation for a depressed city. It was seen as the opportunity to pursuing a qualitative urban, social and economic growth and to finish some desired infrastructures. It also generated a new public concern about the urban issues much broader than previously.

The first HSR line in Spain was inaugurated in the year 1992 from Madrid to Seville on the occasion of the World Exhibition. In the year 1994, the National Plan of Infrastructures gave priority to the HSR line Madrid-Barcelona until the French frontier and, in the route, Zaragoza stood as the main stop between the two cities. Due to the economic recession since 1993, the pace of construction slowed, which allowed to Zaragoza rethinking about the urban integration of the rail infrastructure across the city.

3. The railway infrastructure in the city

The first train in history arrived to Zaragoza in September 1861 from Barcelona, according to Lezáun (2011). The first station was located in the northern shore of the river Ebro. This station was called Arrabal, because of the name of the neighborhood. Two years later, in 1863, the city was also connected to Madrid. The two lines were operated by two different companies, so the company of the Madrid line, MZA, built another station in the southwestern outskirts of the city, finished in 1864. This station was located in El Portillo area, what means “little door” and it was referred to one of the city entrances. These two lines were connected by a bridge across the Ebro River in the Almozara area. The following years more stations were built, such as the Delicias station, in the west and Utrillas, in the eastern part.

Fig 3. Plan of Zaragoza in the year 1869. The train arriving in the southwest periphery of the city, in El Portillo area. Source: Official College of Architects of Aragón

Most of the rail infrastructures were built in the western area, such as a goods station, railway tracks and a garage for repairing and parking locomotives. The city grew through the years and the railways were surrounded by housing, from west to east. A concern about the rails crossing the city kept growing. During the 1960s those tracks were buried. In 1973 a new modern station was built in Portillo and, at the end of the decade, a new highway was built next to the rail line, setting a significant separation between two neighborhoods, Delicias to the north and Almozara to the south. This scar already existed in the end of the 20th century.

4. The Master Plan of Zaragoza or *Plan General* in 1986

The Master Plan of Zaragoza, called *Plan General*, had been approved in the year 1986. This plan was similar to contemporary others such as the Master Plan of Madrid, released in 1985 or the Master Plan of Seville in 1987. These plans were more focused in the urban regeneration of the historic quarters and in the morphological aspects of the city.

Fig 4. Map of Zaragoza in the year 1965. Source: Official College of Architects of Aragón

Fig 5. The process of tunneling the railway across the city, 1970s. Source: Flickr.com

Fig 6. Aerial view of El Portillo area in 1998. Source: Heraldo.es

They reflected the influence of theories which considered the “urban project” as the ideal way to solve the problems of the city planning, as told by Sainz Gutiérrez (2006). These theories emerged in Italy since the 1950s and 1960s (Rogers 1953, Aymonino, Rossi 1966) and were developed in France since the 1970s and 1980s (Huet, 1974, Panerai and Mangin, 1999).

The plans of the 1980s were the first ones in the era of democracy and they were very ambitious. According to Leira (1993), the City Councils turned their efforts and illusion in the General Town Planning thinking that the document was going to solve all the city problems. These plans posed the general strategy of the city evolution and the vision of the future, growth developing a high grade of detail in any intervention, including the urban design of the inner-city areas.

The Zaragoza planning was not as ambitious as others in the aspects of urban and architectural definition, but coincided with the concerns about the degradation of old town, the needing of social housing and a balanced disposal of public facilities. As Manuel Ramos, author of the plan, noted in 1993, the plan had not in account the relationship of the city in the territory, it was more restrictive than proactive, and it was more focused in the restoration and conservation than in the city future. But, in contrast of this concern about the architectural aspects of urban form, the plan opted for just matching different areas to different regulations, in a clear zoning strategy, less flexible and defined than expected.

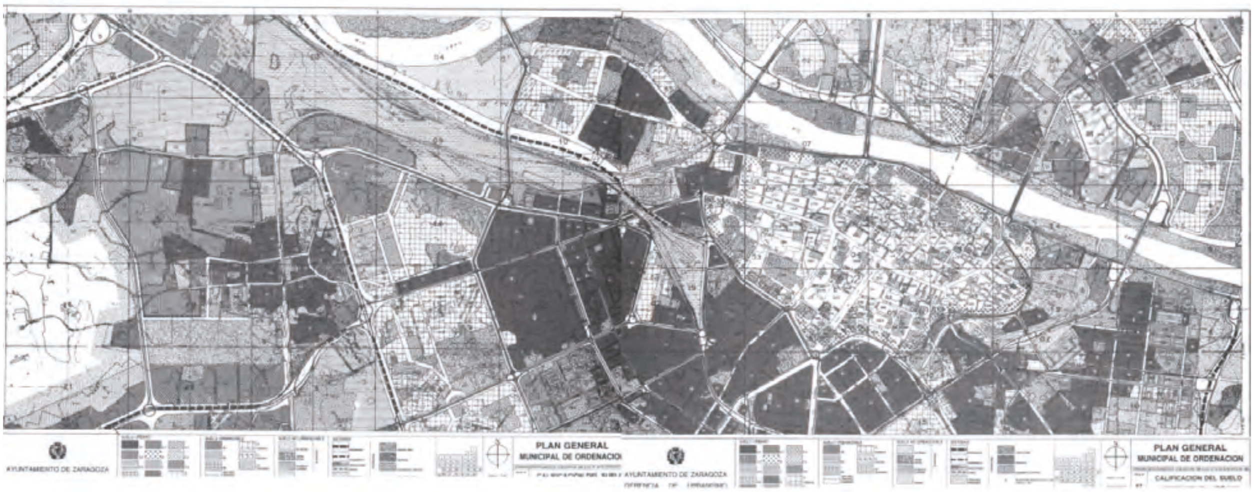


Fig 7. Zaragoza Master Plan of 1986. Urban planning qualification of the city center and the rail infrastructures. Source: Own elaboration from the data provided by Zaragoza City Planning Department.

5. The review of the General Plan from 1992 to 1996

In October 1992, different politic parties thought that the socioeconomic, cultural and strategic conditions of the city and society were changing and the current Master Plan was not able to solve this situation. So, they agreed to start the review of the General Plan. Although the official reason for a new plan was to define and generate the development of the city future, the reality was that the city was suffering an urban expansion and it was necessary to classify more land for urbanizing. Also, it was necessary to find ways to achieve a greater and better economic growth.

In November 1992 the City Council held an urban seminar to talk about the possibilities and needs of the new plan. Leira (1993), author of the Master Plan of Madrid in 1985, told that the new plan should be more strategic and more selective. It should prioritize the aims for the future and this capacity should be transformed into a few objectives, but very clear and selected, because of the scarcity of resources, not only economic but of mobilization capacity and organization. He thought it was necessary to organize physically the future of great cities in a constrained group of integrated actions that allow us to concentrate the efforts in some concrete points that are the strategic lines for the city evolution. The small actions or isolated buildings are also necessary for the city transformation, considering the induced effects that strategic actions could generate in the intermediate and mediate environment.

Ramos told, also in 1993, that cities play a key role in the attraction of development and that it is impossible to attend all the aspects of the city at the same time. So, the strategy of city transformation should be selective and concentrate in actions and pieces capable of generating that transformation. He remarked the need of an “urbanism of action” against the “urbanism of paper”, and the need of more flexibility in planning to give responses to a changing environment.

In March 1996, the municipal plenary meeting agreed to create the Revision Office for the City Master Plan. In November, a first document was drafted and sent to media, professional bodies and business entities, holding public meetings with different neighborhood associations during January and February 1997.

6. Public participation as a key factor to the strategical integration of the rail land in 1997

The first draft of the revision was criticized by some public collectives, such as political parties, neighborhood associations, professional Colleges of Engineers and Architects, etc., which questioned some for the proposals developed by the City Planning Department. The draft was ambiguous about the HSR, the rail infrastructure and its urban integration. In the meantime, the construction works of the HSR line from Madrid had started.

In the city, a deep and broad public debate started about how to take profit of the arrival of the HSR, about the urban integration of the rail land and the best way of implementation. One of the main requests was burying the railway across the city center. At that time the rails ran on the surface creating an urban scar between the two neighborhoods of Almozara, south from the rails, and Delicias, north from the rails. The College of Architects was particularly critical with the extremely regulatory approach and the lack of urban projects without strategic vision and priorities. The highest point of the debate was in July 1997, leaded by Neighborhood Associations and the College of Architects (Monclús, 2006).

The planning draft provided to put the new HSR station in the same location of the former station, in El Portillo area. After the first comments about the area the City planners agreed the need of burying the rail tracks but they considered crucial to maintain the station in a central location. With these suggestions, and many others, the first Advance of the Master Plan was launched on October 1997.

7. The first Advance of the Zaragoza Master Plan

The Advance of the Master Plan was submitted for public consultation in October 1997. Many allegations were made about the railway infrastructure and the arrival of the HSR. According to the Annex 1 of the Master Plan memory, some political parties, such as Chunta Aragonesista, proposed to locate the new station next to the airport. Others, like Nueva Izquierda, suggested putting the station in the Avenue of Navarre, western part of the city, where there was space and the railway goods infrastructure. The College of Engineers and the Business Association claimed to maintain the station of El Portillo.

Although there were many different opinions referred to the station location, a consensus rose about burying the rail line across the city, improving the pedestrian connection of the two neighborhoods. The College of Architects proposed to remove the railway infrastructure in Delicias and relocate all of them in the new logistic platform called PLAZA, located in the periphery and next to the highway and the airport.

The Office for the Master Plan Revision reported in April 1998 that the station should stay in El Portillo area to provide direct access to the city center for the HSR travelers, reinforcing the role of Zaragoza as a nodal point of the line. The location in Avenida de Navarra allowed to create a new public and central space in El Portillo, but moved the station one kilometer away the center. For the City planners, the central location of the new HSR was a priority.

The Advance proposed to formalize an Agreement with the National Administration for the removal in different phases of the railway infrastructure and the urban planning of the land released of the rail uses to create a new area of centrality in El Portillo area and surroundings, emphasized by the burying of the rail line and new station tracks. About to lower the tracks the plan suggested asking for a consulting to decide the best way to solve the question.

8. The Advance of the Master Plan of Zaragoza in 1998. A strategic change

In September 1998, the Advance was approved. In this document the City decided to fix the location of the Intermodal Station in the western part of the railway land, in Avenue of Navarre. The new building was going to be a totally new station next to the small existing one and, at the same time, the rail line would be buried across El Portillo area. This decision was made, apparently, after realizing the technical difficulties of lowering the tracks level.

Luisa Fernanda Rudi, the mayor of Zaragoza at that time, was reluctant to bury the tracks because of the cost. Due to public pressure, she dealt with the Ministry of Public Works agreeing to make a false tunnel covering the rails and changing the location of the HSR station. This decision allowed killing two birds with one stone. On one side, the city could close the urban scar tunneling the rail and please citizens. This option also allowed building the station while maintaining the rail services. On the other side, it was possible to reclassify land to make the operation more profitable, supporting the speculative operation with technical reasons.

The main goal of the operation was now to leverage the relocation to develop a vast new area of centrality since El Portillo, like a hinge between the Centre and Delicias. The new station was conceived as an intermodal centre that included the HSR, the commuter train, and intercity buses, also well connected to public transport lines. The pedestrian accessibility between the two neighborhoods of Almozara and Delicias should be a must. The document also cited that “the new intermodal centre should have a high grade of representation due to its catalyst function of the urban transformation.”

El Portillo area was now liberated of any rail infrastructure and had the possibility to create a large public space whit different uses. The urban transformation should also transform the existing highway in a new urban avenue allowing the pedestrian level crossing and creating multiple transversal connections between the two neighborhoods. The urban design should be defined in further detailed urban projects.

Fig 8. Aerial view from Zaragoza in 2001. Strategic decision.

Source: Own elaboration from the data provided by Google Earth.

The Advance included the new strategic approaches establishing two main strategic operations in the city, operations capable to transform the current structure of the city. Opportunities based in realizations in a short and medium term, with implementation projects involving the territory. These two operations were the rail area in Delicias and Portillo, including the new Intermodal Station and the railway land in Avenue of Navarra, based on the arrival of the HSR to Zaragoza, and the urban transformation appeared in El Portillo with the disappearance of the former rail station. The other main strategic area was the River Ebro waterfronts. These two areas are in the limits of the old town, so both complemented the Integral Plan of the Historic Casco.

9. The Master Plan of 2001

The Plan was definitively approved in June 2001. Regarding to the rail soil, the plan maintained the decisions made in the Advance of 1998, defining the parameters of development of the area, separating the railway land in two main areas of urban renovation, whereby urban planning should be defined by a previous Agreement between the three Administrations. These areas were named Areas of Agreement: AC-19 in Portillo and AC-44, including the new station, in a huge area between the neighborhoods of Almozara and Delicias.

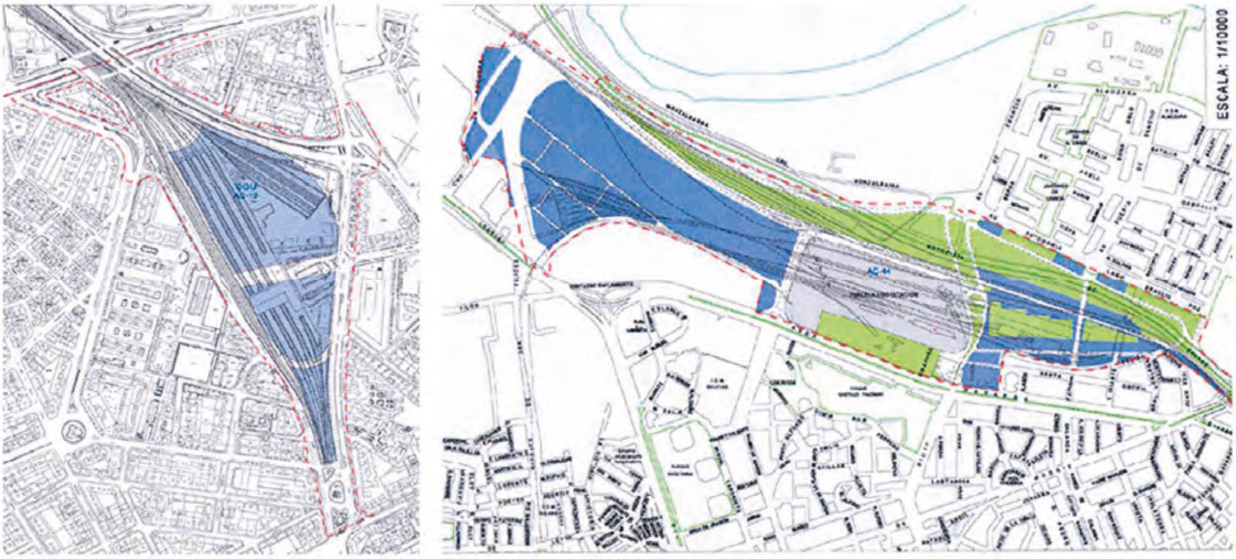


Fig 9. The two areas of Agreement in the definitive Master Plan of 2001: AC-19 in El Portillo and AC-44- in Delicias area. Source: Own elaboration from the data provided by Zaragoza City Planning Department.

Fig 10. Zoning from the 2001 Master Plan, with the relative position of the renewal area. two areas of Agreement in the definitive Master Plan of 2001: AC-19 in El Portillo and AC-44- in Delicias area.
Source: Zaragoza City Planning Department.

10. Strategic plan of Zaragoza in 1998

In May 1994 it is created Ebropolis, a new Association for the Strategic Development of Zaragoza and its metropolitan area. It was funded by the main agents of the city: Administrations, University, the Chamber of Commerce, the Federation of Neighborhoods Association, Local banks and labor unions, among others.

In its foundation Ebropolis (4) emphasizes in articulating public and private interests, and the convenience of a joint action to drive in an adequate way economic and financial resources for the projects that the citizens of Zaragoza demand to achieve an attractive city to live and appropriate city to invest.

The main objective of the Association was to elaborate the first Strategic Plan of the City. The first Strategic Plan was delivered in July 1998. Summarizing, the main goals for the city were:

- Improvement and integration of the infrastructures in the territory
- Implementation of an intermodal center in the new railway station, including bus and commuter train
- Creation of a logistics center of transportation
- Boosting Zaragoza knowledge economy

So, the important questions for the city were similar to the described in the Master Plan, referring to a more economic than spatial approach. Just like other strategic plans, this one was ambitious and covered a broad spectrum or the main issues for the city, but the conclusions were general, needing more concretion and spatial definition through urban projects.

11. Intermodal Station of Delicias

In the meantime, the works of the HSR line had started and also the steps to build the new Station. In July 1999 GIF, state company manager of the railway infrastructure, put out to public tender a restricted competition for the design of the new station, in two phases. GIF proposed a new concept of railway station, inspired in the airport operations, with two different areas, separating arrivals from departures. Another condition was that HSR trains should be completely inside the building. The station should include some different uses, such as a business center, hotels, and retail and leisure areas. The design should provide space also for a Railway Museum.

The competition had several entries but only seven passed to the second phase. Two of the final proposals clearly highlighted. Ricardo Bofill designed a big curved glass roof, oval shaped, that involved the whole building. The proposal also planned the surroundings of the area and drew a main pedestrian connection to the Palace of La Aljaferia, current Regional Parliament. This project gave to the city most of that it was looking for: a symbolic and representative building, an icon. Soon it took the favor of politics, mayor Rudi included, but most people also warned about the problems that a glassed roof and façade could produce in the extreme weather of Zaragoza, especially in summer. There was also a concern in the National Rail Manager about the cost of construction and maintenance of the building.

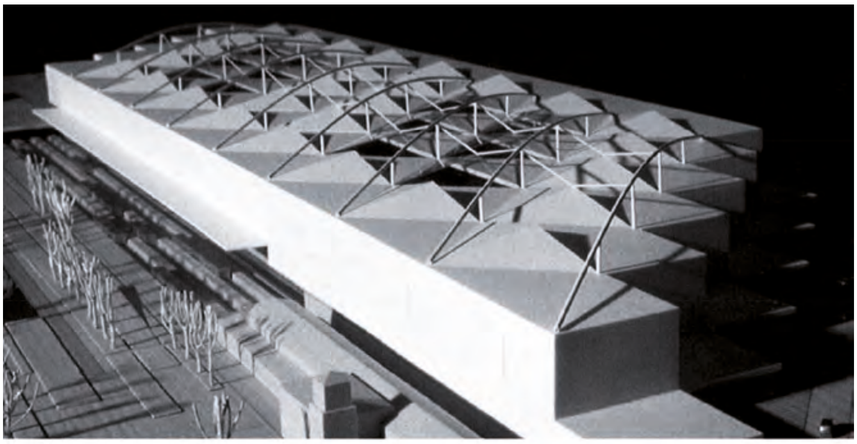
There was another project that was not so spectacular but that fulfilled the conditions of the competition. It was also some kind of iconic but more functional and it was clearly cheaper. The team leaded by the architect Carlos Ferrater (the team included the architects José María

Valero and Félix Arranz, the Engineering Proyectos Civiles y tecnológicos S.A. and Rhein Consult GmbH-Spieker GmbH & Co). Also there was an architect of the city in the team, Valero, which was another value for the local representatives.

There was an institutional hurry about arriving in time to the opening of the line. In January 2000 the project was awarded to the team headed by Ferrater and started a quick process.

The project was redacted in a few months. In July, the project was approved. In August was launched the bidding process for the construction and in December started the first phase works. In June 2001 was launched the tender for the second phase, including the building of the station starting that phase in September 2001. So, while the city was dealing with the process and approval of the Master Plan, the station was being built.

Fig 11 and 12. Model and urban project in the Bofill´s proposal for the Intermodal Station competition. Source: ricardobofill. es.



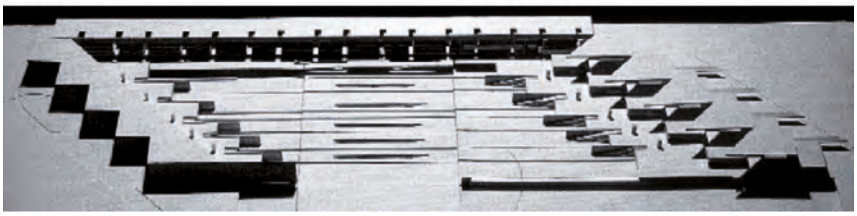


Fig 13 and 14. Model and inner space in the Ferrater´s proposal for the Intermodal Station competition. Source: GIF and ZAV.

The construction was in a hurry because of the institutional commitment to have the line working before the elections in March 2004. The HSR line Madrid-Lleida was inaugurated in October 2003, with a main stop in Zaragoza.

The station was a huge building covering a surface of 130.000 square meters, with an inner space of 600 meters long and 180 meters wide and an inner height of 21 meters. The total cost of the station was of 110 million euros. In the rush to have the HSR trains operating some parts of the building were not finished. The building had operating only one of the two entrance lobbies, the one intended for departures. Neither were finished the hotels, offices, the Rail Museum and the Bus Central Station.

The building received some prizes, as the FAD Prize of Architecture in 2004 and the Brunel Prize in 2005. But soon have several critics from the public. The position of the tunnel matched with the dominant wind direction making the interior very cold. The cost of putting the climate system in the huge inner space discouraged ADIF, the new name of the state managing company, of implementing the installation.

But the part that suffered more by the stresses for finishing were the urban surroundings of the station. Also one access to the building was provided, from the Avenue of Navarre. In the parking, of two floors and 1.200 parking spaces, in a huge space between the station and the Avenue of Navarra, the roof was finished with the waterproofing layer, giving an unpleasant landscape in the area. The rest of the existing rail and road infrastructures were neither removed.

Fig 15. Delicias Intermodal Station environment in the year 2006. Source: ZAV.

Fig 16. Aerial view of the rail land area and the Expo site in progress, 2006. Source: ZAV.

12. The Expo project

During the election campaign of May 1999, the Socialist Party brought to light the celebration in the city of an International Exhibition in the north bank of the river Ebro for the year 2008. The idea came from the architect Carlos Miret who joined in the campaign. The location was in the northwestern bank, locating the pavilions nest to river. The main reference was the exhibition in Lisbon 1998, leveraging the riverfront location to regenerate the whole area.

The Socialist Party lost the elections but, according to Miret (2007) to expand the desire of the Expo, he created the Cultural Association Zaragoza Expo 2008. The project had a remarkable acceptance in the city and soon began to gain political supports. The mayor of the City, Rudi, was named President of the National Parliament in March 2000. The new conservative Mayor, José Atarés, was not very convinced about the Expo project but neither opposed.

The continuous development of the project and the increasing public support achieved a political consensus to gain the bid. The project was sent to Madrid to gain support of the National Government. The candidacy was hardly developed and in December 2004, Zaragoza won the celebration of the International Expo against Trieste and Thessaloniki. Then started an accelerated process to convert the Ranillas meander and to use this event for a broader scope.

Fig 17. The Expo site, Water Park and Ebro riverfronts in 2008. Source: ZAV.

13. Agreement between Administrations: Zaragoza Alta Velocidad 2002, S.A

Since 1998 there had been several contacts between the different administrations about the urban integration of the rail land in the city. The main issues have been agreed in previous years but there was needed the agent to implement the operation. In February 2002 was signed an Agreement between three institutions: The Ministry of Public Works, the Regional Government and the City Council. The administrations signed in the Agreement (5) that they were conscious about the centrality of the areas concerned which allowed obtaining capital gains once the land was reclassified with buildable uses. They pretend reinvest those economic benefits in the implementation of urban and infrastructural works. These actions could be listed in:

- Reposition of the existing railway infrastructures
- Integration of the new rail network in the local environment and landscape.
- Urban transformation of the soil land that abandon their railway system.
- Implementation of the road system that complement the former actions giving service the new railway network.

The total investment projected in 2002 was 414 million Euros. In 2006, the projection raised to 1 billion Euros. In the year 2016, the total investment realized were almost 600 million Euros, and the pending works for urbanization and rail works transfer. To reach these goals, the three Administrations agreed creating a society to facilitate the coordination of the railway works and to promote the urban transformation derived from the changes in the rail system. The society was created in June 2002 with the name of Zaragoza Alta Velocidad 2002, S.A. (ZAV from now on), that could be translated as Zaragoza High Speed. The main tasks of the society were:

- Developing urban proposals for the land transformation.
- Hiring, execution and payment of the different works
- Selling the new parcels and buildable surfaces derived from the planning implementation.

The first duties for the society were to define the urban planning for the requalification of the area and to hire the contracts for the relocation of the railway framework to the logistic platform PLAZA, nearby the airport. This new area included a new goods station, facilities for repairing trains and train depots.

Fig 18. The relocation of the rail platform infrastructure next logistic platform PLAZA and the airport. Source: ZAV.

14. Urban planning in Portillo area, AC-19.

The process of urban planning was not easy for the society from the beginning. The City planning department had their own ideas for the area and wanted to remain its criteria. The department raised a verbal agreement with the Society; the society would define the planning for the Delicias area and the City Council would define the Portillo area. Both entities would accept the other´s design.

Among the whole area, the most strategically area was Portillo. Located in the centre of the city was relevant to define correctly the urban design elements. The uses provided in this place were mainly public facilities and a big park, called to be the central park of the city.

To define the area there had been a public competition in the year 1999. This competition was won by a local team of various architects: Franco-Pemán and Cerouno Architects. The main idea of the project was to dispose the buildings linearly next to city center, liberating the central part for a generous green space. There was an elliptical tower in the southern area, as an iconic element. The tower was ninety meters high for tertiary or hotel uses. Residential uses, around 700 housing, were displayed in different peripheral parts. City planning department liked the project but there was disagreement with the winner team, mainly economic, and the design was not developed.

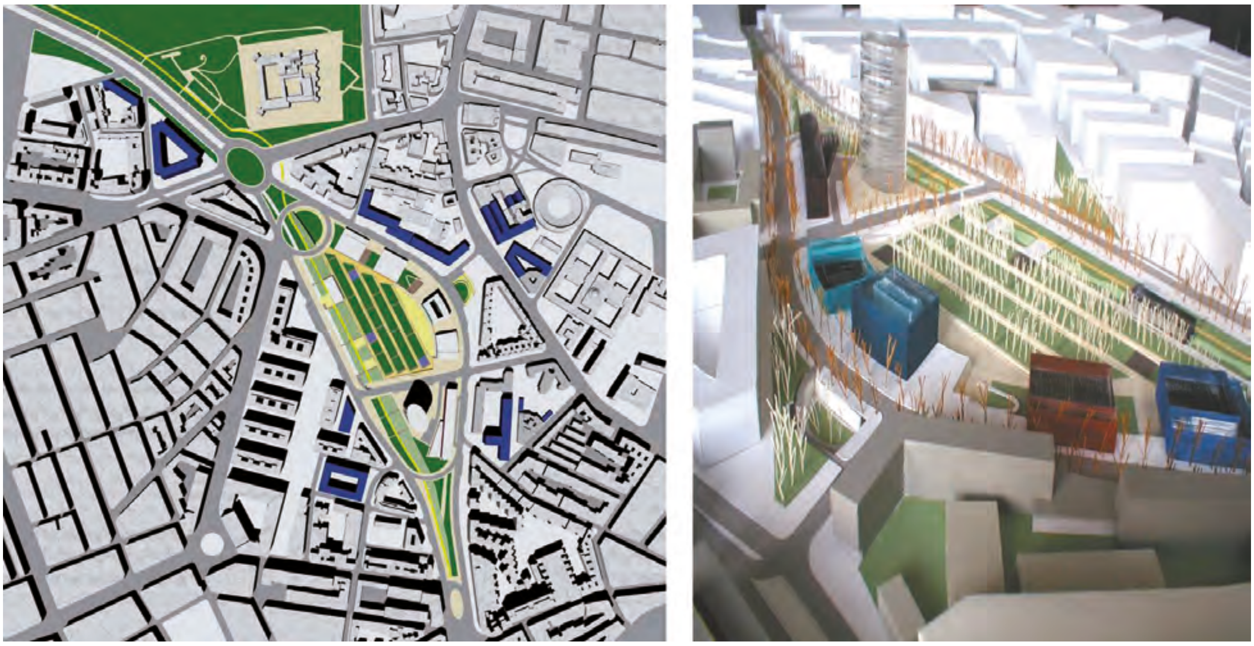


Fig 19. Winning proposal in 1999 by Franco-Pemán and Cerouno. Source: Pablo de la Cal.

City planning department developed the Master plan for the area in 2003, taking the winner proposal as a base, but changing some questions. The tower was moved to the northern part, because there was more space for a high-rise building and could act more as an iconic image from the entrance of the city. The height of the tower was also reduced, from 90 meters high to only 20 floors and an a estimated height of 70 meters for not doing too significant in the skyline. The uses were also changed. The residential uses were erased and the tower for tertiary uses was the only building with lucrative uses. Three parcels for public facilities were disposed in the border of the area with Anselmo Clavé Street, in the Eastern part, providing a big green area in the central part of the area.

The plan was finished in December 2003, but the Delicias area was just beginning to define urban planning and the City Planning Department preferred to wait to the other area´s design.

The plan had to wait more than a year to be published. In that period of time there was a major change, including a residential building in the southern part for 220 dwellings, as a result of political agreements to include some more works inside the ZAV Agreement.

Fig 20. Aerial view of El Portillo area in 2002.

Source: ZAV.

Fig 21. Master Plan of El Portillo, G-19-1 area, in 2005 by Zaragoza City Planning Department.

Source: City Planning Department.

15. Urban planning in Delicias area, AC-44.

ZAV launched in April 2003 the competition of the Master Plan in Delicias area, AC-44. The main objectives of the design were removing the infrastructural barriers between the two neighborhoods of Almozara and Delicias, solving the existing differences in ground level, giving priority to pedestrian and public transports, creating a relationship between the urban and natural environment, developing a mixed-uses area, displaying public facilities to the needs of citizens in different levels, quality architecture, materials with energetic efficiency and new urban infrastructures, such as subterranean technical galleries and automated waste collection.

Several teams presented offers and in September 2003 the competition was won by a Spanish multidisciplinary team with local representation called Entorno 3. The team was composed by IDOM Engineering and several local architects, such as Julio Clúa and Manuel Castillo, with the collaboration of Javier Monclús, among others.

The team tried a new method of public participation and the exposure of first drafts had more than one hundred proposals. In the meantime, this area and the Agreement as a whole was used as a political tool and the way for funding some other works and infrastructures in the city as, for example, a new subway line. Then it started a political discussion between the representatives of different ZAV partners, which delayed the progress of the project. At last, near November 2004 the partners reached an agreement about the external and financial issues of the development. One of the terms was to increase the density of the area through residential uses.


Fig 22. Aerial view of Delicias area in 2001-2002.

Source: ZAV.

The team could finish the design, including the new conditions and the more than hundred suggestions that had been received during the design process. But in April 2005, when ZAV showed the design to local technicians and to the press, there was a quite surprise. The city planning department did not like the design and neither the Neighborhood Associations of Delicias and Almozara. Both, municipals and neighbors considered that there was too much residential density near their neighborhoods and there was a lack of public spaces between the new areas. For the city planning department there was not bioclimatic solutions in urban design. The worst feeling was the major infrastructural role in the design without a pedestrian point of view. The plan was considered too expensive, with no real needs. It provided a new exit road tunnel from Portillo. Also, the western area had a very complicated grid which made difficult urbanizing and building the different blocks. The locals were also against the street of only one direction, putting all the entrance to the city in the old Avenue of Navarra, needed of an urgent renovation, and putting all the exit way on a new road, onto the buried rail tracks.

City planning managers started in a secret way to prepare their own proposal, drawn in a few days. The City plan had a more traditional grid in the western part, avoiding huge infrastructures and high-rise buildings near inhabited areas. The proposal provided a huge park in the area between the two neighborhoods and erased some towers in front of the intermodal station, next to Avenue of Navarre. ZAV did not accept the local plan and it was enraged with the Planning Department. The winning team had been working for more than a year and a half and the municipals pretended to do radical changes in few days. So, it started a fight that moved up to the local press and political level.

Timing for the Expo 2008 forced a political and technical agreement. The final design took elements from both plans. The buildings in front of the Almozara neighborhood were removed and in this place, was created an equipped park. The plan incorporated several environmental considerations in the final draft. The road tunnel and the elevated road at the entrance of the city stayed. After some argues with the team, some of whom resigned, the master plan was approved definitively in February 2006. The urbanization project had started and there was almost no time to finish the works needed for the Expo.

Fig 23. Master Plan of Delicias, G-44-2. area, in 2005 by Entorno 3. Source: ZAV.

Fig 24. Changes in planning after the agreement. Master Plan by ZAV. Source: ZAV.

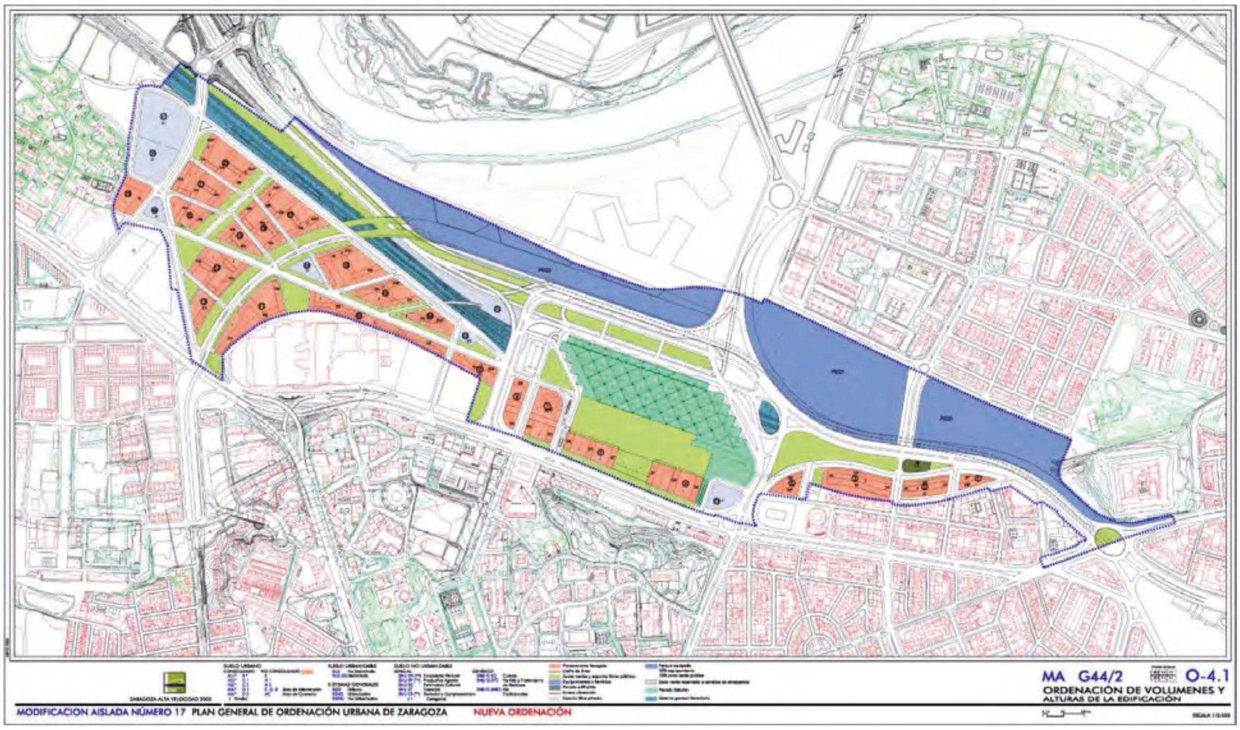


Fig 25. Zoning in the definitive Master Plan in G-44-2 area. Source: ZAV.

16. Digital Mile

The Major Juan Alberto Belloch and this Office were trying to improve the knowledge society in the city. This was also one of the mandates of the first strategic plan. During the year 2004, the City hired McKinsey consulting to this search. After meetings with different agents, the company concluded that the best location to develop a new district of urban innovation was the former railway land of the city, the Portillo and Delicias areas. Then they prepared a Director Plan of Digital Mile to implement an urban district innovation.

The City Council hired MIT School of Architecture and Planning for the development of the urban project. One of the main ideas was the creation of a Digital Campus with two nodes: The Center for Art and Technology in Delicias and the Media Library in Portillo. The idea was to dispose one public facility in each side of the Digital Mile to create synergies.

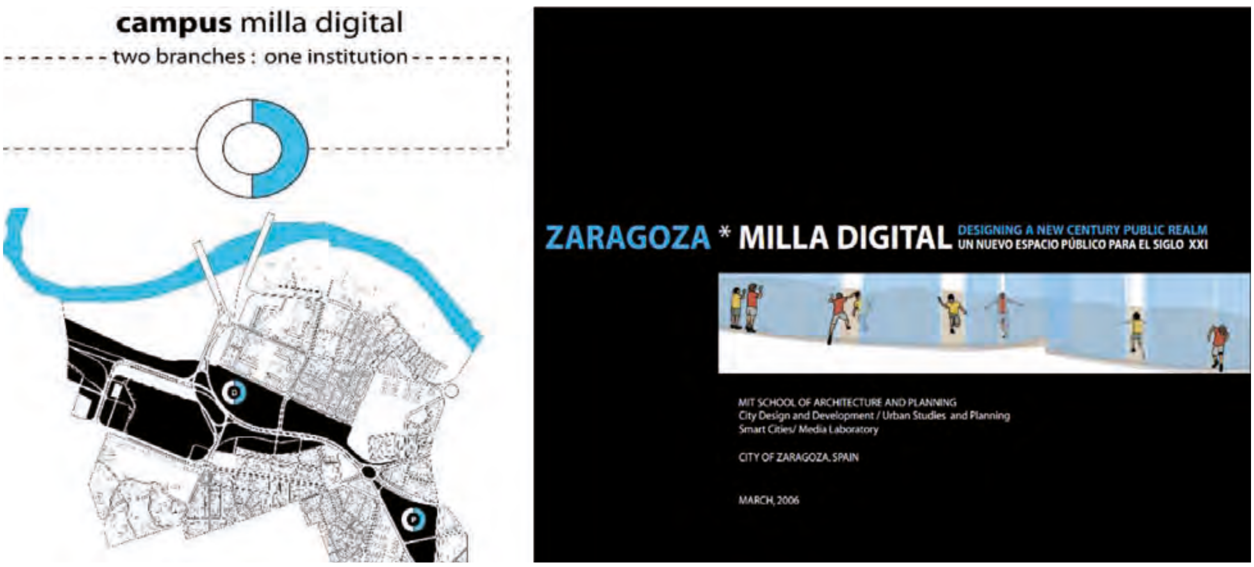


Fig 26. Concept of Digital Campus and publication by Frenchman and Mitchell from MIT School of Architecture and Planning. Source: City Council.

Digital Mile was conceived as a digital district, a district of innovation, an urban area focused in the development of the digital infrastructure knowledge society. According to Fernández-Ges (2017), a digital district is an area focused in activities related to ICTs and knowledge economy but it is not a technological park. It is designed as a city: a place to live, to work and to learn 24 hours a day, seven days a week. The main aim of a digital district is making an innovative and sustainable city. Some examples of urban projects conceived as digital districts are Arabianranta in Helsinki; 22@ in Barcelona, or Orestad, in Copenhagen.

Neither ZAV and the City Planning Department embraced the idea of a Digital Mile. ZAV was more interested in urbanizing and selling plots, and these concepts signified more conditions to urban design and more difficulties to sell parcels. For the City Planning Department this concept was more about urban marketing and it was far from their urbanistic ideas. The weak relationship between the two Offices did not help to include easily these concepts in urban planning.

The Mayor´s Office finally forced to include these concepts in the G-44-2 regulations, related to digital infrastructure, home automation and the two digital public facilities. The City Council built years later the Center for Art and Technology, but with the change of local government in

2015 and the economic crisis, the rest of the Digital Mile project has not been yet developed and it does not seem that this project will happen.

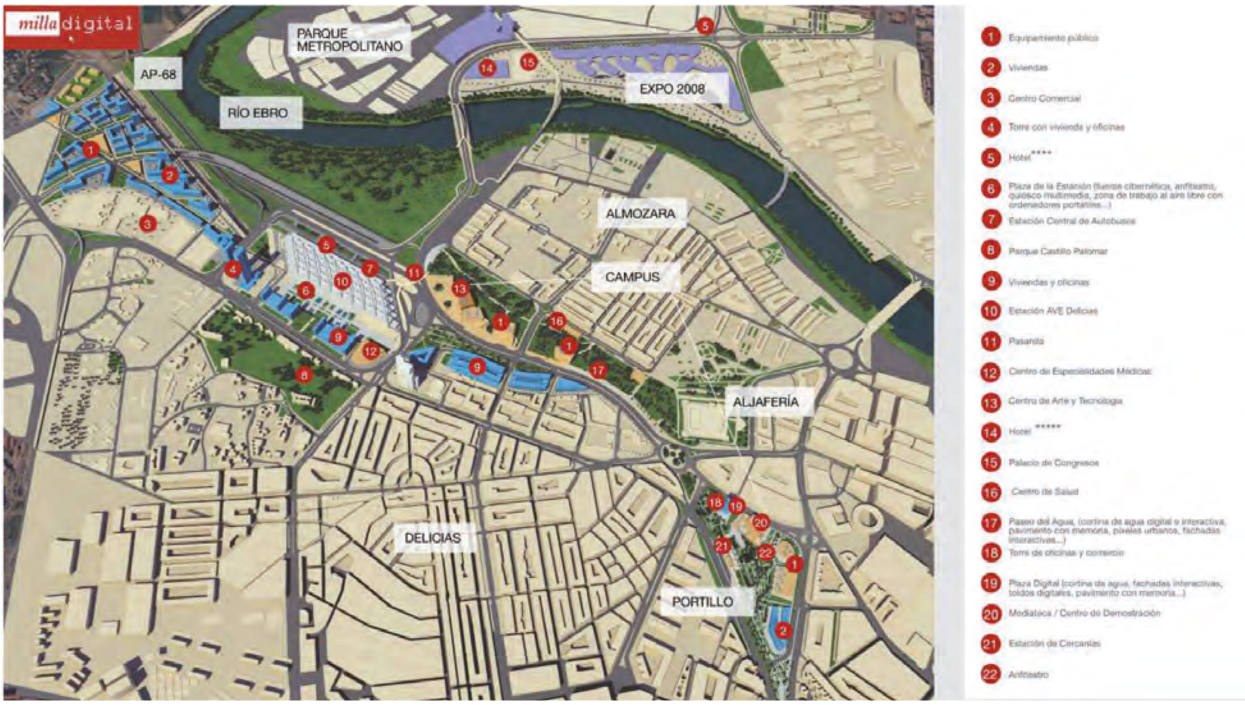


Fig 27. Display of uses and public facilities in Digital Mile. Source: City Council.

17. Selling the first real estate plot

To sell the first parcel was necessary to change the planning of the area, extracting one parcel and classifying as a urban soil. Once separated from the area AC-44, the parcel could be sold. Selling this first parcel was crucial to make possible the operation to start. A bid was launched in January 2006. In this first competition, the real estate developers were asked to make an economic offer and an architectural design, being more valuable the economic offer, although the design proposed should have a minimum quality.

The parcel had 285 dwellings and a flexible design that could reach thirty floors. It was sold by 82 million Euros, the highest price paid ever in the city. to NOZAR, a national real estate company. There was another offer with a higher rated architectural design, but the price difference with the second bid was unbeatable. Nevertheless, the winning tower was very elegant with good quality design.

The neighborhood became worried with the danger of gentrification accusing the administrations and ZAV to be speculative with the public land. Nevertheless, this situation encouraged to the administrative entities to develop more works and infrastructures.

To build the design was necessary to do a special plan regulating the architectural volumes and urbanization of the area. The administrative procedures took a long time to be approved and when the company was able to get the license the economic crisis had arrived and the company could not start building.

18. Urban development works

The first urbanization works in the two areas started in January 2007. The delays in the process of urban planning collided with the real difficulty of finishing in time for the Expo 2008. In the hurry to complete the works needed for the inauguration, in June 2008, the huge site was divided in several phases. For the City Council, the critical works were the entrance to the city, the new elevated highway and the completion of the third ring road of the city, just in front of the departures side next to the intermodal station, because this road were the connection to Expo site.

Fig 28. Winning proposal from Nozar with B. Tobías in Avenue of Navarre area. Source: ZAV.

During that year and a half, the society dealt with 25 different actions at the same time and finished works for a total amount of more than 500 million Euros. The impossibility of developing the total surface of the area led to leave after the Expo the parts not needed during the exhibition. So, like the mentioned case of the Intermodal Station building, the urbanization of the areas was not totally finished, giving a precarious image in some parts.

The expenditures of ZAV during this period were substantially higher than the money provided by the first parcel. The society could not sell more parcels, in the administrative process of rezoning. So, it had to ask for a loan of 400 million Euros that was going to pay when they could sell the remaining plots.

Fig 29. Works at Portillo and Delicias areas in 2008, during the Exhibition. Source: ZAV.

19. Expo site after the 2008 exhibition

The International Exhibition was held from 14th June to 14th September 2008. The event had less national and international impact that foreseen with only 5,6 million visitors when it was foreseen to have more than 7 million visitors.

But the event had a deep impact in the proud and illusion of the citizens. Many people thought that the city was not going be able to handle such an event, but it could, for the first time in its history. The Expo showed to the people of Zaragoza that it could be possible. This feeling could be checked in the comments and press of those days.

Expo and the Accompanying Plan, that coordinated many of the collateral actions brought a lot of works and infrastructures that the city was waiting for years, such as the river banks of the Ebro, the Green Ring, the third and fourth road rings, a new airport and and the first commuter train line, among others.

The city had a plan for the day after, but just one day after the Expo finished, Lehman Brothers announced their bankruptcy and started the economic crisis. All the projects and works planned after the Expo were paralyzed. The city had a great credit debt for their percentage in the Expo works and it was not capable to execute new actions.

Expo site were planned to be a business park, being a part of the new CBD of the city, together with the Digital Mile. But the park sold very few offices and had to change the scheduled uses. The National Government left the consortium and a new company was created for the management of the park, Expo Zaragoza Empresarial, with a 98 percent of the Regional Government and a 2 percent of the City Council.

The conversion of the pavilions to business offices finished at December 2010. Almost no one office was sold or rented. The spaces were mainly occupied by Regional Government departments and the City of Justice. There were around 1.500 workers in the area by 2015, but many of the Expo landmarks are not in use, as the Bridge Pavilion, Spanish Pavilion, Aragon Pavilion and the Water Tower, mainly due to a tax problem between the City and the Regional Government. The Bridge Pavilion is only opened for pedestrian use some times during the year. The most used spaces of the area are the Water Park or Parque del Agua and the riverfronts, for leisure activities.

Fig 30. Scheme of uses in Expo Empresarial, post-Expo business park. Source: Pablo de la Cal

20. Digital Mile and Barrio del AVE, since 2009. Work in progress.

The ZAV credit debt of 400 million Euros blocked the possibility to finish the pending works: the urbanization of El Portillo, the parks next to La Almozara, the road tunnel and the urbanization of the Delicias western part. In the public competition launched in September 2007 to sell four parcels only two of the four were sold, with no bid in the other two. Another public tender was held in the year 2010 for those two parcels, again without bidders. ZAV decided then to wait until a better economic situation. in the meantime, they presented some planning modifications to improve the volume distribution and uses towards some more sustainable and marketable plots.

In El Portillo, G-19-1 area, a Master Plan modification was drafted by the City Planning Department to include a new cultural landmark, Caixa Forum. The building was promoted by the Catalonian bank after a competition won by the architect Carme Pinós. The modification was approved the same year, the construction began in 2013 and the building was inaugurated in June 2014. In 2013 ZAV proposed another Master Plan modification to interchange the uses of the residential and tertiary parcels and to divide the area in two phases to selling the residential uses. The modification was approved in 2015 by the City Council but ADIF, the new National Manager of Rail Infrastructure sued the resolution because of the regime of the buried land and transfer rail dependences cost. Recently it was an agreement between the two administrations, but the area is still not developing.

In Delicias area, G-44-2, ZAV proposed in March 2014 another modification of the Master Plan to change the uses and the volumes of the parcels in urbanized areas to improve the bioclimatic conditions and to make them more attractive to real estate investors. After this there were two different tenders in 2015 and 2016 of the two plots in front of the intermodal station, considered the best parcels in the area, but both bids were unsuccessful. Now there is planned a new bid reducing prices and improving the payment terms.

The former tower in Avenida de Navarra has still not been built today, but a local real estate developer has bought it recently quite cheaper, is now selling the dwellings and they expect starting the building in a few months. Maybe this operation could open up the real estate market for the area creating a beacon effect.

Fig 31. The HSR and Expo areas in 2017. Source: Google Earth.

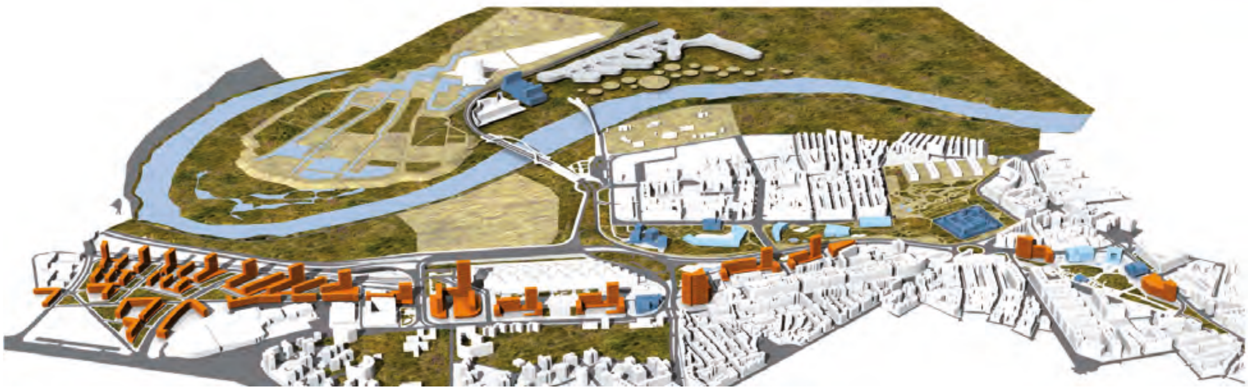


Fig 32 and 33. Aerial views of the Urban Project in the HSR land, after the different planning modifications, in 2017. Source: ZAV

21. Strategic urban projects

The urban actions developed in these areas of Zaragoza had similar characteristics to other Strategic Urban Projects. These developments, named by Portas (2003) urban projects of the "third generation" appear since the 1990s. Due to the lesser capacity of the Administration these projects operate only in strategic areas to rely on their synergic capacity for the rest of the city. They are also strategic because take concepts and procedures from strategic plans. They are called strategic urban projects by Monclús (2003) and Carmona (2001, 2005) called them "Great Urban Projects" because of his big scale. For her, they are the result of globalization, that modifies the relationship between State and markets y gives cities more importance the economic development.

These projects are mainly developed by public initiative. Because of the scale, the implementation is longer than previous urban projects. They have an ambivalent relationship with urban planning. On one hand derive from the General Master as a starting point, but in the majority of cases operate apart from planning. Examples of this kind of projects are the urban renewal of the Batimore port area, the urban transformation of Barcelona by the Olympic Games or Euralille, in France. And more recently, cases such as La Confluence, in Lyon, Kop van Zuid in Rotterdam or Hafen City in Hamburg.

22. Conclusions

Strategic urban projects in Zaragoza had a great influence from the iconic architecture since previous years, from the “miraculous architecture” according to Moix (2010). It was also influenced by the politics of great events and from an excessive infrastructural view of the city. This is evident in the intermodal station building. In its design prevailed the big scale and monumentality over the permeability and the relationship with the surroundings. The station is already now seen as a huge independent object in the territory. As Pie (2000) states, the interest of the local and railway authorities matched in converting the new station in a real estate and urban renewal operation. And the railway company was interested in the profits generated by real estate generation to finance part of the investments.

According to Pie (2000), in the era when the rail transport goes underground and the metro entrances are simple access in the urban skin, it is a contradiction the emergence of great roofs in monumental shapes, that it might seem more to symbolic and propagandistic needs more than to the demand of this new technology. The ceremony of travel in the contemporary era needs more of efficient interchanges than solemn nodes.

These projects were the result of an optimistic and wealthy era, where almost everything was possible. The strategic decision of changing the new station to Delicias area assumed a strong and immediate growth of the city, a growth that has not happened and it not foreseen for years. 200.000 square meters of tertiary uses in Delicias area and more than 150.000 square meters in the Expo site were clearly excessive for the Zaragoza size. Surely, if the city had today to undertake this process, the results had been totally different, developing a smaller and more functional station, with and urban design of more but smaller buildings varying typologies and without all the elevated and tunneled roads infrastructure.

The urban projects were also the result of the excessive political influence but a lack of leadership and consensus, prevailing particular political interests extending planning over time and losing a precious time, decisive to finish the urbanization and create a new neighborhood.

Some interventions created uses do not really needed. They created these needs, that later was difficult for the city to deal with. Many of the buildings emerged for the Expo still are not being used and it will be difficult to renovate them: Spanish Pavilion, Aragon Pavilion, the Bridge Building and the Water Tower. The urban projects that have been more successful are those needed before the Expo: the new airport, the ring roads, the Convention Center, and above all, the Water Park and riverfronts.

Results show as well the need to incorporate all the stakeholders in the process; not only the Administration or professionals, but also citizens and real estate developers. Maybe if real estate agents were incorporated from the beginning of process, the subsequent failed bids would not have taken place.

Great scale projects have been questioned for different questions: being too costly for the city, an excuse for a real estate speculation and an instrument for the personal political promotion, with absence of social cohesion, territorial impact, lack of sustainability. Besides, these projects hinder other investments in the city and the territory.

The economic and real estate crisis delayed or stopped the majority of these projects, and in the last years another paradigm has raised, as the environmental sustainability, the social cohesion, public participation, knowledge economy and an integral approach in urban regeneration.

Nevertheless, strategic urban projects have changed cities in many cases, in a way broader than the areas of action. Several public spaces have been created in many cities through strategic urban projects, as in Barcelona, Lisbon, Bilbao, Zaragoza, Hamburg or Zurich, and the relationship between the city and its natural environment has improved. Most successful have been those where public space had a major role in the design and definition of the project. So, the challenge is to obtain enough flexibility of adaptation and resilience to adapt to new urban paradigms.

These projects need realistic objectives, solving existing needs in the city, usually identified in the general or strategic planning of the city. The project will be successful if contribute with public spaces and facilities demanded by citizens, instead of those that try to create the needs. A correct and fluid relationship and communications between the different parts is needed in the management.

Projects that show certain flexibility in the design are more resilient than the rigid ones. The more adaptable is, the more successful over the implementation period. Projects that stresses in the conception and design of public space, understanding the city as a space for social relationship achieve a greater identity with the citizens than those considering the city as a space for business.

Fig 34. Expo riverfronts before and after the International Exhibition. Source: Pablo de la Cal

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Long Term Implications of HSR on Small cities: Ciudad Real and Puertollano revisited 25 years after the arrival of the HSR

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Abstract

Up to 10-15 years after the arrival of the HSR to two small and isolated Spanish cities a considerable amount of studies about the territorial and urban impacts/implications of HSR were done based on the cities of Ciudad Real and Puertollano. Their distance to major cities (at least 200 km to any cities of more than 100.000 inhabitants) made it easy to try to isolate the impacts/implications due to HSR from those derived from other reasons.

The paper does the same analyses that were undertaken 15-10 years ago, to evaluate those implications/impacts that have been consolidated on a greater long-term perspective and those which have changed and/or disappeared (less permanent more variable).

These two cities are compared to other similar ones, as it was done in *Serrano, R, Garmendia, M, Coronado, J.M, Pillet, F. y Ureña, J.M.* (2006) **Análisis de las consecuencias territoriales del ave en ciudades pequeñas: Ciudad Real y Puertollano**, Estudios Geográficos, vol. LXVII, n. 260, pp. 199-229. (ISSN-0014-1496) and even previously in *Fariña, J, Lamiquiz, F y Pozueta, J.* (2000) **Efectos Territoriales de la implantación de infraestructura de accesos controlados**, Madrid, E.T.S. Arquitectura, Universidad Politécnica de Madrid, Cuadernos de Investigación Urbanística, n. 29.

The policies/strategies implemented in these two cities are also revisited, as it was done in *Ribalaygua, C., Ureña, J.M., Coronado, J.M., Escobedo, F., Guirao, B., Menéndez, J.M., Rivas, A. y Rodríguez, F.J.* (2004) **"Alta Velocidad, integración metropolitana y proyectos territoriales. El caso de Ciudad Real y Puertollano"**, URBAN, n. 9, pp. 30-44.

The two conclusions derived from revisiting these analyses undertaken 10-15 years ago in these two HSR cities show that:

The change in growth tendencies produced shortly after the HSR arrival:

- a positive change in the tertiary city of Ciudad Real between 10 and 20 years after the arrival of HSR, that tends to be maintained after these first 20 years, with a slight diminution tendency.
- a negative change in the industrial city of Puertollano until 10 years after the arrival of HSR that tends to be maintained between 10 and 20 years and worsens between 20 and 25 years

The projects/strategies being developed 10-15 years after the HSR arrival can be classified in the long term into three groups:

- those that tried to change the territorial model in general are having big difficulties,
- those that adapt the station urban surroundings in general are being more successful -the success of those that tried to attract new activities in general is greatly influenced by the type of city (industrial vs tertiary) and the national overall economic dynamism (economic cycle).

Keywords: *high-speed rail, long term effects, urban systems, small cities.*

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1. Introduction

This section is dedicated to explain the context of the research presented in the paper. In April 1992 Spain inaugurated its first 471 km of High-speed Rail (HSR), the Madrid-Seville line. This line was going to serve only these two cities and Cordoba, but in 1989 Ciudad Real and Puertollano were also included in the project, because it had to pass close to them anyway. These two cities had been for two centuries distant from the main Spanish transport corridors.

Shortly after the HSR services were in place a new medium distance HSR service was created to connect Ciudad Real and Puertollano only to/from Madrid reducing this travel distance by two thirds and opening up the possibility of daily commuting to/from Madrid with a HSR travel time around one hour. This made that these two small cities improved tremendously their connection to Madrid (around 20 services per day and sense), to the other cities in the corridor (ten services per day and sense) and through them to other cities/regions.

The implications derived from HSR (an only passenger railway service) in these cities described in literature (Urena, 2002 & 2002a; Ribalaygua, et al., 2003 & 2004; Ureña, et al., 2005; Menéndez, et al., 2006; Serrano, et.al., 2006; Garmendia, et al., 2008, 2009, 2011 & 2011a; Ureña, et al., 2009; Ureña, 2012) can be synthesised in the following:

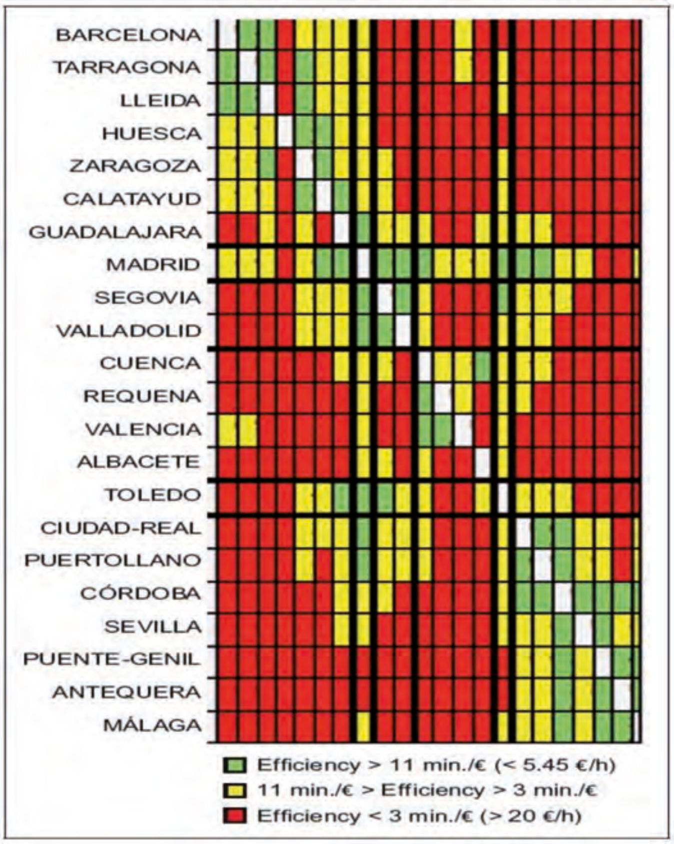
- Growth expectations not fulfilled. An important population growth was expected, as if they were suburban metropolitan cities (with campaigns in Madrid of “Come to live at Ciudad Real”).
- Time distances to other main settlements in the province are equalized to those to Madrid and Cordoba.
- Generation of high professional level commuters (twice as many from Ciudad Real and Puertollano to Madrid than reversely).
- Attraction of quality services (health, university, etc.) to these cities, with high qualified professionals commuting from Madrid.
- Development projects related to transportation and leisure (Airport, Golf and Gambling tourist destination) and to economic activities.
- Location of inhabitants within the two cities were not substantially influenced by the location of HSR stations.

The enlargement of the Spanish HSR network with ulterior lines (see Figure 1), Córdoba-Málaga,Madrid-Barcelona, Madrid-Valencia and Alicante and Madrid-Valladolid-León and MadridValladolid-Zamora, improved the connectivity of these two small cities with direct HSR services to most of the cities along these new lines (all except Segovia, Valladolid, León and Zamora) providing a great efficiency of HSR, only behind Madrid (see Table 1)[1]. In a certain sense, these connectivity improvement has made these two small cities become cities in movement, with their inhabitants traveling frequently to other places for multiple purposes.

1 The HSR tunnel connecting Atocha and Chamartin Madrid stations, to be inaugurated soon, will allow direct HSR services from Ciudad Real and Puertollano to the cities along the North (Segovia, Valladolid, Palencia) and Northwest (Zamora) lines, improving even more the connectivity of these two small cities.

Figure 1: High Speed Rail Lines in Spain 2017: Madrid-Seville, present HSR lines in operation and under construction, and conventional lines adapted to HSR

Table 1: Useful minutes at destination per euro of all possible links using HSR



Source: Coronado, et.al. (2013)

Ciudad Real has a high proportion of HSR passengers per year in relation to its population (13.3 HSR passengers per inhabitant) and also important although smaller Puertollano (10.0 HSR passengers per inhabitant). This amount of HSR passengers diminished around 20% during the crisis years and has recovered during the recent economic recovery years.

In general, studies on the implications of new transportation investments are undertaken prior and shortly after the investment. The opportunity of reassessing the implications several years later diminishes, since other factors mix up with the new transportation investment; for this reason, ex-post long-term studies are scarce. Nevertheless, since Ciudad Real and Puertollano are still relatively isolated, 200 km to the nearest city above 100.000 inhabitants, the short/longterm comparison may sound more useful, since fewer factors mix with the HSR.

2. State of the art

This section reviews the scientific literature on the subject of comparing the short and long-term implications of new transportation infrastructures.

In several countries, Environmental Assessment, as an internationally accepted methodology, has to evaluate immediate and long-term effects of construction and operation of major proposed transport infrastructure projects on the environment (Goodenough and Page, 1994) and major spatial plans (Ureña and Español, 2006). In other countries, Territorial Assessments are also compulsory with similar immediate and long-term evaluation requisites. Their interest is their requirement to evaluate not only immediate but also long-term envisaged effects, and, as a consequence, to find mitigation measures.

There are many ex-ante evaluations of expected immediate and long-term effects, there are fewer short-term ex-post measurements of produced effects after the operation of new transport infrastructures and even fewer long-term ex-post measurements of produced effects. Long-term effects studies are frequently theoretical, without empirical basis (Bonatti & Campiglio, 2013).

Ojha, Vrat and Sharma (2016) proposed a System Dynamics approach to explore long-term implications (25 years) of quality of Highways on manufacturing growth, by exploring 8 highway maintenance/repair/construction scenarios and considering that improved highways will produce growing manufacturing and additional movement of goods, and thus, increased deterioration of highways, several refeeding loops (see Figure 2).

Figure 2: Relations between Highway quality and length and Manufacturing output

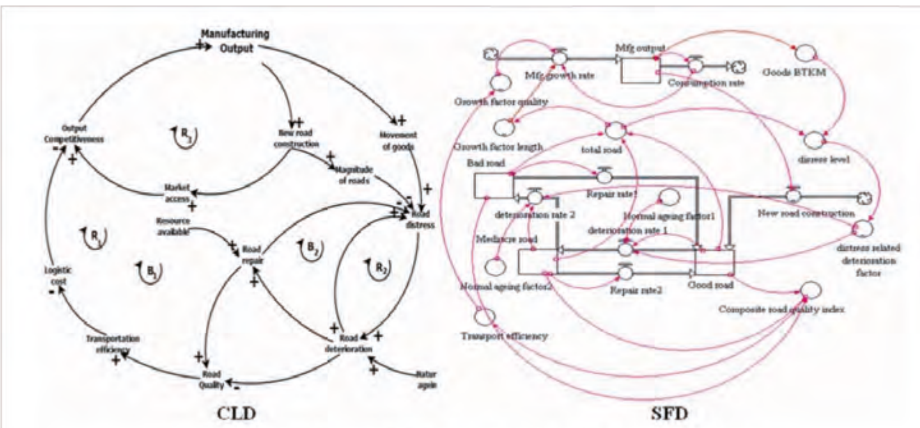


Fig. 1—CLD and SFD between the Highway quality and its length on manufacturing output.

Source: Ojha, Vrat and Sharma (2016)

These studies help planners to envisage the long term implications of policies, while their problem is that their internal rationale is based on ex-ante observations (regressions, etc.), but no ex-post measurements.

Elaborated ex-ante studies on the implications of major new transport infrastructures have to consider several aspects (Vickerman, 1994):

- The uncertain impact of transport infrastructure since improvements in external connections are usually two way, due to small contribution of transportation costs on total goods costs (3-4%) and due to transport can clearly be substituted for other inputs.
- The effects have to be considered on a multiregional basis.
- The implications continue to depend on how individual decision-makers and policymakers respond to the opportunities presented.

Thus, an added recommendation is to consider both objective (data) and subjective (policies, strategies) analysis.

The few long-term ex-post studies frequently use comparative studies to explore the implications. Berger & Enflo (No Date) explore Short- and Long-Term Impact of Railroads comparing cities that gained access to the railroad network to cities that did not. Berger & Enflo (No Date) indicate as additional precaution that has to be taken into consideration in these comparative studies, that it is not straightforward to identify the impact of infrastructure, because investments are typically allocated to already growing areas; thus comparisons have to ensure that they include growing cities (with transportation demands) and not growing ones (without much transportation demand). Comparing cities that gained and not gained early access to railway in Sweden, 1855-1870, Berger & Enflo (No Date) concluded that cities with early access to the railroad network:

- property values were higher, manufacturing employment increased, establishments were larger, and more information was distributed through local post offices, - continued to grow faster for
- a better part of the 20th century,
- today are substantially larger compared to initially similar cities.

Combination of ex-ante and ex-post analysis to determine the influence of transport infrastructure investment are starting to be used, although ex-post assessments are often performed only a few years after complete implementation of projects, often 3 to 5 years (Griskeviciute-Geciene & Lazauskaite, 2011). On top, ex-post analysis are frequently done in the form of Cost/Benefit analyses concentrating on determination of direct effects having monetary values, such as the reduction of travel time value, vehicle operating or infrastructure maintenance costs, without determination of more wide scope of socioeconomic indirect effects (Griskeviciute-Geciene & Lazauskaite, 2011). Best practices in several countries include direct and indirect aspects on ex-post analyses (see Figure 3).

The optimum would be to combine along time three types of studies. First, ex-ante studies on immediate and long-term expected effects. Second, ex-post studies shortly after infrastructure operation on immediate measured effects, and compare them with the expected immediate effects. And third, ex-post studies long after infrastructure operation on the long-term measured effects, and compare them with the expected long-term effects and with the measured shortterm ones. This will highlight the differences between expected and measured effects. This will also allow to refine methodologies for ex-ante evaluations, by trying to deduct differences between predefined rationales and realised rationales.

Figure 3: Summarized criteria of ex-post assessment on transport infrastructure projects

Object / Criteria	Cities bypasses	Motorways, highways (major projects)	Streets-Road networks connections	Bridges, viaducts
Direct Impacts				
Travel Time Savings	-	+	+	+
Vehicle Operating Cost	+	+	+	+
Safety	+	-	+	-
Induced travel	-	+	+	+
Service Quality	-	-	+	+/-
Environmental Impacts				
Noise	+	+/-	+	+/-
Emissions	+	+/-	+	+/-
Nature and landscape	+/-	-	+/-	+/-
Natural resources	-	-	+/-	+/-
Economic Indicators				
Investment costs	+	+	+	+
User benefits	+	+	+	+
Indirect Social Economic Impacts				
Land Use	+/-	+/-	-	-
Modal shift	-	-	-	+/-
Employment	+	+	+	+
Social Inclusion	-	-	+/-	-
Reliability	-	-	+/-	+/-
Accessibility	-	+	+	+
Efficiency and Output	-	+/-	-	-

Source: Griskeviciute-Geciene & Lazauskaite (2011)

Serrano, et.al. (2006) suggested that the implications of the HSR in Ciudad Real and Puertollano should consider the following time scenarios, improving what was prior done/proposed by Fariña, et.al (2000):

- Before there was any idea of having the new infrastructure.
- When it was known that the new infrastructure will exist but still is not in operation.
- When the new infrastructure is being built.
- Shortly after the new infrastructure was in operation.
- During the first ten years of operation of the new transportation infrastructure.

The aim of this paper is to add another time lapse, 15 more years of operation of the new infrastructure (up to 25 years since initial operation). This is important because, as Serrano, et.al. (2006) suggested, research should be aware that the effects of new transport infrastructures on transport would take place rapidly, while territorial effects will take longer.

Assessing the implications of new transport infrastructures long after their complete implementation (i.e. 25 years later) has the added problem that other factors mix up with the new transportation investment, and this exerts greater difficulty to ex-post long-term studies. Another problem is that data/statistics may change, due to change on collection/elaboration criteria or even due to collection cancellation.

3. Statistical Data Comparison over 25 years

The paper tries to do the same analyses that were undertaken 15-10 years ago, to evaluate those implications/impacts that have been consolidated on a greater long-term perspective and those which have changed and/or disappeared (less permanent more variable).

Ciudad Real and Puertollano are compared to other similar cities, as it was done in *Serrano, et al.* (2006) and previously in *Fariña, J, Lamiquiz, F y Pozueta, J.* (2000)**.** Ciudad Real is compared to other small provincial capitals and Puertollano to other small industrial cities, in both cases cities which are neither close to the seaside nor to the five bigger Spanish metropolitan areas (at least 80 km in both cases) -see Table 2-.

TABLE 2. Cities compared with Ciudad Real and Puertollano

CIUDAD REAL	PUERTOLLANO
Albacete	Andújar
Ávila	Baeza
Badajoz	Bailén
Cáceres	Bolaños de
Cuenca	Carolina (La)
Huesca	Daimiel
Jaén	Linares
León	Manzanares
Lérida	Pozoblanco
Lugo	Solana (La)
Orense	Úbeda
Palencia	
Soria	
Teruel	
Zamora	

Fuente: Fariña, et. al., 2000.

None of the cities compared had HSR at the previous two comparison moments, while now some of those compared with Ciudad Real have HSR. This is the case of Albacete (2010), Cuenca (2010), Huesca (2005), Lérida (2003), Orense (2011) and Zamora (2015).

Statistical comparison was done through four aspects, first, population elaborated by the national statistical institute, second and third, market share and touristic index elaborated by Banesto and La Caixa banks and forth, housing numbers, building years and empty ones elaborated by the national statistical institute and housing price elaborated by the Ministry of Development.

Fariña, et.al. (2001) did the comparison of population during the first 5 years of HSR existence (from 1992 to 1996), a very short period; while the market share and the touristic index was only studied one year prior the existence of HSR (1991).

Serrano et al (2006) did the comparison of:

a. The demographic evolution in order to consider if the processes are different in three different stages: first, before even knowing about HSR existence (1975 – 1986), second, when decisions have been taken but the infrastructure is not finish (1986 – 1991), and third, during the first ten years of existence (1991 – 2001).

b. The evolution of economic variables (market share and tourism indexes) between 1991 and 2002 – 2003.

c. The age, use and price of housing between 1991 and 2001.

The paper presented here is able to do the comparisons along more years but only with fewer variables. At present, population data is available, market shares and touristic indexes data have been discontinued, data about housing numbers, building years and empty ones are available and finally housing prices data by municipality offered by the Ministry of development have been discontinued. Thus statistical comparison cannot be undertaken for the long term in many of the initially selected variables, it could only be done with the same data and sources for population and housing (except prices). This paper, shows the initial results of a comparison only of the population data.

3.1 Population Comparison over 25 years

The comparison of Ciudad Real with all the other selected provincial capitals (see Table 3 and Figure 4) shows that it has a total growth greater than all the other capitals except Albacete. Albacete is the biggest one, which more than doubles Ciudad Real population size.

During the period prior to the arrival of the HSR, when it was already being built (1981-1991) Ciudad Real grew more than all the others, except one (Lugo). During the period just after the HSR (1991-2001) it grew more than all of them, except one (Albacete). During the fourteen years later (2001-2014) it grew more than all of them, except one (Cuenca).

TABLE 3

Population evolution of capital Cities compared to Ciudad Real (base 100 year 1991)

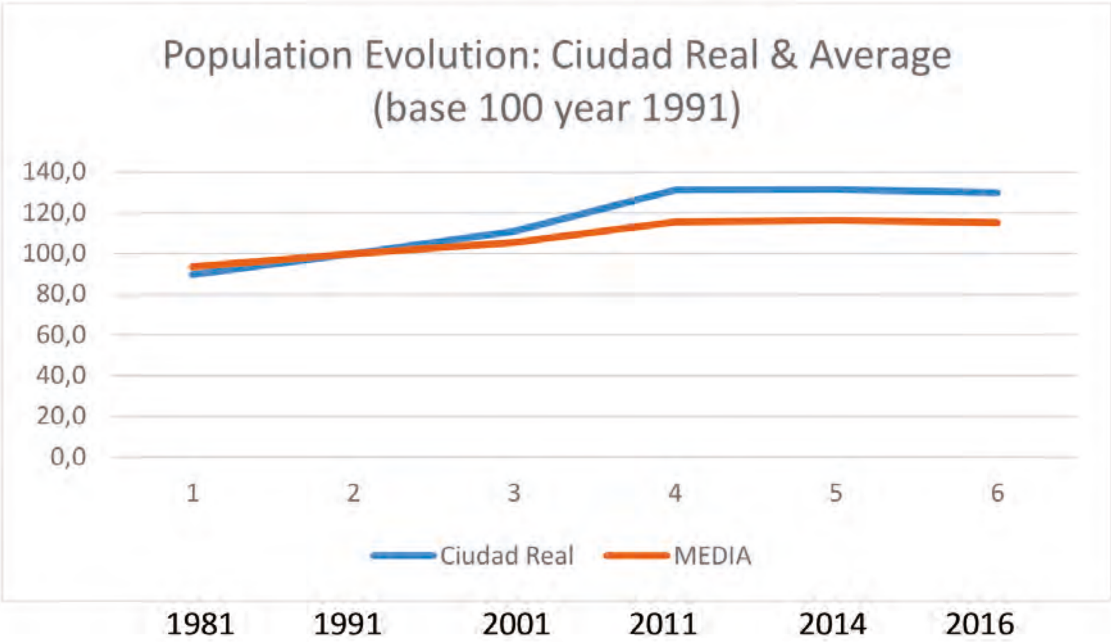
Municipality	1981	1991	2001	2011	2014
Albacete	90,1	100	114,5	131,5	132,7
Ciudad Real	89,6	100	110,9	131,3	131,4
Cáceres	96,3	100	110,9	127,4	128,5
Teruel	99,1	100	109,4	121,7	125,2
Badajoz	93,6	100	109,2	123,3	123,1
Jaén	93,4	100	109,0	112,4	112,2
Soria	99,0	100	108,6	123,1	122,1
Cuenca	97,6	100	108,2	130,3	130,2
Ávila	90,8	100	108,1	127,7	128,2
Lugo	88,9	100	106,2	117,1	118,4
AVERAGE	93,5	100	105,4	115,6	116,2
Huesca	100,5	100	104,7	115,9	119,0
Orense	93,5	100	104,6	103,4	104,0
Palencia	95,1	100	102,5	102,1	103,0
Zamora	92,6	100	100,6	100,5	99,9
Lérida	97,8	100	100,1	121,9	124,2
León	91,1	100	90,9	90,8	90,0

Source: *Instituto Nacional de Estadística*

Ciudad Real also grows more than the average of these cities (see Figure 4).

Figure 4:

Population Evolution: Ciudad Real and Average of Compared Citie



Source: Instituto Nacional de Estadística

It seems that the provincial capital city of Ciudad Real, the first stop of the Madrid-Seville HSR line, an administrative, service and university city, has taken a positive growth path in comparison to other similar provincial capital cities. Nevertheless, while during the 20 first years after the arrival of the HSR, its comparative growth seems to increase in comparison to the average of the other cities, during the last four/six years this positive growth difference seems to be maintained (see Figure 4).

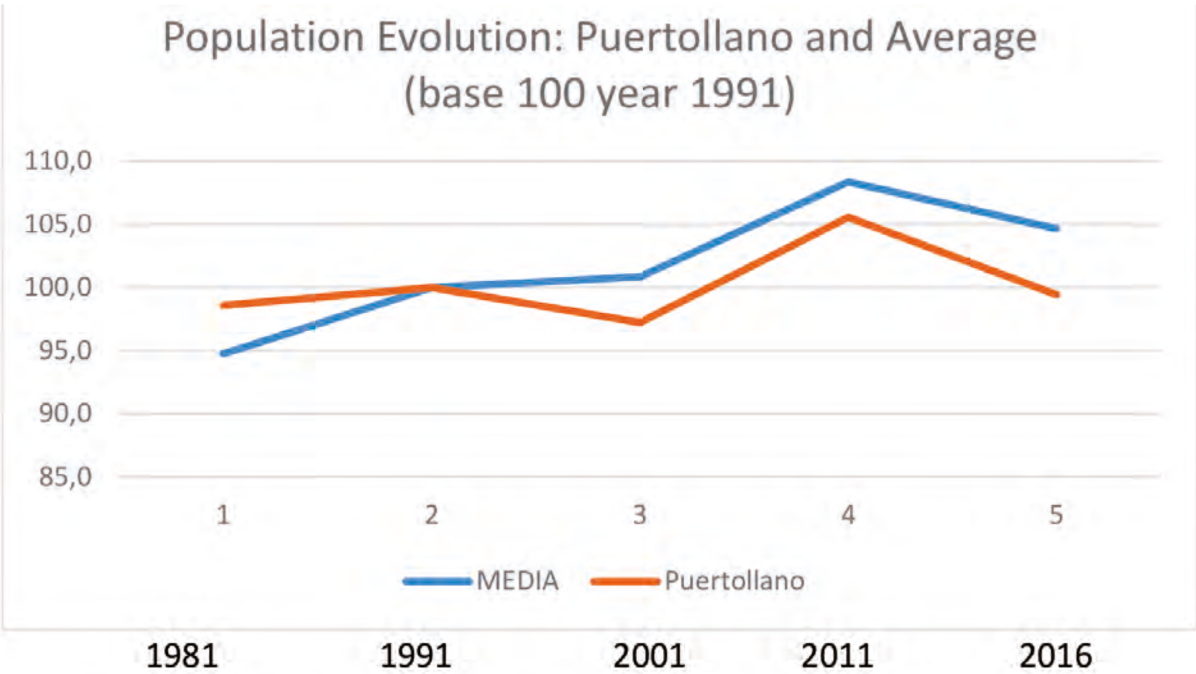
In the case of Puertollano its comparison with the other selected industrial cities (see Table 4 and Figure 5) shows that its total growth is smaller than all the other cities except one (Baeza). During the period prior to the arrival of the HSR, when it was already being built (1981-1991) Puertollano grew less than all the others, except two (Daimiel and La Carolina). During the period just after the HSR (1991-2001) it grew less than all of them, except for two (Baeza and Manzanares). During the sixteen years later (2001-2016) it grew less than all of them, except three (Bailén, Andújar and Linares).

TABLE 4. Population evolution of industrial Cities compared to Puertollano (base 100 year 1991)

	1981	1991	2001	2011	2016
Bolaños	98,6	100	110,6	124,0	119,1
Úbeda	89,8	100	101,5	112,2	109,0
Pozoblanco	88,1	100	106,2	114,8	112,0
Solana (La)	96,0	100	106,2	116,9	113,7
Bailén	92,9	100	105,5	111,5	107,6
Daimiel	100,3	100	105,4	115,2	113,5
MEDIA	**94,7**	**100**	**100,8**	**108,3**	**104,6**
Baeza	83,7	100	86,3	92,8	91,0
Manzanares	96,7	100	96,3	105,0	100,8
Andújar	97,6	100	105,9	109,2	106,1
Carolina (La)	100,7	100	101,8	108,3	107,1
Linares	93,4	100	98,9	104,6	100,7
Puertollano	**98,6**	**100**	**97,2**	**105,5**	**99,4**

Puertollano grows less than the average and during the last few years it seems to reduce even more its comparative growth (see Figure 5). The industry of Puertollano is monothematic and based on petroleum energy, a sector with decreasing employment ration, while the other cities industries are more diversified.

Figure 5: Population Evolution: Puertollano and Average of Compared Cities



Source: Ribalaygua, et.al. (2004)

It seems that the industrial city of Puertollano, the second stop of the Madrid-Seville HSR line, has taken a negative growth path in comparison to other similar industrial cities. A transportation means only for persons, together with the proximity of Ciudad Real also served by HSR is reducing and or extracting the dynamism of this industrial city. In this bipolar setting, HSR seem to extract from Puertollano and add to Ciudad Real.

Comparing the population findings of the analysis undertaken 10 years ago by Serrano, et. al (2006)[2] with those of the present longer term analysis the findings are not identical but similar; thus, it could be argued that the usefulness of long term population evolution analysis is not crucial. Nevertheless, longer term analysis suggests that the growth population dynamism of Ciudad Real (the administrative city) is maintained in relation to that observed post HSR but ten/fifteen years earlier, while that of Puertollano (the industrial city) seems to worsens in relation to that observed ten/fifteen years earlier. Thus the longer term population analysis does provide some additional qualitative differences.

4. Comparison of strategies

Usually, cities with new HSR connections attract/generate many urban projects, from the city itself, of from external/foreign investors trying to take advantage of the accessibility and image improvements. The policies/strategies implemented in these two cities are also revisited, as it was done ten years ago, ten years after the existence of HSR in *Ribalaygua, C., Ureña, J.M., Coronado, J.M., Escobedo, F., Guirao, B., Menéndez, J.M., Rivas, A. y Rodríguez, F.J.* (2004) **"Alta Velocidad, integración metropolitana y proyectos territoriales. El caso de Ciudad Real y Puertollano",** URBAN, n. 9, pp. 30-44.

Ribalaygua, et.al. (2004) studied the effects of HSR upon this HSR corridor ten years after it started to operate. They considered mobility and territorial structures, and made special attention on big projects that can only be understood under their close link to HSR. Here we are interested in their findings in relation to the main projects and to global planning criteria.

The relevance of comparing projects 10 years and 20/25 years is what Ribalaygua, et. al (2004) indicated that mobility changes may happen rapidly (few years after HSR), while changes on territorial structures need more time to happen.

Around ten years after the arrival of HSR the implications that were considered relevant were called "Effects on urban planning and the appearance of territorial scale projects" (Ribalaygua, et.al., 2004).

In relation to the municipal development urban plans, Ciudad Real renewed his in 1988, and a new one was approved in 1997, while Miguelturra, an adjacent town of 10000 inhabitants functionally integrated in the Ciudad Real socioeconomic dynamism, approved a new municipal development urban plan in 1994. On the contrary, Puertollano only started a new planning document in 2002, 18 years after the previous plan dating from 1984, and ten years after the arrival of High Speed Train.

In the case of Ciudad Real, the urban analysis done by Fariña et al. (2000) concluded that the impact of HSR in planning was very important, although not by itself and the opportunities it created, but because of the new locations of the tracks and the station. In fact, the stronger effects in the city were located in the old railway brownfields, transformed into residential land.

Ribalaygua et al. (2004) indicated that the new urban plan defined a city three times bigger than the 1987 plan, with a combination of very high and very low-density areas. As a result, four main urban spaces appeared: the compact urban nuclei of Ciduad Real and Miguelturra, a

2 *These are the conclusions/findings on this aspect by Serrano et al (2006) "Del análisis demográfico entre 1975 y 2001 se puede concluir que Ciudad Real mejora claramente su ritmo de crecimiento a partir del AVE en comparación con la media de las capitales similares, pasando de crecer solo un poco más que la media antes del AVE a crecer el doble que la media después del AVE; mientras que Puertollano empeora claramente su ritmo de crecimiento a partir del AVE en comparación con la media de las ciudades similares, pasando de crecer algo menos que la media antes del AVE a ser el núcleo que más decrece después del AVE."*

tourism destination called “Reino de Don Quijote”, and the future private airport and its industrial area. This last project was approved as ‘Singular interest project’ an exceptional planning legal figure of the Regional Land Use Law, and therefore was assumed by the city planning (FIG).

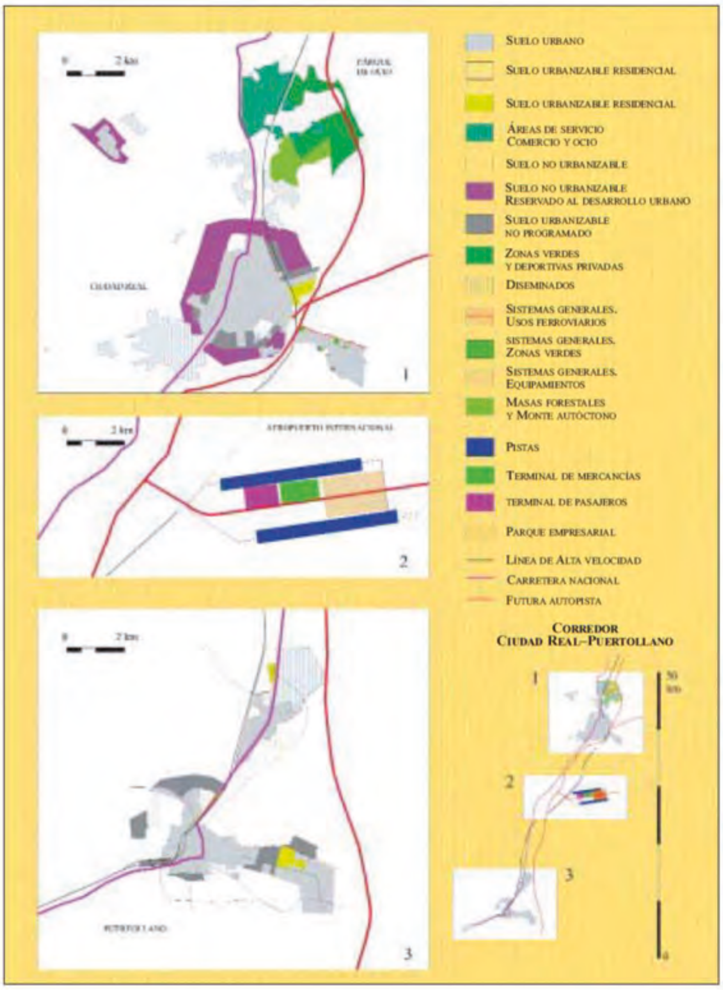
Nevertheless, the urban patters, building typologies and distribution, etc. created with the new urban plan of Ciudad Real did not take into consideration the opportunities that may have appear between the new station and the existing city centre. The plan left several barriers between the city centre and the station (a park, and old prison, etc.) and there were no intervention planned to improve this connection. On the contrary, on the other side of the tracks, new lands for tertiary and industrial activities was reserved.

In 2011 Ciudad Real started to revise its municipal development urban but the real sate crisis started in Spain in 2008 stopped its elaboration process as its growing in population and urban land previsions soon were found oversized (66000 new dwelling units, and housing for a population of 184.000 inhabitants (Rodríguez-Doménech, 2012).

Urban Development Planning documents seem to maintain a hope that these HSR cities will grow importantly, but reality doesn’t follow, maintaining slow growth rates, and thus making it much less urgent to approve new development plans. Ciudad Real approved its new Urben Development Plan just before the Spanish real state crisis, thus with abundant new possible urban expansion, which is still able to cope with today’s urban growth, thus there little need to approve a new urban development plan.

Figure 6:

Urban Development Plans: Ciudad Real-Miguelturra, Puertollano and airport area.



Source:

Ribalaygua, et.al. (2004)

Ribalaygua, et.al. (2004) consider three territorial scale projects: Airport, El Reino de Don Quijote Kingdom and the “Polígono Industrial Avanzado”.

At that moment, the airport was at the time in its initial building phases besides the HSR line (see Figure 6). The expectations were very important: a relevant air cargo activity thanks to the space availability and the size of the infrastructure big enough for the biggest existing planes and space for freight warehouses. Also, the arrival of low cost passenger companies was expected, thanks to the high speed connections to Madrid, even a High Speed Rail station in the airport was planned. The terminal was also going to be connected with a new crossing point of two motorways linking Lisboa with Valencia and Madrid with Cordoba, and also the connection with conventional rail was envisaged.

It was expected that the airport would have had an important potential market, due to land availability and an uncongested air space and due to its location besides a motorway crossing point and the HSR. This will allow, the airport promoters thought, would open up opportunities for merchandises and passengers traffics.

Today the airport is completed, has been in operation for about four years and then it was closed. The important financial depth of the airport and the important involvement of the regional Caja de Ahorros has meant that, following the airport’s closure, it has been sold at a much lower price and is in the process of being reopened, although it is not still sure when this reopening will take place. The new project is mainly oriented to freight and plane maintenance services, with a new big hangar under construction at this moment. The second consequence is that the regional Caja de Ahorros has been absorbed by a conglomerate of other public Banks.

In the meantime, some of the activities that were thought for this airport have been attracted by other airports (heavy plane maintenance by the Teruel Airport, European War Helicopter by the Albacete airport, etc.). The huge industrial area that was established and furbished besides the airport is totally empty.

The Don Quijote Kingdom Tourist destination was described by Ribalaygua, et.al. (2004) as a residential land that was already considered in 1997 city urban plan. In 1999 its surface was significantly increased (doubled) when a new leisure development project was proposed to the city council with hotels, a thematic park, golf courses and 6000 new housing units. It was a real state land development that should have increased substantially the residential land of the city and that may have change its urban structure, because this new development is 8 km apart from the existing nucleus, divided by the high-speed line, with the casinos and thematic park in one side and the golf courses in the other (see Figure 6). When Ribalaygua et al.(2004) wrote their article, the smaller golf course and some of the infrastructure was under construction, while permits were expected to start building the first residential developments.

Nowadays only a small part of the infrastructure investment (streets) is done and no houses (6.000 were planned) have been built and from the Tourist facilities (Casinos, thematic park and 36 holes Golf Course) only a 9-hole golf course is in operation. The developers have gone bankrupt and there are no news about possible plans for the half urbanized land.

The Polígono Industrial Avanzado located besides the HSR station was described by Ribalaygua, et.al. (2004) as a 24 hectares industrial area also besides an existing one by the traditional road to the east. This new Advanced Industrial Area was supposedly proposed for activities/businesses interested to develop new technologies and services and making use of the near university campus and its privileged accessibility. This initiative received substantial financial support by the EU due to its proximity to HSR and to being linked to new technologies.

Nowadays, this Polígono Industrial Avanzado is just above 50% occupied and activities do not have the additional expected technology role. Nevertheless, in other parts of the city (by the University Campus) a few industrial/consulting activities have been located, as if in this small city proximity to the HSR station is not necessary since all the city is close to the station. This lack of need to be close to the HSR station was already stated by Garmendia, et.al., (2008) for residential location.

Nevertheless, other high technology related activities are developing at Ciudad Real in more conventional locations, not in these territorial projects, for instance the University and the new provincial hospital. These activities are getting consolidated, but not without some problems, since the public expenditure reduction in parallel with a reduction of demand is probably meaning that they are having less demand, since some of the persons that demanded them can now solve their demand in higher class markets such as Madrid.

The conclusion that can be raised is that this city of Ciudad Real, although its great personal accessibility improvement via HSR, is only being able to change its traditional role at a very small pace, much smaller that it was expected, and over the existing urban land more so that along peripheral new development projects. It has to be considered that both the airport and the Don Quijote Kindom have a peripheral location.

In relation to Puertollano, Ribalaygua, et.al. (2004) did not consider any additional territorial projects. Nevertheless, Puertollano has had several small size development initiatives, all of them were initially proposed more than 10 years after the arrival of the HSR. These initiatives are an industrial incubator, a technical school of plane pilots, several solar panel factories, etc. most of them have lasted only a few years.

5. Conclusions

The two conclusions derived from revisiting these analysis undertaken 10-15 years ago in these two HSR cities show that:

The change in the growth tendencies produced shortly after the HSR arrival:

- a positive change in the tertiary city of Ciudad Real between 10 and 20 years after the arrival of HSR, that tends to be maintained after these first 20 years, with a slight diminution tendency.
- a negative change in the industrial city of Puertollano until 10 years after the arrival of HSR that tends to be maintained between 10 and 20 years and worsens between 20 and 25 years

Thus, although some differences appear between the population analysis undertaken 10/15 years ago and those undertaken at present, no great differences are shown, thus longer term population analysis do not seem to be crucial. Nevertheless, this is what happens with a 25 year long term period of study, what this does not demonstrate is that analysis undertaken with longer periods may not show greater differences. An additional consideration if that the analysis has only been undertaken with population total numbers, additional analysis of population age, employment, education level, etc. may provide other evidences.

In relation to projects/plans, the conclusions of this study seem to point out that the projects/strategies being developed 10-15 years after the HSR arrival could be classified in the long term into three groups:

- those that tried to change the territorial model in general are having big difficulties, with a possible subdivision:
  - those already totally built and related exclusively to transport (airport) may have a difficult but comparatively better promising future
  - those not totally built and related to attracting new activities (leisure) may have a much more difficult future if any.
- those that adapt the station urban surroundings in general are being more successful, although lack to attract new technologies
- those that tried to attract new activities in general their success is greatly influenced by the type of city (industrial vs tertiary) and the national overall economic dynamism (economic cycle).

Thus, it seems that the analysis of plans/projects provides additional relevant conclusions.

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Impacts of station accessibility and regional heterogeneity on HSR ridership

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Abstract

This paper examines how accessibility to the station impacts HSR ridership considering regional heterogeneity. Our study targeted on Taiwan High-speed rail (THSR). Monthly ridership data of THSR from 2007 to 2015 have been obtained from eight stations that are currently in operation. With a panel data set shown as two dimensions, a region *i* and time *t*, two-way error components model was applied in this study. Our results suggest that differences in the regional heterogeneity measured by population, road infrastructure supply, car ownership and business, would influence the HSR demand pattern. We further show that bus service (shuttle bus and BRT) would induce more demand than rail services (MRT/TR). In addition, our results show that the demand was also influenced by station's allocation; the one closest to city center had attracted more ridership. Under these findings, we discuss the way for pursuing long-term demand for HSR through improving accessibility to HSR stations and increasing quality of rail travel.

Keywords: *High speed rail; Travel demand; Access mode; Taiwan; Accessibility*

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1. Introduction

Taiwan high-speed rail (THSR) opened its operation from 2007. The system primarily relies on imported rolling stock from Japan and supplemented with European traffic management system. Through connecting the island's economic corridor north to south, serving almost 90% of the industry and the population. It had progressively reformed Taiwan into a "One-day living circle". The nearly 350 kilometers investment has significantly reduced the travel time from 4 hours into 1.5 hours, which the interregional accessibility of the Western coast Taiwan has naturally improved (Li et al. 2015).

To further illustrate this impact of intercity travel market share, traffic volumes of individual modes have been obtained from Taiwan's Ministry of Transportation and Communications (MOTC) are shown in Table 1. As a consequence of the THSR introduction, the ridership and intercity market share shifted between different travel modes between 2005 and 2015. Expressway buses, and domestic airlines experience negative trends while conventional rail demand (Taiwan railway, TR) remained stable during the first year of THSR operation and has since then been increasing. Private car though, seems have not experienced such impact from THSR but one should note that the expressway network (total length) had increased to 8.9% since 2005, and most of the extended sections were those areas that THSR could not be served. The average annual growth ratio for each mode since 2005 is 0.1% for cars, -3.86% for buses, 3.23% of Taiwan rail (conventional rail), and -5.89% of domestic airlines respectively; while THSR increased 7.53% per year on average.

Cheng (2010) investigated the initial stage operation and the aggregated demand of THSR; though he concluded that unsatisfied ridership (compared to previous forecasting) is the major concern for THSR system operator and the authorities, the ridership, service frequency, load factors (seat occupancy) are continuously increasing. As demand keeps growing, new stations opened, new access/egress mode opened/connected to stations, these impacts of station accessibility and regional heterogeneity, however, were not cleared and yet not disclosed from literature.

Table 1. Aggregated Intercity Ridership of Travel Modes in Taiwan

Travel Mode	Unit (market share)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Private Vehicle	million cars	479.1	480.6	475.5	453.9	457.1	464.8	479.6	482.8	498.9	449.1	479.2
	(%)	(52.0)	(52.7)	(51.9)	(49.4)	(49.9)	(49.8)	(50.1)	(50.5)	(52.1)	(49.2)	(50.9)
Bus	million Pax	252.8	245.2	242.3	246.4	237.8	232.8	220.6	197.1	173.9	172. 0	169.0
	(%)	(27.5)	(26.9)	(26.5)	(26.8)	(26.0)	(24.9)	(23.0)	(20.6)	(18.2)	(18.8)	(18.0)
Conventional Rail	million Pax	169.6	169.0	169.7	178.7	179.4	189.8	205.8	220.3	227.3	233. 0	232. 0
	(%)	(18.4)	(18.5)	(18.5)	(19.4)	(19.6)	(20.3)	(21.5)	(23.1)	(23.7)	(25.5)	(24.7)
Domestic Airlines	million Pax	19.29	17.36	12.71	9.85	9.23	9.73	10.48	10.68	10.55	10.55	10.56
	(%)	(2.1)	(1.9)	(1.4)	(1.1)	(1.0)	(1.0)	(1.1)	(1.1)	(1.1)	(1.2)	(1.0)
THSR	million Pax	-	-	15.56	30.58	32.35	36.94	41.63	44.53	47.49	48.02	50.56
	(%)			(1.7)	(3.3)	(3.5)	(4.0)	(4.3)	(4.7)	(5.0)	(5.3)	(5.4)
Total	**million Pax**	**920.8**	**912.2**	**915.8**	**919.5**	**915.9**	**934.1**	**958.1**	**955.4**	**957.9**	**912.6**	**940.5**

Source: Ministry of Transportation and Communications (MOTC)

Taken the perspective from a regional point of view, this paper examines how access transportation affects the local demand of THSR. It is a suitable case study for researchers to investigate the impact of a single HSR route for the country and to understand the passenger's travel behavior. Especially the differences among region's economic developments and city characteristics, how it would influence HSR demand over time.

2. Literature Reviews

Accessibility is quite an important topic, especially for transit system as already confirmed by many studies. Murray (2003) noted that accessible and efficient service is vital features, especially for well-utilized public transit systems. Mitra and Saphores (2016) investigated the recently published studies which identify the impacts of accessibility on property value of transit. They also argued that a positive relationship between accessibly improvements and property values has been verified by a number of literatures ((e.g., Cervero and Kang (2011) for Seoul's Bus Rapid Transit; Debrezion et al. (2011) for road accessibility on office prices in the Netherlands; or Dubé et al. (2013) for commuter rail accessibility in Montreal).

Accessibility to rail station becomes more important factor for rail transit in particular. The accessibility of the railway station can be a factor in determining if rail is chosen as a travel alternative (Hine and Scott, 2000; Krygsman et al., 2004; Wardman and Hine, 2000; Wardman and Tyler, 2000; Brons et al., 2009). In order to provide highest quality se1vices to its users, railways need to pay attention not only to the standard qualitative and quantitative indicators, but also to the accessibility of the railway station (Bogovic et al, 2003). Brons et al. (2009) indicated that rail operators aiming at increasing rail use must consider the aspect of satisfaction with its level. Here, they argued that access-to-the station is an important part in passengers' overall satisfaction with rail journey. Many past studies have also confirmed the importance of accessibility to the station. Keijer and Rietveld (2000), Rietveld (2000) and Givoni and Rietveld (2007) investigated the accessibility of rail travelers to the railway stations focusing on their mode choice (Brons et al., 2009).

The high-speed rail (HSR) is becoming more and more popular as a representative transport mode of railway in recent years. Therefore, based on the above literatures, access-to-the station is also one of the major factors which should be considered carefully in the case of HSR. According to the report of California High-Speed Rail Authority, it should be important to prioritize and obtain a balancing of many transport modes for station accessibility so that all users will be safe and comfortable moving to and from the HSR station and surrounding areas. Moreover, Eidlin (2015) argued that "high speeds (HSR) should be prioritized in sparsely populated places, while maximizing connections should be the primary consideration in densely populated places". Referring to these, intraregional station accessibility might be one of the issues at stake in the problem of securing sustained HSR demand

This paper continues the line of research on access to railway stations as an extension study of Li and Schmöcker (2014) and it has two broad aims as follow. First, to demonstrate that factors of access-to the station serves as a key element in explaining passenger demand of HSR with regional heterogeneity such as socioeconomic characteristics. Secondly, to investigate which public transport between bus and urban rail system is the most influential on increasing HSR ridership. This would also show the degree of influence by access transport modes on increase of accessibility to HSR station. The Taiwan HSR network is used as a case study as mentioned earlier.

3. Data

3.1 Station Accessibility by Region

One of the issues at stake would be intraregional station accessibility; Su et al. (2012) discusses that five out of eight stations are located in suburbs and far away from the CBD (central business district) area (except Taipei, Banciao, and Zuoying); where they found intercity travelers from around these stations are less willing to use THSR. In terms of this, the THSR stations which located in a peripheral location did not have a direct transit connection with its corresponding CBD at the beginning. This has reduced the travel time benefits in many cases compared to conventional rail. For example, the traveling time from Taipei to Tainan is 110 min, but from Tainan HSR station to downtown requires a traveling time around 35-40 min. Therefore, the lack of access to these HSR stations needs to be solved; THSR operators realized that creating a seamless journey for their travels is essential.

To this end, THSR has been working on improving its station accessibility since the operation. By cooperating with other stakeholders, THSR increased the level of service of access links and implemented new feeder lines. The reduced access/egress time to stations enhanced station accessibility. Table 2 indicates the time and types of access links to THSR. Four categories of access mode could be distinguished, MRT (mass rapid transit), TR (Taiwan Railway), BRT (bus rapid transit), and free shuttle buses offered by THSR. Considering the low cost and efficiency of deployment, THSR attempted to use BRT and shuttle buses which delivered a direct connection between THSR station and its corresponding CBD at the beginning years of 2007 and 2008. MRT and new feeder line constructed by TR takes longer construction time/cost, but expects higher capacity and frequency. We note that in a few stations, the shuttle bus had been suspended soon after the railway links (MRT and TR) began their operation.

Table 2. Access Modes for THSR station

Station \ Access Modes	MRT	Taiwan Railway	BRT	THSR Shuttle Bus
Taipei and Banciao[1]	●	●		
Taoyuan[2]	◎ (2017.02)			◎ (2008.02)
Hsinchu[2]		◎ (2011.11)		◎ (2008.02-2012.05)*
Taichung[2]	○ (2019)	◎ (2007.11)		◎ (2007.11)
Chiayi[2]			◎ (2008.02)	
Tainan[2]		◎ (2010.11)		◎ (2008.02)
Zuoying[1]	◎ (2008.03)	●		◎ (2007.11-2008.04)*

Note:

- Superscript[1] denotes stations which located within / close to CBD
- Superscript[2] denotes stations located in suburb areas
- Number within parentheses indicates actual or scheduled year/month of opening, where superscript* denotes links suspended after a new link connects to stations
- ●: Links implemented / exist before THSR
- ◎: New links after THSR opened
- ○: Links currently under construction

For the stations close to the CBD, access links had been integrated with THSR before opening. Taipei and Banciao station are both located within the Taipei metropolitan area and are integrated nodes in the TR and MRT networks, the MRT network extended the network length from 74.4km in 2007 to 112.8km in 2012. While Zuoying station was constructed with Xinzuoying station (TR) at the beginning of the operation, the number of TR services increased from 117 per day to 159 at the end of 2012. On the other side, Taichung HSR station later constructed pedestrian flyovers to nearby Xinwuri stations (TR) in late 2007. Smaller metropolitan areas such as Hsinchu and Tainan instead implemented new TR feeder lines (Luijia line and Shalun line) to its HSR station in 2010 and 2011. These improvements induced THSR ridership demand as well as reduced HSR station access/egress by private vehicles from 59.5% in 2008 to 51.5% in 2010 (Su *et al*., 2012). Furthermore, Taoyuan has an MRT project that connects to its CBD, THSR station, and Taoyuan International Airport was opened in 2017. Based on the aforementioned effort improved by THSR, the impact of intraregional accessibility to THSR station ridership need to be further examined. (See Figure 1)

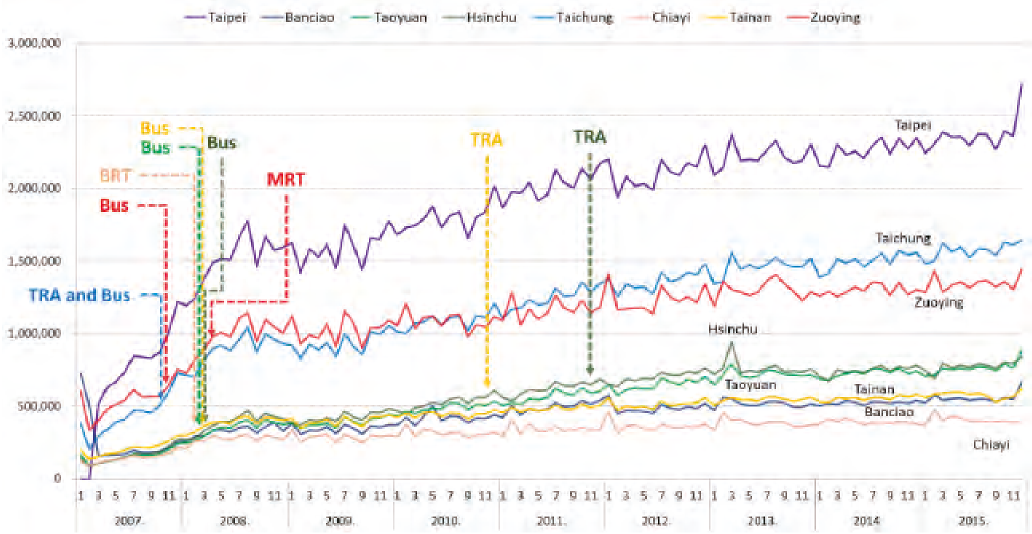

Figure 1 .THSR monthly ridership and opening time of access transport to the station

As representing , three types of parameters were considered to THSR station location in terms of accessibility measurement: a) direct distance away from its corresponding downtown b) access mode via road infrastructure such as bus service (BRT, shuttle bus), and c) access mode via rail service (MRT, TR). First one is measured by distance from city center to the station as shortest path (km). Here we assumed that shorter distances represent better accessibility. For the other two variables, the access link could be considered as binary dummy variable, i.e. if bus/rail is connected to the station 1, or not 0. This is one of the limitations of this paper have been that access link measures for all THSR station are complex and may result in difficulty of comparing their impact across different stations. These two dummy variables also indicate the specific month when access links connected to THSR stations as panel data which has a double subscript, region *i* and time *t*.

3.2 Variables for Region Heterogeneity

Based on previous studies, parameters that significantly influence aggregated THSR ridership had been specified as found by Li and Schmöcker (2014). Taipei is the capital and largest city of

Taiwan with a population of around 6.6 million at the end of 2012. The station was dominated by all kinds of travelers, including business travelers as well as local and some foreign tourists. Zuoying (located in Kaohsiung city) and Taichung station represent the 2nd and 3rd largest metropolitan areas located in the south and middle of Taiwan's west coast respectively. The rest of the stations listed in order of ridership are Hsinchu, Taoyuan, Tainan, and Chiayi, which are considered as second or third-tier city, from the 3rd group. Note that Banciao is located in the Taipei metropolitan area as a satellite station dispersing the mass demand from Taipei. Therefore two cities, Taipei and Banciao were considered together as one region in this study.

We consider regional heterogeneity mentioned briefly in above and assumed that regional heterogeneity would measured by some socioeconomic variables such as population, car ownership (%), total length of road (km), fuel price and business scale by city as underlying independent variables *(*X_{itk}) (. These were obtained and calibrated into the regional scale of monthly data from 2007 to 2015. For brevity we omit descriptive statistics as shown in Figure 2.

The region of Taipei and Banciao shows the highest value of population and business scale while the lowest ratio of car ownership compared to other cities. This might come from Taipei being the capital of Taiwan. The highest road supply rate is shown in Taichung with a high ration of car ownership. This implies that better mobility by car use would be in case of Taichung even this is located in the middle of Taiwan. In addition, regarding explanatory variables which explain THSR station demand, Li et al. (2015) we also considered two time specific factors, including a variable for years (X_y), which shows time since operation after THSR opening, in order to reflect the trend of increased demand over time and a dummy variable for summer vacation (D_s), to reflect some induced demand such as leisure trips. Thus the variables for regional heterogeneity also have a form of panel data which has a double subscript, index *i* and time *t* as same as variables of accessibility*.*

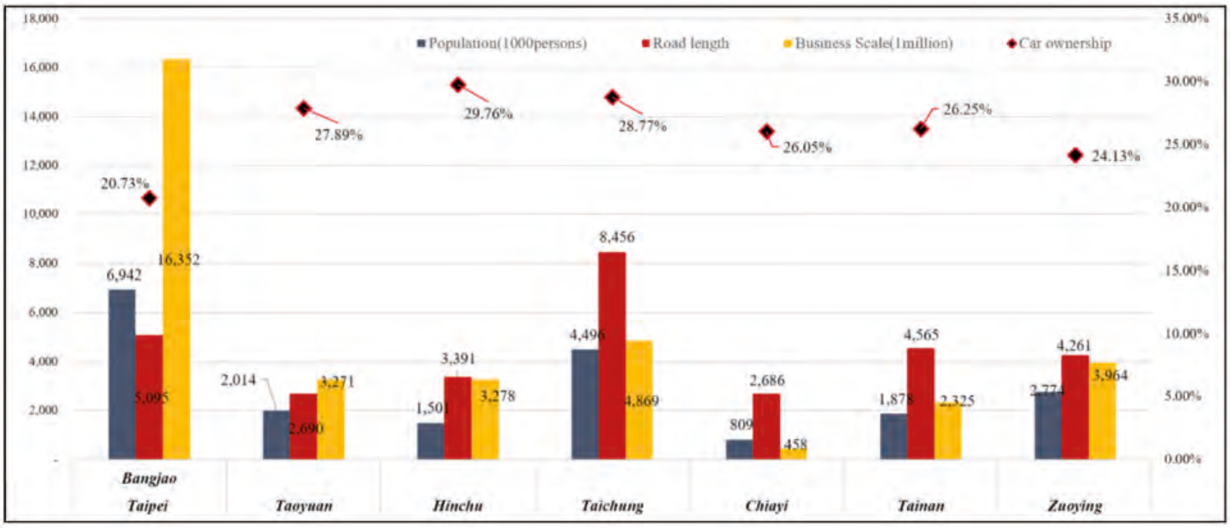

Figure 2. Descriptive statistic of socioeconomic variables by major city

4. Methodology

This study uses a two-way error component model, a kind of panel model, to mitigate the errors occurred from unobserved heterogeneity in terms of location regions and time. A two-way error component random effect model was applied in this study where we control the unobserved effects, presented by month and city as random variables. Baltagi (*2013*) noted that a panel data model differs from a regular time-series or cross-sectional regression in that it has a double subscript on its variables, i.e.

$$y_{it} = \alpha + X'_{it}\beta + \varepsilon_{it},\ (i = 1, \dots, I;\ t = 1, \dots, T), \tag{1}$$

where i represents location and t represents time. The i subscript therefore denotes the cross-section dimension, whereas t denotes the time-series dimension. Here is a scalar, β is a Kx1

$$\varepsilon_{it} = u_i + \mu_t + v_{it},\ (i = 1, \dots, I;\ t = 1, \dots, T), \tag{2}$$

$$y_{it} = \alpha + X'_{it}\beta + u_i + \mu_t + v_{it},\ (i = 1, \dots, I;\ t = 1, \dots, T), \tag{3}$$

where u_i denotes the unobserved regional effects, μ_t denotes the unobservable time effect, and v_{it} is the remainder stochastic disturbance term. Here, $u_i \sim IID(0,\sigma_u^2)$ and/or $\mu_t \sim IID(0,\sigma_u^2)$ and $v_{it} \sim IID(0,\sigma_u^2)$ independent of each other, it is possible to obtain the two-way random effect error component model. In addition, X_{it} is independent of u_i, μ_t and v_{it} for all i and t. Inference, in this case, pertains to the large population, which the sample was randomly drawn from.

In this study, we estimate two models. First model only includes socioeconomic variables and then transport accessibility variables would be considered as an additional factor in the second model. We are going to identify whether accessibility variables are important as much as socioeconomic factors to the model which explains HSR ridership. Our hypothesized model could be expressed as follows;

$$y_{it} = \beta_0 \cdot \beta_k X_{itk} \cdot \beta_y e^{X_y} \cdot \beta_s e^{Ds} \cdot e^{\varepsilon_{it}}, \tag{4}$$

Here, taking a log to equation (4)

$$\ln(y_{it}) = \ln(\beta_0) + \textstyle\sum_k^K \beta_k \ln(X_{itk}) + \beta_y X_y + \beta_s Ds + \varepsilon_{it},\ \varepsilon_{it} = u_i + \mu_t + v_{it}, \tag{5}$$

Where, i=city (region) and t=month, X_k=socioeconomic factors(population fuel price, business scale, road supply, car ownership), X_y=year, Ds=dummy for summer, Then, our hypothesized second model with transport accessibility variables is presented as follows:

$$\ln(y_{it}) = \ln(\beta_0) + \textstyle\sum_k^K \beta_k \ln(X_{itk}) + \beta_y X_y + \beta_s Ds + \sum_n^N \beta_n \ln(A_{itn}) + \sum_{n*}^{N*} \beta_{n*} \delta_i A_{itn*} + \varepsilon_{it} \tag{6}$$

Where, A_n=station location (distance from CBD to (HSR station(km)) and A_{n*}=Rail and bus transit (dummy variable) are added as transport accessibility variables.

5. Model Estimation

The estimated time-random/region-random effects two-way error component models' results are shown in Table 3. By the model 1, we examine how socioeconomic indicators and time/seasonal factors which have been verified variously in previous studies, explain THSR ridership considering regional heterogeneity. Additionally, this study also examines how the factors of access-tothe station enhances model fits towards THSR ridership. Thus, Model 2 contains all socioeconomic elements of the Model 1 as well as accessibility factors. Both models are statistically significant, supported by the Chi2 statistic of 0.000, moreover all coefficients of explanatory variables are significant at the 5% level; (coefficients significant at the 1% level are shown in bold)

From our finding, regional specific socio-demographics (i.e. population, car ownership, length of road network, business scale), fuel price by year as well as time dummy variables are always being significant generally explain THSR demand. Population and car ownership are most influential variables to explain THSR ridership by region, since population may represent the market size of the travel demand and HSR works as an alternative transportation mode instead of car use. Therefore, this indicates that higher number of HSR users can be shown in the cities with high population and low car ownership ration. Furthermore, the length of road network, fuel price, business scale that shows the revenue per company, is found positive to local THSR ridership. In addition, the seasonal factors, the summer vacation and the element which shows how long after the opening of THSR, performed well to explain the local demand as well. The demand is found positive significant in the summer suggests that vacation activities has induced HSR demand. Moreover, the number of THSR users increases as time passes after system opening. This result shows the “mass effects” which argued by Schmöcker et al. (2014) and “adaptation effects” suggested by Lit et al. (2015). According to Li and Schmöcker (2014), the negative perception of the traveler at the beginning of operation has been observed, such as safety concerns, unreliable ticketing, or the reservation system that prohibited some potential users to taking rides (Cheng, 2010). However, this general perception might possibly have been changed over time, where more travelers recognized the advantages of HSR, travel time saving, level of services, easier to access than before and other advantages related with perception. These conversions of perceptions would enlarge HSR travelers from a small number of population group penetrates into the majority. This was resonated by Schmöcker et al. (2014) who discussed that “mass effects” can be significant determinants of long term demand adaptation. One persuades a few to change their behavior initially in order to encourage a large number of people to follow later. There is then a potential of enduring significant demand increases as the new service might increase its attractiveness over time if more start to join it. Li et al. (2015) proposed an econometric time-series model to predict aggregated THSR ridership on long-term demand. This study takes into account on THSR local demand to understand the impact of “adaptation effects” as well as access link regarding other general explanatory variables.

The result of Model 2 is also quite similar results with those of the Model 1 in the case of a socioeconomic variable by region. However, we considered three of accessibility variables here additionally. All are significant but has different sign in the coefficients. Especially the station location has negative value, unlike the other two accessibility variables. It implies that the number of passengers is smaller as the station of the HSR is located far from the city center. On the other hand, the ridership demand would be induced if buses or railway public transportation is connected to the HSR station. In addition, when we compared to the transit system in an aspect of access-to-the station, bus system (BRT and shuttle bus) has a larger influence than rail transit (MRT and TR). From the result of the Model 2, we identified that accessibility to HSR station is also an important factor in explaining the demand for HSR as much as socioeconomic indicators.

Table 3. Results of model estimation

<table>
<tr><th colspan="2">Variables</th><th colspan="3">Model 1</th><th colspan="3">Model 2</th></tr>
<tr><th colspan="2">Y_{it}:Ridership</th><th>Coef.</th><th>Std. Err.</th><th>pvalue</th><th>Coef.</th><th>Std. Err.</th><th>pvalue</th></tr>
<tr><td rowspan="5">Socioeconomic variable by region</td><td>population</td><td>2.714</td><td>0.503</td><td>0.000</td><td>4.280</td><td>0.499</td><td>0.000</td></tr>
<tr><td>Car ownership</td><td>-6.651</td><td>0.439</td><td>0.000</td><td>-4.817</td><td>0.389</td><td>0.000</td></tr>
<tr><td>Road length</td><td>-0.756</td><td>0.149</td><td>0.000</td><td>-0.359</td><td>0.128</td><td>0.005</td></tr>
<tr><td>Fuel price</td><td>0.199</td><td>0.058</td><td>0.001</td><td>0.186</td><td>0.049</td><td>0.000</td></tr>
<tr><td>Business scale</td><td>0.235</td><td>0.109</td><td>0.031</td><td>0.295</td><td>0.091</td><td>0.001</td></tr>
<tr><td rowspan="2">Time dummy variable</td><td>year</td><td>0.224</td><td>0.008</td><td>0.000</td><td>0.174</td><td>0.007</td><td>0.000</td></tr>
<tr><td>Summer season</td><td>0.060</td><td>0.234</td><td>0.012</td><td>0.061</td><td>0.021</td><td>0.004</td></tr>
<tr><td rowspan="3">HSR station accessibility variable</td><td>Station location</td><td colspan="3">-</td><td>-2.734</td><td>1.191</td><td>0.022</td></tr>
<tr><td>Bus accessibility</td><td colspan="3">-</td><td>0.296</td><td>0.018</td><td>0.000</td></tr>
<tr><td>Rail accessibility</td><td colspan="3">-</td><td>0.053</td><td>0.019</td><td>0.005</td></tr>
<tr><td colspan="2">Constant</td><td>472.113</td><td>15.575</td><td>0.000</td><td>385.896</td><td>14.035</td><td>0.000</td></tr>
<tr><td rowspan="3">Random effects parameters</td><td>Region identity</td><td>1.610</td><td>0.598</td><td>-</td><td>1.921</td><td>0.607</td><td>-</td></tr>
<tr><td>Time identity</td><td>0.053</td><td>0.101</td><td>-</td><td>0.051</td><td>0.009</td><td>-</td></tr>
<tr><td>sd(Residual)</td><td>0.182</td><td>0.005</td><td>-</td><td>0.152</td><td>0.004</td><td>-</td></tr>
<tr><td colspan="2">Log likelihood</td><td colspan="3">160.829</td><td colspan="3">289.798</td></tr>
<tr><td colspan="2">Wald chi square</td><td colspan="3">2771.64</td><td colspan="3">4307.17</td></tr>
<tr><td colspan="2">Prob>Chi2</td><td colspan="3">0.000</td><td colspan="3">0.000</td></tr>
</table>

In order to re-verify that the elements of accessibility are important and to find out which model is more appropriate to explain HSR ridership, we tried to compare Model 1 and 2 by statistical method. Burnham and Anderson (2004) note that the first step for model selection would be to establish a selection criterion, such as the Akaike information criterion (AIC) or the Bayesian information criterion (BIC). AIC is an usual selection criteria which were well adopted in past studies, however BIC also has been suggested in recent studies. One advantage of the BIC over traditional hypothesis testing is that it has good properties under conditions of weaker regularity compared with the likelihood ratio test (Roeder et al., 1999; Kim et al. 2013). In addition Keribin (1998) demonstrated that under certain conditions, the BIC consistently determines the right number of components in the mixture model (Lee and Timmermans, 2007; Kim et al. 2013). In this study, we are going to confirm which model has a high model fit and then to select more appropriate models between the two based on BIC with consideration of AIC. Those formulas are:

$$AIC = -2LL + 2K \qquad BIC = -2LL + \frac{\ln N}{K}, \tag{7}$$

where LL is the value of the log-likelihood function at convergence and means the level of model fit, K is the number of parameters in the model, and N is the total sample size (Wen and Lai 2010; Kim et al. 2013). Through BIC and AIC values reported in Table 4, it could be an appropriate way to check which model is better. Since LL indicates the level of model fit, the model which has a lower value of AIC and BIC could be selected. A comparison of BIC and AIC values indicated that model 2 which considered THSR station accessibility could be identified the proper model than model 1 in order to explain THSR ridership.

Table 4. AIC and BIC analyses for model selection

Model	df	Log-likelihood at convergence	AIC	BIC
Model 1	11	160.829	-299.6584	-248.8523
Model 2	14	289.798	-551.5967	-486.9344

6. Discussion and Conclusion

Our analysis suggests that differences in regions economic developments and city characteristics would influence HSR demand pattern. Furthermore, in discussion on the demand impact from THSR access links, our result shows analysis that improvement of access links does seem to affect ridership. It also suggests that access links of public transportation appear to be important factors to induce HSR ridership. The result also indicates bus service (shuttle bus and BRT) would induce more demand than rail services (MRT/TR). The THSR accessibility improvement is essential from our observation, once the link connects to those which located in peripheral locations, it generally induces THSR station demand. In addition, especially our findings illustrate the demand influenced by station's allocation, the one closed to city center had attracted more ridership. Our models capture the effect of accessibility to the station as well as socioeconomic variables which show regional heterogeneity on HSR demand by using panel data. Clearly this finding would support our hypothesis to model estimation.

Providing sufficient station accessibility is essential for THSR due to the remote location of stations. Obviously stations located in the CBD provide more access links than rural area. In this paper, the access quality was measured as binary variables (e.g. If connected with transit network, 1, or 0); For stations located within CBD's we show that service improvements to metro and local rail links that existed prior to THSR opening do not appear to have an influence on THSR demand. However, for most of the THSR stations located in peripheral locations and without any public transport access at the beginning of HSR operation, the first access link connected would stimulate the station demand, i.e. THSR shuttle buses (Hsinchu and Tainan) and BRT (Chiayi);. This is why the influence of connectivity in case of bus system was derived more strongly than that of the rail transit. This is the result in the same line with Li and Schmöcker (2014).

We argued that station accessibility affects on quality of rail travel in the beginning of this paper. Nevertheless a lot of rail operators still have underestimated its impact. Tentatively, we suggest that general accessibility through public transport is important, but further improvements do not necessarily generate additional journeys. Further work for this analysis could be much improved if panel data on modal split of how people access HSR would be available as well as how much time to access to the station by mode. From another point of view, as it is rapidly entering a super aging society, explanatory variables capable of responding to changes in household structure and average age users should also be considered in the model which explains the long-term demand of HSR.

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High-speed rail and urban development in Spain from 1992 to 2016

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Abstract

In April 1992 started the first High-Speed Rail service between Madrid and Seville in Spain. In other countries, usually, the HSR services are introduced when conventional train services accomplish its top capacity. However, Spanish decide explain its HSR network to all the territory. On the other hand, traditional theory of economic growth say that infrastructures are necessary but not sufficient to economic growth. In this sense, investment in infrastructures, especially in transport infrastructures, is justified, in general, for promoting economic growth. Today, 25 years after first HSR services in Spain, a large HSR network connect many Spanish cities with a length of 2,444.1 km in 2013. Really, HSR network is a territorial laboratory to test the theory about relationship between new transport infrastructure and economic growth. In addition, from 1992 to now, economics trends in Spain has three cycles: crisis cycle 1992-1997, expansive cycle 1998-2007 and crisis cycle 2008-2016. According classical theory, new transport infrastructures allows comparative advantage to cities with new services. In consequence, today is a good moment to realize a comparative analyze between Spanish cities with or without HSR services. The population of each city is a good indicator of economic trends. In fact, cities with economic growth increase population while cities with negative economic growth decrease population. However, the analysis is more complicated because of two causes. On the one hand, the most important cities connected by HSR form metropolitan areas with special interior dynamics. For example, maybe city center can decrease while metropolitan area increase. On the other hand, the start of HSR services on each city is different because the network increase progressively. So is it necessary a special progressive comparison. This paper shows the evolution of inhabitants of cities that have HSR services and compare this evolution whit general evolution of Spain in function of date that HSR services started. On the other, hand the main cities are the center of their respective metropolitan areas. In this situation, another comparative analysis has been realized for metropolitan areas. The results show that the HSR has served to consolidate and extend the hinterland of the main metropolitan areas with interesting and significant exceptions. In fact, HSR services includes two kind of services: long and average distance. Really, the services for average distance explain the relationship between HSR and metropolitan areas evolution.

Keywords: HSR territorial impact, regional development, urban development, cities system.

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1. Introduction

High-speed railway (HSR) services began in Spain 25 years ago. Really, in 1987, the Rail Transport Plan to improve conventional train services and its railway network was approved. However, few years after, government decided put off the plan and execute the first High-Speed line (AVE services in Spanish) between Madrid and Seville, which opened in the Universal Exposition of Seville in 1992. This service have speed about 300-350 km/h and begin in Spain the new railway network with UIC gauge. Investment in this infrastructure consumed all planned budget for conventional rail plan. Train Station in Madrid for High-Speed was located in Atocha Station in city centre.

Table 1. Network railway high-speed evolution in Spain. Origin: ADIF and VIA LIBRE.

Services start date	Strech	HST Rail line	HS length (km)	% railway
1992, April	Madrid-Sevilla	Madrid - Sevilla	477,8	3,86
2003, October	Madrid-Zaragoza-Lleida	Madrid - Barcelona - France	1025,8	7,93
2005, November	Madrid-Toledo	Madrid - Sevilla	1049,9	8,17
2006, December	Lleida-Camp de Tarragona	Madrid - Barcelona - France	1253,2	9,57
2006, December	Córdoba-Antequera	Córdoba - Málaga	1253,2	9,57
2007, December	Madrid-Valladolid	Madrid - ValladolidGalicia	1492,5	11,18
2007, December	Antequera-Málaga	Córdoba - Málaga	1492,5	11,18
2008, February	Camp de Tarragona-Barcelona	Madrid - Barcelona - France	1600,5	11,89
2010, December	Mollet-Girona &Figueres-Pertús	Madrid - Barcelona - France	2135,7	15,25
2010, December	Madrid-Cuenca-Albacete-Valencia	Madrid - Valencia - Murcia	2135,7	15,25
2011, December	Ourense-Santiago-A Coruña	Atlantic Axis	2225,4	15,78
2013, January	Barcelona–Figueres,complet	Madrid – Barcelona – France	2444,1	17,32
2013, June	Albacete-Alacant	Madrid - Valencia - Murcia	2444,1	17,32

Progressively, according to reports of ADIF and VIA LIBRE, the new railroad network increase accord table 1. As the high-speed network has expanded also increased passenger network as you can see in table 2. In figure 1, you can see the HSR network in Spain in 2015. In this date, HSR services also started to the cities of Zamora (December 2015), Palencia and Leon (September 2015 both). Note you that the number of passengers is low in relation to the length of high speed lines built. According Albalate & Bel (2012; 2015), the length of Spanish high-speed rail network is more extensive than the networks of France, Germany or Japan but with a relationship km of network par inhabitant very high.

The fact that the historical rail network having a width different from the general European gauge has conditioned much decision making (Miralles, 2017). In general, instead of prioritizing the transformation of conventional lines with more passenger traffic, successive governments opted for an extensive transformation of the entire network to serve the greatest number of cities by passenger services with origin in Madrid (Bel, 2010).

To increase the use of new infrastructure, ADIF improved services by “average distance trains”. These are services provided to cities relatively close to each other. In these cases, the average speed of travel is about 200 km/h, lower than in long distance services.

Table 2. Evolution of passengers by HSR in Spain (millions). Origin: Ministerio de Fomento (Spain) and RENFE-OPERADORA.

Figure 1. Network High-speed railway in Spain in 2015. Origin: ADIF.

Today, 25 years after start the HSR services, is possible to analyze the territorial impacts made by this new infrastructure, more specifically on the economic development of cities and regions that have this new transport service.

As de Rus (2015) reminds us, infrastructures are a necessary condition for economic development but not sufficient. Besides, he reminds us that the productivity increases with the investment in public capital. However, the Law of Decreasing Returns is also applicable in this field. So the effect of the additional investments being lower when the network presents a more advanced state as has been demonstrated in the Spanish case (Reig Martínez et al, 2007).

It is now possible to contrast these approaches once again. In fact, the new services of HSR are a comparative economic advantage with respect to cities or regions that do not have them.

Consequently, the cities or regions with HSR services should show greater economic growth than those do not have such services. On the other hand, the population growth is an indicator of economic growth. Therefore, it is possible a comparative analyze of the population growth of cities/regions with/without HSR services and to test if there is any relationship between them.

The population data series corresponds the period 1991-2016. In this period there is three economic cycles: crisis cycle from 1991 to 1996, expansion cycle from 1997 to 2007 and crisis cycle from 2008 to currently (today is complicated to stablish a data finish for this cycle). The situation is the same for all Spain. Therefore the cities with HSR services, in general, should have taken advantage of their comparative advantage over all economic cycles.

2. Objectives

The objective of this research is test the relationship between the new HSR services and the economic development of cities or regions with the new services measured by the population growth indicators.

Specifically, if the cities or regions where the new HSR services have been implemented, have experienced greater economic growth, as measured by the growth of their population, than those where HSR services have not been implemented. Or, if there have been changes in the trend of population growth before and after the start of services.

3. Methodology

The analysis focuses on the growth that has occurred in cities and regions with HSR services and their comparison with those that do not have such services.

The "Instituto Nacional de Estadística" (INE), *Statistics National Institute* in English, has annual dates of inhabitants for all municipalities of Spain by the "Register of inhabitants" from 1996. Before it exit dates of municipal inhabitants in each Census. Census dates are not annuals. They have only been made in certain years. Particularly the last Inhabitant and Houses Census corresponds to the year 1991. The first HSR services started in 1992.

The methodologies to take inhabitants dates are different in Census and Register of Inhabitants but our interest is focused in growth, not in total inhabitants, to do a comparative analysis. So this difference is not relevant.

The work analyse three matters:

- The population growth of all cities or regions with HSR services compared with the population growth of all cities or regions without HSR services.
- The population growth of each city with HSR services compared with the population growth of all cities with/without HSR services and trend changes.
- The population growth of each city/region with HSR services compared with the population growth of all cities/regions with/without HSR services and trend changes.

The analysis of first matter present two problems. On the one hand, the list of cities with/without HSR services changes over time. This problem has been solved as follow. Each year has been considered with or without HSR services according to the number of months with HSR services. Only when the number of months is greater than six, the year is considered with HSR services. This is the year of change and, from this year, the all population of cities with HSR services increase. The indicator selected to show the population growth is:

$$IC_{n+1} = \frac{P_{n+1} + P_n}{P_n} IC_n$$

Where P is the population in year *n+1* or *n* and IC is the Index of growth in year *n+1* or *n.* The year 1991 has been established as a 100 base, that is, IC_{1991}=100 for all variables. Besides, the population according to the "Register of Inhabitants" is the population on date of first of January of each year. So the indicator IC calculated with this data show the growth produced the previous year. The last IC calculated is for growth of 2015 year.

When a year is a year with new cities with HSR services, the all population of cities with/ without HSR services are recalculated.

On the other hand it exist the problem of metropolitan areas. Often, the city centre of these areas are urban saturated municipalities. For example, Madrid or Barcelona have the area of their municipal territory saturated by urban uses from a long time. Consequently, they cannot increase urban areas and they cannot increase population into their municipal areas (or the growth is very conditioned). This geographical condition breaks the relationship between population growth and HSR services.

In addition, the geographical areas of metropolitan areas changes over time when commuting travels increased and new areas or municipalities are integrated into it (Feria et al, 2016). This work, to solve this problem, include two analysis. The analysis with the population growth of cities and the analysis with the population growth of provinces where are located the cities that are city centre of any metropolitan area. The provincial area is an approximation of metropolitan area where, usually, there are adequate free zones for urban expansion and, thus, the urban saturated effect is eliminated. Certainly, their total population isn't the population of metropolitan area but the index of population growth is representative for the metropolitan population growth.

4. Results

4.1 Population growth of all cities with HSR services versus all cities without HSR services Table

Table 3 shows the evolution of Population Growth Index of all cities with HSR services, all Spain and all cities without HSR services. The graphic show that the cities without HSR services have a Growth Index (IC or *Indice de Crecimiento* in Spanish) similar to Spain while the cities with HSR services have a much smaller IC, even decreasing between 1991 and 2000. Only in two last years of the series, 2014 and 2015 after 22 years started first HSR services, there is a change of trend: cities with HSR services increases growth while cities without HSR services decreases growth.

However, as mentioned above, the result may be erroneous due to urban saturation of the municipalities that are central nucleus of metropolitan areas. Next point explain the results considering metropolitan areas.

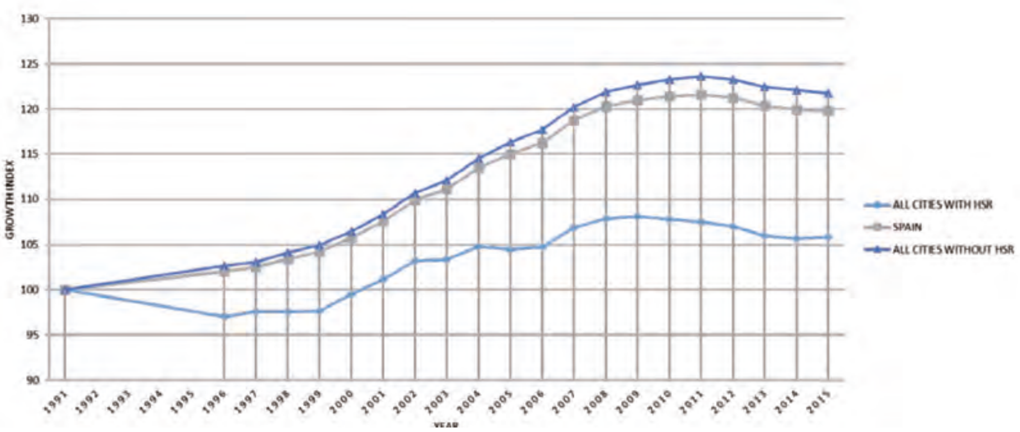

Table 3. Population Growth Index of cities with/without HSR and Spain.

4.2 Population growth of all cities and metropolitan areas with HSR services versus all cities and metropolitan areas without HSR services

Table 4 shows the evolution of Population Growth Index of all cities and metropolitan areas with HSR services, all Spain and all cities without HSR services. Remember that metropolitan areas have been assimilated to the provinces where they are located. The list of metropolitan areas considered as provinces is: Alacant, Barcelona, Córdoba, Madrid, Málaga, Sevilla, Tarragona, València, Valladolid and Zaragoza. Obviously these provinces accumulate a large part of the population of Spain.

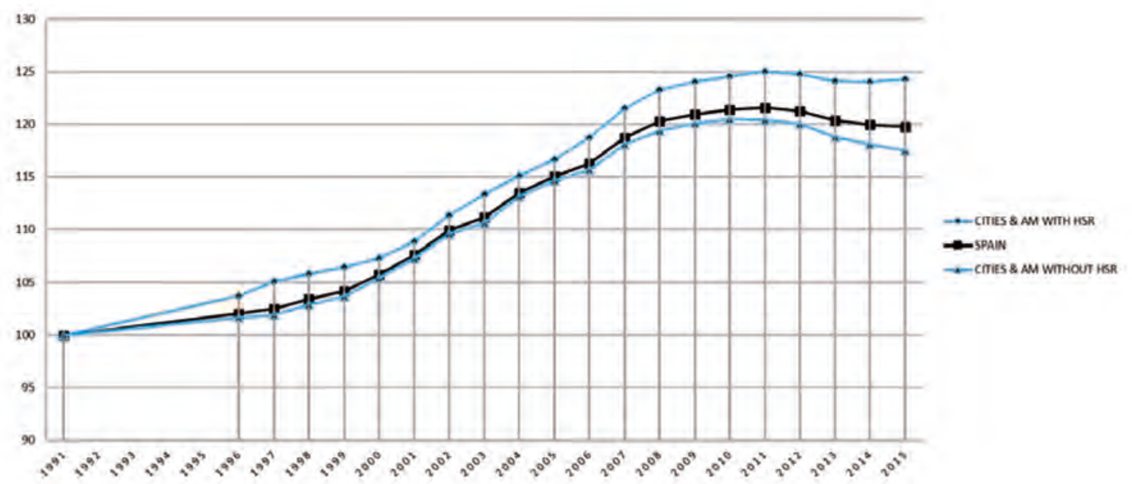

Table 4. Population Growth Index of cities and metropolitan areas with/without HSR and Spain.

This table is contradictory with the previous one. In this case cities and metropolitan areas with HSR services show a growth greater that Spain and cities without HSR services. However the differences aren't significant except in last period. The growth of cities and MA without HSR services is the same as that of Spain until about 2010. After 2010 these cities and MA have had a smaller growth than the one of Spain.

On the other hand, cities and MA with HSR services, from about 2006, have had a growth greater than the one of Spain. However, from about 2011, the differences of growth between cities and MA with or without HSR services increase significantly. The data seem to show that, during the period of the economic crisis, cities and MAs with HSR respond better and increase their relative growth relative to those without HSR.

The question is: Has the greatest growth been caused by the HSR services? Or rather, has the HSR served to reinforce a global trend of expansion of metropolitan areas produced by other causes?

Probably the correct answer is the second because of different studies about metropolitan areas show that metropolitan areas are expanding all over the world, also in Spain (Vheeler, 2008; Feria, 2016).

4.3 Population growth of each city with HSR services

Now the paper start the analysis of population growth of different cities with HSR services from start its. The first HSR services started in 1992 in the cities of Sevilla, Córdoba, Puertollano, Ciudad Real and Madrid. Table 5 show the Growth Index of these cities and general Growth Index for all cities with/without HSR services and Spain.

As you can see, only the city of Ciudad Real has an IC that stands out above the rest. Surprisingly Madrid and Sevilla have a very low IC over the period and decreasing from about 2011. Their IC trends are less than general dynamic for all cities, both those with HSR services and those who do not. In any case, the city of Puertollano has a decreasing trend of the index, despite being located very close to Ciudad Real.

In two last years, 2014-2015, Madrid changes the trend according to general evolution of all cities with HSR services and increase the IC. By contrast, Sevilla continues decreasing its CI. Sevilla increase its IC between 1991 and 2002. From the year 2002, its IC has been steadily decreasing.

Maybe, in the case of Ciudad Real, this city joins the metropolitan area of Madrid because new HSR services allows commuters travels. By contrast, Sevilla shows that new infrastructures are necessary but not sufficient condition to economic development.

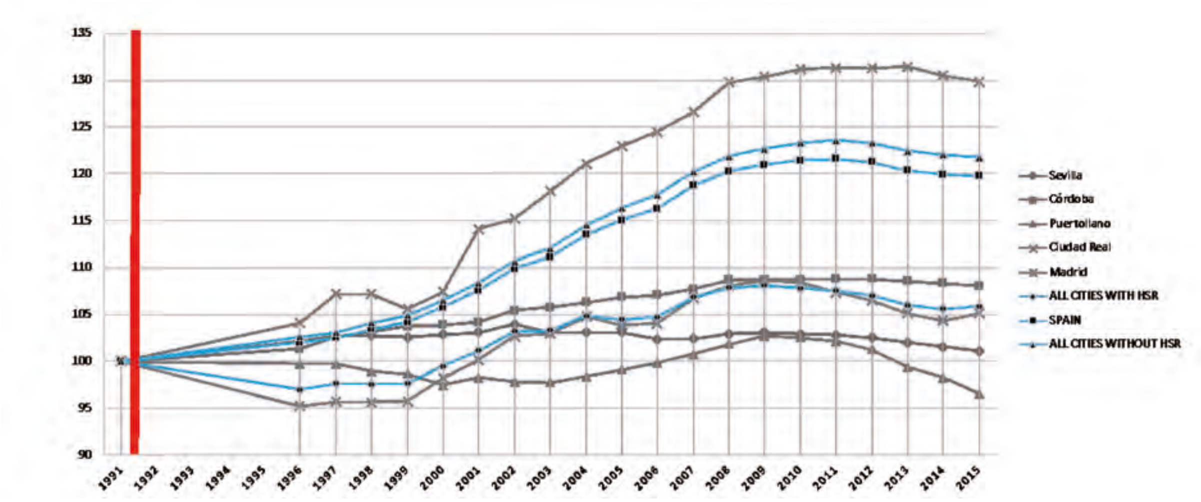

Table 5. Population Growth Index of cities that started HSR services in 1992.

Table 6 shows the evolution of IC of Guadalajara, Calatayud, Zaragoza, Lleida, Tardienta and Huesca cities when HSR services started in 2004. This table shows the case of Guadalajara as a case similar to Ciudad Real. From 2004, the growth of IC of Guadalajara is very high. Curiously, this is a special case because HSR station of Guadalajara is very far of Guadalajara city and most of the rail travel between Guadalajara and Madrid is done by conventional train, not by HSR services. Again, the most probable cause of this growth is the integration of Guadalajara in the Metropolitan Area of Madrid.

The case of Lleida is similar. The increase of IC of Lleida is greater than cities with HSR services from about 2008, when started HSR connection with Barcelona. Therefore, it is possible to understand that Lleida joins to the Metropolitan Area of Barcelona about this date. Maybe it is also the same case of Huesca with respect to Zaragoza. Nevertheless, the city of Calatayud, located near to Zaragoza, has an erratic evolution.

Tardienta is a special case because of is a city with a very low population (about 1.000 inhabitants) and HSR station built for other reasons.

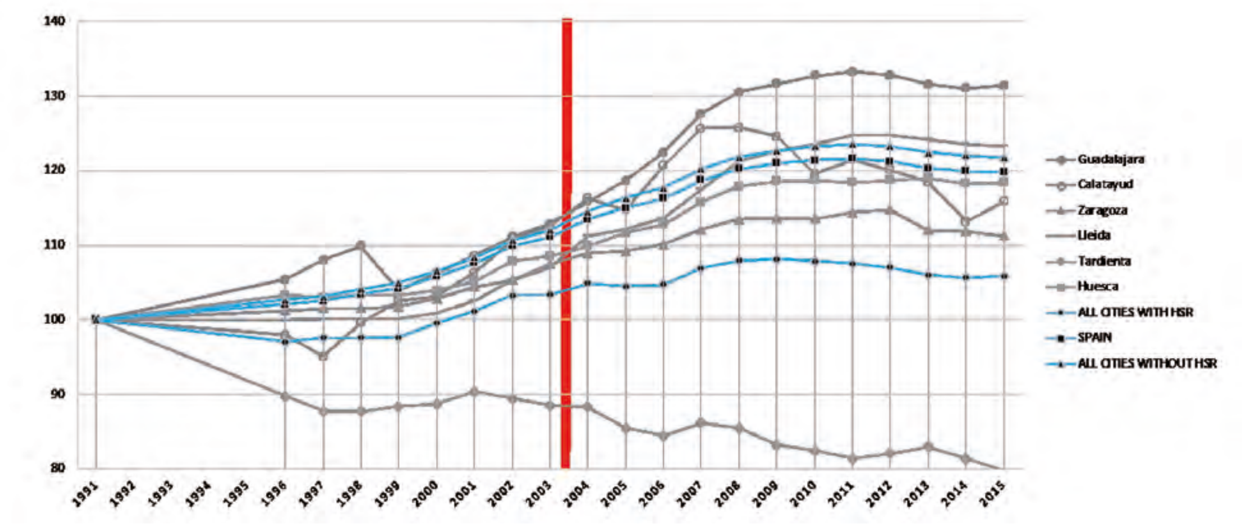

Table 6. Population Growth Index of cities that started HSR services in 2004.

Table 7 shows the case of Toledo city. This case is similar to Ciudad Real city, but you can see that the process of integration in Metropolitan Area of Madrid started before HSR services began. Therefore, in this case, HSR services has helped to join Toledo in the MA of Madrid.

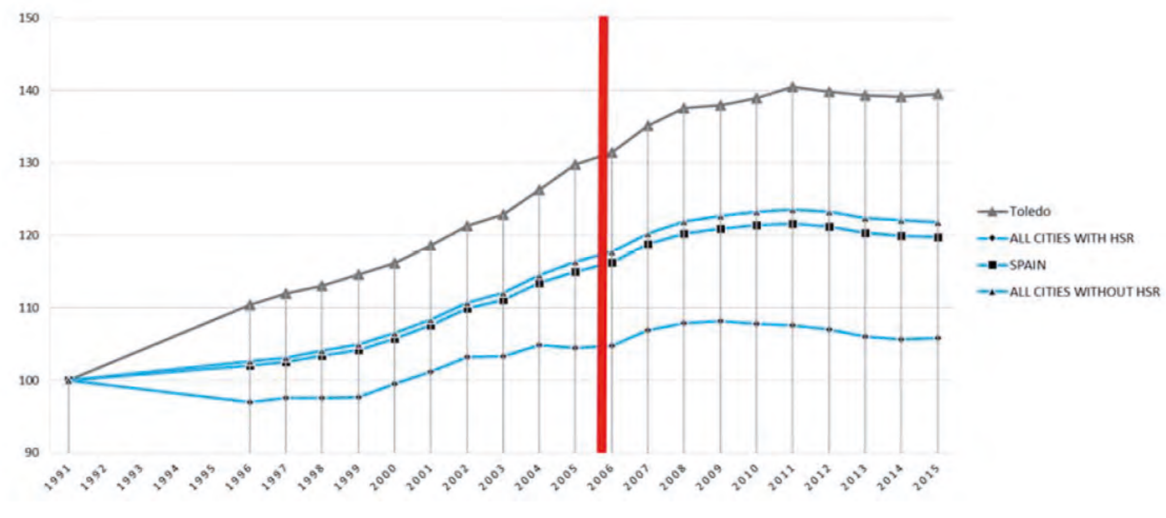

Table 7. Population Growth Index of cities that started HSR services in 2006.

Table 8 shows the cases of cities of Puente Genil, Antequera and Tarragona where HSR services started in 2007. To understands these cases is difficult, especially the case of Tarragona. Puente Genil and Antequera are two cities with low population (between 25.000 and 50.000 inhabitants) and little changes of population can produce larges changes in IC. However, Tarragona city is near to Barcelona. The period 2003-2009 seems to show an integration process in Metropolitan Area of Barcelona but from 2010 the trend change to decreasing.

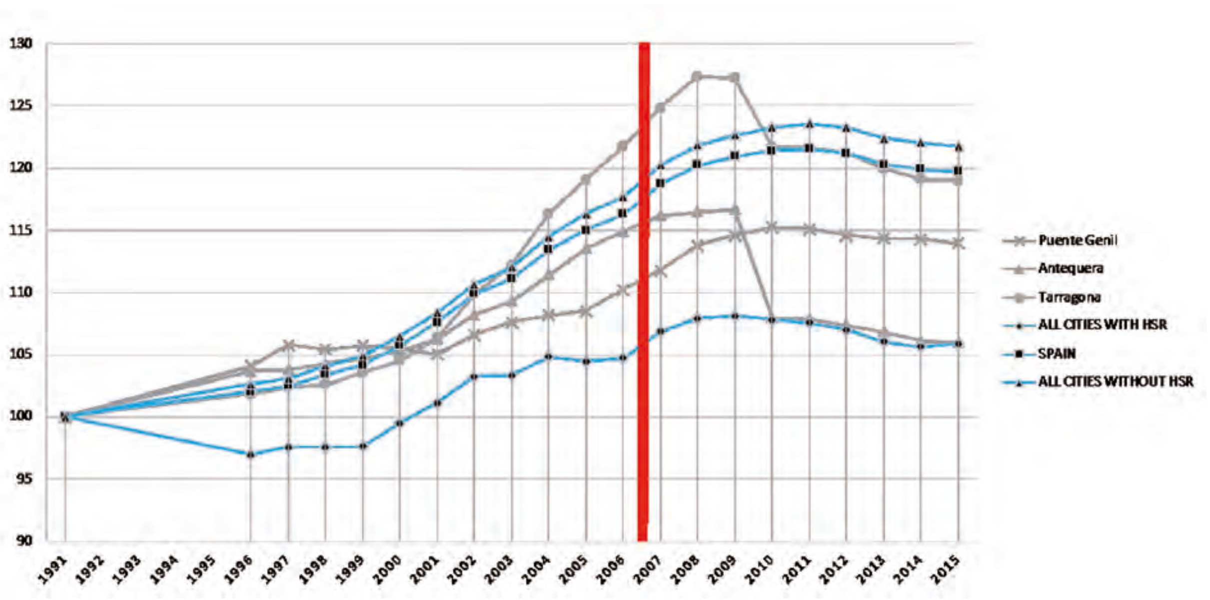

Table 8. Population Growth Index of cities that started HSR services in 2007.

Table 9 shows the cases of cities of Málaga, Segobia, Valladolid and Barcelona where HSR services started in 2008. The evolution of IC shows that Segovia and Valladolid, by contrast with Guadalajara, Toledo and Ciudad Real, not joins to Metropolitan Area. Segovia and Valladolid shows a decreasing trend of IC, especially after HSR services began in 2008.

Barcelona city shows a stabilised situation, maybe because of urban saturated effect. Málaga presents a trend of stable IC that does not change with the beginning of HSR services.

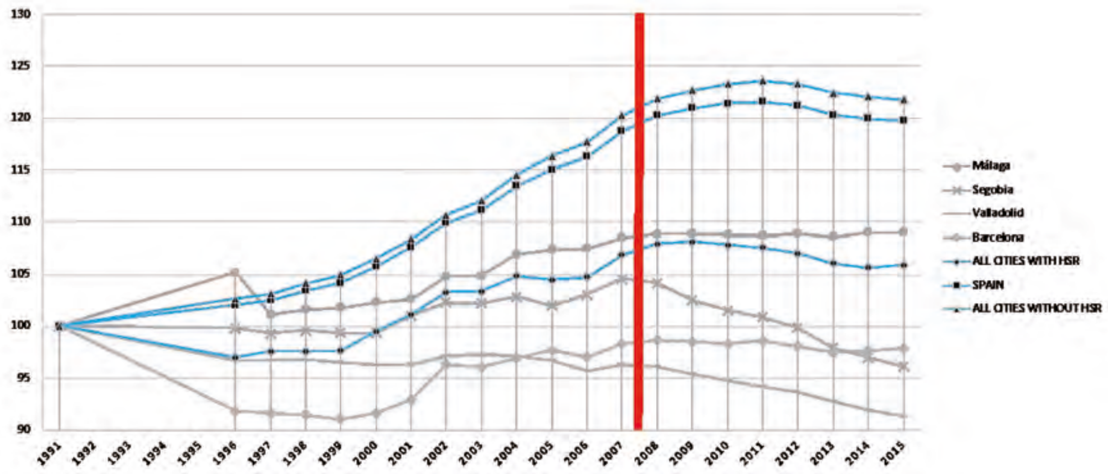

Table 9. Population Growth Index of cities that started HSR services in 2008.

Table 10 shows the cases of cities of Cuenca, Requena and València where HSR services started in 2011. The IC trend of Cuenca is similar to Guadalajara, Toledo and Ciudad Real. The process of increasing IC began about 2003 before HSR services started. Probably is a process of joining with Metropolitan Area of Madrid. From 2011, trend change and IC decrease.

València city present a trend similar to all cities without HSR services.

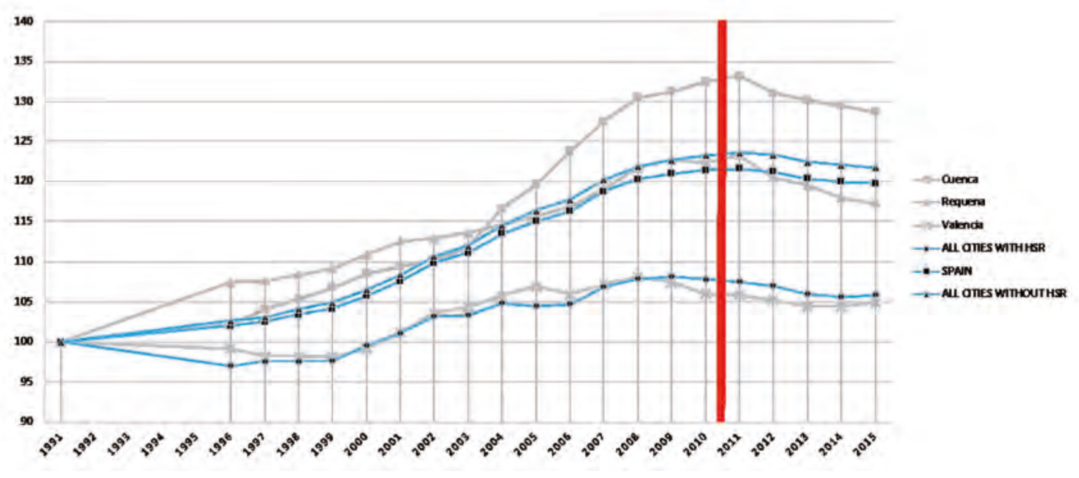

Table 10. Population Growth Index of cities that started HSR services in 2011.

Finally, Table 11 shows the cases of cities of Girona, Figueres, Albacete, Villena and Alacant where HSR services started in 2013. Except the case of Villena, all the other cities present ICs trend similar to cities in process of metropolitan integration: Girona and Figueres with Barcelona and Albacete with Alacant or Madrid. In all cases, the process of metropolitan integration started long time before HSR services began.

Alacant is the only metropolitan city centre that has an IC trend above the IC of Spain, all cities with HSR and all cities without HSR.

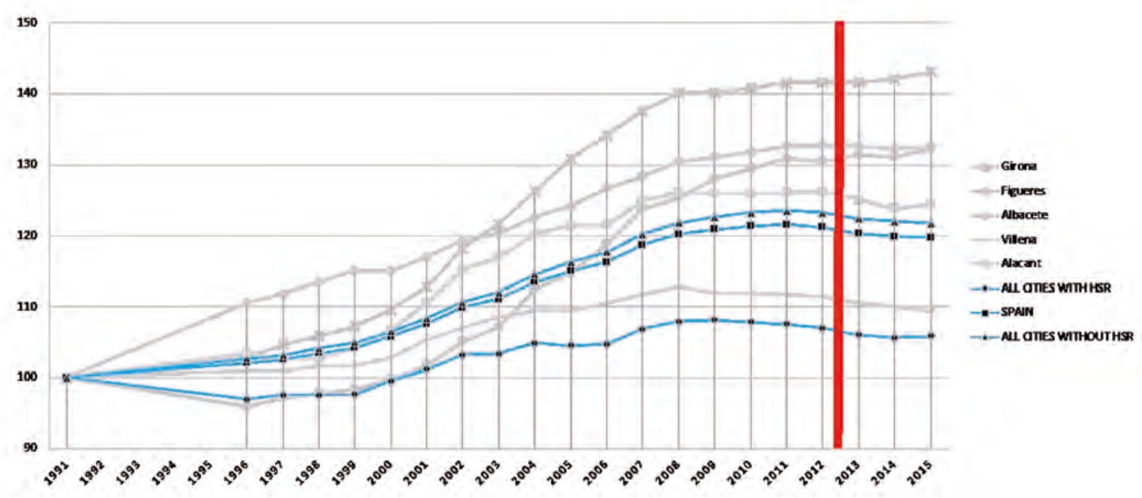

Table 11. Population Growth Index of cities that started HSR services in 2013.

4.4 Population growth of each city and metropolitan areas with HSR services

Now I show the ICs trend with provincial population in the cases of cities that are city centre of metropolitan areas (MA): Alacant, Barcelona, Córdoba, Madrid, Málaga, Sevilla, Tarragona, València, Valladolid and Zaragoza.

Table 12 shows the cases of cities and MA of Sevilla, Córdoba, Puertollano, Ciudad Real and Madrid where HSR services started in 1992. In this table, the IC trend of metropolitan area/ province of Madrid is similar to the IC trend of Ciudad Real city. This fact is more coherent with the economic dynamic of metropolitan area of Madrid and more reasonable that the IC trend of Madrid city showed in table 5. In addition, if Ciudad Real city is integrating in metropolitan area of Madrid then is reasonable that both have the same IC trend. Noto you also that in last two years of 2014 and 2015, the IC trend of MA of Madrid change to increasing. In fact, during economic crisis period of 1991-1996, IC of MA of Madrid increase but not very much. During the economic expansion period of 1997-2006, the IC trend increase significantly. When started the economic crisis in 2007, the IC trend of MA of Madrid change to stopping and from 2013, the IC trend now change to increasing it. This IC trend is general to cities & MA with HSR services while cities & MA without HSR services maintain the IC trend to decreasing.

The MA of Sevilla shows a period from 1991 to 1999 with a high IC trend. However, from 2000 to 2009 (economic expansion period), it IC trend is lower that one of Spain and all cities with or without HSR services. That is, the HSR services not produced better economic development that other cities or MA of Spain. Only from 2010, in crises economic period, the IC trend change and move to values similar of Spain but always lower that values of all cities & MA with HSR services. This analysis, as in previous point 5.2 for Sevilla city, shows again that new infrastructures are necessary but not sufficient condition to economic development.

The same case is the case of MA of Córdoba. In this case the calculus of IC has been done with the population of province/MA of Córdoba. The results show an IC trend very lower than Spain or all the other cities & metropolitan areas.

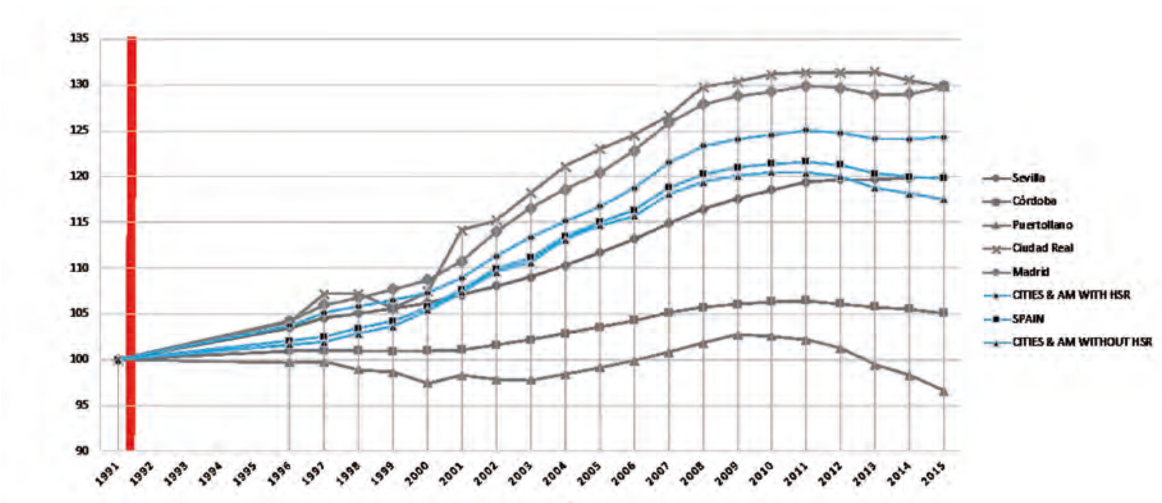

Table 12. Population Growth Index of cities/metropolitan areas that started HSR services in 1992.

Table 13 shows the cases of cities and MA of Guadalajara, Calatayud, Zaragoza, Lleida, Tardienta and Huesca where HSR services started in 2004. In this case the metropolitan area of Zaragoza shows a IC trend parallel and next to trend of Spain and cities & MA without HSR services but always lower that its. Again it is the same case of Sevilla and Córdoba.

The results about Guadalajara are the same that in previously analysis. Also in the case of Calatayud with a chaotic trend that not shows any integration process in metropolitan area of Zaragoza. Also the results are the same in the case of Lleida.

Huesca has a trend similar to all cities and MA without HSR services. The case of Tardienta already is commented previously.

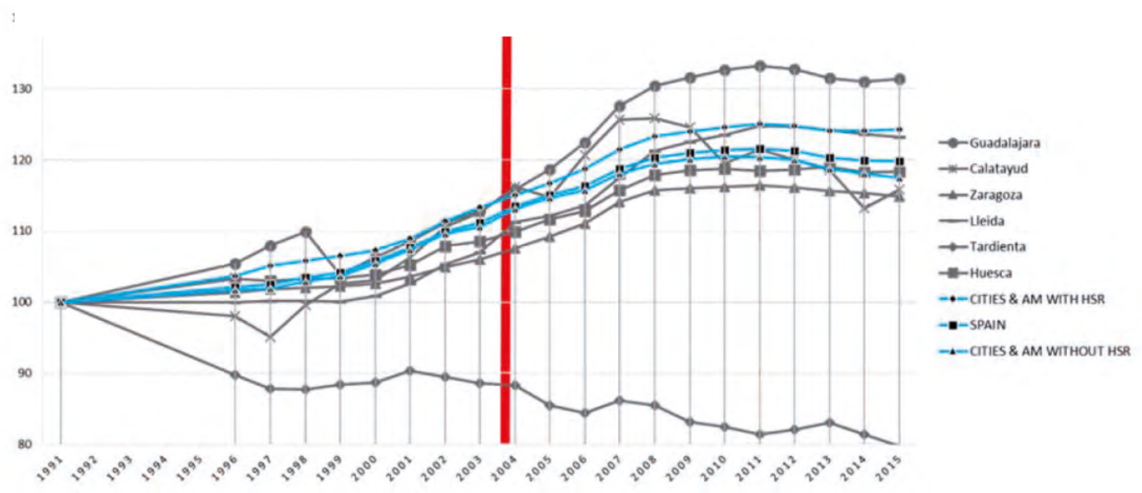

Table 13. Population Growth Index of cities/metropolitan areas that started HSR services in 2004.

Table 14 shows the case of Todelo where HSR services started in 2006. This new table not shows anything new respect to previously analysis.

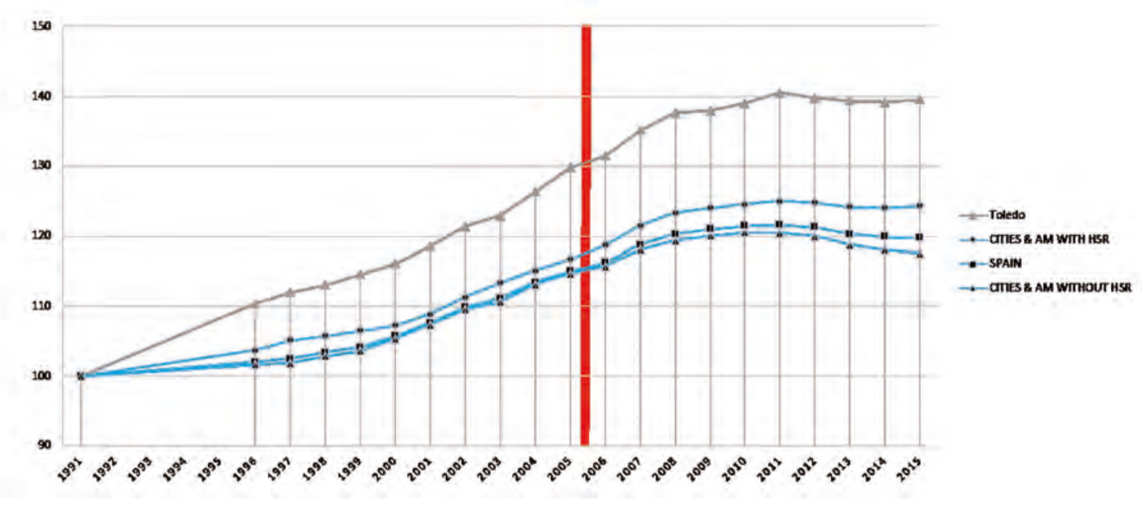

Table 14. Population Growth Index of cities/metropolitan areas that started HSR services in 2006.

Table 15 shows the cases of cities and MA of Puente Genil, Antequera y Tarragona where HSR services started in 2007.

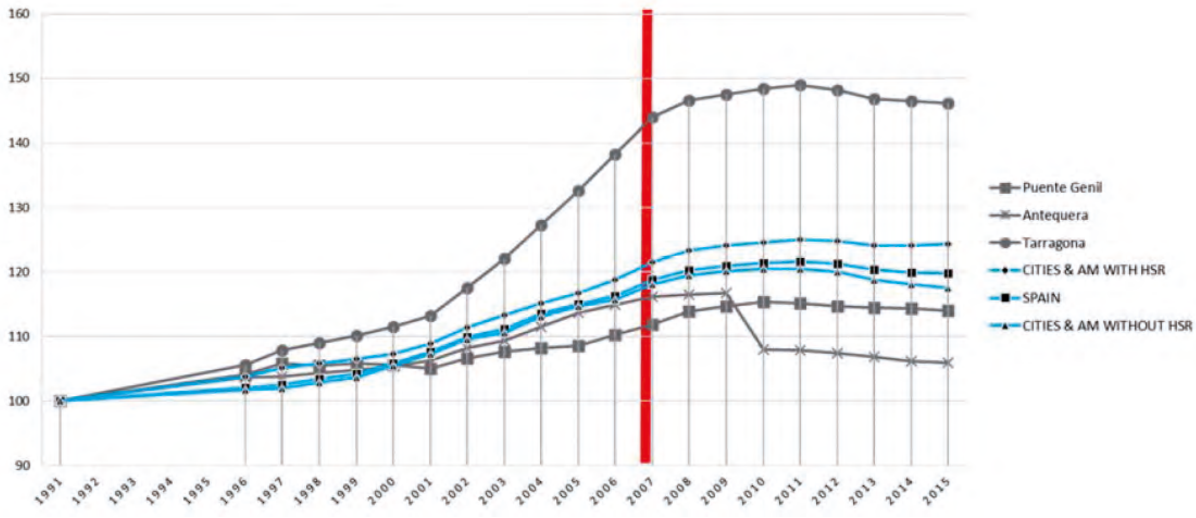

Table 15. Population Growth Index of cities/metropolitan areas that started HSR services in 2007.

Puente Genil and Antequera not show an increasing trend of their ICs after started HSR services. Tarragona shows a very growth of IC from 2000 to 2007 (economic expansion period), before HSR services started. After the HSR services started (economic crisis period), the increase of IC stopped to final of series. We can understand these results as the process of integration in metropolitan area of Barcelona stopped.

Table 16 shows the cases of cities and MA of Málaga, Segovia, Valladolid and Barcelona where HSR services started in 2008. In this case the MA of Málaga shows the greater IC increases over all economics periods before and after HSR services. By contrast, Segovia city and MA of Valladolid have the lowest IC trend. Your attention in fact that Segovia and Valladolid are located on the north of Madrid to similar distance as Guadalajara, Toledo or Ciudad Real. So, the IC trends of Segovia and Valladolid show that these cities aren't in process of integration in MA of Madrid. Particularly, Segovia show an IC decreasing especially from HSR services started in the city in period of economic crisis.

Interesting is the case of province/MA of Barcelona. The IC of Barcelona show a trend parallel to all cities with HSR services from about 1997 but more low in about 5-7 points always. Also the IC of MA of Barcelona is always lower than all the other cities and MA. From 2008, the IC stopped according to general trend of cities and MA with HSR services. This form maybe explains the IC forms of Lleida and Tarragona which also stopped its IC increases from 2008. The MA of Madrid also shows the stopped trend of IC from 2008, however the initial IC of Madrid in this period is greater than the IC of Barcelona. The begin of HSR in 2008 not produced an increase of economic activity in Barcelona, Tarragona and Lleida. However, as other cities/MA with HSR services, the two last years changed the trend increasing IC.

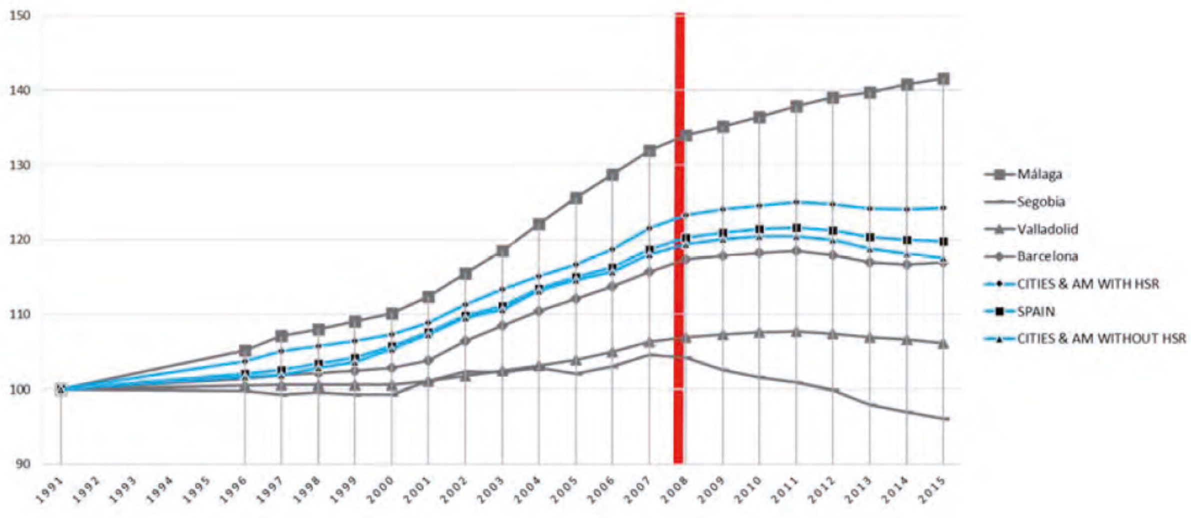

Table 16. Population Growth Index of cities/metropolitan areas that started HSR services in 2008.

Table 17 shows the cases of cities and MA of Cuenca, Requena and València where HSR services started in 2011. As you can see, the case of Cuenca is similar to Guadalajara, Todelo or Ciudad Real with a period of high IC increasing from 1997 to 2008 before HSR services started. From 2009, the IC change to decreasing especially after HSR started.

The MA of València show a trend of IC very similar to general of Spain with an increasing period until 2011, when HSR started, and a decreasing period after. HSR services not show effects in economic development.

Requena is a town with about 20.000 inhabitants and have an evolution of IC independent of HSR services. It has an important increasing period from 1991 to 2004 greater than Spain. After, from 2005 to 2015 the evolution of it IC is similar to Spain with an increasing period to 2010 and a decreasing period to 2015. The begin of HSR services in 2011 not help to Requena to integration in MA of Valencia.

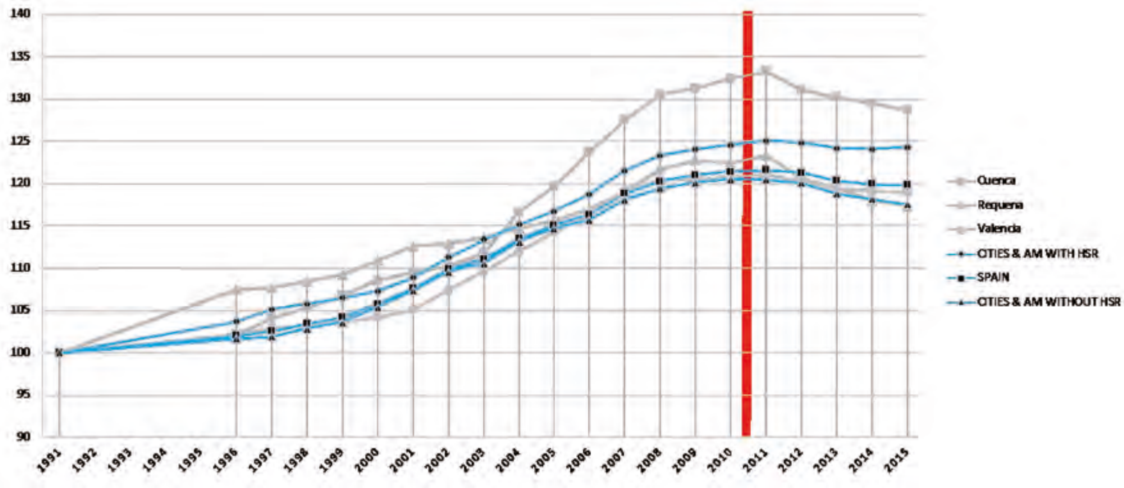

Table 17. Population Growth Index of cities/metropolitan areas that started HSR services in 2011.

Finally, table 18 shows the cases of cities of Girona, Figueres, Albacete, Villena and the MA of Alacant where HSR services started in 2013. In this case, the MA of Alacant or better Alacant/Elx shows a high increasing period of it IC until 2007, very greater than Spain or all other cities with or without HSR services and before HSR services started. On the other hand, similar to Barcelona, Madrid or Valencia, IC stopped from 2008. The begin of HSR services in Alacant/Elx not shows a change of trend.

Girona shows a trend similar to Lleida and Tarragona with a period of high increasing of IC until 2007, before HSR services started. Also Figueres that maintain the increasing of IC after 2008 despite to start the period with IC minor that 100. Therefore, the cities of Lleida, Tarragona, Girona and Figueres show trends similar that indicates a process of integration with Barcelona. Girona and Figueres show, as a Barcelona, a trend change in two last years of series.

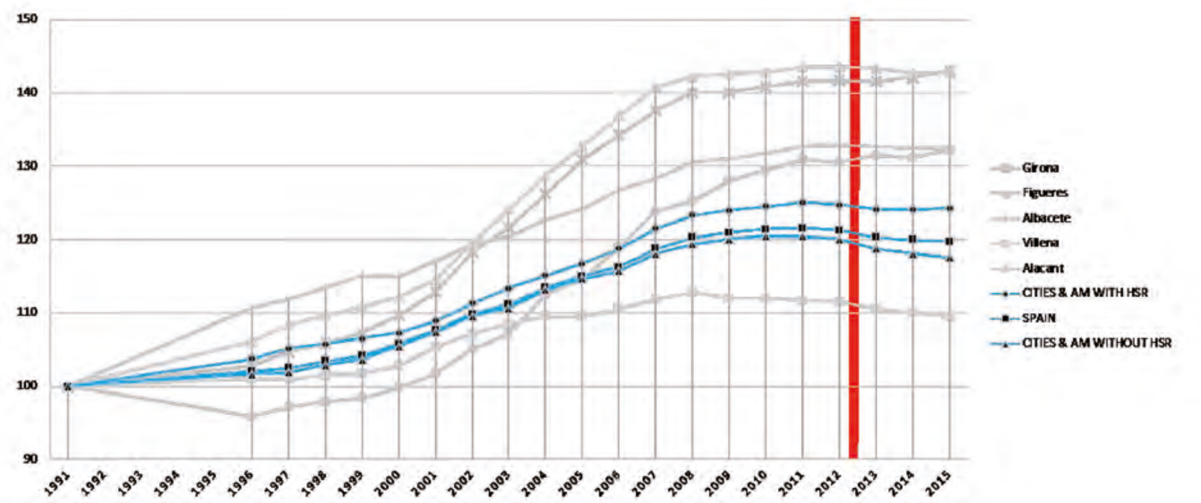

Table 18. Population Growth Index of cities/metropolitan areas that started HSR services in 2013.

Villena, a city of about 35.000 inhabitants shows a trend lower than Spain and other cities. This fact indicates that not exist a process of integration in MA of Alacant/Elx.

Albacete show a trend significantly greater than Spain or other cities however is very fast of Madrid and, consequently is not reasonable to think that it is in process to integration on MA Madrid. Respect to the MA of Alacant/Elx, Albacete is more fast that Villena is, consequently the process of integration in MA of Alacant/Elx must be previous for Villena. On the other hand, Albacete not shows trend changes after HSR services started.

5. Conclusions

According to the analysis can make the following conclusions:

- All cities and metropolitan areas have their own economic dynamics usually independent of HSR services. HSR services can help these dynamics but not necessarily. Therefore, HSR services is not synonym of economic progress.
- It is possible to identify different kind of IC dynamics for different cities and metropolitan areas.
- The metropolitan areas that always present a positive trend of IC higher than Spain

or other cities and metropolitan areas are Madrid (HSR 1992), Málaga (HSR 2008) and Alacant/Elx (HSR 2013). Probably Madrid has benefited from radial network because of all the connections go through Madrid.

- Guadalajara (HSR 1992), Toledo (HSR 2006), Ciudad Real (HSR 1992) and Cuenca (HSR 2011) show trends of IC that indicates an integration process in MA of Madrid. These processes began before HSR services started. By contrast, this process has not been carried out either in Segovia (HSR 2008) or Valladolid (HSR 2008) with similar location on the north of Madrid.
- Lleida (HSR 2004), Tarragona (HSR 2007), Girona (HSR 2013) and Figueres (HSR 2013) show trends of IC that indicate integration process in MA of Barcelona. These processes began before HSR services started.
- The HSR services have not generated an economic development of metropolitan areas of Sevilla (HSR 1992) and Zaragoza (HSR 2004).
- The case of IC trend of MA of València is more similar to MA of Barcelona than MA of Madrid.
- The most important increases of IC were produced in period 1997-2007 for Ciudad Real city, MA of Madrid, Guadalajara city, Toledo city, MA of Tarragona, MA of Málaga, Cuenca city, Girona city, Figueres city, Albacete city and MA of Alacant/Elx with or without HSR services. The tables show that, in general, the date on HSR started is independent of the process of increasing IC. The IC increasing process of the MA of Barcelona in this period is smaller.
- The HSR services is likely to help some cities in their integration process in nearby metropolitan areas: Ciudad Real, Toledo, Guadalajara and Cuenca in the MA of Madrid; Lleida, Tarragona, Girona and Figueres in the MA of Barcelona. In contrast Segovia and Valladolid do not have this integration process.

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Urban Impacts

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Study of Transit-Oriented Development model implementation on the surroundings of Alicante high-speed rail station

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Abstract

This study analyses the relationship between urban planning and mobility, focusing on the surroundings of Alicante high-speed rail station, using the TOD (Transit-Oriented Development) model. In practice, the research covers an area within a radius of 500 metres from the high-speed rail station.

TOD standard focuses on a shared vision on urban development and transport planning, with the aim of maximising the benefits of public transport while considering the broader emphasis on users. Besides, it provides a new quantitative value on the area to be assessed and also on the existing urban potential by means of descriptive parameters. Furthermore, careful planning together with land-use design are essential to enhance and value not only public transport but also pedestrians and cyclists.

The study concludes with a number of key points which could serve as a basis for improving the area, with a special focus on reducing the use and predominance of private vehicles, as well as on giving priority to pedestrians and cyclists in order to optimise the socio-economic potential of the high-speed station and its surroundings.

Keywords: regional efficiency, country comparison, high-speed rail, TOD

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1. Introduction

The study is carried out in the city centre of Alicante city, the capital of a Province located in the south-east of Spain. The population of Alicante is about 330.000 inhabitants and half million including its metropolitan area (INE, 2017).

Regarding socioeconomic activities in the city, it is prominent in the services sector, having more than the 65% of active population and 133.104 companies working in it; industry and construction sectors employ 22% and around 65.500 companies (INE, 2017).

Overall, we can say that the Alicante is a medium-sized city engaged mainly in the services sector, being tourist activity very intense.

As for high-speed rail in Alicante city, it first arrived in 2013 offering 18 services. The demand studies predicted that it would be one of the busiest lines in Spain. The line saves around an hour compared with the previous conventional services. Thus, after the first year, the number of passengers increased up to 1,732,000 (renfe, 2014).

Along with the introduction of high-speed rail, the city planned to bury the tracks. Nowadays, this project is focused on suggesting ways to integrate land use and mobility based on TOD model and TOD standard guide in a most effective manner.

For that purpose, the actual area measuring TOD parameters working in the field is being studied. Then, keeping in mind the social and cultural situation of the city, the evaluation and actions to be taken on the area around the high-speed rail station are being developed and planned.

It is important to note that this project is one of many other that have been carried out regarding the arrival of high-speed rail to the city, including studies of demand, passenger profile, economic impact, etc.

2. State of the art

2.1 Description of the study area

The urban area around the high-speed rail station is a consolidated urban area for more than 30 years. The built area is around 5.000 m^2 and the buildings include 5 to 8 level blocks with commercial premises on the ground floors and private houses above. There is a predominance of residential use but there are lots of offices near the avenues. Besides, the main commercial streets are near the station and some equipment can be found. This area is one of the densest in the city and offers almost all types of shops and services.

As for the surrounding streets, some of them have been recently refurbished, improving the quality of the area. In some cases, the pavements have been widened, giving then more space to the pedestrians.

Figure 1: City centre of Alicante with the high-speed rail station. Source: Google Maps.

Figure 2: Uses of surroundings of the high-speed rail station. Source: own work.

2.2 TOD model

First of all, in order to apply the TOD standard model, the developed area must comply with the following requirements:

Being located within a 1-kilometre maximum walking distance to a high-capacity transit station, or within 500 meters walking distance to a direct service to a highcapacity transit line.

The direct service should be of 15 minutes maximum headway, and 5 kilometres or less to a high-capacity transit line.

Having a complete, safe walkway network. All destinations should be connected to each other and the stations by protected walkways.

Creating at least one new, publicly accessible street, pedestrian path, or passageway connecting two different public right of ways. This new link can be on private property but must be open daily for a minimum of 15 hours, and offer a safe and complete walkway.

Transit-Oriented Development model (TOD) is a tool for evaluation, exploration and policy direction focused on sustainable transport integration and land use planning and design. It tries to guide the development and urban planning in order to maximise the benefits of human-centred public transport. TOD model goes beyond making buildings around transport corridors, as it means high quality, careful land use planning and design of structures to support, make easier and prioritize the use of public transport, walking and cycling. TOD model has been created to assess new urban designs.

The TOD standard model used for this project uses a scoring system distributing 100 points between 21 indicators. The points distribution determines in approximate terms the impact of every step in a new TOD urban area (ITDP, 2014).

The TOD standard model has the next 8 principles with its 21 indicators (ITDP, 2014):

- Walk. Principle 1: the pedestrian network is safe and complete, active and vibrant and temperate and comfortable.
- Cycle. Principle 2: the cycling network is safe and complete and the parking and storage is ample and secure.

- Connect. Principle 3: walking and cycling routes are short, direct varied and shorter than motor vehicle routes.
- Transit. Principle 4: high-quality transit is accessible on foot.
- Mix. Principle 5: trip lengths are reduced by the provision of diverse and complementary uses and lower-income groups have short commutes.
- Densify. Principle 6: residential and job densities support high-quality transit and local services.
- Compact. Principle 7: the development is in an existing urban area and traveling through the city is convenient.
- Shift. Principle 8: the land occupied by motor vehicles is minimized.

The scoring system is designed to make a quantitatively measure of how a project takes advantage of land use, reduces motor vehicle use and increases the number of users in public transport, cycling and walking.

The principles are measured as follows:

	PRINCIPLE 1	WALK	15	Points
A	The pedestrian realm is safe and complete			
1.1	Walkways	Percentage of block frontage with safe, wheelchairaccessible walkways	3	Points
1.2	Crosswalks	Percentage of intersections with safe, wheelchair accessible crosswalks in all directions	3	Points
B	The pedestrian realm is active and vibrant			
1.3	Visually active frontage	Percentage of walkway segments with visual connection to interior building activity	6	Points
1.4	Physically permeable frontage	Average number of shops and pedestrian building entrances per 100 meters of block frontage	2	Points
C	The pedestrian realm is temperate and comfortable			
1.5	Shades and shelter	Percentage of walkway segments that incorporate adequate shade or shelter element	1	Point
	PRINCIPLE 2	CYCLE	5	Points
A	The cycling network is safe and complete			
2.1	Cycle network	Percentage of total street segments with safe cyclingconditions	2	Points
B	Cycle parking and storage is ample and secure			
2.2	Cycle parking at transit stations	Secure multi-space cycle parking facilities are provided at all high-capacity transit stations	1	Point
2.3	Cycle parking at building	Percentage of buildings that provide secure cycle parking	1	Point
2.4	Cycle access in buildings	Buildings allow interior access for cycles and cycle storage within tenant-controlled spaces	1	Point

	PRINCIPLE 3	**CONNECT**	**15**	**Points**
A	**Walking and cycling routes are short, direct and varied**			
3.1	**Small blocks**	Length of the longest block	10	Points
B	**Walking and cycling routes are shorter than motor vehicle routes**			
3.2	**Priorized connectivity**	Ratio of pedestrian and cycle intersections to motor vehicle intersections	5	Points
	PRINCIPLE 4	**TRANSIT**		
A	**TOD requirement: high quality transit is accessible on foot**			
4.1	**Walk distance to transit**	Walk distance (meters) to the nearest transit station	TOD requirement	
	PRINCIPLE 5	**MIX**	**15**	**Points**
A	**Trip lengths are reduced by providing diverse and complementary uses**			
5.1	**Complementary uses**	Residential and non-residential uses combined within same or adjacent blocks	10	Points
5.2	**Accessibility to food**	Percentage of buildings that are within 500 meters radius of an existing, or planned, source of fresh food	1	Point
B	**Lower income groups have short commutes**			
5.3	Affordable housing	Percentage of residential units provided as affordable housing	4	Points
	PRINCIPLE 6	**DENSIFY**	**15**	**Points**
A	**Residential and job densities support high quality transport and local services**			
6.1	**Land use density**	Average density in comparison to local conditions	15	Points
	PRINCIPLE 7	**COMPACT**	**15**	**Points**
A	**The development is in an existing urban area**			
7.1	**Urban site**	Urbanised areas number near to existing urbanised areas	10	Points
B	**Travelling through the city is convenient**			
7.2	**Transit options**	Number of different transport line stations short distance accessible	5	Points
	PRINCIPLE 8	**SHIFT**	**20**	**Points**
A	**The land occupied by motor vehicle is minimized**			
8.1	**Off-street parking**	Total off-street area dedicated to parking as a percentage of total land area	10	Points
8.2	**Driveway density**	Average number of driveways per 100 meters of block frontage	2	Points
8.3	**Roadway area**	Total road area used for motor vehicle travel and on-street parking as percentage of total land area.	8	Points

3. Changes happened

Since the arrival of the HSR to Alicante, the quality of public spaces and shops in the station has been notably improved.

Apart from the actions implemented at the station and the re-distribution of its spaces, the surroundings have changed and are still changing. One of the examples can be found on the first block in front of the train station. Since 2013, when HSR arrives to Alicante, new stores have been opened and others have been upgraded. The most relevant change has been the opening of new car rental offices. All these changes are visually explained on the following figures and table.

Figure 3: Front of a block near the train station on February 2010. Source: Google Maps Street View.

Figure 4: Front of a block near the train station on May 2016. Source: Google Maps Street View.

Legend:	Business changing	Business related to train station activity

	HSR arrival in June				
	February 2010	March 2013	March 2014	May 2015	May 2016
	Station avenue parking works			Station sidewalk upgrade	
Right side	Parlour	**Parlour**	Car rental Goldcar	Car rental Goldcar	Car rental Goldcar
	Pharmacy	**Pharmacy**	Pharmacy	Pharmacy	Pharmacy
	Lottery	**Optics (change location)**	Optics	Optics	Optics
	Fast food	**Fast food**	Fast food	Car rental Sixt	Car rental Sixt
	Optics	**Car rental Europcar**	Car rental Europcar	Car rental Europcar	Car rental Hertz
	Coffee shop	**Coffee shop**	Coffee shop	Coffee shop	Coffee shop
	Barber shop	**Barber shop**	Barber shop	Barber shop	Barber shop
Left side	Shoe shop	**Shoe shop**	Shoe shop (posters change)	Shoe shop	Shoe shop
	24 hours shop	**24 hours shop**	24 hours shop	24 hours shop	24 hours shop
	Lawyers office	**Lawyers office**	Lawyers office	Lawyers office	Lawyers office
	Credit office	**Gold buyer shop**	Gold buyer shop	Led lights shop	Led lights shop
	Dental clinic	**Dental clinic**	Dental clinic	Dental clinic	Dental clinic
	Grilled chicken shop	**Grilled chicken shop (posters change)**	Grilled chicken shop	Grilled chicken shop	Grilled chicken shop
	Bakery	**Bakery**	Bakery	Bakery	Bakery
	Kebab	**Kebab (local upgrade)**	Kebab	Kebab (posters change)	Kebab
	Clothing store	**Clothing store (local upgrade)**	Clothing store	Clothing store	Clothing store
	Coffee shop	**Coffee shop**	Coffee shop (local upgrade)	Coffee shop	Coffee shop
	Drugstore	**Drugstore**	Drugstore	Drugstore	Herbalist

4. Results

The results were obtained by measuring every principle following the guide and working in the field. In the chart below, the results of applying TOD standard to the urban area around the high-speed rail station are shown:

Category			Possible points		Points
			Minimum	Maximum	
WALK					
1.1	Walkways	Percentage of block frontage with safe, wheelchair-accessible walkways	0	3	2
1.2	Crosswalks	Percentage of intersections with safe, wheelchair accessible crosswalks in all directions	0	3	1
1.3	Visually active frontage	Percentage of walkway segments with visual connection to interior building activity	0	6	5
1.4	Physically permeable frontage	Average number of shops and pedestrian building entrances per 100 meters of block frontage	0	2	2
1.5	Shades and shelter	Percentage of walkway segments that incorporate adequate shade or shelter element	0	1	1
Total			0	15	11
CYCLE					
2.1	Cycle network	Percentage of total street segments with safe cycling conditions	0	2	0
2.2	Cycle parking at transit stations	Secure multi-space cycle parking facilities are provided at all highcapacity transit stations	0	1	1
2.3	Cycle parking at building	Percentage of buildings that provide secure cycle parking	0	1	1
2.4	Cycle access in buildings	Buildings allow interior access for cycles and cycle storage within tenantcontrolled spaces	0	1	0
Total			0	5	2
CONNECT					
3.1	Small blocks	Length of the longest block	0	10	8
3.2	Priorized connectivity	Ratio of pedestrian and cycle intersections to motor vehicle intersections	0	5	3
Total			0	15	11
TRANSIT					
4.1	Walk distance to transit	Walk distance (meters) to the nearest transit station	-	-	T.O.D.
Total			-	-	T.O.D.

Category			Possible points		Points
			Minimum	Maximum	
MIX					
5.1	Complementary uses	Residential and non-residential uses combined within same or adjacent blocks	0	10	4
5.2	Accessibility to food	Percentage of buildings that are within 500 meters radius of an existing, or planned, source of fresh food	0	1	1
5.3	Affordable housing	Percentage of residential units provided as affordable housing	0	4	0
Total			0	15	5
DENSIFY					
6.1	Land use density	Average density in comparison to local conditions	0	15	15
Total			0	15	0
COMPACT					
7.1	Urban site	Urbanised areas number near to existing urbanised areas	0	10	10
7.2	Transit options	Number of different transport line stations short distance accessible	0	5	5
Total			0	15	15
SHIFT					
8.1	Off-street parking	Total off-street area dedicated to parking as a percentage of total land area	0	10	4
8.2	Driveway density	Average number of driveways per 100 meters of block frontage	0	2	2
8.3	Roadway area	Total road area used for motor vehicle travel and on-street parking as percentage of total land area.	0	8	0
Total			0	20	6
TOTAL					
Total points			0	100	65

4.1 Evaluation

Apart from the previous quantitative results, another type of evaluation is needed as the model does not take it into consideration. From our point of view, some aspects should have been kept in mind.

First of all, the scoring system drastically rewards passing some thresholds. This may mean that a difference of one percentage point could imply an increasing of 5 points, while in some cases, a difference of 20 percentage points could not carry any reward, depending on the indicator. This evidences a lack of equality and may identify the need of a non-gradual distribution of the points. Yet it is an equilibrate model, based on quantitative measures and not only on qualitative ones.

In addition, the habits and characteristics of the citizens have not been taken into account. The societies are not all identical and some policies may be well accepted in one city but may not be in another. It is important that the area of application is open to those type of projects so as not to cause refusal (it could be measured by surveys). Thus, the need for taking measures to let people know about the benefits of this type of planning could be measured.

On the other hand, the model is centred on the route, on the pedestrians moving around the streets, and it forgets the ones standing there. The model does not make any reference to urban furniture, benches, squares or any other places where people could meet just for having a good time.

Overall, TOD standard model is a complete and effective work tool. It provides quantitative measures from objective parameters. These parameters are easy to be measured and indicate the situation of the studied area in relation to essential indicators of urban mobility.

5. Conclusions and suggested actions to be taken in the studied area.

The conclusions obtained from the results of the study are:

Walk: to develop neighbourhoods that promote walking. This principle has 11 points out of 15, it seems a good score. Getting into detail, the 3 points lost have in common that the car has a predominant position in the street as opposite to pedestrians. It is clear that the pedestrian network is insufficient. In short, nowadays the area around the station enhances the use of cars instead of walking. The other point lost concerns visually active frontage, that is, the quantity of shop and building windows on the front, providing security to the pedestrians.

Figure 5: Frontage of the high-speed rail station. Source: own photo.

Cycle: to give priority to non-motorised transport networks. This principle has 2 points out of 5. The reason is that there is no cycle path. The majority of cycle routes are in the roadways and share space with motor vehicles limited to 50 km/h, thus becoming non-secured spaces. The reason is the same as in the previous point, the own car has a predominant position. The 2 points obtained come from the existence of the cycle parkings, but they are mainly outdoors, including those in the high-speed rail station.

Figure 6 and 7: Cycle spaces in Plaza Seneca in the surroundings of the high-speed rail station. Source: own photos.

Connect: to create dense street and route networks. This principle got 11 points out of 15 possible. In this case, 2 points were dropped because of the excessive length of some blocks, making waking less attractive. The other 2 points were dropped because of the predominant position of the road network.

Transit: to foster development around high-quality transport. This principle is accomplished as the area of activity has been delimited to the station surroundings. This principle is thought to be applied to the development of new cities or areas.

Mix: to design a plan for mixing uses. This principle got 5 points out of 15. The alarming result is due to the lack of diversity on the land use. There is a clear predominance of residential use. The only positive aspect is that every building has easy access to fresh food (within less than 500 meters). We cannot either find affordable housing in the area, thus excluding low income people from living there and marginalising them to the city outskirts.

Densify: to optimise transport capacity and density. This principle has the maximum score with 15 points. The reason is that the station surrounding is one of the densest area in the city.

Compact: to create compact areas with short distance access. This principle got 15 points out of 15. This can be explained by the fact that the station is located in the city centre and can be considered as the most important commercial area in decades. Therefore, it is almost fully urbanised and there is a good public transport service with many lines.

Shift: to enhance mobility by regulating roadway use and parking. This principle got only 6 points out of 20, the worst result. It once more highlights that the area around the station is far too focused on parking areas and use of motor vehicles.

5.1 Suggested short-term actions

To pedestrianize and to complete the pedestrian network: ideally, pedestrian routes would be created in the area but this must be done in a progressive way.

Firstly, is needed to complete the pedestrian network acting on Luis Sanchez Octavio Toledo Street giving more pavement and making it wheelchair accessible. Also, is proposed to act on Alcala street stairs making a complete a permeable pass through the street.

Figure 8: Luis Sanchez Octavio Toledo street. Source: Google Maps.

Figure 9: Stairs of Alcala street. Source: Google Street View.

Secondly, the following streets are suggested to be pedestrianised: Maisonnave avenue, Estación avenue, Salamanca avenue and some streets (all in the future) between Maisonnave and Estación avenues.

As a result of this, the traffic in the adjoining steets, as well as the public transport lines, should be reorganised. Besides, vehicles supplying goods to the shops and residents and residents who have a garage in the area should be allowed. In addition, other pedestrianisation cases in the city are good examples to this action. There are examples of successfully pedestrianized streets in the city, such as San Ildefonso Street, Castaños Street or San Francisco Street, which have gone from being marginalised areas to becoming one of the city's major leisure highlights.

This action is aimed to define a pedestrian area around the commercial area by the station, enhancing it and empowering pedestrians against vehicles.

Figure 10: Castaños street. Source: Google Street View.

Cycle network creation: the creation of a secure cycle network is suggested, at least around the station. Firstly, cycle ways separated from the roadway should be built using the off-street parking areas in the current cycling-allowed streets. By doing so, off-street parking is reduced, thus giving more space for bicycles and pedestrians. In order to complete the cycle network, the following streets should be redesigned: Bono Guarner street, Juan Ortega street and Aguilera avenue. The result would be that no building will be further than 200 meters from the network.

Figure 11: Separated cycleway in the surroundings of the high-speed rail station. Source: own photo.

Figure 12: A high capacity cycleway with physical protection, turning lanes and an advanced stop line for cyclists in Hangzhou, China. Source: TOD standard 2.1.

Actions on the parking spaces: the purpose is to increase bicycle parking areas inside the public parking destined to cars in Estación avenue. This area is really small so the goal is to extend it up to a quarter or even half of the first-floor surface. The same actions are suggested to be taken in Maisonnave avenue parking spaces.

The previous measures should go together with an increase in the parking fares, as a deterrent against the use of cars, as well as social fares for bicycles (free-parking at the beginning).

The peak time for the use of parking places (Alicante city council, 2016) is around 11:00, approaching an occupancy rate of 90%. The rest of the day the demand is around 50-60%.

Figure 13: Maisonnave parking at low demand times. Source: own photo

Figure 14: Bicycle parking at the high-speed rail station. Source: own photo.

Figure 15: Multi-space and covered racks for cycle parking are provided along the BRT corridor in Guangzhou, China. Source: TOD standard 2.1.

5.2 Long-term actions

Long-term actions are those requiring higher investment for each point to be increased. They are mainly related to use mixing, affordable housing and the elimination of large blocks. For this point, recommendations are provided as specific proposals should be studied at the moment of implementation.

- Anyway, the objective would be to delete the largest residential blocks, non-urbanised land and the station's parking are in order to create green areas, offices, hotels and affordable housing buildings. It would also be essential to continue reducing off-street parking spaces, as well as roadways, in the station area in favour of pedestrians and cycle networks.

After the implementation of the suggested actions, TOD model would increase in 10 points (around 15.38%).

Category			Possible points Minimum	Possible points Maximum	Points
WALK					
1.1	Walkways	Percentage of block frontage with safe, wheelchair-accessible walkways	0	3	3
1.2	Crosswalks	Percentage of intersections with safe, wheelchair accessible crosswalks in all directions	0	3	1
1.3	Visually active frontage	Percentage of walkway segments with visual connection to interior building activity	0	6	5
1.4	Physically permeable frontage	Average number of shops and pedestrian building entrances per 100 meters of block frontage	0	2	2
1.5	Shades and shelter	Percentage of walkway segments that incorporate adequate shade or shelter element	0	1	1
Total			**0**	**15**	**12**
CYCLE					
2.1	Cycle network	Percentage of total street segments with safe cycling conditions	0	2	2
2.2	Cycle parking at transit stations	Secure multi-space cycle parking facilities are provided at all highcapacity transit stations	0	1	1
2.3	Cycle parking at building	Percentage of buildings that provide secure cycle parking	0	1	1
2.4	Cycle access in buildings	Buildings allow interior access for cycles and cycle storage within tenant-controlled spaces	0	1	1
Total			**0**	**5**	**5**
CONNECT					
3.1	Small blocks	Length of the longest block	0	10	8
3.2	Priorized connectivity	Ratio of pedestrian and cycle intersections to motor vehicle intersections	0	5	3
Total			**0**	**15**	**11**

Category			Possible points		points
			Minimum	Max-mum	
TRANSIT					
4.1	Walk distance to transit	Walk distance (meters) to the nearest transit station	-	-	T.O.D.
Total			**-**	**-**	**T.O.D.**
MIX					
5.1	Complementary uses	Residential and non-residential uses combined within same or adjacent blocks	0	10	4
5.2	Accessibility to food	Percentage of buildings that are within 500 meters radius of an existing, or planned, source of fresh food	0	1	1
5.3	Affordable housing	Percentage of residential units provi-ded as affordable housing	0	4	0
Total			**0**	**15**	**5**
DENSIFY					
6.1	Land use density	Average density in comparison to local conditions	0	15	15
Total			**0**	**15**	**15**
COMPACT					
7.1	Urban site	Urbanised areas number near to exis-ting urbanised areas	0	10	10
7.2	Transit options	Number of different transport line stations short distance accessible	0	5	5
Total			**0**	**15**	**15**
SHIFT					
8.1	Off-street parking	Total off-street area dedicated to par-king as a percentage of total land area	0	10	5
8.2	Driveway density	Average number of driveways per 100 meters of block frontage	0	2	2
8.3	Roadway area	Total road area used for motor vehicle travel and on-street parking as percen-tage of total land area.	0	8	5
Total			**0**	**20**	**12**
TOTAL					
Total points			**0**	**100**	**75**

5.3 Comparative and analysis

- **WALK**: promote walking-friendly neighbourhoods. The two actions taken in Luis Sánchez Octavio Toledo and Alcalá Streets make it possible to have a complete pedestrian network, thus allowing an increase of 1 point (going from 2 to 3). One of the parameters that has slightly been improved is the number of crosswalks towards all directions, hereby enhancing the pedestrian network against the roadway one.

- **CYCLE**: to prioritize non-motorised transport networks. One of the areas of action was to create a safe cycle network. After doing so, the score for this indicator has increased up to 5 points out of 5 (3 point increase). Nowadays, buildings are around 400 meters away from safe cycle routes whereas, after the first stage is accomplished, they would only be less than 200 meters away.

  The bicycle parking areas in the station would remain the same but, after the actions taken in Maisonnave avenue and Estación avenue parking spaces, the sheltered parking area for bicycles would be increased. Whereas nowadays only 76% of the buildings have bicycle parking spaces, by taking the above mentioned measures, the rate would go up to 100%.

  Finally, an obligation for building regulations to foresee access of bicycles to every building allows a 1-point increase. Besides, existing buildings should be forced to comply with this obligation.

- **CONNECT**: to create dense networks in streets. The percentage of blocks shorter than 130 meters remains equal. The modifications would be done in a long term due to their high economic and social cost.

- **MIX**: mixing plan. The indicator shows a 5-point mark out of 15 in both cases. It is because the action has to be taken as a long-term aim due to its high economic and social cost. The actions consists on expropriations, demolitions and new urban areas over a residential consolidated area. Furthermore, it has been agreed to progressively design a social housing plan with is not currently available.

- **COMPACT**: This principle has obtained the highest score in both cases. However, the number of transport lines has been increased as a result of the creation of a denser cycling network. The fact that some public transport lines would be affected from the pedestranisation of the streets should be considered so as not to reduce the coverage of public transport service, which is a key element of this planning model.

- **SHIFT**: to increase mobility by regulating roadway and parking uses. A significant improvement is noted in this his last principle, going from 6 to 12 points out of 20. The percentage of land dedicated to non-essential vehicle parking areas increases in 1 point. The percentage of driveways in the building's entrances increases from 0 to 5 points (being the measurement less than one percentage point from the goal of 8 points).

  To sum up, the above mentioned measures may not imply a substantial improvement but it could be considered acceptable for a first stage. In addition, because of the unequal measuring system that the TOD standard model uses, some of the improvements done have not been rewarded in the corresponding parameters.

In short, the suggested actions would constitute a step in the right direction and the guidelines for a middle/long-term model would be fixed. Besides, it would mean an upgrade in the quality of life and urban mobility according to the criteria from TOD standard model.

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Urban Regeneration on railway lands

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Abstract

For the first time in history, the population living in cities has surpassed the rural population, and this trend is increasing every day. And according to the UN in 2050 the urbanites will be 70% of the population of the planet. We have entered a new era. The Urban Era Cities are today the engines of economic development, innovation catalysts and investment multipliers (they already account for 70% of GDP). But they also face serious problems arising from increased pollution, high noise levels, excessive resources consume, CO^2 emissions, congestion, spending of time, etc.

These both sides of the coin, makes necessary to work for mitigate the negative effects of urbanization and enhance the positive ones, and the only way to do this is through a good urban and infrastructure planning.

Faced with this challenge, major cities in developed world are carrying out major redevelopment and Regeneration Urban Land Projects, recovering degraded areas, industrial zones, obsolete or unused infrastructures inside the city, to create new quality vibrant spaces for citizens, parks, housing, offices, shops and urban infrastructures on areas with optimal accessibility and connection around the High-Speed railway Station. They achieve then to minimize the resources needed (soil, commute, energy and time), and create more compact and efficient cities that face the necessary growth, in a more sustainable way.

Milan, Perth, New York, San Francisco, Frankfurt or London have already completed these. Redevelopment Projects and their success is setting an example for other cities like Sydney that is following its wake with a budding macro Project now in planning stage.

All these Projects have in common the essence of recovering railway lands for the city, increasing the value o public domain and transforming into public spaces and Real Estate developments that help to self-financing the expensive infrastructures required.

The main Spanish cities have already joined this trend of Urban Regeneration. Madrid aspires to get on this boat with the largest of all the Redevelopment Projects proposed.

However, it have been found notable differences between the designed Projects in Spain and those carried out in other countries, which can help us to understand each other and to learn from their successes and mistakes.

Keywords: # Urban development· Regeneration # High-Speed railway Station # Self financing, Projects # Railway lands.

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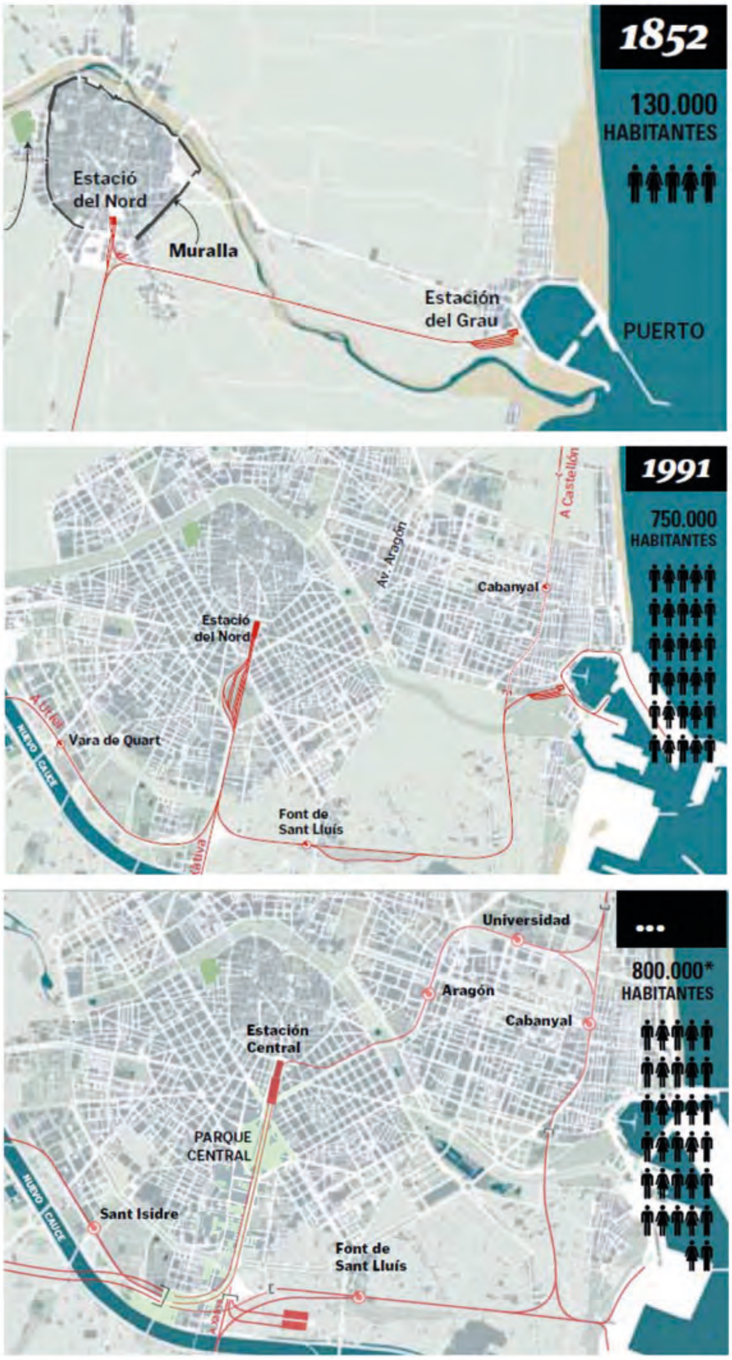
1. Introduction

In recent years we are celebrating in many main cities of Spain the railway arrival hundred and fifth anniversary. An event that becomed in a great change in its history, its dynamics, itseconomy and its way of relating with the world.

The later urban phenomenon has been similar in all of them. The cities have been growing around the railway node until gobbled the railway stations and their annexed facilities, that although they were originally constructed in the urban fringe, happened to be irremediably inthe central nucleus of the city.



Valencia City from 1852 to present

Historical aerial views of the railway lands gobbled by the cities of Zaragoza, Valencia and Alicante (above)

Since then, the Railway-City couple has been, complex and convulsive, and the celebrations for its arrival were transformed into annoyances, walls, pollution, noise, disintegration and rupture of the urban net. The city and the railroad help and need each other, but they give their backs as “proud lovers”.

Hundred and fifty years later, the arrival of the High Speed Railway, has served as a spur for the integral reconsideration of the railway equipment in the cities. Major works of adaptation and improvement of the existing vast railway facilities are needed to accommodate new traffic, new gauges and new technology.

2. The oportunity

Remodeling these railway infrastructures, entails very high cost and the space needed is not always available due to the city’s gulp of its “hated lover”. But the problem that this urban takeover had generated was not only a problem, but a strategic opportunity for the railroad, but also and specially, for the city.

These railway installations, which need to be refurbished and improved, are occupying now a large amount of land in the center of the cities, lands that have an extraordinary urban value because of its strategic location.

On one side they are central plots, with optimal accessibility with the city and on the other side they are next to the High Speed Train Station which give them a privileged access to railway communications and to the main business centers of the country and the world!

This fact, endows these soils with a valuable potential that allows them to fight in unbeatable conditions with other urban plots, but that needs to be transformed to add value and deliver his full potential.

Blending this cost-benefit tandem, with the fact that cities demanded the disappearance of these railway installations, whose coexistence with the city had become conflictive, arises the possibility of cooperating!

What if we modernized and removed the railway station´s complementary facilities outside from the city center?

What if we integrated rail access in a kindfull way with its surroundings?

What if these costly works could be self-financed with the value of railroad lands?

It would be to square of the circle!

3. The Railway-City Integration Agreements

As a result of this situation arises the Railway-City Integration Agreements with the deal of develop ambitious Urban Redevelopment Projects to create a new centrality around the Railway Station that increase value of the railway lands become unneeded for railway operation.

In 2002, Integration Agreements began to be signed between three levels of Spain Administrations. The first city to sign was Zaragoza in March 2002. It was followed by Barcelona, Logroño and Gijón (2002); Valencia, León, Valladolid and Alicante (2003); Murcia and Cartagena (2006), and lastly Palencia, Vitoria and Almería (2008 and 2010).

The Integration Agreements served to confirm the interest, to establish the commitments of the parties, and to estimate the costs of the projects.

The Ministry of Public Works pays the costs of the High Speed arrival and yields their lands, the City Council design and deliver the Urban Planning and also yield their urban rights, the Autonomous Communities approve the Urban Planning and contributing to Railway-City integration works.

Finally, the capital gain of the plots, after their conversion, regeneration and valorization, would help to finance the necessary and high investments for the railroad and the city.

All Administrations are essential to carry out the process of urban regeneration, and **all of them obtain benefits of it**. The owner of lands is the Railway Infrastructure Administrator (Adif) which achieve to upgrade its facilities and the City Council gain quality urban space for the citizens. But this transformation has a high cost and **all actors must cooperate and work together** within one overarching, shared vision to achieve the **common goal**.

Rendering of Urban Planning solution. New urban district proposed for **Zaragoza**

4. The Rail-Urban Integration Societies (SIF)

As a result of these Public Agreements, Rail-Urban Integration Companies were created. These Companies are corporations with 100% public capital, in which Ministry of Public Works owns 50%, the City Council have 25% and the Autonomous Community with the other 25%.

These Societies were created to be the **drivers behind the railway transformation and urban redevelopment**, coordinating three public administrations involved, from the perspective of the self-financing based on the capital gains of the disused lands.

The Companies could also use the necessary financing channels in order to solve the financial gap generated by the large initial infrastructures investments needed to make possible to obtain future Real Estate incomes.

Rendering of Urban Planning solutions proposed for, **Valencia** *(up) and* **Alicante** *(below)*

5. Change of scenery

Over the past 15 years, the "story" has changed so much due to many obstacles and setbacks that happed along the way, and have made the square of the circle has not been so easy.

The first one was the **Spain Real Estate bubble** that between 1998 and 2007 caused land and housing prices to rise six times faster than wages and the CPI, and that an overvaluation of this kind of assets was accepted by all actors naturally.

During this period, the official appraisals increased each year the expected incomings of these railway plots, increasing prospect gains that allowed to dream with greater scope infrastructures planned[1].

The second one occurred when **considerably increased budgets** were throwed by developing Construction Projects. Some of them were offset by higher contributions from the devoted Administrations; others were diluted in the higher income estimations.

The third was the **global financial crisis**, which meant for Spain the end of the Real Estate bubble and the banking crisis of 2012. The drastic decrease of credit meant a speed worsening conditions for the Societies to be financed.

As a result of this tricky financial situation, the **Spanish Constitution was reformed** in 2011 with the objective of guaranteeing budgetary stability and spending ceilings for Public Administrations were stabilized, limiting indebtedness capacity of the Societies (SIF)

The crisis became in unemployment increasing and rising of social movements and politic formations with **ideas of economic-productive model change** and questioning of the current political system. From this movement comes up the last aspect arose to shake the foundations of the model and the landscape.

Since May 2015, these new formations have won many of the main Spanish City Councils (Barcelona, Madrid, Valladolid, Zaragoza, Alicante, Valencia, Cartagena ...) changing the political panorama Integration Societies Boards of Directors and modifying investment priorities and urban development models.

6. What is being done in the rest of the world?

The complex coexistence of railway and city is by no means an exclusive problem of Spain, not even of Europe. It is a situation that has already been faced by many cities of the world solving it through **different proposals for integration** that we could call hard and soft.

A soft solution in which the city adapts itself to the railroad while maintaining the railway infrastructure over land, but executing environmental and landscape treatments to the infrastructure that improve and upgrade its coexistence with the urban net. Footbridges, underpasses for pedestrian and cars, anti-noise screens ... This is a solution commonly used in European cities and also valid and used in many of Spanish cities.

But in many other cases a much more drastic solution has been chosen, in which it´s the railroad which transform itself (variants, relocations out from the city, undergrounding ...) to redevelop its lands in vibrant urban spaces, new centralities of the city with great value. Value used to finance the expensive necessary infrastructures for that makeover.

Today, there are many cities in the developed world that have embarked on these complex Rail-Urban operations for transforming their railway soils. There are examples of successful

Projects that have already been carried out in **Milan** *(Porta Nuova)*, **New York** *(Hudson Yards)*,

Perth *(Perth City Link)*, **London** *(Kings Cross)*, **Stuttgart** *(Stuttgart 21)*, **Frankfurt** (*Europaviertel*), **San Francisco** *(TransBay)*, **Berlin** *(EuropaCity).* Other Projects are now beginning to take place, following the success of its neighboring cities **Sydney** *(Central to Eveleigh)*

All Projects, with the same vision of Urban Regeneration and self-financing basis, has approach

1 The appraisals were based, on actual market sales at that time. In 2007, the Zaragoza Society offer its first parcel on the market, selling it almost twice the bid price.

this type of hard Rail- Urban Integration through complex infrastructure operations and Real Estate developments .

But in addition, these great projects of Urban Regeneration have been carried out during (and despite) one of the worst economic crises in modern history, while the Spaniards remain stagnant or in a slow progress.

Where does their success reside? **What can we learn from them?**

Initial and future images of the Redevelopment of railway lands in Perth, New York and Sydney

Initial and future images of the Redevelopment of railway lands in London, Milan and San Francisco

7. The cities of the future

Today, cities are definitely the engines of economic development, innovation catalysts and investment multipliers (they produce 70% of GDP with 50% of the population). But they also face serious problems due to pollution, high noise levels, excessive resources consumption, CO_2 emissions, congestion, time consumption, etc ...

These both sides of the coin make more than ever necessary to work for **mitigate the negative effects of urbanization and enhance the positive ones**, and the only way to do this is through good urban and infrastructure planning.

Faced with this challenge, major cities in the developed world are carrying out major urban regeneration and recycling soil projects, recovering degraded areas, industrial areas, disused infrastructures, to create new quality spaces for citizens, green areas, housing, offices, shops, vibrant new districts, and urban infrastructures on areas with optimal accessibility in the surroundings of the High Speed Railway Station.

They achieve with this Redevelopment Projects to minimize resources (soil, displacement, energy and time), and create more compact and **efficient cities that face the necessary growth, in a more sustainable way**.

The main Spanish cities have already joined this trend of Urban Regeneration. Madrid aspires to get on this boat with the biggest of all the Projects planned.

However there are notable differences between Spanish Projects and those carried out in other countries, which can help us to understand and to learn from their successes and mistakes.

- Do all urban regeneration operations have similar sizes?
- Is the initiative public or private?
- What kind of urban development do they propose?
- How are these expensive operations been financed?
- How much building floor is generated by the reconversion of soils? What is the current result of these projects?

8. Conclusions

Once we analyze where we have come from, and how we have walk the path, the most important thing is to find solutions so that we can move forward and succeed in carrying out this Urban-Rail Redevelopment **Projects that are necessary for cities and their inhabitants**.

On the way, we have found that other countries have already successfully undertaken these complex Re urbanization Projects, transforming them into new urban areas with vocation to become vibrant centrality, revitalizing and increasing value of the soils. All these project´s dimension have transcended the area they transform, with a global impact on the whole city.

Most of international Projects analyzed have already been successfully finished, which is not the case of any of the Spanish ones which are nowadays under development or still planning. That is why we analyze the keys to success of those who go ahead, to copy their successes, learn from their mistakes and to draw conclusions.

The first of the aspects that calls attention is the **size of the transformed areas**. Among all the similar Urban-Rail Redevelopment Projects analyzed, the Spanish ones are remarkably much more larger than ones developed in other countries, doubling and tripling even to the international projects.

It seems likely it would be more feasible to carry out this type of developments, if **undertaken on smaller projects**.

Country	City	Project Name	Size
France	Paris	La Defense	31 Ha
UK	London	Canary Wharf	46 Ha
EEUU	New York	Hudson Yards	11 Ha
Australia	Perth	Perth City Link	14 Ha
Italia	Milan	Porta Nuova	29 Ha
UK	London	Kings Cross	27 Ha
España	Madrid	Distrito Castellana Norte	**311 Ha**[2]
	Valencia	Valencia Parque Central	60 Ha
	Zaragoza	Zaragoza Alta Velocidad	**107 Ha**
	Gijón	Gijón al Norte	17 Ha
	Barcelona	Barcelona Sagrera	**149 Ha**
	Logroño	Logroño Integración del Ferrocarril	22 Ha
	Valladolid	Valladolid Alta Velocidad	**100 Ha**
	Alicante	Alicante Alta Velocidad Nodo del Transporte	47 Ha
	Murcia	Murcia Alta Velocidad	21 Ha

(2)

Table 1: Size of Urban Regeneration Projects

Source: Own elaboration

In Spain, the sponsors carrying out this type of Projects are mostly public, except for the one of Madrid, which is nowadays private initiative (under negotiation), but not in other international operations. Although they have needed to rely with the Public Administration support, the initiative and funding in this kind of Projects is mostly private. The main reason for the slowing of the Spanish projects has been the financial and Real Estate crisis, and the impossibility of raising the indebtedness of the Public Companies, due to belonging to the Public Administration sector; this would increase the National Public Deficit. But the similar Projects analyzed in New York, Perth, or Milan, that were also carried out during the same global financial crisis, has gone ahead basically for one reason: to have assured external financing.[3]

2 *Under currently negotiation.*

3 *In many cases, initial investors have now left the Project after completion of urban development such as Milan, where the new district was acquired in 2015 by the Qatar Investment Authority (2.000M€) thanks to the good expectations of the regenerated district.*

Country	City	Project Name	Sponsor
Francia	Paris	La Defense	Public
UK	Londres	Canary Wharf	Private
EEUU	New York	Hudson Yards	Private
Australia	Perth	Perth City Link	Public-Private
Italia	Milán	Porta Nuova	Private
UK	London	Kings Cross	Private
España	Madrid	Distrito Castellana Norte	Private[4]
	Valencia	Valencia Parque Central	Public
	Zaragoza	Zaragoza Alta Velocidad	Public
	Gijón	Gijón al Norte	Public
	Barcelona	Barcelona Sagrera	Public
	Logroño	Logroño Integración del Ferrocarril	Public
	Valladolid	Valladolid Alta Velocidad	Public
	Alicante	Alicante Alta Velocidad Nodo del Transporte	Public
	Murcia	Murcia Alta Velocidad	Public

(4)

Table 2: Sponsor of Urban Regeneration Projects

Source: Own elaboration

The most striking aspect of analysis is the **model of city proposed**, which is showed by building coefficient: All the Urban-Rail Regeneration Projects designed today in Spain have building coefficient much smaller than its equivalents in other parts of the world.

The most important Urban Redevelopment Projects in Paris and London at the end of the SXX (La Defense and Canary Wharf) were designed with much higher coefficients (4 times greater), The Hudson Yard Project at New York is ten times bigger and the Perth Project is double from Spanish ones average building coefficients. The urban development planned in these Projects is always for a **high density city model**.

It seems that without the idea of reaching the 1980´s European Projects high densities (45m^{2}c/m^{2}s), nor the current ones in Manhattan (9m^{2}c/m^{2}s which logically draw a different city model from the Mediterranean one), it might be necessary to tend in Spain to **greater plot ratios, in order to make more economic sustainable** these high expensive but high necessary Urban Regeneration Projects.

4 *Under currently negotiation*

Country	City	Project Name	Building Coef
Francia	Paris	La Defense	4,20 m^2_t/m^2_s
UK	London	Canary Wharf	5,36 m^2_t/m^2_s
EEUU	New York	Hudson Yards	9,55 m^2_t/m^2_s
Australia	Perth	Perth City Link	3,30 m^2_t/m^2_s
Italia	Milán	Porta Nuova	0,86 m^2_t/m^2_s
UK	Londres	Kings Cross	2,1 m^2_t/m^2_s
España	Madrid	Distrito Castellana Norte	1,05 m^2_t/m^2_s [5]
	Valencia	Valencia Parque Central	1,05 m^2_t/m^2_s
	Zaragoza	Zaragoza Alta Velocidad	0,65 m^2_t/m^2_s
	Gijón	Gijón al Norte	0,76 m^2_t/m^2_s
	Barcelona	Barcelona Sagrera	0,8 m^2_t/m^2_s
	Logroño	Logroño Integración del Ferrocarril	0,59 m^2_t/m^2_s
	Valladolid	Valladolid Alta Velocidad	0,86 m^2_t/m^2_s
	Alicante	Alicante Alta Velocidad Nodo del Transporte	0,47 m^2_t/m^2_s
	Murcia	Murcia Alta Velocidad	1,00 m^2_t/m^2_s

(5)

Table 3: Building coefficient of Urban Regeneration Projects

Source: Own elaboration

Another aspect differentiate in a striking way with world Projects, is the final **uses of the new district created**. If in the major international Urban-Rail Redevelopments the main use is offices and commercial use, in Spain, by contrast, the majority use is housing.

This will always depend on each city and the necessary market studies, but it is logical that if what is sought is to create a new centrality around a very important transport node such as a High Speed Train Station, to increase value of these soils, a **more balanced mix of uses would be highly recommended** to achieve this goal.

5 *Under currently negotiation*

Country	City	Project Name	Housing use percentage
Australia	Perth	Perth City Link	37,60%
EEUU	New York	Hudson Yards	4,76%
Italia	Milán	Porta Nuova	28,00%
UK	Londres	Kings Cross	35,60%
España	Madrid	Distrito Castellana Norte	58,26%
	Valencia	Valencia Parque Central	80,00%
	Zaragoza	Zaragoza Alta Velocidad	64,29%
	Gijón	Gijón al Norte	90,00%
	Barcelona	Barcelona Sagrera	73,00%
	Logroño	Logroño Integración del Ferrocarril	100,00%
	Valladolid	Valladolid Alta Velocidad	78,64%
	Alicante	Alicante Alta Velocidad Nodo del Transporte	78,00%
	Murcia	Murcia Alta Velocidad	71,30%

Table 4: housing use percentage of Urban Regeneration Projects

Source: *Own elaboration*

But where the most important efforts must be done is undoubtedly to enhance the value and **reinforce the key strengths that these soils have** beyond the hundreds of square meters gross.

In all cases they are the best location plots that allow them to compete in unbeatable conditions with the rest of available floors. We have ground **in the heart of historic city center** with optimal local connection with the host towny, and they are **next to the High Speed Train Station** with privileged accessibility to the big business centers of the country and the world.

This binomial gives these plots a **valuable potential** for a future scenario of more efficient and sustainable technological business models towards which, like it or not, we are tending toward, in this increasingly global and competitive world.

Some of these answers can help us to advance at the crossroad where these projects are now in Spain, but one of the main conclusions is that **the unstoppable evolution of cities simply does not allow the possibility of not doing anything**.

If we want our cities to compete with the world's leaders ones, we can´t condemn these Projects and future opportunities to the non-execution, only because of the complex change of scenery that has occurred.

No one doubts today the success of the large urban Regeneration Operations of ***La Defense*** in Paris or ***Canary Wharf*** in London, the result of the reconversion of industrial and port soils. Both changed the use of soils in order to regenerate degraded areas to convert them in urban icons and symbols of modernity of both cities.

The transformation now is not an option. It is only in our hand that this evolution may be done in the most sustainable and efficient way.

The **Regeneration Projects on railway lands will help achieve this objective**, recycling and recovering centric and optimally communicated plots, so that they stop being a rupture and become a union, stop being a scar and become a focus for creating value, attraction of investment and especially in places that contribute to improving the quality of life of all citizens.

"Our Struggle for Global Sustainability will be won or lost in Cities"

Ban Ki Moon

Secretary General of the UN

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Territorial and enviromental impacts

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KEYNOTE

The railway station as link of electromobilty

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Abstract

The railway station aims to become an important link of the electromobility chain within the city.

In order to reach the decarbonisation of transport goal, the electric car will be an important part of the new urban scenario in the urban mobility.

The intermodality between the train and the road will be easier if the electric car is parked in the railway station. During the time that customers are using the train for travelling, the electric car is being charged in the car park. When the customers come back to pick up their electric car, it will be completely charged.

The energy necessary to feed the cars' battery could be available from the breaking energy of trains. The railway energy network is independent from the city's energy network, then it is a good opportunity to create a big area of recharge for electric vehicles without interference with the energy power plan of the city's network.

According to a study of ADIF, in the Sevilla-Santa Justa station occurs an average of 180 passenger train arrivals per day, so the energy generated by braking reaches 9 MW/h per day; this is an annual total of nearly 3 GW/h. Given that an electric car takes 17 KW/h for a 100 km travel, the energy generated would have been used to run nearly 53,000 km per day in electric cars, saving 4.5 tonnes of CO2 per day.

But the technical connection with the catenary in the railway station is not trivial, ADIF developed an experimental research project that provided the necessary experience to:

• Energy storage systems: technologies of supercapacitors and batteries; Energy accumulators, as its name suggests, allow to store energy in any of its forms, so that it can be used later. In this way gets undock the demand of power generation.

• Electric vehicle recharging points: Recharges carried out by type 2 usually do not move from the 16A single phase, for normal recharging. Raising the nominal current of the system until the 32nd for processes fast charge. Where the supply system is three-phase, and for rapid recharging systems power level rises until the 63rd.

• Information and communication technologies: The different subsystems that could be used are: Energy management, User management, Supervision and Control System, E-maintenance,

• Energy efficiency and quality of network The set of power systems installed on micro intelligent network formed by the catenary, quality network and loads, distributed storage system, are intended to extract, modify, store, and manage the electrical energy in the most efficient way possible, always ensuring the quality, reliability, robustness, and security of electricity supply.

• E-maintenance: E-Maintenance as a maintenance strategy, i.e., a method of electronically using real-time data obtained from the equipment using digital technologies (mobile devices, sensors, technology, Internet, etc.) as a maintenance plan (i.e., a structured set of tasks with an interdisciplinary approach that includes the monitoring, diagnosis, prognosis) may be considered (decision and control processes), as a type of maintenance (based on CBM, proactive and predictive maintenance) or as a maintenance support (i.e., resources and services needed to carry out the maintenance).

• Business plan: Development of a methodology that includes the procedures to commissioning technical modules. Also, proposal of different business cases, legal aspects, identifying investment, costs and savings by determining the repayment (payback) period of the facility.

Keywords: Electric Car, mobility, regenerative braking, Ferrolinera, sustainability , CO2 redution, railway, catenary,

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1. The objective

The objective of the project *Ferrolinera 3.0* is the development, experimentation and validation of an innovative system for charging of electric vehicles (EV), through the use of clean energy from regenerative braking of trains, high speed and the metro network.

The main aim of this innovative project is to install a network see recharging points connected to the railway network, called *Ferrolineras,* that offer to the market a new technological solution for this type of electric recharge processes. In addition, the project includes the installation of a photovoltaic system as extra supply source of energy, which will serve as a power booster if necessary by the end user. A pilot study in two different locations, the laboratory of energy of ADIF and the new Metro of Málaga will be developed to test the feasibility of the proposed innovation. Object of the project is also lay the foundations of your market and put in exploitation.

In specific terms, the objectives pursued with the development of this project are as follows:

- Demonstrate the feasibility of a new technology not previously scrutinised for any entity making an effect tractor on the promotion of sustainable energy.
- Help balance future electrical load expected that it will exist on the network of transport and distribution of electrical energy, to make possible the use of own electrical infrastructure of the railway, which permit the collection of important technological synergies.
- Contribute to sustainability through the use of clean electrical power that the rail system produces in the processes of trains braking. For DC systems, this energy dissipates into heat if there are no reversible substations in the network.
- the development of one of the largest electric vehicle recharging infrastructures; contributing to the demand for electric vehicles by the population
- To promote the development of one of the largest electric vehicle recharging infrastructures; contributing to the demand for electric vehicles by the population

2. The specific objectives

The specific objectives of the project are:

- Develop the constituent elements of the *Ferrolinera* as new electric vehicles charging system:
  - Structure.
  - Trickle charge system I fast charge.
  - Storage of the energy generated in braking of trains.
  - Remote management platform.
  - The user management system.
- Develop photovoltaic support to the *Ferrolinera* system.
- Install and test the above items. The trials will be conducted in real railways.
- Validation and generation of technical specifications.

KEYNOTE

- Analyze the manufacture and subsequent marketing of the product for all rail environments, including the export of the same to other countries.

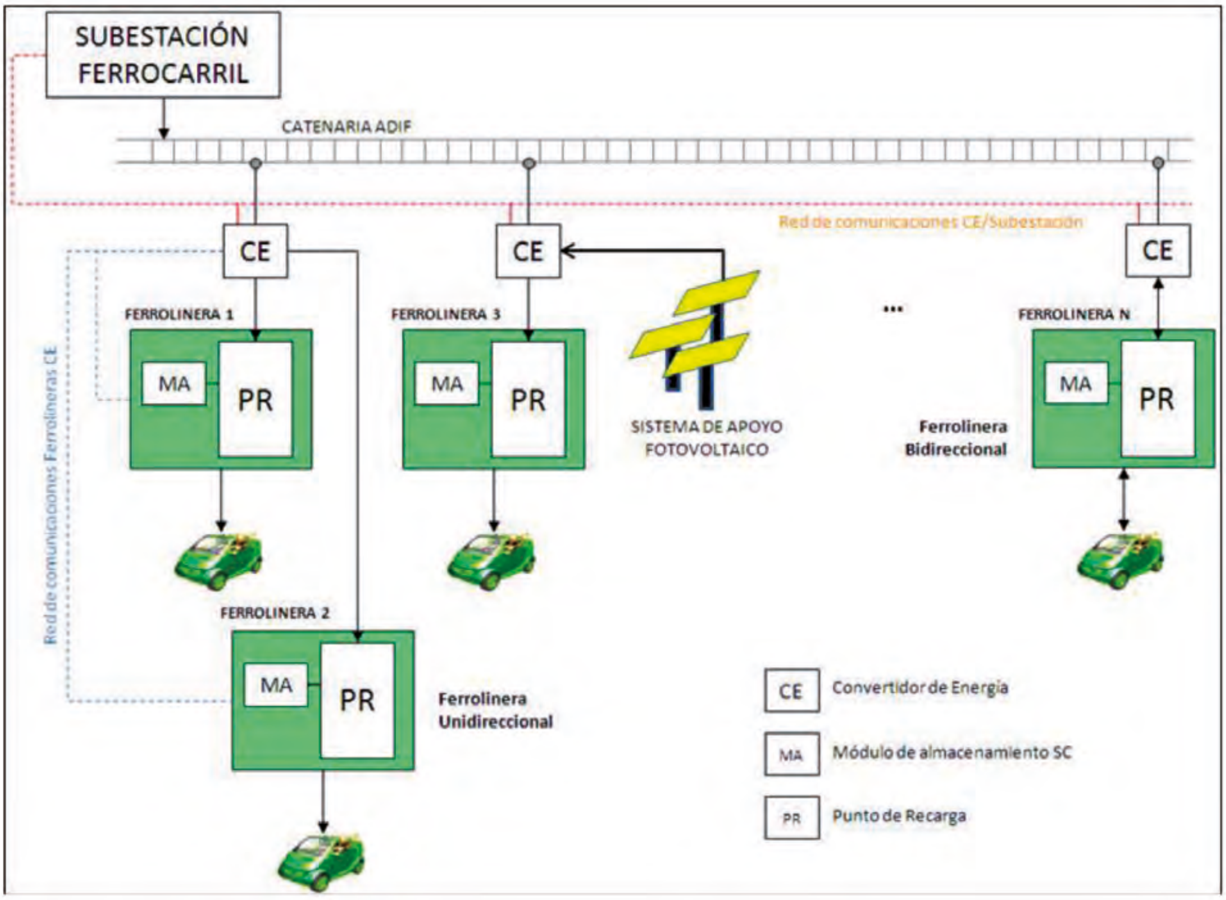


Figure 1: Overview of the project Ferrolinera 3.0.

2.1 The system

This schema considered different Ferrolineras distributed in the system. And reflects realistically what is the system, being a general explanation as follows:

- There is a railway catenary, which is powered by an electric traction substation.
- Every true kilometre there is a point of connection to the catenary. This point feeds a power converter (converter DCAC for a catenary DC or even a transformer for singlephase alternating current).
- The inverter is connected to the Ferrolinera of ADIF, having a storage module MA which focuses the energy from the electric braking of trains. As you will see later, this module will be developed with supercapacitors I Technology batteries.
- PR is the point of charging that is next to the storage system, the Ferrolinera

- There may be a support system photovoltaic that feeds the Ferrolinera through your appropriate CE.
- There are also bi-directional Ferrolineras, i.e., that batteries of the vehicle to which feed can in turn contribute to the power of the electric rail system if there was demand for this.
- There is a communications network that connects all EC computers with the management team of the substation, in a manner that emit instructions of operation to each CE based on the curve of the substation load. Although it is not indicated in the above scheme, this system is also connected to the corresponding planning and traffic control system (Note: as you will be indicated later, this communications network is not in the scope of the present technological project).
- In addition, for those EC feeding several Ferrolineras also exists an internal communications network that regulates the operation of each one of them according to the EC control setpoint (Note: as you will be indicated later, this network of communications Yes is in the scope of the present technological project).

2.2 Ferrolinera: electric recharging point on the railway network

The concept of *Ferrolinera* has been designed by Adif and refers to that point of recharging of electric vehicles is connected to an electric rail network.

The unique characteristics of the electric rail system are represented, mainly, by the very randomness of electrical loads, while dealing with movable loads (trains). It based this type of charging differentiate independently with respect to other concepts. It should be noted that in ADIF there are fed to 3,000 V DC (3,000 V DC) traction and traction networks fed to 25,000 V AC single phase (25,000 V AC). 3,000 V DC networks are used in the conventional network while the 25,000 V AC mains is used on high-speed lines.

The main problem of power electric vehicles en masse from a railway catenary is the modification of the electrical substation load curve (SE) corresponding. As is to be expected, if there are additional electrical loads represented by trains, the nominal power of the substation may be reduced, there may be significant technical limitations to supply more trains. This fact does not matter because in any case it would not be permissible to feed electric vehicles at the expense of limiting the power to trains.

Figure 2 represents in schematic way the existing in one substation any load curve (blue). This type of load curves is characterized by its irregular profile due to the characteristic of the burden the train (load variable in space and time).

In the event a series of Ferrolineras is connected to the catenary, a constant overhead (PA) is generated to substation (red). If Pmax is the maximum power that the substation can provide, there is that from the moment of connecting these new burdens might be considered overrides specific on Pmax. To all intents and purposes, these overrides are represented by tips to the substation is not able to satisfy, which would cause that promptly not you could feed the trains (or the burden represented by the Ferrolineras) according to the demanded power. As you can see in the figure, the overhead is represented by PB.

It should be noted that ADIF has registered the Ferrolinera mark under application M2965746-6 of the Spanish Office of Patents and Trademarks.

KEYNOTE

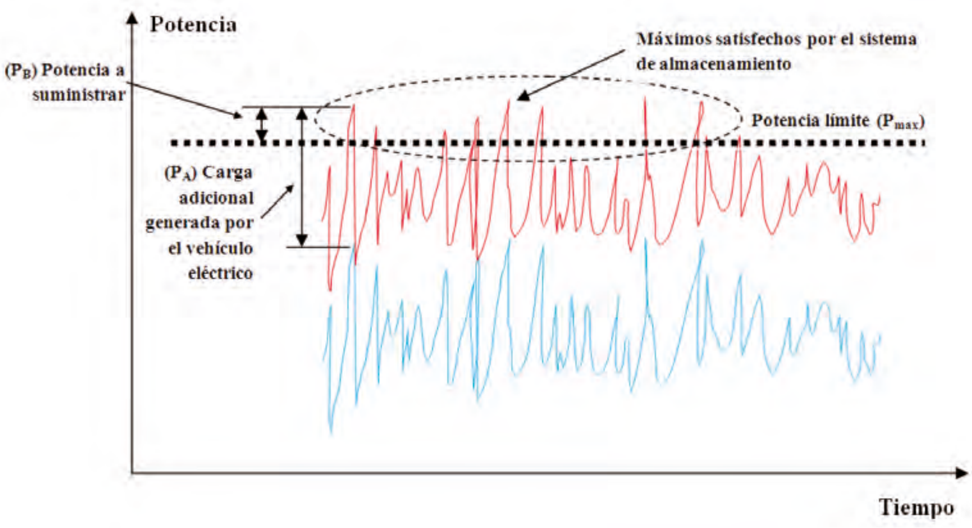


Figure 2: Explanatory scheme

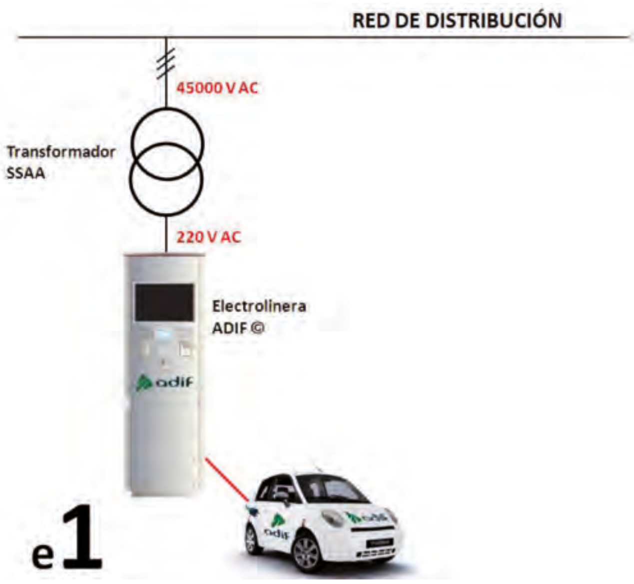
2.3 Background: Ferrolinera 1.0 and 2.0

The Ferrolinera 1.0 project, now completed, must encompass as a first pilot project to analyze possible problems that may occur in this type of cargo operations. It has been tested in the laboratory of energy of ADIF, four scenarios of an electric vehicle charging. This has been used a commercial charger, although different own electronic equipment enabling connection to the electric rail system has been developed.

The Ferrolinera 2.0 project, currently under development, is based on the above results and aims to continue working with a commercial but already plugged charger out of the controlled environment, such as the laboratory of energy of ADIF. Precisely, the objective is to install a Ferrolinera connected to the electric rail system (catenary) on the AVE station Maria Zambrano (Málaga).

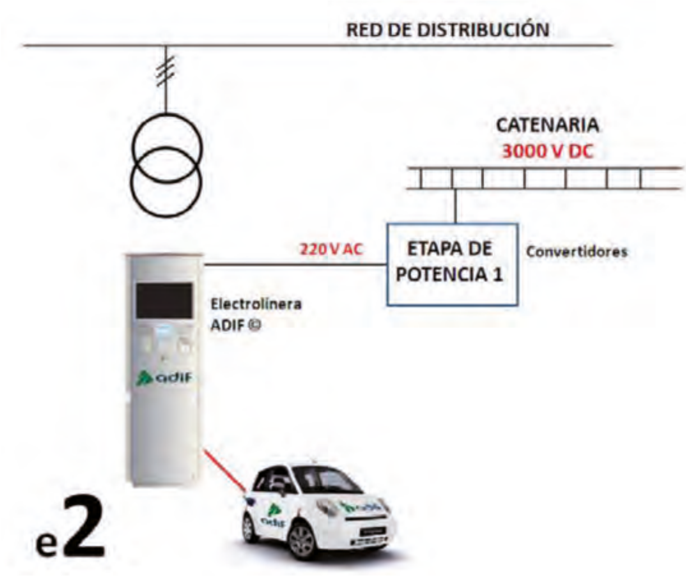
2.3.1 Project 1.0 Ferrolinera: stage 1

Consider the power of the Ferrolinera from a reducing transformer of a distribution line voltage. Does not require additional specific equipment.



2.3.2 Project 1.0 Ferrolinera: stage 2

This scenario considers the power of the Ferrolinera from the network of 3000 V DC traction. A power electronic converter is required to be connected to the network and thus adapt the voltage levels to the Ferrolinera.



2.3.3 Project 1.0 Ferrolinera: stage 3

The possibility of feeding the Ferrolinera from a team of storage of the energy generated in braking of trains is incorporated. I.e., the charging system would have the possibility of power from two sources (dual charge):

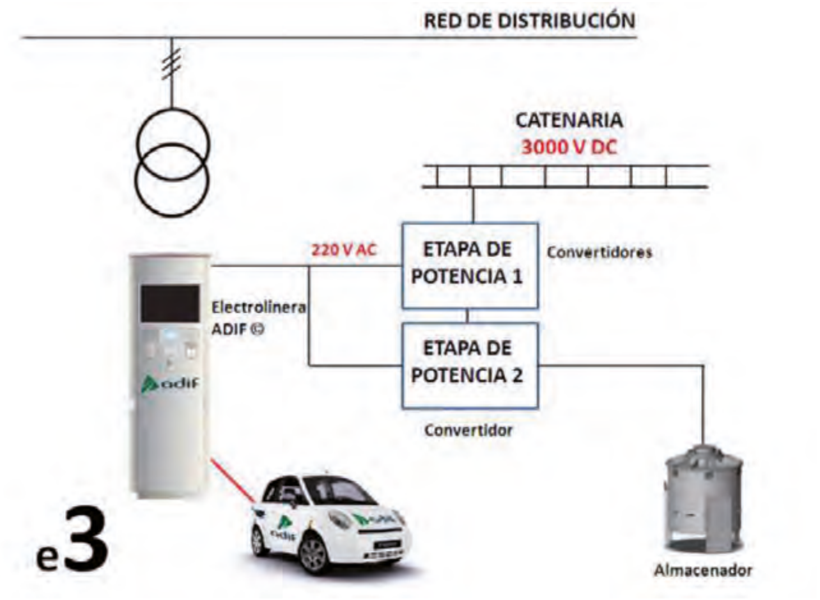
1. Directly from the network of 3,000 V DC (stage 2) traction
2. From a storage system

The introduction of a system that stores electrical energy (in this case, one that is generated when trains hinder recovery and is not consumed by other existing in the corresponding electrical canton trains) would compensate the needs generated by the Ferrolineras. In this way, the storage system would provide the PB power Ferrolineras module. I.e., the power of the Ferrolinera only from the traction network may cause a limitation to the power supply of the trains, especially in periods of high traffic density.

The incorporation of a storage system would allow that in these cases the Ferrolinera feed from such a system, there is no technical limitation to the power of trains while the system has enough energy (in any case, the periods of maximum points should not be very long at the time).

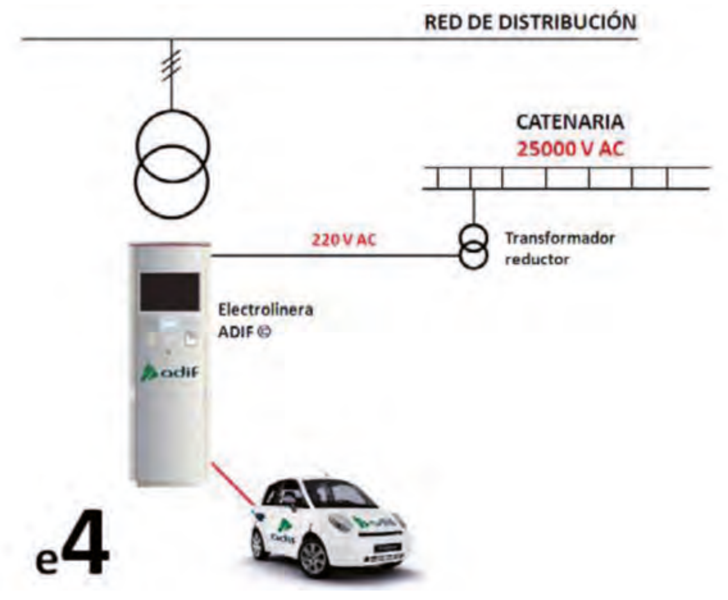
It should be noted that used in the previous functionality control system has been recently patented by ADIF under application number 201130502 of the Spanish Patent and Trademark Office.

KEYNOTE



2.3.4 Project 1.0 Ferrolinera: stage 4

This scenario considers the power of the Ferrolinera from the 25,000 V AC traction network and requires a reducing transformer, a surge protector and a filter harmonics, connected to the network, to adapt the voltage levels to the Ferrolinera.



The description and the scope of the project are represented in Figure 7. It will be developed and installed more than one Ferrolinera, so that they can interconnect among them through the management system proposed, also developed in this project. The entire system will be tested and tested in the laboratory of energy of ADIF, exist a remote monitoring from the Railway Technologies Centre in Malaga; it is there where the management of the project will be developed. While the bulk of the project will be tested in the laboratory of energy, has been seen practicing other two Ferrolineras in the electrical system of Metro de Malaga (network to 750 V DC).

The connection will be made to the system of direct current as that introduces a major technological component in the project. The project will develop the following elements and main concepts:

- Ferrolinera standard and quick
- Interface and communications between Ferrolineras connected to a single computer energy converter
- Ferrolinera (supercapacitors) distributed storage system
- Interface and communications of e-maintenance and management of the system
- Computer power converter
- Use of photovoltaic solar energy infrastructure
- Network quality control system

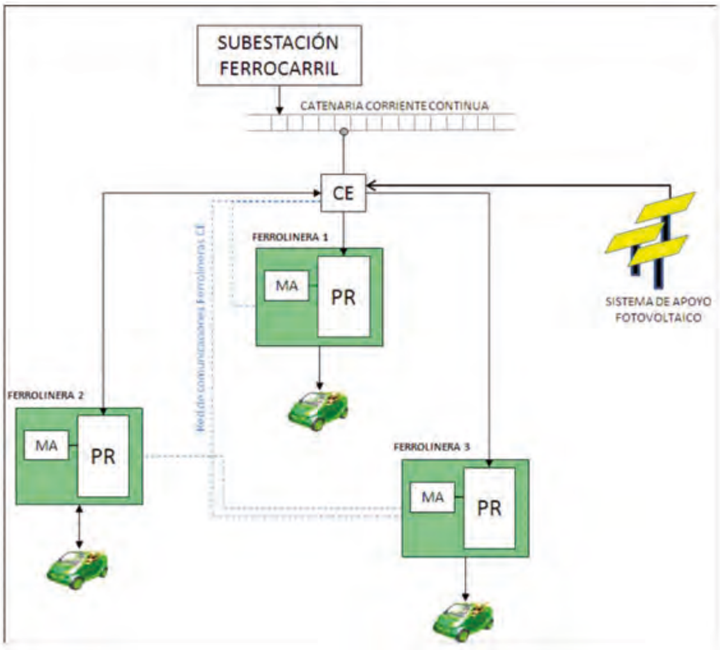


Figure 7: Project scope

Within the scope of the project covers various activities of research, development and innovation of the technology necessary to continue optimizing the use of electricity from the power of ADIF network itself, as well as the use of clean energy regenerated by the train during braking. A third source of energy from a photovoltaic system is added to the project.

It uses storage distributed in the own recharging stations and not concentrated on an electrical substation of traction (this approach best reulta from an energy point of view).

In addition, the power electronics equipment necessary to carry out the energy transfer between the catenary, distributed storage system, and integrated renewable energy sources, as well as to ensure the quality of the generated power cruising will be developed. This technology looks for an increase in the energy efficiency of the system, not only causing their own functionality, but which also derives from the individual optimization in the design of each of the teams that comprise.

This will be complemented by the development of TIC's kind technologies which carry out the communication of all these systems existing in the installation, allowing monitor, manage and control the information resident in the system: energy flows, State of the storage condition of the points of recharge, existence of faults in the system, signs of alarm, charging the user network quality, etc.

2.4 State of the art of the technologies involved

Five are the object of study and development technological lines:

- Systems of energy storage technology
    - Technology of supercapacitors
    - Battery technology
- The recharging of electric vehicles (PR-VE) point technology
- Technologies of information and communication technologies (ICT)
- Technologies for energy efficiency and network quality
- E-maintenance

2.4.1 Storage systems

Energy accumulators, as its name suggests, allow to store energy in any of its forms, so that it can be used later. In this way gets undock the demand of power generation. With respect to the electric system, these devices improve their efficiency and reliability, absorbing the energy produced from the network during the valleys of demand (low cost of generation), either from intermittent renewable energy sources in case of existence of surplus, and releasing it in the moments of greatest demand, high cost of generation or when there is no other source of energy available. The main technologies for the purpose of storage are:

- Electrochemical batteries. (Applicable in this project)
- Supercapacitors. (Applicable in this project)
- Magnetic storage (SMES) Superconductor
- Kinetic energy (flywheels) geostructural
- Storage of compressed air
- Pumped hydropower

Taking into account that the energy requirement for this project requires a storage system medium energy density and with a great capacity of response, only listed previous technologies will be explored to fund the first two.

In general, energy storage devices are used basically in four scenarios:

- Increase the efficiency of electrical systems, to reduce the need for backup generation, providing power in the daily demand peaks
- Increase the reliability of the system, to reduce the chance of outage. (Applicable in this project)

- Increase the availability of renewable sources (solar, wind, etc.). (Applicable in this project)
- Increase the efficiency and the rational use of energy in industrial processes

2.4.2 Electrochemical batteries

Devices capable of accumulating power by electrochemical processes. This energy is then returned almost in its entirety. This cycle will be repeated a number of times, given by the useful life of the device. There are various types of batteries with different characteristics (lead batteries, alkaline batteries of manganese, nickel-cadmium, nickel metal hydride, lithium ion, polymer lithium, etc). This type of battery energy density varies between 30 and 130 WhKg. It is a secondary electrical generator. Does not produce electricity, but it frees up that has been previously stored during its load. The number of uploads and downloads will be limited by its useful life.

ADVANTAGES: higher density power against other geostructural.

DISADVANTAGES: low upload speed and download allowed. (they are not devices capable of absorbing large ends of power loads or provide downloads without that do not impact negatively on its useful life). His performance is not very high, on the order of 80, due to its internal resistance, which is remarkable in the processes of loading and unloading of the device. Another unfavorable feature is the own self-discharge over time due to the leakage resistance. Some types of batteries are the so-called "memory effect", in which each refueling is limited voltage or storage capacity, due to high current, high temperatures, the ageing of the device, making impossible the use of all its energy. A no less important disadvantage is the high toxicity of heavy metals taking part in some types of batteries, which constitute a serious environmental problem. You are trying to reduce this toxicity with replacement by new less polluting substances. The main existing battery technologies are:

- Lead-acid
- NaS
- NI-CD
- Ni-Mh
- Li-ion

Batteries used in sources of energy energy storage systems renewable are stationary batteries. They are low content of antimony lead-acid batteries. They have approximately 2,000 life cycles when the depth of discharge is a 20 (i.e. that battery will be with your load 80) and some 1,200 cycles when the depth of discharge is 50. These batteries have one self-discharge less 3 and an efficiency of 75. They can withstand 80 downloads and have a life of about 15 years. They are used in installations of great powers. You can get the operating voltage required by the Association in a number of these devices. Of Li-ion, whose highest densities of power, energy and higher yields make them more attractive for these applications. In the case of lithium-ion batteries industrial, have capacities ranging from 4 Ah to 400 Ah, although their prices are well above the stationary lead-acid batteries.

The main characteristics of these devices are listed below:

- Energy density: 20-100 WhKg
- Power density: 20-200 Walter Kissling GAM

- Power range: for systems of up to 100MWh
- Power range: 1kW-30MW
- Loading and unloading times: hours
- Number of charge and discharge cycles: 1,000-3,000
- Performance: 75-99 according to technologies
- Self discharge rate: 0 - 20 per month according to technologies
- High for Li-ion and NI-CD tools Pb-acid-low prices
- As type may have toxic elements

2.4.3 Supercapacitors

The double layer supercapacitors are electrochemical capacitors with a density of unusually high energy compared to conventional capacitors, typically thousands of times greater than a high capacity electrolytic capacitor. They are storage devices of power with one capacitance greater than a farad, reaching up to thousands of farads. These devices have a maximum of up to 30 WhKg energy density.

The accumulation of energy relies on the confinement of electrostatic charges on small devices, formed by pairs of conductive plates separated by a dielectric medium. The construction and operation is similar to a conventional capacitor on a large scale. The supercapacitors are characterized by being able to be loaded and unloaded in the times on the order of seconds, which makes them especially suited to respond to needs of power tips or short duration power outages. This is because the storage of loads is purely electrostatic.

ADVANTAGES: Because of the speed of loading and unloading, can provide high chargedischarge currents, which instead damages to the batteries. They have a number of cycles of life of millions of times and require no maintenance. They can work in extreme temperature conditions. On the other hand, do not have toxic elements composition, very common in batteries.

DISADVANTAGES: limited capacity to store energy and day of today, its higher price.

The main characteristics of these devices are listed below:

- High capacities: 1-5,000 F
- Energy density: 1-10 WhKg
- Power density: kWKg 1-10
- Loading and unloading times: minutes, seconds
- Number of charge and discharge cycles: 10e6
- Limited operating voltage: 500V-1
- Electrical performance: 95-99
- Very low discharging
- Relatively high price
- Do not need maintenance
- Do not have toxic elements
- Resistance to adverse conditions of temperature

Currently the supercapacitors are classified in accordance with the materials with which they are manufactured. There are mainly four types:

- **Electrolytic double layer carbon spanner supercapacitors.** The main are used sulphuric acid and potassium or sodium hydroxide. In them the solution dissociates into positive ions of sodium or potassium, which accumulates a greater power in the presence of voltage increase of the attraction between loads.
- **Not electrolytic carbon double-layer interfaces supercapacitors.** The main are finished products such as Aerogels, soles, carbon and carbon nanotubes. The Suns are dispersions of solids in liquid found in Brownian motion indefinitely. On the other hand, a gel is a solid that has a large amount of fluid and a structure that allows that both phases combined are. Elected in water metal oxide is formed for the formation of soles for capacitors, high temperatures or with an excess of base to form the Sun. Then the Sun is gelated sent by dehydration or pH increase. Organic soles with resorcinol can also form formaldehyde. The result of the process is the formation of a very porous homogenous material that allows a high capacitance. If the Sun is combined with the carbon interface is calculated that you can achieve a capacitance of 400 farads per gram.
- **Aqueous supercapacitors of double layer with redox pseudo-capacitance oxide.** The main are lithium oxide, ruthenium dioxide, dioxide of Iridium, cobalt oxide and manganese dioxide. The supercapacitors can be manufactured according to the methodology of the previous section to develop a Sun. Another way to get it is by the deposition of metal oxide by means of a procedure of electrolysis. There have been investigations where capacitances of 400 Fg with ruthenium oxide have reached. Most profitable around 50 Fg supercapacitors has been with nickel oxide. An alternative way to generate the pore structure is the addition of lithium oxide to metal such as Platinum; This material add you acid to remove lithium and keep the porous structure of scale Nano.
- **Conductive polymer supercapacitors.** Conductive polymer as an organic substance that conducts electricity in a metal-like way, with good reversibility between State conducting and non-conducting and mechanical flexibility is defined. The main are of polypyrrol and polyaniline and polythiophene. They have a density greater than 500 Watts per kilogram energy, and even its capacitance properties are studied.

Supercapacitors research is motivated by the enormous advantages that its use represents the development of electrical circuits:

- Great period of operation
- Ability to handle high current values
- Easy to monitor load value
- High efficiency
- Wide range of voltage
- Wide range of temperature
- Long operating cycles
- Ease of maintenance

The life of a supercapacitor decreases as increases its capacitance, but currently there are devices that exceed a lifespan of twenty years with losses in the voltage supplied about a volt. Due to these properties of life and management of voltage and current, the supercapacitors have been used in various applications:

- Hybrid cars
- Energy support
- Energy storage
- Power transfer systems

2.5 Recharging points

Recharges carried out by type 2 usually do not move from the 16A single phase, for normal recharging. Raising the nominal current of the system until the 32nd for processes fast charge. Where the supply system is three-phase, and for rapid recharging systems power level rises until the 63rd. The connection between VE and the point of recharge is carried out through terminals Schuko 74, in the case of the 16A and CETAC 3262A (IEC 60809) in other cases. At any time, this type of connectors present additional threads to those assigned to the power supply and grounding.

Table 1: main features of the current post of recharge.

TECHNOLOGY	
Communications	RS-232, RS-485,Ethernet, Zigbee, PLC, GSM, GPRS
Energy management	Measurement and pricing, network quality, with-high partial and total, intelligent management of recharging
Energy efficiency	Reactive compensation and harmonic filtering
Software	Monitoring and control in real time, telemetry, management of alarms, SCADA, historic generation, multi-user management
Identification	RFID, BAR CODE, magnetic card

2.6 Information and communication technologies

The different subsystems that will be developed in the project are as follows:

Energy management:

- Power catenary-storage system
- Energy storage system–electric car (EC)
- Energy storage system-storage system (Energy for Share)
- Renewable energy system-storage systems
- Interaction quality electrical-micro smart grid (MSG)

User management:

- Charging user

- Load options-EC download (Energy for Share-Charge)
- Connection EC-RP
- Identification of the user

Supervision and Control System:

- E-maintenance
- Supervision of the smart power cruising systems

Data transmission technologies are mainly divided into three groups:

- device interconnection

Table 2: data transmission for device interconnection

Technology	Transmission medium	Transmission speed	The device maximum distance
IEEE 1394	UTP/FO	400 Mbps (V.a), 3.2 Gbps (v.b)	4.5 m - 70 m
USB	USB	12 Mbps (v.1.1), 480 Mbps (v.2)	5m
Bluetooth	Wireless	1 Mbps (v.1), 10 Mbps (v.2)	10m (v.1), 100 m(v.2)
IRDA	Wireless	9.600 bps – 4 Mbps	2 m

- LAN data networks

Table 3: data transmission for LAN networks

Technology	Transmission medium	Transmission peed	The device maximum distance
Ethernet	UTP/FO	100Mbps-1Gbps	100 m - 15 km
HomePlug	Power cord	14 Mbps	650 m^2
HomePNA	Telephone line	10 Mbps	304.8m, 929 m^2
IEEE 802.11	Wireless	54 Mbps (v.a), 11 Mbps (v.b)	33m (v.a), 100m (v.b)
HiperLAN/2	Wireless	54 Mbps	100 m
HomeRF	Wireless	10 Mbps	38 m

- control and automation networks

KEYNOTE

Table 4: control and automation networks

Technology	Transmission medium	Transmission speed	The device maximum distance
Konnex	1.TP0, 2.TP1, 3.PL100, 4.PL132, 5.Ethernet 6.Radio	9600 bps, 3. 1.2 – 2.4 Kbps, 4. 2.4 Kbps	2. 1000 m, 3. 600 m
Lonworks	1. TP, 2. Power cord, 3. Radio, 4. Coaxial, 5.FO	1. 78 Kbps, 1. 1.28 Mbps, 3. 5.4 Mbps	1. 500 m – 2700 m
X10	Power cord	60bps USA, 50bps Europe	185 m^2
BacNet	Coaxial cable, TP, FO	1Mbps-100 Mbps	Con Ethernet sobre TP: 100 m
EIB	1.TP, 2. Power cord, 3.RF, 4.Infrared	1. 9600 bps, 2.1200/2400 bps	1. 1000 m, 2. 600 m, 3.300 m
EHS	1. Power cord, 2.TP	1. 2.4 Kbps, 2. 48 Kbps	
Batibus	TP	4800 bps	200 m a 1500 m Depending on the section of the cable
Cebus	TP, Power cord, Coaxial, Infrared Radio,	10 kbps	Depending on the characteristics of the environment
DALI	Cable par		200 m
Metasys	N2Bus	9600 bps	1219 m
SCP	Par de cable	<10000 ps	
Zigbee	Wireless	20-250 Kbps	10 m – 75 m

2.7 Energy efficiency and quality of network

The set of power systems installed on micro intelligent network formed by the catenary, OURSES, quality network and loads, distributed storage system, are intended to extract, modify, store, and manage the electrical energy in the most efficient way possible, always ensuring the quality, reliability, robustness, and security of electricity supply.

To do this, each of these systems incorporates control and management advanced algorithms giving them independence and autonomy within the MSG, but at the same time they introduce them and synchronized with the rest of the electrical infrastructure that surrounds them. Looking for the efficiency and quality of whole from each of the parties in this way.

However, not only electronic systems interact with each other, the human factor within a system that hosts the project is a variable to take into account. The decisions taken by the owners of the vehicle will influence within the energy management of the micro network. Type of refills, time and simultaneity of the same in the near future transfer of power by the vehicle (vehicle to grid (V2G)), etc., are heavy weight variables in the system. That is why there must be a proper coordination between these and power systems distributed in the MSG.

On the other hand, the manager-operator system may interrupt the autonomy of the system during maintenance, alarm signals, incidents on the line, etc. These operations and decisions will have an impact in greater or lesser extent in the rest of the system so it must be prepared to deal with more efficient, safe and reliable as the new scenario occurring.

That all the subsystems mentioned above presents the coordination and synchronization is required, it is required that there is an element of management to higher level that would monitor system complete and with ability to communicate the State full system to each and every one of its parts. This system receives the name of energy management system.

The different types of converters for power that could appear in the defined system are as follows.

The electronic power converters are systems capable of converting electric energy from one type to another using different electronic devices. These systems are based on semiconductor devices to control or modify voltages and currents. They are used to adapt the nature and levels of voltages and currents between the different parts of an electrical system. Typical applications of power electronics are, among others, the conversion of power alternating (AC) into direct current (DC), DC to AC conversion, the conversion of a non-regulated in a DC voltage regulated DC voltage and the conversion of a given amplitude and frequency in another amplitude and frequency different AC power.

The following classification of converters can carry out depending on the nature of the input and the output of the converter:

- AC/DC converters
- DC/DC converters
- AC/AC converters
- DC/AC converters

AC/DC Converter: This type of converters produces a DC current from an alternating current. Generically they are called rectifiers. Depending on the level of power handling, your topology will be three-phase, high power, or single phase. Last is given to any type of power converter.

DC/AC converter: Commonly called investors and its purpose is the convert direct current into alternating current.

The two remaining cases AC/AC and DC/DC, are used to adjust the amplitude and frequency in the case of the former, the tension between two different stages of an electrical system.

Other options are presented depending on the characteristics of modulation used, number of switches, etc.:

- Matrix converters
- High frequency (HF) converters
- Bi-Level and multilevel converters

MATRIX CONVERTERS: Inverter three-phase crap that consists of a set of bi-directional switches that connect a three-phase load directly to the line of three-phase power.

HIGH FREQUENCY CONVERTERS: This type of converters has an extra stage in the conversion of electrical energy that is to perform the conversion in high frequency.

MULTILEVEL CONVERTERS: These converters have interesting advantages over traditional solutions for the conversion of energy from renewable sources.

An active filter is an electronic device that uses energy stored, either in a capacitor or a coil to deliver I return to store energy under a slogan that seeks to compensate for the disturbance. The slogan is known with the name of reference and his generation is given through the opening and closing of power switches (usually semiconductor). As the disturbance that can be compensated, this will depend on the strategy of control and the way that the filter is connected to the network. Depending on the desired purpose, filter connects in series to the network, correction of disturbance in the tension, in parallel, correction of power disturbances, or as a mixture of both.

2.8 E-maintenance

We define e-Maintenance as a management concept of maintenance whereby assets are controlled and managed over the Internet.

E-Maintenance as a maintenance strategy, i.e., a method of electronically using real-time data obtained from the equipment using digital technologies (mobile devices, sensors, technology, Internet, etc.) as a maintenance plan (i.e., a structured set of tasks with an interdisciplinary approach that includes the monitoring, diagnosis, prognosis) may be considered (decision and control processes), as a type of maintenance (based on CBM, proactive and predictive maintenance) or as a maintenance support (i.e., resources and services needed to carry out the maintenance).

E-Maintenance is an interdisciplinary approach that consists of monitoring, diagnosis, prognosis, and control. Control consists of the evaluation in real time of the assets and the detection of abnormal States. The diagnosis, identifies the causes of advance degradation or failure of the equipment. The Outlook analyzes the impact of the failure on the computer and the system. As a result, they can make decisions and carry out maintenance actions if necessary, with the aim of reducing the number of inspections "in situ" and eliminating unnecessary maintenance activities.

E-Maintenance integrates the principles as applied in the maintenance, by adding a Web service and principles of collaboration. Collaboration is not limited to sharing and exchanging information, but knowledge and intelligence between different units, departments, expert operators and companies in a collaborative environment for the development of better decisions of maintenance throughout the lifecycle of an asset.

The e-Maintenance Management model breaks the physical distances through the creation of intelligent networks using Internet and wireless communication technologies. Thus, a platform e-Maintenance exists when you replace the conventional hierarchical structure by an intelligent structure of (Intelligent Manufacturing Systems IMS). It consists of giving intelligence to components via electronic technology. To do this, it is necessary to have support for Exchange of information and communication networks in real time between the devices. Through a system of alarms set-based monitoring of the conditions of the equipment, it is possible to optimize the priority of peacekeeping activities. The influence of all of these capabilities is even more important when the tasks are characterized by the immediacy and the high mobility of the linked staff.

These potential improvements are summarized below:

- Remote maintenance
- Cooperative maintenance
- Maintenance on-line
- Predictive maintenance
- Troubleshooting

Territorial and enviromental impacts

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Regional diffusion and adoption effects on HSR demand expansion

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Abstract

High Speed Railway (HSR) has been suggested as one sustainable alternative for acquiring regional and nationwide mobility. In order to maintain the sustainability of HSR also within changing socioeconomic structures, it is important to secure its long-term demand. Therefore this study considered the diffusion theory which explains technology adoption in the marketing area, as a basis for explaining HSR ridership increasing by year. Our target area for study is Taiwan High Speed Rail (THSR). By using the monthly ridership data of THSR between 2007 and 2015, we calculated yearly Adoption Effects which describes the spread of THSR among new users. We consider this effect to be a key element to secure long-term demand. Moreover this study demonstrated that city heterogeneity such as social, economic and geographical characteristics influence the Adoption Effect. Based on our findings, we conclude that specifically improving accessibility should be considered as a policy measure to help stabilizing long-term demand especially in an aging society.

Keywords: High Speed Rail, Taiwan, Diffusion theory, Heterogeneity, Demand adoption

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1. Introduction

As interest in high-speed rail (HSR) rises around the world its network is rapidly expanding across continents. HSR is currently in more than 20 countries in operation (including the UK, France, Germany, Belgium, Spain, Italy, Turkey, Japan, China, Korea, and Taiwan). The predicted demand before construction is often overestimated though compared to the observed HSR ridership in particular in the first years of operation as discussed in Li et al (2016) with Taiwan data and Demizu et al (2017) with data from Tohoku, Japan. They argued this could be the lack of sufficient consideration regarding the time people require adapting to new transportation systems. In the case of the Northeast Japan Shinkansen extension project from Hachinohe (Aomori) to Shin-Aomori (Aomori) which started operation in 2010, the transportation density was 8,300 {(rail passenger-km per day)/rail km-operated} in the initial year but it has grown to 8,800 in 2011 and it reached 9,000 one year later (JR, 2016). To achieve a stable, high demand within a short time period after construction is an important issue though for sustainable HSR planning and its operation.

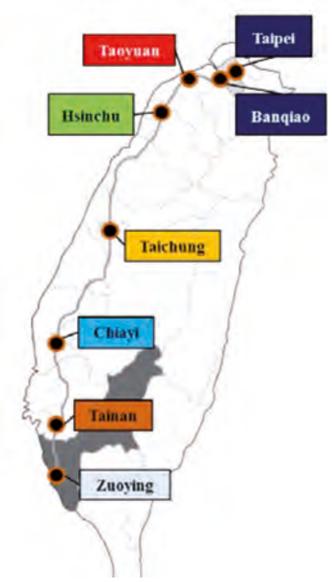

Fig. 1 THSR route and stations

In order to investigate the pure impact of a single HSR project for the country and passenger's travel behavior, we take Taiwan as a case study area. THSR (Taiwan high speed rail) connects the two largest metropolitan areas, Taipei and Kaohsiung, within a travel time of about 90 minutes. The THSR operation between Banqiao (Taipei) and Zuoying (Kaohsiung) started in January 2007. Subsequently, it extended to Taipei Station in central Taipei two months later. The target period of our research is from March 2007 to April 2015. Within this time period no further stations were opened. The eight HSR stations that are operated in this period are shown in Figure 1.

Table 1. Information of city with THSR station

No.	Name	City scale	Distance from capital, Taipei (km)	Travel Time from Taipei Sta. (min)	Population(thousands)		
					2007	2015	Annual Growth Rate
1	Taipei/ Banqiao	L	0	0	6,402	6,672	0.52%
2	Taoyuan	S	36.4	22	1,913	2,062	0.94%
3	Hsinchu	S	66.3	35	883	970	1.18%
4	Taichung	M	159.8	49	2,588	2,742	0.73%
5	Chiayi	S	245.7	89	826	795	-0.48%
6	Tainan	S	308.0	106	1,867	1,885	0.12%
7	Zuoying	M	339.3	94	2,761	2,779	0.08%

THSR monthly aggregated ridership from March 2007 is obtained when for the first time all eight stations were in operation. The ridership in the first month was around 919 thousand and gradually increased by 7.4% per month on average reaching 2.97 million in August 2007. In 2008, passenger numbers almost doubled and the average daily ridership continued to grow to over 138,525 passengers per day in 2015. Figure 2 illustrates though that the growth rates differ by city. The city with the highest growth rate is Hsinchu (1.63%), and the city with the lowest growth rate is Zuoying which is the farthest station from the capital Taipei. This might imply that the needs for HSR is higher in Hsinchu before the opening, though it could also mean that Hsinchu has fast generated additional trips after the HSR opened. In the case of other cities, the THSR ridership is increasing at a relatively higher rate after the opening and the growth rate of cities located between Taipei and Taichung seems to be higher than for cities located in south of Taichung. For more discussion on the general factors influencing Taiwan's HSR demand we refer to Li et al (2015).

In this study we are considering HSR as a new transportation system with which the population might not be familiar with in the beginning. Familiarity here means a general lack of considering HSR in one's choice set which might be due to a wide range of reasons such as lack of information but also issues such as trust in the system. In line with product adoption literature we consider that factors related to information spread through social interaction are important to identify how quickly people adopt to HSR.

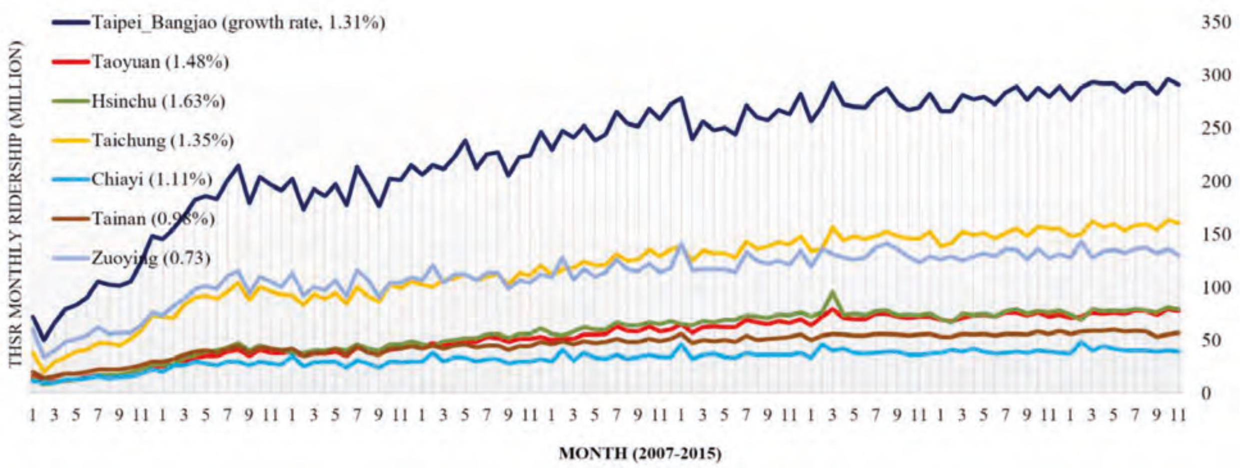

Fig. 2 THSR monthly ridership and averaged growth rate by city

2. Literature Review

The effect of social interaction on decision making has been receiving significant attention. Hartmann et al. (2008) implied that social interactions occur when individuals affect others' choices directly. They suggested that word-of-mouth (WOM) could be considered a key element in social interaction. This is arising through inter-related outcomes which are the factor to represent WOM. Further they noted that WOM is endogenously chosen by individuals, and hence viewed as an action, rather than a characteristic. Park and Chung (2006) also noted that general phenomenon as to how consumer information is spreading through various networks can be referred to as WOM. It has been confirmed through various previous studies that consumers' satisfaction, evaluation, compliments, and complaints related to new product/technology purchasing or using have an effect on other users' choice behaviour and attitudes. Including the effects of mass media and advertisements, Hong and Lee (2014) report that about 80% of buyers are influenced by someone's direct referrals when making decisions.

Numerous models having been developed to assess the role of WOM in the diffusion process (Dodson and Muller, 1978; Mahajan et al., 1990; Mazzarol, 2011). This was first noted by Brooks (1957) as the influence on consumer purchase decisions and the role of opinion leaders in purchasing behavior. Engle et al. (1969) described early adopter of new product and service usually provide positive WOM and this is used to be a combination of media. Therefore a positive relationship between WOM and advertising has been established in marketing literatures according to Day (1971) and Lampert and Rosenberg (1975). Mazzarol (2011) described that the diffusion of innovation is a social process in which interpersonal communication plays a key role. In some transport studies, this diffusion of innovation has been considered. Costa and Fernandes (2012) identified the diffusion of urban public transport modes i.e. trams and trolleybuses, as well as organization of public transport markets across European cities. Jensen et al. (2016) predicted the potential demand for electric vehicles through combining disaggregate choice models and diffusion models based on the assumption that innovation penetrates the market for new product or technology over time through a diffusion process. Wei et al. (2009) conducted a comparative analysis on the traditional vehicles and EV by the forecast model based on diffusion theory which was developed to identify the market expansion of EV in different fields.

One might expand the application range though further to daily travel behaviour. Abou-Zeid et al. (2013) noted that the “informational mass effects” mentioned by Schmöcker et al. (2014) and the “interaction effect in loose social networks” proposed by Ben-Akiva et al. (2012) are related to WOM. These studies describe the effect of WOM on transport behaviour such as illegal parking, unauthorized crossing, mode choice and attitudes. Belgiawan et al (2016) try to quantify social network effects for mode preferences. Abou-Zeid et al. (2013) discuss further resulting examples of social psychological marketing and public effects for transport management.

Related to the methodology chosen in the following, Parkes et al. (2013) presents an analysis of the recent increase in the number of public bike sharing systems in Europe and North America with the data examined through the lens of diffusion theory. In this study we consider HSR demand under the assumption that the individual usage of high-speed railway might be affected by social interaction. We suggest the results could be the basis to predict the demand patterns of a new railway system in the future as well as to manage HSR sustainably.

3. Methodology and Assumption

Bass’s diffusion theory has been considered as a good starting point for modeling the long-term penetration pattern of new technologies (Jensen et al., 2016; Lilien et al., 2000). Bass (1969) observed that market absorption of new products or technology can be explained through a model with two groups and then suggested the behavioral theory that an innovative product/technology is usually adopted first by a few people, “innovators”, who in turn influence others, “imitators” to adopt it. The innovators can be hailed as a small population group who can adopt new technology as soon as the product is on the market. Then imitators follow by also adopting these slowly after some time until market satisfaction is reached. Generally this leads to an S-shaped curve that describes the diffusion of a new product/technology as shown in Figure 3.

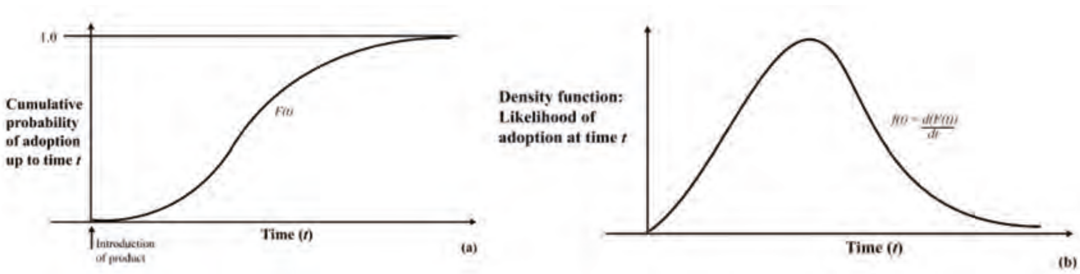

Fig. 3 S-curve (Cumulative curve) (Left) and Density function (Right) in Bass Diffusion Model

The Bass model can also be interpreted by a hazard rate. The interpretation of the hazard is that if it is multiplied by a small time increment it gives the probability that a random purchaser who has not yet made the purchase will do so in the next small time increment (Wang, 2012). The hazard rate indicates "the portion that adopts at t given that they have not yet adopted", thus this formula can be written as follows:

$$h(t) = {f(t)}/{1 - F(t)} \qquad (1)$$

The probability of adopting by those who have not yet adopted is regarded as a linear function of those who have previously adopted it, i.e.

$$f(t)/(1 - F(t)) = p + qF(t)$$

$$h(t) = p + qF(t) = p + q \cdot Y_t / N, \quad t > 0 \qquad (2)$$

Where *h(t)* means the conditional likelihood that HSR users will adopt the innovation at exactly time *t* since introduction, given that the users has not adopted before that time *ft* is the likelihood for any randomly selected individual to adopt at time *t* (Rate at which the probability of adoption is changing at time *t*), and *F(t)* is the market saturation at time *t* (Probability density function of adoption at time *t*). *Yt* is the accumulated number of customers who have already adopted the innovation by time *t* and *N* is a parameter representing the total number of HSR users in the adopting target segment, all of whom will eventually adopt HSR. *p* is the "innovation coefficient"' and *q* is the "imitation coefficient". Bass (1969) calibrated the curve and parameters *p* and *q* for a range of products ranging from lawn moreover to microwaves.

We hypothesize that we can use the product adoption model also to improve estimates regarding HSR demand uptake. It is important to note that our interpretation of *p* and *q* changes. Originally in the model, the interpretation of these coefficientscan be directly associated with "innovators" and "imitators". In the case of HSR travel though it is not a "single purchase" we are interested in but the general increase in using HSR. We therefore re-interpret *p* as "innovative diverted demand" and *q* as "diverted and induced demand" considering features of transport demand in this study as shown in Figure 4. Therefore *p* means here that demand plus some initially diverted demand from other transport modes and *q* could be interpreted as later diverted demand as well as newly induced demand through the existence of HSR.

In the following, considering HSR utilization as demand of new transportation, we confirm the diffusion phenomenon and further the rates of innovation and imitation are calculated on the basis of a diffusion model based on the hypothesis as mentioned in above. We further estimate a model to verify that there would be influences of city heterogeneity on diffusion phenomenon of HSR ridership.

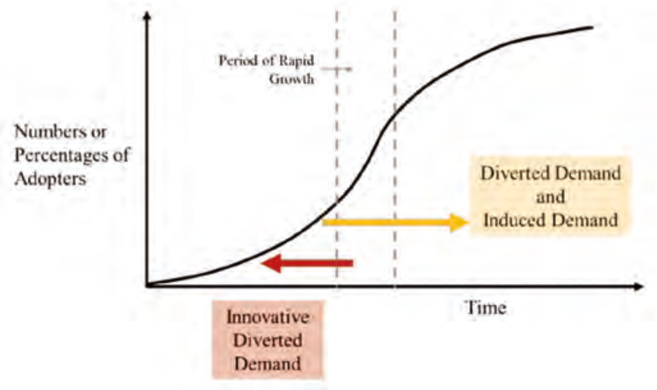

Fig. 4 S-curve representing rate of HSR adoption over time

4. Adoption Ratio and City Heterogeneity

We assumed that diffusion effects are different by year after opening as well as by city. Based on diffusion model, the city-specific annual values of and are obtained as following.

$$y_t = Nf(t) = \left(p + \frac{q}{N}Y_t\right)(N - Y_t)$$
$$= pN + (q-p)Y_t - \frac{q}{N}Y_t^2,\ \ t > 0 \quad (3)$$

Equation (3) could be regarded as quadratic equation Y_t of thus the coefficients could be estimated by a *Least Square Method.* This estimation was carried out by city and year with the results shown in Appendix. All estimates by city and year are significant at 0.01% error level, except for 2007. Table 2 shows the mean value of diffusion rates by city. Here, the diffusion rates in 2007 were not calculated due to small sample size, therefore we assumed that *Adoption Effects* in 2007 is the same as in 2008 for model estimating. Chiayi is showing the highest *p* value followed by Taipei/Banciao and Taichung. Taoyuan has the lowest rate of innovative diverted demand among the cities. For diverted and induced demand, Hsinchu has a high value followed by Taichung and Taoyuan. Zuoying and Tainan, the cities farthest from the capital, show the lowest rates of *q*.

For our focus on expected long-term demand growth, we now suggest the concept of “Adoption Ratio” obtained as the ratio between *p* and *q*:

$$\text{Adoption Ratio} = \frac{\text{Diverted and Induced Demand}}{\text{Innovative Diverted Demand}} = \frac{q}{p}$$

The “Adoption Ratio” shows how strong the latent impact for increasing a long-term demand is compared to the initial demand growth during the first few months since HSR operation starts. The higher the ratio the more we can expect a continuous, fairly steady growth. Therefore a high ”Adoption Ratio” means strong *Adoption Effects.*

As shown in Table 2, Taoyuan and Hsinchu both show high adoption ratio. We note that both cities can be classified as comparatively small cities and both are located close to the capital. Also when we see Figure 5, we observe that roughly two city groups are divided that lie above or below the curve for Taipei/Banqiao. Each group has a strong *Adoption Effects* the order of city size, Small, Small and Middle i.e. Based on the line of Taipei/Banqiao(L), Taoyan(S) and Hinchu(S) as well as Taichung(M) are belong to the group above. And the group below include Tainan(S), Chiayi(S) and Zuoying(M). From these observations we hypothesize that the city characteristic elements such as size and distance from Taipei, the capital and economic centre of Taiwan, affect *Adoption Effects*. Therefore, in the next section we analyse what factors, which reflect city heterogeneity, determine the level of *Adoption Effects*.

Table 2. Result of diffusion rates by city

Nº	City	Averaged Rate of Innovative Diverted Demand ($\bar{p}$)	Averaged Rate of Diverted and Induced Demand ($\bar{q}$)	Averaged Adoption Ratio ($\bar{p}/\bar{q}$)
1	Taipei/ Banqiao	0.0005815	0.043152	108.4584
2	Taoyuan	0.0004741	0.047560	155.2722
3	Hsinchu	0.0005012	0.052259	152.0790
4	Taichung	0.0005663	0.044495	124.1517
5	Chiayi	0.0006310	0.042222	98.0602
6	Tainan	0.0005522	0.038128	101.3215
7	Zuoying	0.0005516	0.036622	91.5447

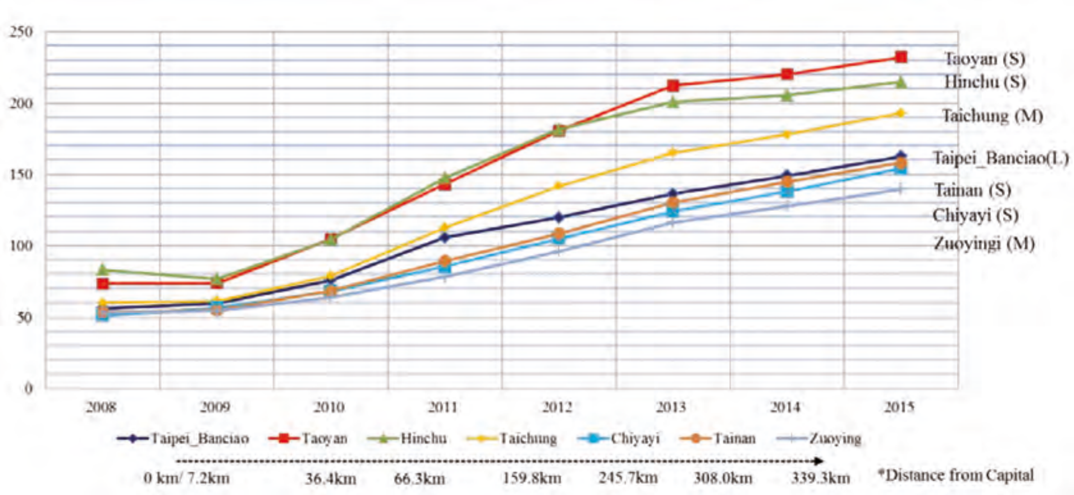

Fig. 5 Plot of Adoption Ratio by City (S: small sixe city, M:middle size city, L:Large size city)

5. Factors affecting on HSR Adoption Effects

5.1 Model Structure and Factors

Our data set consist of the panel data set $\mathbf{X}_k$ with observations x_{itk}. i is the city index and t denotes the year. Therefore this study uses a fixed effect (FE) one-way error component model. We then associate the *Adoption Effects* y_{it} by city and year using the following model;

$$y_{it} = \mu + \boldsymbol{x}_{it}\boldsymbol{\beta} + e_{it}, \quad i = 1,2\cdots,7, \quad t = 0,1,\cdots,8 \tag{4}$$

Here μ is a scalar representing the intercept, β is κ a 1 vector. Thus note that χ_{it} is fixed over i. The error component e_{it} is decomposed as below;

$$e_{it} = \alpha_t + u_{it} \tag{5}$$

Where α_{it} denotes the unobservable year specific effect and U_{it} denotes the remaining disturbance. Combining Eqs.(3) and (4), we have a region-fixed effect one-way error component regression model

$$y_{it} = \mu + x_{it}\beta + \alpha_t + u_{it} \tag{6}$$

Considering the data for all the samples, this model may be written as

$$\begin{pmatrix} y_{\sim 1} \\ \vdots \\ y_{\sim i} \end{pmatrix} = \begin{pmatrix} \mu 1_t \\ \vdots \\ \mu 1_t \end{pmatrix} + \begin{pmatrix} X \\ \vdots \\ X \end{pmatrix} \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_k \end{bmatrix} + \begin{bmatrix} 1_t & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1_i \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \vdots \\ \alpha_t \end{bmatrix} + \begin{pmatrix} u_{\sim 1} \\ \vdots \\ u_{\sim i} \end{pmatrix}$$

$$\rightarrow \mathrm{y} = \mu(1_i \times 1_t) + X\beta + Z\alpha + u, \tag{7}$$

Where

$$y_{\sim 1} = (y_{i1}, y_{i2}, \cdots y_{it}), u_{\sim 1} = (u_{i1}, u_{i2}, \cdots u_{it}), \mathrm{Z} = I_t \times 1_i$$

is the matrix of dummy variables associated with α. *X* represents the matrix of time-varying regressors on *t* samples for i^{th} repeat and is of the form

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1k} \\ \vdots & \ddots & \vdots \\ x_{t1} & \cdots & x_{tk} \end{bmatrix} \tag{8}$$

Here the *X* matrix is same for all the repeats. Since α_t are assumed to be fixed year specific effects with remainder disturbance stochastic, this fixed effects model is an appropriate specification if we are focusing on a set of cities where THSR stations located.

Since we also hypothesized *Adoption Effects* of HSR ridership is quite influenced by status of social and economic situation by time as well as city heterogeneity, the estimated model considers six independent variables i.e. X_{1it} , distance from capital of Taipei to city *i* at year *t* (km); X_{2i}, city size of city *i* (Large:3, Medium:2, Small:1); X_{3it}, distance from city center to HSR station(km) of city *i* at year *t*; X_{4it}, Total length of road network (km) of city *i* at year *t* ; X_{5it}, Aging population ratio of city *i* at year *t* (%); X_{6it}, Business scale (Total amount of sales (Taiwan dollar)/ Number of enterprise) of city *i* at year *t*.

5.2 Modelling Results

Table 3 shows the results of the model estimation which considers *Adoption Effects* as dependent variable and the model is found to be statistically significant. Moreover it is shown that all considered six independent variables are statistically significant at 95% confidence level.

A positive (negative) coefficient of the independent variable represents a greater probability for larger (smaller) *Adoption Effects*. Only the explanatory variable of business scale has a positive coefficient and this means that as the economy grows, the size of *Adoption Effects* also increases. In line with the results in previous section, the farther from Taipei and the larger the city, the lower the *Adoption Effect* tends to be. In addition, it is verified that cities with a good accessibility to HSR station close to city center have a strong *Adoption Effects*. Instead, the higher the supply of road network, the lower the value of Adoption Effects. This illustrates that cars are the competitive transport mode of high-speed railway in Taiwan due to country size. Among the explanatory variables, the variable which has the greatest influence on *Adoption Effects* is aging. The proportion of the elderly population has a negative impact on the level of *Adoption Effects*.

Table 3. Model estimation results

Variables		Coef.	Std. Err.	Z	p-value
Dependent var.	y: Log(Adoption Effect)				
City scale characteristics var.	x_1: Log(Distance from Taipei)	-0.068	0.007	-9.31	0.000
	x_2: City size	-0.065	0.021	-3.06	0.002
HSR station access var.	x_3: Log(Station location)	-0.225	0.016	-13.92	0.000
	x_4: Log(Road length)	-0.067	0.032	-2.13	0.033
Socioeconomic var.	x_5: Log(Aging ratio)	-0.737	0.058	-12.65	0.000
	x_6: Log(Business scale)	0.089	0.023	3.96	0.000
Year dummy var.	α_1: 2008	0.016	0.026	0.62	0.538
	α_2:2009	0.062	0.026	2.37	0.018
	α_3:2010	0.299	0.026	11.41	0.000
	α_4:2011	0.605	0.027	22.77	0.000
	α_5:2012	0.831	0.027	30.67	0.000
	α_6:2013	1.015	0.028	36.45	0.000
	α_7:2014	1.118	0.029	38.67	0.000
	α_8:2015	1.205	0.029	41.87	0.000
Constant		2.611	0.288	41.87	0.000
Random variables	sd(Residual)	0.049	0.004	-	-
Log likelihood		101.202			
Wald chi square		5627.40			
Prob>Chi2		0.000			

In addition, the estimated dummy variable's coefficients show that temporal changes after THSR opening also influenced on *Adoption Effects* positively. Figure 6 could be interpreted that *Adoption Effects* increases gradually as time goes. However, this is not likely to last, as according to diffusion theory, at some point we would expect a decrease. This result also supports our hypothesis for defining of *Adoption Effects* as the latent impact for increasing a long-term demand since HSR operation starts. When we see the changes in exponential function[1] of dummy coefficients, there was a sharp increase in 2011 (after 4 years from opening). This remains at similar levels until 2013, but decreases from 2014. This, in turn, implies that the effect of temporal changes on *Adoption Effects* can be weaker over time. Therefore, in order to maintain a high level of *Adoption Effects* for securing long term sustainable HSR ridership as well as a high level of continuous demand growth, it may be necessary to pursue additional policy strategies considering the factors which are considered in our estimated model.

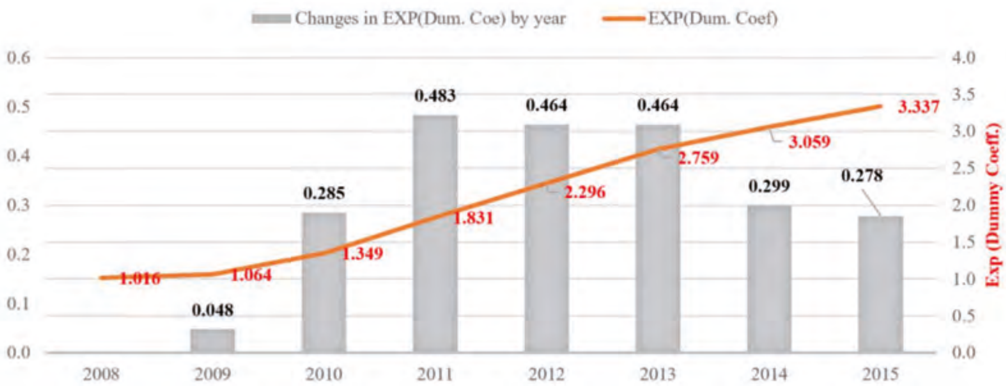

Fig. 6 Impacts of temporal change on Adoption Effects

1 *In the estimated model, the dependent variable is Log(Adoption Effects).*

6. Discussion and Conclusions

Sustaining demand growth especially for new introduced transportation system has been becoming an important concern and issue over the world. HSR has been suggested as one alternative for acquiring sustainability in mobility to car and air travel of the decade. Moreover, there is no doubt that HSR can promote economic development. In this study we investigated how to promote HSR sustainably focusing on its long-term demand. Our major findings are detailed as following.

First of all, with adopting a diffusion modeling in marketing study fields, we identified that there is diffusion effects on HSR demand and this was different by city. Therefore, it is suggested that new transport systems could be compared to other new products or technologies and their market penetration patterns. Secondly, we calculated the impacts of “innovative diverted demand” and “diverted and induced demand” on HSR demand by city. It was verified that degree of impacts differed by city. Therefore, one of main conclusion of this paper can be that the demand growth pattern might be significantly related to urban regional characteristics. By estimating a fixed effect (FE) one-way error component model, it was demonstrated that city heterogeneity such as social, economic and geographical characteristics influence *Adoption Effect* which explain long-term demand and are a key factor to promote sustainable transport. Therefore, in order to operate the sustainable HSR system, it is necessary to understand the characteristics of each city and to establish policy measures to reflect them. Here, by estimated model, it was presented that accessibility to the station could be an important element to raise *Adoption Effects*. Our study implies that an accessible station is not only likely to generate a large initial demand but also leads to continuous increase of demand. This we suggest is an important finding. From this result, it could be implied that it is important to improve the accessibility and psychological distance to HSR use which citizens have, although geographical and social factors should be taken into consideration when determining the station location. Therefore, some policy approaches which forward reducing public’s psychological distance and increasing accessibility to HSR station should be urged in order to secure to long-term HSR demand.

In addition, we also find that an increase of elderly population would influence on securing long-term demand of HSR negatively. This finding could be interpreted as “Since the elderly may not be able to make business trips, the increase of elderly population rate can have a negative impact on long term demand growth for high-speed railways”. Chen and Haynes (2015) noted that HSR has been increasingly attractive mode for business traveler who have a high value of time than other travelers. Our analysis suggests that it is difficult to “gradually persuade” and to create continuous demand growth among an older, non-working, population. Especially among an ageing population that dislikes public transport for various reasons such as fears of safety (Schlag, 2008; Karthaus and Falkenstei, 2016) it might hence be difficult to create a large demand if the initial acceptance has not been large. Further research on confirming this is though needed.

More generally, we suggest one implications of our findings is that it illustrates that not only hard measures such as fare adjustment and network expansions are needed to secure long term. We might postulate that the coefficient p is also related to advertising effect and q presents word-of-mouth effect (Mahajan et al., 1995). Therefore, the study results can be interpreted as showing that marketing strategies to transportation service is possible for sustainable operation of the transportation system. Indeed, according to Kim (2008), various marketing strategies to KTX (Korea Train eXpress) have been implemented over the past several years in order to successfully enter the high-speed railway transportation market. To support this conclusion further, it would be important though to understand if the *p* and *q* differences among the cities can be also explained with attitudinal factors and/ or regional specific HSR promotion efforts.

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8. Appendix

Index and city		1	2	3	4	5	6	7
		Taipei/ Banqiao	Taoyuan	Hsinchu	Taichung	Chiayi	Tainan	Zuoying
Rate of Innovative Diverted Demand (p)	2008	0.001906	0.001496	0.001619	0.001922	0.002054	0.001661	0.001497
	2009	0.001233	0.001085	0.001122	0.001241	0.001301	0.00123	0.001218
	2010	0.000586	0.000448	0.00046	0.000563	0.000682	0.000616	0.000692
	2011	0.000286	0.00025	0.000244	0.000271	0.000371	0.000325	0.000384
	2012	0.000222	0.000167	0.00017	0.000179	0.000236	0.000216	0.000234
	2013	0.000169	0.000127	0.000144	0.000137	0.000167	0.000149	0.000156
	2014	0.000137	0.000117	0.000134	0.000118	0.000133	0.00012	0.000128
	2015	0.000112	0.000103	0.000117	9.93E-05	0.000105	0.0001	0.000105
Rate of Diverted and Induced demand (q)	2008	0.10753	0.110378	0.135075	0.115986	0.105102	0.089316	0.080044
	2009	0.074225	0.080327	0.086243	0.076407	0.074112	0.068017	0.066531
	2010	0.04464	0.046999	0.048286	0.044735	0.046684	0.042229	0.044421
	2011	0.03035	0.035767	0.036039	0.030603	0.031864	0.029107	0.030151
	2012	0.026669	0.030134	0.030834	0.025466	0.024793	0.02348	0.022589
	2013	0.023066	0.026982	0.028857	0.02259	0.020742	0.019501	0.01821
	2014	0.020509	0.025881	0.027595	0.020982	0.018336	0.017454	0.01636
	2015	0.018228	0.024014	0.025141	0.01919	0.016142	0.015922	0.014669
Adoption rate ($\frac{q}{p}$)	2008	56.41449	73.78651	83.45631	60.33129	51.15934	53.78259	53.47707
	2009	60.2088	74.00546	76.85228	61.58675	56.9441	55.28747	54.63313
	2010	76.11386	105.0194	104.8553	79.43253	68.49952	68.53677	64.22159
	2011	105.9876	143.3079	147.7062	112.9444	85.88177	89.64759	78.53006
	2012	119.9717	180.8442	181.8714	142.0875	105.1915	108.7815	96.53571
	2013	136.5497	212.4424	201.004	165.4063	124.1764	130.7404	116.7347
	2014	149.4149	220.4313	205.7258	178.1118	138.2544	145.2074	128.0983
	2015	163.0062	232.3404	215.1608	193.3128	154.3745	158.588	140.1268

Territorial and enviromental impacts

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Perspectives of territorial development linked to the future high-performance rail lines in Eastern Andalusia.

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Abstract

According to territorial and infrastructural planning in Andalusia, as well as to the proposed definition for the Mediterranean Corridor, this paper aims to explore, as its title indicates, the prospects for territorial development linked to the future high-performance rail lines in Eastern Andalusia. This is within the general objective of improving the territorial integration of future railway infrastructures in the planning stages, in the network of cities in Eastern Andalusia in order to take advantage of all its local potential and, in short, to increase its territorial capital.

Thus, in relation to other experiences and to the existing socio-economic reality, the processes of contraction of space are determined that will promote the new networks and the forecast of their territorial incidence. Future strategies are proposed around the new railroads for the proper use and stimulation of local potentials, the minimization of the tunnel effect and its polarizing consequences on the territory. In addition we consider the establishment of proposals for the optimization of the positive territorial impact of future rail corridors, with the proposal of spaces of logistic opportunities, to establish actions for intermodal coordination and with future territorial projects, etc.

Keywords: Territorial development, High Speed Rail, Eastern Andalusia.

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1. Introduction

The traditional isolation of Eastern Andalusia Giving the topographical difficulties of this area they have produced the traditional isolation of Eastern Andalusia with the rest of the country. They have traditionally defined the natural existing corridors which have also established a clear distribution of the territorial crossroads as can be appreciated in a first geographical approximation. See Figure 1.

Although the whole region has an equilibrated and integrated in the rank-size model urban system, and all the provincial capitals have a certain metropolitan structure, as it is presented in the Territorial Regional Spatial Plan (COPT, 2006). See Figure 2.

This paper will consider the rail lines in Eastern Andalusia which comprises the four eastern provinces: Almeria, Granada, Jaen and Malaga. To complete and to give coherence to our study the cities of Algeciras (120,600 Hab.), in the province of Cadiz, and Cordoba (328,300 Hab.) will also be considered. The line between Cordoba and Malaga (569,000 Hab.) could be considered the limit between Western and Eastern Andalusia. Within these provinces their capital cities and their main populations, their connections to the regional and national capitals –Seville (690,600 Hab.) and Madrid (3,166,000 Hab.)- and the eastern connection to Murcia (441,000 Hab.) will be considered.

Despite the traditional underdevelopment situation of the rail lines in Eastern Andalusia, the current scenarios and projects of the new high-performance rail lines allow new perspectives of future territorial development linked to them to be drafted. The former, present and future situations of the rail lines will be considered to evaluate their territorial effects.

Regarding these territorial effects it is necessary to pay attention to the multiple scales to be considered that have been tested in a previous work over this territory (Huertas, 2013), and to the diverse territorial dimensions. However in this paper, given the limitation in extension, they will be focused on the spatial implications of the inter-urban relations at a sub-regional scale.

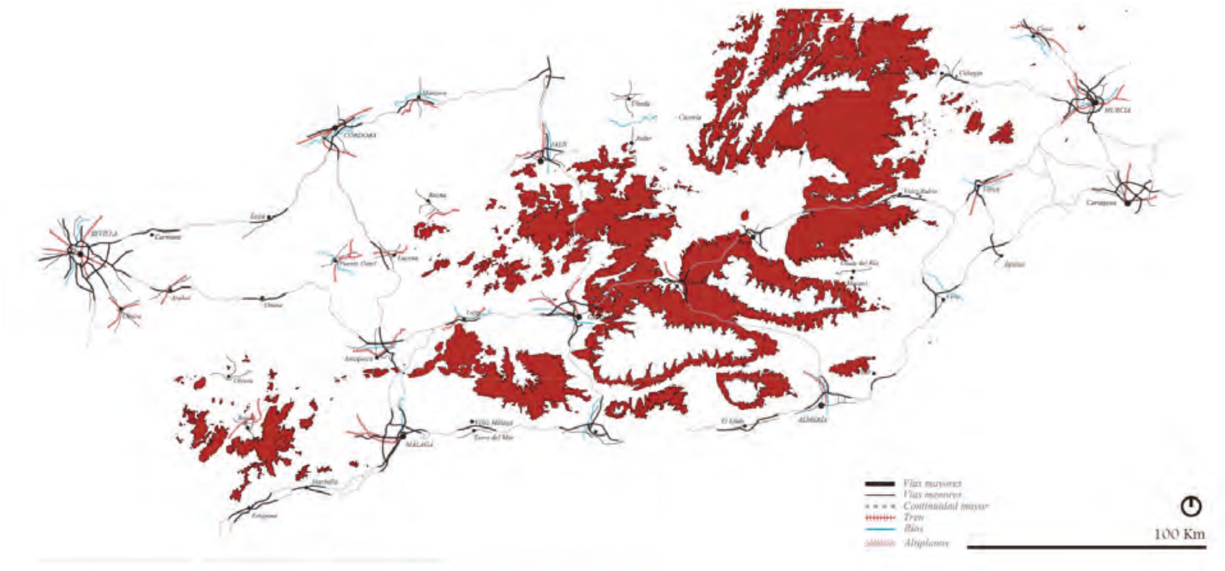

Figure 1. Territorial corridors and crossroads in Eastern Andalusia. Source: Huertas (2013).

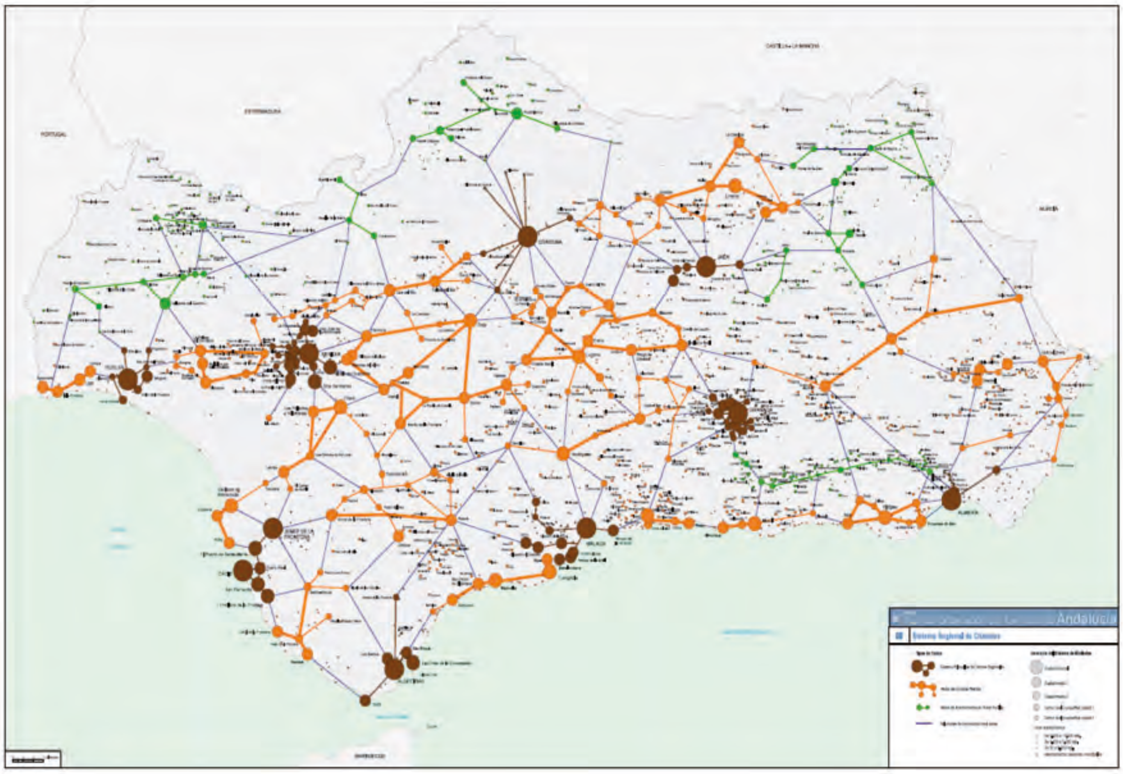

Figure 2. Urban System of Andalusia in the Territorial Regional Spatial Plan. Source: COPT (2006).

2. Former and present rail line situations In Eastern Andalusia.

The situation of the rail lines in Eastern Andalusia during the last decades of the past century was marked by its underdevelopment and an obsolescence process that had its most severe example with the closing and dismantling of the line between Guadix (18,800 Hab.) and Almendricos -towards Lorca and Murcia- in the nineties, which lost the unique direct eastern rail connection of the region. Since then it was necessary to take a big detour from Guadix to the station of Alcazar de San Juan at the same latitude as Valencia and continue to Albacete, Valencia or Barcelona. Then Almeria (193,000 Hab.) had a unique inland connection to the national capital or the east by a conventional single track and non-electrified line through Guadix – Moreda – Linares-Baeza and Alcazar de San Juan.

In contrast to this loss, in parallel the first High Speed Rail (HSR) line in Spain in western Andalusia connecting Madrid and Seville was being developed and opened in 1992. It started the process of development of new HSR lines following other international experiences, which have been developing with the standard international gauge (1435 mm) different from the conventional or Iberian gauge (1668 mm), and with these two different gauges co-existing in the rail network, the HSR for passenger traffic and the conventional for mixed passenger and freight traffic (Ureña, 2012).

During the first years of the last decade, the main actions in this area were the development and later opening of the HSR between Cordoba and Antequera (41,100

Hab.) (in 2006) and between Antequera and Malaga (in 2007), connecting these cities with the Madrid-Seville line, and reducing by more than an hour the time between Cordoba and Malaga. This new HSR line changed the orientation of the passenger services of the eastern cities of Granada (235,000 Hab.) and Jaen (114,700 Hab.) to Madrid, which since then use a mixed HSR-conventional long distance service, instead their conventional northern lines in their natural communication towards the nation capital. However the underdevelopment situation of the Eastern Andalusia's rail network was maintained, without direct train services between the neighbouring cities of Jaen and Granada, nor potential rail metropolitan services in this city (García, 2012). Thus the line between Cordoba and Malaga could be considered the limit between Western and Eastern Andalusia, since, as can be seen in the Figure 3 showing the existing rail lines and their stations -most of them without rail services-, there is a considerable gap in the current rail network development between the two areas of the region.

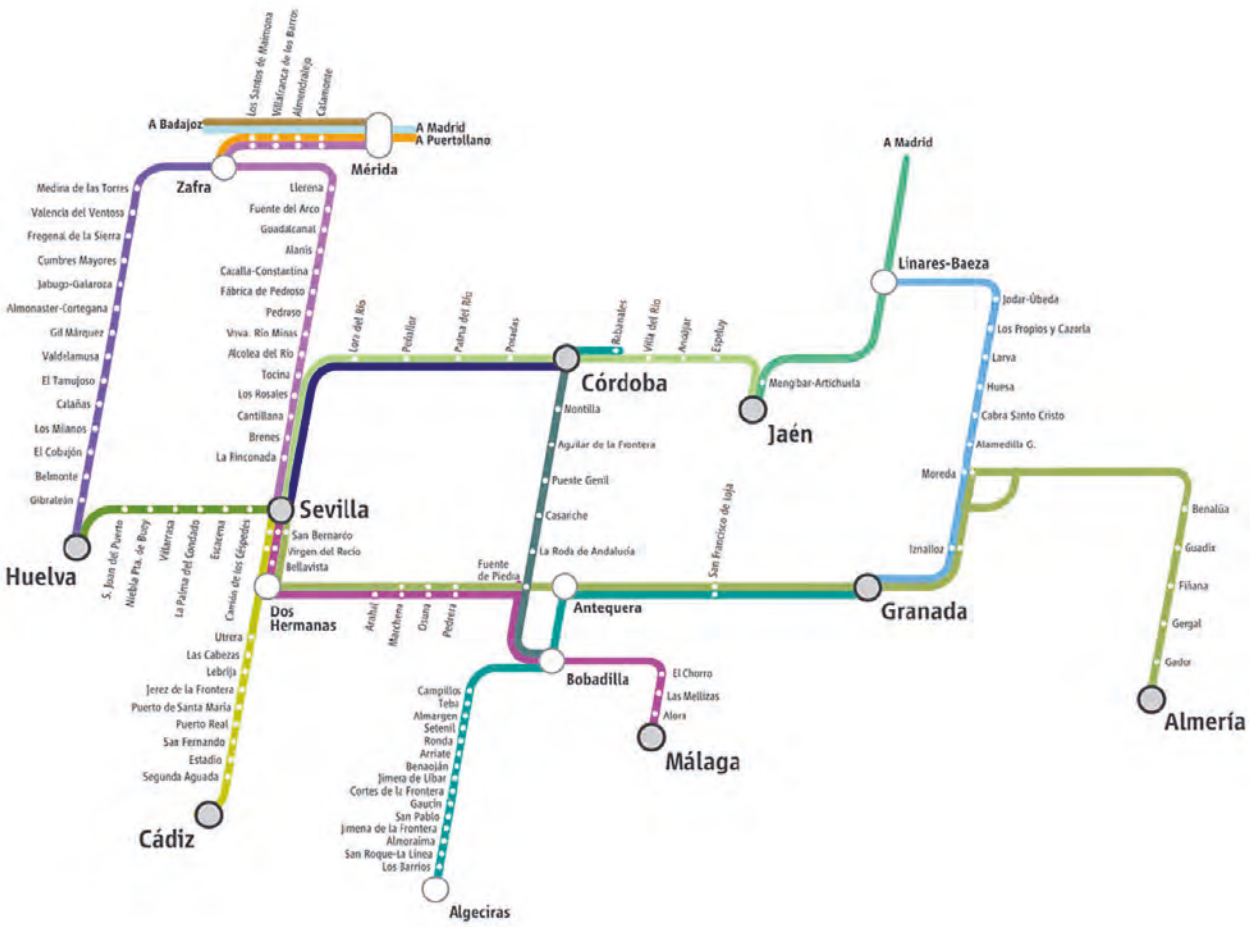

Figure 3. Present rail lines and stations in Andalusia. Source: RENFE

The stations´ location also limits its functionality and its relationship with the cities. In the case of the provincial capital cities they are adequately central, but in the case of the other stations they are distant from the city centres, as the lines were built in most of the cases for colonial reasons. As for example the Linares-Baeza station is 7.4 Km distant from Linares (58,800 Hab.),and the station of Moreda has a very weak relationship with the little village of the same name (590 Hab.) because it is 2.1 Km distant. Nevertheless in the current HSR development the railoriented logic is also imposed, as the location of the station of Antequera-Santa Ana seeks only an adequate rail connection but it is 20 Km distant from the city and isolated in the middle of the country only linked by a small road access. However they are now rebuilding Antequera’s station at the edge of the city for the renewed rail line towards Granada.

With respect to the ports-rail links in Eastern Andalusia the inexistent and weak connections that were recognized decades ago are maintained (Gómez y Grindlay, 2001). Thus Almeria’sport is still without a rail link since the eighties and studies are being made as to whether this should be underground in the frame of a railway integration protocol in the city. The port of Motril had a cable connection which disappeared in the sixties, but historically lacks a rail link to the rail network. The port of Malaga located alongside the city centre has a weak rail link limited by various level crossings over the main urban roads. Recently attempts have been made to reuse the tracks for the transport of clinker towards Antequera during night hours but this has not been successful. The port of Algeciras has the most freight movement in Spain and has rail links at the most important docks, but has a limited rail access from the nineteenth century line Bobadilla-Algeciras, which passes by the city of Ronda (34,400 Hab.).

Therefore, at the beginning of the present decade the situation of the Eastern Andalusia rail network, excepting the indicated two new HSR lines, was a conventional single track and nonelectrified set of lines with limited speed in many sections. In addition for freight transport one of the most important limitations is the train length restriction of 500 m, due to the limited passing tracks when they should be at least of 750 m or longer to be competitive.

The next table demonstrates this severely underdeveloped rail network situation of Eastern Andalusia at the beginning of the present decade.

Table 1. Rail network situation of Eastern Andalusia in 2010 (HSR lines in bold):

LINE	LENGH (Km)	TRACK	GAUGE	ELECTRIFIED	MAX. SPEED (Km/h)	SERVICES
Algeciras - Bobadilla	176	Single	Iberian	Non	110 (limited)	Mixed Pass. & freight
Almeria - Murcia	Non-existing	-	-		-	-
Almeria - Moreda - (towards Granada or Madrid)	124	Single	Iberian	Partially	110 (limited)	Mixed Pass. & freight
Antequera - Malaga	55	Double	International	Yes	350	Passenger
Bobadilla - Antequera - Granada	131	Single	Iberian	Non	140 (limited)	Mixed Pass. & freight
Bobadilla - Malaga	80	Single	Iberian	Yes	160 (limited)	Mixed Pass. & freight
Cordoba - Antequera	100	Double	International	Yes	350	Passenger
Cordoba - Bobadilla	129	Single	Iberian	Yes	140 (limited)	Mixed Pass. & freight
Cordoba - Espeluy - Jaen	135	Single	Iberian	Yes	140 (limited)	Mixed Pass. & freight
Granada - Moreda	57	Single	Iberian	Non	140 (limited)	Mixed Pass. & freight
Guadix - Almendricos (towards Lorca -Murcia)	Dismantled	-	-	-	-	-
Jaen - Espeluy - Linares-Baeza - (towards Madrid)	61	Single	Iberian	Yes	140 (limited)	Mixed Pass. & freight
Linares-Baeza - Moreda - (towards Almeria)	126	Single	Iberian	Non	140 (limited)	Mixed Pass. & freight

Source: ADIF

According to this situation the connection times between Andalusian capitals has been excessively long, and there is no connection between some of them, for example Jaen-Granada or Almeria-Algeciras/Cordoba/Jaen/Malaga, as can be seen in the next table 2. As an example, the previous mixed services existing between Granada and Madrid took 4h. 35min. and the connection with the regional capital were 3h. 22 min between Granada and Seville and between Almeria and Seville was prolonged for more than 5 hours.

Table 2. Present rail travel time between Andalusian main cities and Madrid (hours:minutes).

	Algeciras	Almeria	Antequera	Cordoba	Granada	Jaen	Malaga	Madrid	Seville
Algeciras	-	-	2:54	3:14	4:20	-	4:00	5:35	4:31
Almeria		-	3:40	-	2:23	-	-	6:45	5:45
Antequera			-	0:37	1:11	-	0:21	2:16	1:29
Cordoba				-	2:30	1:33	1:00	1:44	0:45
Granada					-	-	2:31	4:35	3:22
Jaén						-	3:19	3:53	3:00
Málaga							-	2:20	1:55
Madrid								-	2:20
Seville									-

Source: RENFE

2.1 Freight rail transport and logistic situation

As it was indicated in a study about freight transport in the Mediterranean Corridor with traffic data of 2007, the rail transport mode is extremely weak in this southern area (Cadiz, Malaga and Granada provinces) with a participation only of 1.5%, against the 4% in the eastern area (from Murcia to Gerona) (INECO, 2011), and has remained thus over the last decades (Gómez and Grindlay, 2001). This is a consequence of the lesser development of the rail corridor in this area and the lesser potential volume of traffic, both due to the reduced distances because of reduced international traffic and due to its nature, with few minerals, cars or container flows. However a potential growth in the intermodal transport, and international cars and agriculture products traffics (INECO, 2011) was considered. However the main rail nodes of the area, Bobadilla and Moreda, have a limited logistic potential as they are located far from the high capacity roads and developed areas.

Since the previous regional infrastructures plan with horizon 2013, the regional administration has promoted the Logistic Andalusian Network with 11 main nodes, 7 with maritime connection and 10 with rail connection, and latterly they have been incremented to 13, linked to the main transport axes and consume/production areas (CFV, 2016). However in their development a great disparity east-west in Andalusia can be observed, as almost all the logistic areas of the western area have been developed already and the logistic areas of the eastern area are being developed, as can be seen in the next tables 3 and 4, and in the figure 4.

Table 3. Situation of the logistic areas of the Logistic Andalusian Network

Logistic Area	nº	Situation
Seville, Malaga, Cordoba and Algeciras Bay	4	On service
Antequera (Malaga), Nijar (Almmeria), Majarabique (Sevilla), Bailen (Jaen) and enlargment of Malaga	5	In phase of advanced planning
Andujar and Linares (Jaen), Motril (Granada), Huelva, and Granada.	4	In phase of study or elaboration of planning documents
TOTAL	13	

Source: CFV (2016)

Table 4. Gross surfaces of the logistic areas of Andalusia and their situation.

PROVINCE	LOGISTIC AREA	GROSS SURFACES (Ha.)						
		ON SERVICE	%	IN DEVELOPMENT	%	IN PLANNING	%	TOTAL PROVINCE
Almería	ZAL Almería					200		300
	N.L. Níjar			100				
Cádiz	Z.L. Las Aletas			159				452
	ZAL Bahía de Algeciras (4 Sectores)	86		145		62		
Cordoba	P.L. Córdoba	23				13		36
Huelva	C.L. Huelva					18		18
Granada	C.L. Granada					120		150
	C.L. Motril					30		
Jaen	Puerto Seco de Linares			99				210
	C.L. Bailén					32		
	A.L. Andújar					79		
Málaga	CTM Málaga Trávenez	27						392
	CTM M. Buenavista			37				
	Puerto Seco Antequera			328				
Sevilla	CTM La Negrilla	25.5						232.5
	C.L. Majarabique			207				
TOTAL		161.5	9	1,075	60	554	31	1,790.5

Source: Author based on data from CFV.

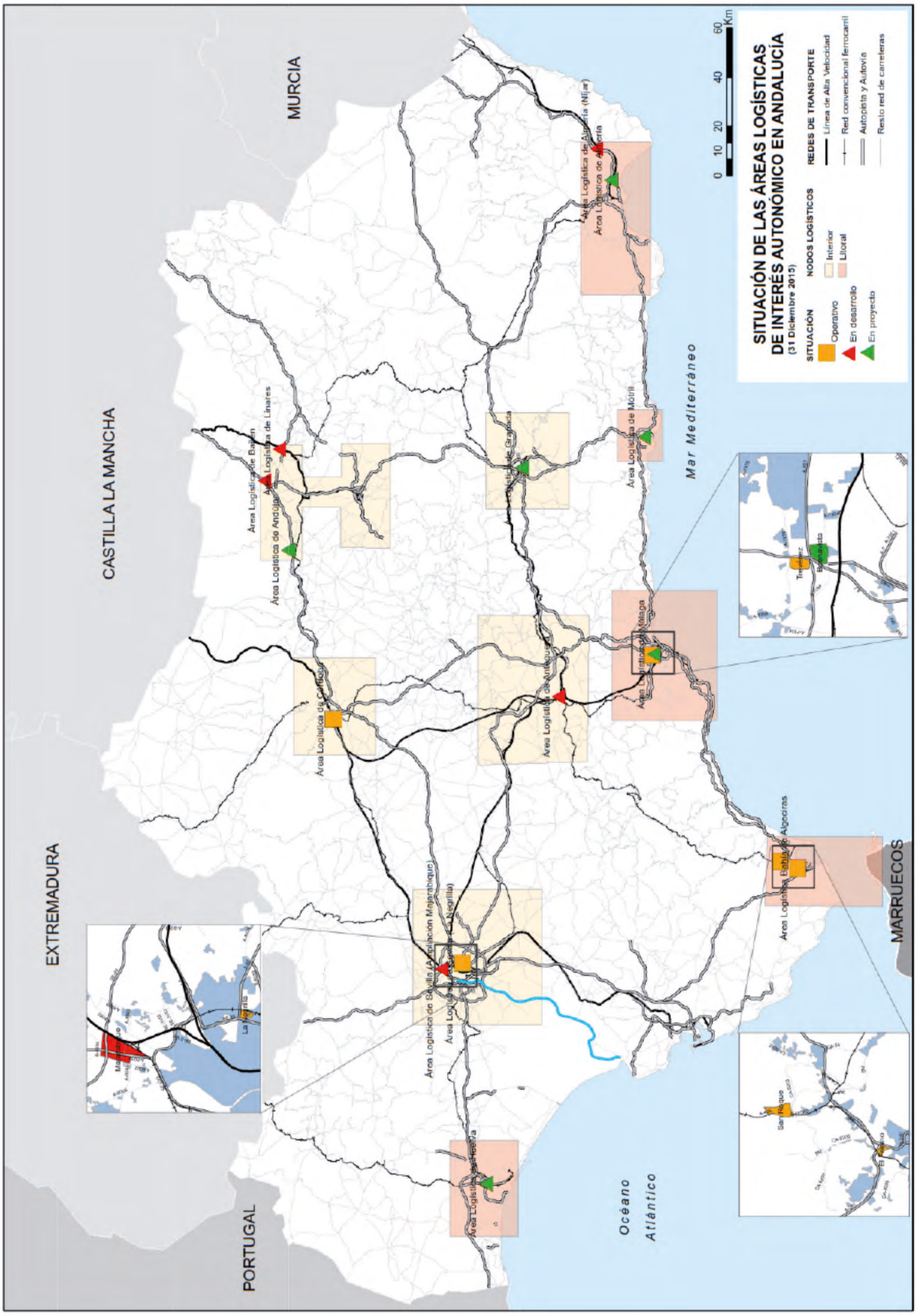

Figure 4. Surfaces of the logistic areas of the Logistic Andalusian Network. Source: CFV (2016)

3. Present rail deveolpment and future scenarios

The current rail development in Spain is guided by the infrastructure politics established in the last national infrastructure plans. They will set out the future scenarios of the rail system. The actions to transform this system in the central element to articulate the intermodal transport services, for both passenger and freight were determined as a priority (Ministerio de Fomento, 2005).

The present national infrastructure plan, the Housing and Transport Infrastructure Plan (PITVI) 2012-2024, establishes a long term complete objective network, as a planning final image for the national HSR network. Figure 5 (Ministerio de Fomento, 2015). It constitutes an extraordinary and non-realistic picture of a complete set of HSR lines all over the country. In Andalusia these lines were also previously considered in the regional territorial plan (COPT, 2006) (Figure 6) and later appeared as high-performance rail lines –as they will have less speed than the first HSR developed- and studied corridors in the regional infrastructure plan and its last revision (CFV, 2016). These include the eastern lost connection of the transversal rail axis from Granada to Lorca (Murcia), and the difficult connections from Granada to the coast (the city-port of Motril), and the coastal rail line connecting from Almeria to Malaga and Algeciras.Therefore the revised regional infrastructure plan (PISTA 2020) include all these proposed actions of the national plan as studied corridors: Almeria - Malaga-Algeciras; Madrid – Jaen; Cordoba – Jaen; Granada – Motril; Granada – Lorca (CFV, 2016), and they could be considered for a more distant scenario.

Figure 5. Spanish High Speed Rail Network expected in the Transport Infrastructure Plan.

Source: Ministerio de Fomento (2015)

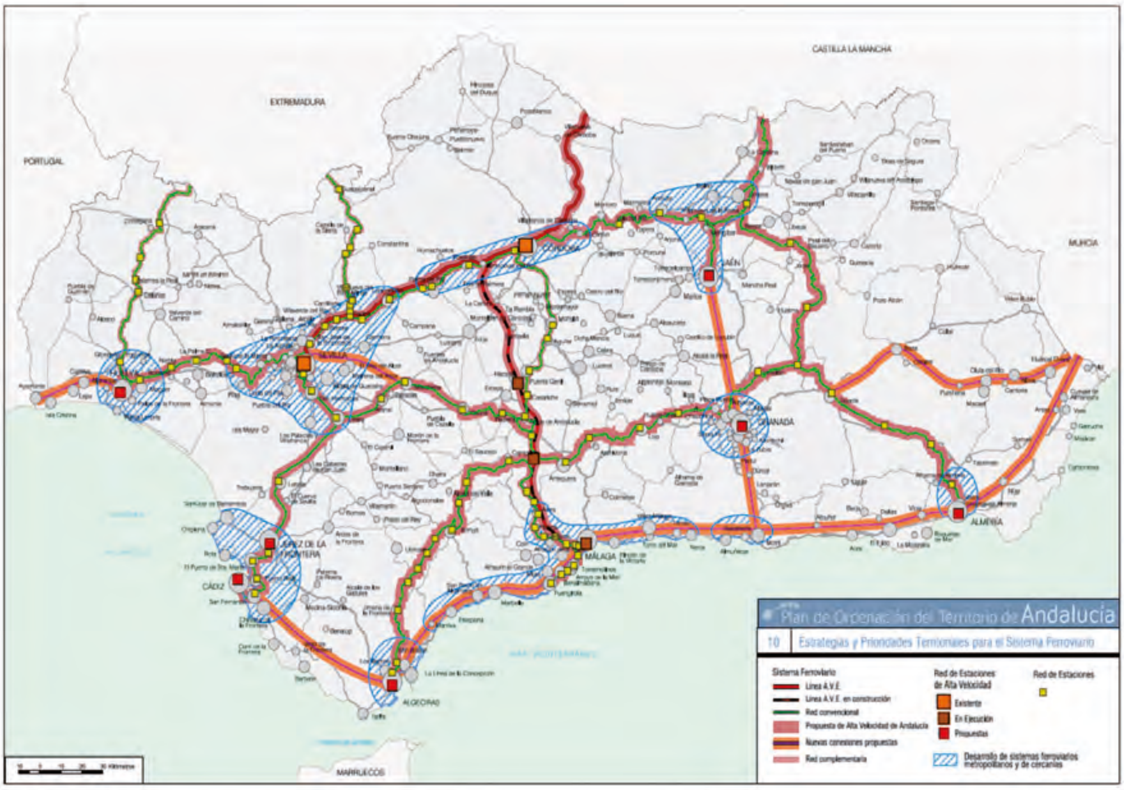

Figure 6. High Speed Rail lines proposed in the Regional Territorial Plan of Andalusia.

Source: COPT (2006)

However this ambitious scenario is going to be framed by the Trans-European Network Transport (TEN-T), established in the nineties but deeply revised and last defined in 2013. In this area the network is constituted by the European Mediterranean Corridor in its two lines: one inland, Algeciras – Bobadilla –Madrid – Zaragoza – Tarragona, and another with two sections, first inland Sevilla – Bobadilla – Almeria, then coastal to Murcia and Tarragona – Barcelona to connect with the French border at Portbou (Ministerio de Fomento, 2015). The natural course of the second line of the Corridor should have been all littoral from Almeria to Algeciras, according to the proposed connections of the national and regional infrastructure plans. However the topographical difficulties of the Andalusian Mediterranean coast imposed the longer inland route (more than 200Km) of the Corridor. See Figure 1.

The actions planned for this transport corridor are going to set a more realistic first scenario, thus these actions should be in service, according to the European directive, by 2030 (CFV,2016), however the current projects and works, which are financed by European funds, should be finished by the end of 2023, matching the final year scenario of the contemporary national infrastructure plan (2024). Thus the actions of the European Mediterranean Corridor will help to define the considered intermediate scenario (2030), and the rest of the lines studied and proposed at the national infrastructure plan could be considered for a distant scenario (2050).

The Mediterranean Corridor has a high strategic importance for Andalusia, because it connects the region with the more economically dynamic areas of the country and with the rest of Europe, where great transport demands for both passenger and freight are produced. Thanks to this the whole rail infrastructure from the French border to Almeria is being improved and from there to Algeciras in an inland route through Granada and Bobadilla, which passes by the city of Loja (20,600 Hab.), with a high travel time reduction and a complete functional segregation of passenger and freight traffic. The final image of this transport corridor integrated with the European network will include a basic and competitive freight rail line which guaranties the continuity and capacity needed, connecting ports and logistics platforms, allowing the circulation of 750 m length trains and making freight independent from passengers. It also considers for passengers a continuous high-performances rail line all through the corridor connecting the main cities (INECO, 2011). Figure 7. The actions that are currently being developed for the Mediterranean Corridor are a new direct connection Seville - Malaga / Granada via Almodovar and La Marota, the new line for mixed services between Antequera and Granada, a new line for mixed services between Murcia and Almeria, and the renovation and improvements of the conventional lines between Algeciras and Bobadilla, and between Almeria and Granada, with the change of all platforms and its complete electrification in international gauge and for mixed services (Ministerio de Fomento).

Figure 7. The Mediterranean Corridor and logistic nodes of Andalusia. Source: CFV (2016)

The expected situation of the rail network of Eastern Andalusia for the intermediate scenario around 2030 is shown in the next table 5:

Table 5. Rail network situation of Eastern Andalusia around 2030 (HSR lines in bold):

LINE		LENGH (Km)		TRACK (*)	GAUGE (**)	ELECTRIFIED	MAX. SPEED (Km/h)	SERVICES
Algeciras - Bobadilla	Algeciras-Ronda	160	50	S/D	Int. & Iberian	Yes	160	Mixed Pass. & freight
	Ronda-Almargen		40				220	
	Almargen-Bobadilla		70				350	
Almeria - Murcia		199		Double	International	Yes	300	Mixed Pass. & freight
Almeria - Moreda - (towards Granada or Madrid)		124		S/D	International	Yes	300	Mixed Pass. & freight
Antequera - Malaga		55		Double	International	Yes	350	Passenger
Antequera - Granada		125		S/D	International	Yes	300	Mixed Pass. & freight
Bobadilla - Antequera - Granada		131		S/D	International	Yes	300	Mixed Pass. & freight
Bobadilla - Malaga		80		Single	Iberian	Yes	160 (limited)	Mixed Pass. & freight
Cordoba - Antequera		100		Double	International	Yes	350	Passenger
Cordoba - Jaen		135		Single	International	Yes	300	Mixed Pass. & freight
Granada - Moreda		57		Single	International	Yes	300	Mixed Pass. & freight
Guadix - Lorca (towards Murcia)		In Project/Construction?						
Jaen - Linares-Baeza - (towards Madrid)		61		Single	International	Yes	300	Mixed Pass. & freight
Linares-Baeza - Moreda - (towards Almería)		126		Single	Iberian	Non	140 (limited)	Mixed Pass. & freight

Source: ADIF

(*) S/D: There will be sections with single and others with double track

(**) There will be sections with both Iberian and international gauge but the intention is to adopt international gauge finally.

According to the actions mentioned the expected travel times between the main cities where stations are probable have been estimated:

Table 6. Estimated rail travel times between main Andalusian cities in the intermediate scenario around 2030 (hours:minutes):

	Algeciras	Almeria	Antequera	Cordoba	Granada	Guadix	Jaen	Linares	Loja	Malaga	Madrid	Murcia	Ronda	Seville
Algeciras	-	3:13	1:40	2:08	2:18	2:43	2:48	3:02	2:03	1:57	3:40	4:12	1:08	2:21
Almeria		-	1:32	1:57	0:55	0:30	2:11	1:52	1:10	1:46	3:27	1:00	2:09	2:17
Antequera			-	0:30	0:35	1:00	1:10	1:29	0:20	0:17	2:12	2:31	0:37	0:47
Cordoba				-	1:03	1:27	0:40	0:59	0:50	0:47	1:42	2:57	1:07	0:40
Granada					-	0:25	1:51	1:33	0:15	0:52	2:47	1:55	1:12	1:23
Guadix						-	1:41	1:23	0:40	1:16	3:05	1:30	1:37	1:47
Jaén							-	0:18	2:06	1:27	1:53	3:11	1:47	1:20
Linares								-	1:48	2:25	1:35	2:52	2:06	1:33
Loja									-	0:35	2:32	2:09	0:57	1:08
Malaga										-	2:20	2:46	0:53	1:04
Madrid											-	2:40	2:50	2:15
Murcia												-	3:08	3:17
Ronda													-	1:16
Seville														-

Source: Authors. Times have been estimated theoretically from the expected medium speeds. The real service times will be defined by the operators.

Times theoretically estimated are slightly less than current rail service travel times but future improvements in the existing rail lines and more efficiency in the services and their connections have been considered. The weakness of the eastern connections of Jaen can also be observed due to the limitations of the Linares-Baeza - Moreda rail line if it is not renovated. There probably won't be direct rail services between Granada and Jaen if this line is not improved, as the travel time is double than that by road, and paradoxically Jaen's airport is the same as Granada's.

As has been indicated, another more distant scenario could be considered regarding the projections of the national infrastructure plan which foresee a complete number of connections. For this remote scenario around 2050 could be estimated as the completion of the rest of connections: The littoral rail line Almería-Motril-Málaga-Algeciras, and the inner connections Granada – Motril and Guadix-Lorca, which will reduce these travel times to Murcia. The improvement of the line between Linares and Moreda should also be considered.

4. Territorial implications linked to the future High-Performance Rail Lines in Eastern Andalusia.

4.1 Territorial effects associated to the passenger flows.

With respect to the passenger flows, thanks to the Mediterranean Corridor an extraordinary increase of passenger transport demand from Almeria towards Catalonia is foreseen (they could be multiplied by 20) and even more from Murcia and the Valencian Community (which could be multiplied by more than 300), while the global passenger transport demand in the rest of the Corridor, including our study area, would be multiplied by 2.5 (INECO, 2011). Nevertheless it is probable to consider greater increments in the future scenario.

As they have been widely studied in many cases, the main effects associated to the future high-performance rail lines in Eastern Andalusia are linked to the great travel time reductions which are gained, but focused around the stations giving a polarized development model.

In the present case these effects will be associated not only with the significant travel time reductions but also to the emergence of new direct relations between the main close cities which now are not connected.

With respect to the widespread diversity and dimensions of the territorial effects that need to be covered, in this paper they will be focused on the spatial implications of the inter-urban relations at sub-regional scale.

According to other national and foreigner experiences, deeply studied by Prof. J.M. Ureña and his research group, the spatial implications of the new HSR lines can be summarized "in three different processes: changes in functional integration of HSR cities, spatial and urban hierarchy reorganization, and city restructuring" (Ureña et al., 2012, p. 132). Thus the new HSR services will allow the appearance or consolidation of commuting inter-urban relations in one hour, and business, often day return, travel in 2 to 3.5 hours´ travel time, as has been recognized (Ureña et al., 2012, pp. 133-134).

In synthesis, as stated by Ureña et al. (2012, p. 140), the inter-urban territorial implications of the new HSR lines are: "Increased metropolitan processes at half and hour's and one hour's HSR travel time; re-articulation of medium-sized cities to the system of metropolises; new isolated transportation poles; and collaboration between small, distant cities". The first one comprises two processes: "discontinuous metropolitan expansion at one hour's HSR travel time", and "metropolitan reinforcement at half an hour's HSR travel time". In addition "there is evidence that discontinuous metropolitan expansion is happening in small cities with an HSR station within one hour's HSR travel time (200 Km) from the centre of metropolises" (Ureña et al., 2012, pp. 141-161).

In connection with the above mentioned similar processes can be anticipated in this case according to the foreseen changes in accessibility, as following:

- The future rail direct connections between all the Andalusian main cities, and the expected competitive services, will enable the high mobility that characterized the named current world "metapolis" (Asher, 2005).
- The fact of the balanced urban system formed by the provincial capitals of Eastern Andalusia and their equivalent functional level, and given the historical loss of the centrality of Granada with respect to the coastal capitals, this will predictably give an equilibrated relationship between them which will imply around an hour or an hour and a half rail travel time. However the increase of the flows for specific functions and services offered in each one of them is expected. Thus the greater attractiveness of the metropolitan capital of the sunny coast and its socio-economic and cultural attractions will become more important.
- In this sense an equilibrated relationship between them, and cooperation policies to reinforce the present polycentric urban system, would be desirable, and consolidating the regional metropolitan structures into a complex urban network, as other cases in the world (Boix, 2003; Marull et al., 2015). Thus the conformation of the Southern European's Polycentric Metropolis can be predicted, as other mega-city regions in Europe (Hall and Pain, 2009).
- – This reinforcement of the adequate polycentric urban system existing according o the European and Regional spatial strategy and Plan (EC, 1999; COPT, 2006) also helps to balance the regional spatial development patterns in the national context (Ureña, 2012).
- As has also been identified in other cases, decentralization opportunities will also appear in this area, especially in the case of Antequera. The new east-west rail link will reinforce the existing north-south axis between Cordoba and Malaga and the recovery of its central regional geographical situation. It would be a great political opportunity for the regional equilibrium against the prominence of the regional capital.
- The relationship with the regional capital, currently poorly served by public transport (as, for example, nowadays there is no service to Seville from Granada arriving before 11:30am, and there is a limited air service from Almeria), will obviously be reinforced as the new rail travel times will be very competitive as seen in Table 6. However, given the mentioned equilibrium existing between cities a limited solely metropolitan integration with Seville can be expected as the considered conformation of the Southern European's Polycentric Metropolis.
- The competition between air and future rail services in the direct relationship between Almeria and Seville -currently with more than 23,000 passengers per year by plane (CFV, 2016)- will be limited as the future train services duration will be more than double that of current air services (55 min), but if total air travel time is considered including airport displacements and waiting times, the rail services can be competitive as they will be relatively similar.
- Due to the political-administrative dependency, the natural tendency is to reinforce the relationships between the medium cities with their provincial capital, as is seen between Puente Genil and Cordoba (Ureña et al., 2012), or will probably be in the case of Antequera and Ronda with Malaga, and Linares with Jaen. However currently there is a lack of metropolitan integration of Antequera with Malaga by rail because of the 20 Km distant existing station that will be solved by its renewed station close to its city centre for the new rail line towards Granada. In the case of Ronda the new rail travel time to Malaga of less than an hour will increase their reciprocal relationships.

- The exception could be the case of Algeciras in the province of Cadiz, only linked to the provincial capital by road and a recently built highway, where the improved rail link will reinforce its relations in the contrary direction towards Eastern Andalusia. A certain integration between Guadix and Almeria -just half an hour distant- is also possible, but this city remains a little closer to its provincial capital.
- In the province of Granada, given the reduced travel time between the capital and the cities of Loja and Guadix, the reinforcement of metropolitan relationships between them, and the incorporation of these two populations of a circle of medium cities around the provincial capital (Cabrera, 2010), to the present metropolitan area of Granada will be clear.
- The relation with the national capital will be highly increased for business, and there will be numerous, often day return, journeys, as all the Andalusian capitals will be situated from 2 to 3.5 hours' rail travel time to Madrid.

For the remote scenario the new connections will probably give rail access to the littoral relevant populations of Almeria, Granada and Malaga provinces such as El Ejido, Motril, or Velez Malaga-Torredelmar, and inner populations of Granada province such as Baza. Some of these will be firstly connected to the rail network in the case of the coastal cities –except Velez-Malaga which was connected to Malaga-, and will recover the lost connection in the eastern link in the case of Baza. Naturally the coastal capitals of Almeria and Malaga would reduce the rail travel time between them.

With respect the stations' location, as Ureña et al. (2012, p. 137) recognizes, "central locations in small cities help their competitiveness", and the intermodal connection with the public transport system will also be very relevant. In the study area the stations of the capital cities are adequately central, and they are well connected to the urban and metropolitan public transport systems. The current arrangements of the HSR lines are also linked to the developments in the stations of the area, with actions of enlargement, renovation and urban integration in the stations of Algeciras, Almeria, Granada and Jaen (Ministerio de Fomento, 2015). These physical transformations will generate changes in the mobility patterns and land uses and will have impact on economic and social structures and dynamics, which will produce other physical transformations caused by the new patterns and increased mobility, as has been studied in other cases (Bellet at al., 2012). As can be expected, these improvements in the stations will also encourage the passenger increase in future rail services.

4.2 Increase of freight traffic and the logistic potential

The end of the proposed and projected actions to complete all the rail lines of the Mediterranean Corridor, which should be in service by 2030, will give a continuous and competitive way of a more sustainable transport. In addition there is a great coincidence of the lines of this corridor with the location of all the logistic areas of the Logistic Andalusian Network and their expected surfaces, which also should be completed and in service by the same horizon. All of these will possibly provide a complete integration of the regional rail and logistic network with the national and European transport networks. The rail freight, which is competitive for distances longer 500 Km, will reduce the peripheral character of this area and will connect it with central Europe.

These existing and future logistic areas will improve the port-rail and road-rail inter-modality for an easy change of transport mode and will increase the integration of different transport modes.

Naturally these improvements in the rail and logistic transport system will produce relevant increase of freight transport demands, mainly in the relationships with origin/destination of this southern area. According to the strategic plan for the freight rail transport impulse it is expected to multiply by more than twice the current low participation quota of the railway freight transport. However the mixed use of the railway lines for both passenger and freight will have reduced maintenance costs but serious management problems (INECO, 2011). According to the last national infrastructure plan the foreseen evolution of transport demand shows an average increase of 1.5% annually for freight transport until 2024 (Ministerio de Fomento, 2015).

Finally thanks to the development of all the proposed intermodal areas and the improvement of the rail lines, reducing freight times and increasing competitiveness the increase of the global logistic potential of all this area can also be considered.

5. Conclusions and Proposals

Among the above mentioned territorial effects the foreseen future formation of the Southern European Polycentric Metropolis in Andalusia can be underlined, and the reinforcement of their existing adequate polycentric urban system. Also the gain of regional territorial centrality of Antequera, with its new station located at the edge of the city centre, which will give new opportunities of political-administrative facilities decentralization, and its metropolitan integration with Malaga is to be highlighted.

The new metropolitan relationships among medium cities and their provincial capitals should be emphasized, and the expected intensification of the relationships with the regional and national capitals for administrative and business purposes.

The Mediterranean Corridor will offer a continuous and competitive way of a more sustainable transport and will enable a complete integration of the regional rail and logistic network with the national and European transport networks.

As the corridors and crossroads are topographically clearly defined, the location of the proposed logistic areas of the Logistic Andalusian Network are linked to the main transport axes and consumer/production nodes. However there is a lack of a logistic area that is clearly needed in the crossroads of the A-92 North and South within the rail line near Guadix linked to the provincial road network, as has been previously recognized (Grindlay, 2014). This area offers a space of real logistic opportunity.

The need for the connection of the two lines of the Mediterranean Corridor, not only between Antequera and Cordoba but also between Moreda and Linares-Baeza, is also proposed. Moreover, the improvement of this line is demanded from the Jaen province to reinforce the logistical role of the dry port of Linares and the connection of the Almeria area with the centre of the peninsula (CESPJ, 2017).

The minimization of the tunnel effect will come with an adequate connection of future rail proximity services with a complete territorial public transport system for a suitable intermodal coordination with a great multimodality as proposed in the European spatial strategy.

The future new developments to be proposed around the new railroads should stimulate the local potentials and should focus on its multiscale and it multidimensional reality, compatible with a multifunctional use.

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A methodological approach to analyze the territorial appropriation of high-speed rail from interactions between actions and representations of local actors

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Abstract

In response to the difficulties in discriminating the specific transport impact from other factors influencing economic and spatial development, researchers are now focusing more on understanding the process by which territorial changes occur to explain how economic and social agents and local authorities have appropriated the new transportation system. This appropriation plays a crucial part in the territorial dynamics. The diversity of economic and spatial changes produced by high-speed rail indicates the existence of multiple modes of appropriation which vary according to the location of stations, the mobilization of local stakeholders confronted with the transport operators' logic and the geographical and historical context of the infrastructure implementation.

Appropriation is defined as a dialogical and identity process that must be explained in order to facilitate the understanding of the gradual and mutual adjustments between the transportation system and the territory. The analysis of the mechanisms of high-speed rail transport appropriation opens up new research opportunities in the quest to respond to a three-pronged issue:

- firstly, the issue of improving the understanding of the relation between the agents involved in the territorialization of the transport infrastructure by analyzing the interrelation between transport practices, the functioning of firms and development projects;
- Secondly, the issue of observing the "image" effect linked to the individual and collective representations of high-speed rail;
- and lastly, the issue of examining the temporal dimension of the territorialization process.

Thus, my contribution rests on the conception of an analysis grid to explain how appropriation has gradually taken shape throughout the various stages of the high-speed line project. Inspired by Brunel and Roux's research work on consumers' habits, this analytical grid aims at reporting on the modes of HSR appropriation, emphasizing the temporality of the process. Appropriation is, in fact, a long-term evolutionary process which has started long before the implementation of the new infrastructure and continues even after the trivialization of its uses.

Keywords: High-speed rail, territorialization process, appropriation, practices and representations, image effect.

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1. Introduction

Faced with the great diversity of territorial implications of high-speed rail (HSR) and in response to the difficulties in discriminating the specific transport impact from other factors influencing economic and spatial development, researchers are now focusing more on understanding the process by which territorial changes occur, to explain how economic and social agents and local authorities have appropriated the new transportation system through their behaviours, practices and representations. If appropriation plays a crucial part in territorial dynamics, it's necessary to decipher its mechanisms in order to facilitate the understanding of territorial reconfigurations linked to the arrival of high-speed rail. Appropriation is considered as a collective construction process resulting from the multiple interactions between the agents involved in the territorialization of the HSR system. The focus is on examining how political and institutional strategies have acted upon other agents' practices throughout the different stages of the HSR project and how the companies' expectations and users' representations of high-speed rail have influenced the decisions and strategies adopted by the political sphere to strengthen the territorial integration of the new transportation supply.

Defining the territorial appropriation of high-speed rail from the relations between the actions and the representations of local actors requires the development of a specific methodological approach which simultaneously takes these various social interactions and the temporal dimension of the process into account. This approach is presented in three sections. After mentioning the issues of an analysis focused on appropriation, the article proposes a dynamic perspective of the process by transposing the analysis grid conceived by Brunel and Roux (2006) for the study of consumers' habits and finally reviews the methods used to analyze the process of appropriation that participates in the territorialization of a new transport infrastructure.

2. Scientific issues of an analysis focused on the appropriation of high-speed rail

2.1 The decisive role of the territorial appropriation of high-speed rail

The complex interdependencies between transport, society and territory make it difficult to dissociate the effects of a transport infrastructure from other factors involved in economic and spatial changes. Many scientific studies have shown that the infrastructure and the new conditions of accessibility are, ultimately, only development opportunities that territorial actors have to grasp by the means of accompanying measures and appropriate development strategies. So appropriation is recognized as a condition of success for the territorial development projects which started with the commissioning of a new transport infrastructure. For example, regarding the North European high-speed line, P. Menerault has clearly shown that the territorial changes linked with the improvement of rail accessibility closely depended on the national, regional and local modes of appropriation of the high-speed rail service (Menerault, 1996, 1997 and 2000). By analyzing the impact of the French eastern European high-speed line on the activation of tourist resources in Reims, Bazin, et al. (2010) have highlighted that the collective appropriation of the HSR service and the ability of actors to collaborate were the key to the emergence of the positive "effects" of the infrastructure. In order to understand how the territory appropriates the new transport supply, a few works focus on the actors' strategies and logics (Blanquart, et al., 2010; Chaplain, 1994; Cohou, 2000). Cecilia Ribalaygua has conducted a very detailed analysis of enhancement strategies that intended to anticipate, support and promote the arrival of high-speed rail in small-sized Spanish cities and has emphasized the major influence of these strategies in the spatial and economic changes she has observed (Ribalaygua, 2006).

Ultimately, the issue must be seen from another angle. Instead of inquiring into the "effects" of the new transport supply on spatial organization, it is better to start from the territory as a whole in order to analyze how it has generated the infrastructure, has adjusted to the new conditions of accessibility and has appropriated the new transport supply. As C. Chaplain has shown in her PhD dissertation on the Channel Tunnel and the French Northern high-speed line, the understanding of the actors' behaviours and practices that accompanied the infrastructure project, from conception to completion, is essential for analyzing territorial dynamics (Chaplain, 1994). As F. Plassard has written concerning the relations between transport and territory, the commissioning of a new transport infrastructure *« renvoie au fonctionnement global de la société qui, par cette construction, s'approprie son espace et transforme progressivement son territoire conformément au système de valeurs qui lui donne sa cohérence globale »*[1](Plassard, 2003).

Prolonging these works, my research on the HSR stations has shown that, according to geographical and historical contexts, the process of territorialization of high speed rail has encountered a number of territorial inertia which is due as much to "the effects of place" as to the appropriation modes of the new transport supply by territorial actors. The degree of appropriation of the potentials of high-speed rail has been a major factor of the involvement of local actors in the decision-making process leading to the choice of the location of HSR stations, and in the implementation of coherent and coordinated strategies improving the territorial integration of high-speed rail. When local actors anticipated the opportunities presented by the connection to the HSR network, not only did they widely get involved in obtaining a location of the station in compliance with their territorial development project but also in implementing measures to strengthen the territorial integration of the high-speed rail service. Focusing on the locations of stations, these analyses suggest the existence of different modes of appropriation which vary according to the degree of centrality of railway stations, the mobilization of local actors confronted with the transport operators' supra-territorial logic and the temporal context of the HSR project implementation (Facchinetti-Mannone and Bavoux, 2010; Facchinetti-Mannone, 2012). These different elements result in highly diversified territorial dynamics which can be highlighted by an analysis of the appropriation of high-speed rail.

2.2 Appropriation : a multifaceted notion

In geography, the concept of territory is used in conjunction with the notion of appropriation which is a many-sided notion and a cross-disciplinary one which refers to a dual process within the usual meaning of the term. First, the term 'appropriation' means "to adapt something to specific uses, needs or expectations". Secondly, it may be defined as the action of assigning oneself the ownership of something, taking possession of an object or a place, or acquiring experience or knowledge. It involves the exercise of a form of power, the preparation of a strategy and the construction of an identity.

In a heuristic perspective, this dual meaning and the numerous definitions of the notion of appropriation have led me to examine the scientific works dealing with the appropriation of public spaces and that of innovation. The purpose is to specify how the various disciplines which have studied these topics define and mobilize the concept in order to provide a theoretical and methodological framework to improve the comprehension of the appropriation process. A first review of the French scientific literature has shown several common characteristics particularly fruitful to analyze the process of appropriation of high-speed rail. Based on « *la confrontation de deux potentialités, la potentialité d'un monde présentant de l'appropriable à un individu et la potentialité de ce même individu à s'approprier les objets et espaces dans*

1 *[Translation: the commissioning of a new transport infrastructure "refers to the overall social functioning which, through this construction, appropriates its space and gradually transforms its territory, in accordance with the system of values that gives it its overall coherence"]*

une quête identitaire » [2]2 (Cova et Cova, 2001), appropriation is a dynamic process derived from complex systems of interdependence (Fischer, 2011) between the possessive, adaptive and identity dimensions of the notion.

By its possessive dimension, appropriation is first a conflictual process in which social actors are confronted with a certain number of constraints (Fischer, 2011), which they have to take into account and even to surpass. Analyzed from the angle of the power relationships expressed by struggles for the appropriation of places, from the territorial marking of individuals and groups or from the oppositions between the design logic and the user’s (De Certeau, 1990; Perriault, 1989), this underlying conflictual dimension is an essential key to understanding the appropriation process of high-speed rail. Even if the strategies of appropriation adopted by the territorial actors of intermediate cities remain subject to the supra-territorial logics of transport operators, they have revealed that some territories have succeeded in reversing the logic prescribed by the railway operator to serve their own expectations while others have not been able to derive the expected benefits although they have obtained a rail service. Because these different "appropriative trajectories" vary according to the spatial and temporal contexts of the location of HSR stations, they invite us to revisit the actors’ interactions occurring during the choices of the location of stations and the implementation of development strategies.

Beyond the diversity of the topics and scientific fields, many research studies have also underlined the dialogical dimension of the appropriation process which involves continuous, progressive and mutual adjustments (Orlikowski, 1996), according to a recursive logic (Brunel and Roux, 2006) between the adaptation of the subject and the modification of the object. As regards urban public places, P. Serfaty has shown that the user adjusts to the function of the place throughout his routine practices which gradually change the sense of place (Korosek-Serfaty, 1988). *Based on the Adaptive Structuration Theory* developed by De Sanctis and Poole (1994) from A. Gidden’s work (1987), this interactionist approach proves relevant to investigate the appropriation of high-speed rail stations and to understand the renewal of territorial structures in connection with the changes in the transportation system. Because it is gradually taking shape in the relation to its object (Jouet, 2000), appropriation takes part in the spatial structuration and the emergence of new territorial dynamics. These greatly contingent territorial changes are the result of a process in which territorial actors interpret the changes introduced by the new transport supply, adapt them to their expectations and incorporate them into their practices, thus modifying the characteristics of the transport supply and the values that it conveys. In the course of interactions, this dual mechanism of adaptation affects the general territorial system which in turn changes the functionalities of the new transportation supply and the actions and representations of local actors, explaining the wide variety of territorial dynamics generated by projects yet designed according to the same logic.

Finally, appropriation constitutes an identity process. Social sciences have thus largely proved that the property of objects, the assimilation of knowledge or the acquisition of experiences have contributed to shaping the identity of individuals. By extension, high-speed rail appears to be an "identity referent" (Brunel and Roux, 2006). The integration to the HSR network doubly contributes to the building of territorial identity. On the one hand, the improvement of accessibility and the modern image linked to high-speed rail change the way the territory belongs to the world and increase its visibility on a national scale and on a European one, as shown by the renewal of the architecture of train stations or the territorial marketing strategies adopted by the cities and regions that have recently joined the “Club of HSR cities”. On the other hand, high-speed rail changes the way local actors consider their territory; the new transportation supply becoming, through appropriation, a medium for territorial identity.

2 *[Translation: “the confrontation of two potentialities: one of a world presenting things that can be appropriated by an individual, and the capacity of this same individual to appropriate objects and spaces in an identity quest”].*

2.3 A multi-pronged problematic approach of the appropriation of high-speed rail

Addressing the issue of the territorialization process of high-speed rail through the prism of appropriation offers the advantage of focussing the analysis on territorial actors. As pointed out by Ripoll and Veschambres, “reasoning in terms of appropriation has the major methodological and theoretical interest to emphasize the spatial dimension of society, rather than the space itself, considered as something distinct, autonomous and external from society " (Ripoll et Veschambres, 2005). Among the numerous stakeholders involved in the territorialization process of the HSR stations, three categories of territorial actors have more particularly attracted my attention (see figure 1): the railway customers, the economic players and the local political and institutional actors.

Differentiated by their practices, relations to places and expectations raised by the new transportation supply, these three groups of actors have a very different role in the territorialization process of high-speed rail. Even if railway users and economic players only have a limited decision-making power over HSR lines and location of stations, their spatial distribution, characteristics and travel practices are widely taken into account during the negotiations concerning the location of stations and the definition of the railway service. Their travel practices and their ways of using HSR stations, which affect the profitability of projects, are also taken into consideration in the design, equipment and layout of these places. Lastly, the way they integrate the station and the new transportation supply into their daily lives has spatial repercussions that influence the territorialization process of the new transportation system. The political and institutional sphere, which has more prerogatives than ever before to negotiate the location and rail service of the stations, has had an unequal influence depending on the geographical and temporal contexts of the implementation of the projects. Whether these political actors have obtained or not a location of a HSR station and services corresponding to their expectations, they have supported the accompanying strategies and territorial development plans set up to improve the territorial integration of the high-speed rail network.

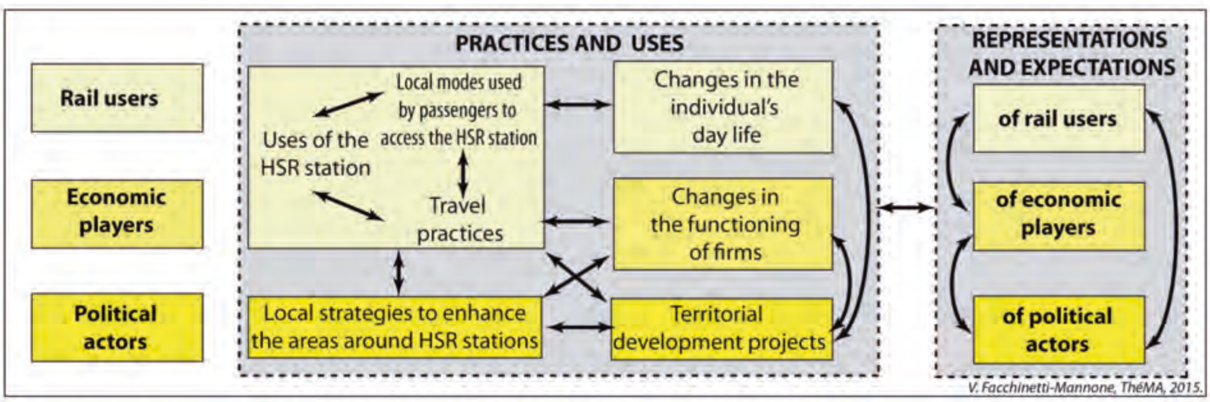

Fig. 1: the appropriation of HSR: a collective construction process

While the forms and mechanisms of appropriation differ according to the types of actors, they are nevertheless interdependent. Thus, after specifying how each of them has appropriated the renewal of transport supply, it will be necessary to analyse the relations which exist between these different modes of appropriation. This interactional approach, which reveals the actors' interactions involved in the territorialization of the infrastructure, considers appropriation as a collective construction process resulting from mutual adjustments between the various forms of appropriation which have been identified. Indeed, if the measures implemented by the political sphere to strenghten the territorial integration of railway stations weigh on the way in which passengers and economic players use HSR, these strategies depend on the various forms of appropriation that have preceded or accompanied them, insofar as territorial planning takes into account, to some degree, the forms of appropriation revealed by the companies' expectations and users' representations.

Appropriation appears in two ways: first through the strategies, practices and uses generated by the new transportation supply, and then through high-speed rail representations and actors' expectations. Practices and behaviours, which refer to the real life experience of the territorial actors, are numerous. The appropriation of high-speed rail can be analyzed through people's travel practices and companies', in relation with their use of stations, and more generally by the way they integrate the new transportation supply into their daily life or in the functioning of their firms. Similarly, the strategies for enhancing the railroad sites and territorial projects linked to high-speed rail reveal the logic of appropriation supported by political and institutional actors (see Figure 1).

If the various studies dedicated to appropriation have emphasized social players' actions, these acts cannot be separated from the representations that gave birth to them. Practices and representations are always linked (Gumuchian, 1991) and constitute two facets of a complex process that closely mingles collective representations, individual perceptions and response and adaptation mechanisms (Taddei and Staii, 2008). The representations led by the renewal of railway accessibility constitute an essential factor in understanding the practices and strategies which induce territorial changes in connection with the implementation of a new high-speed line. Thus, my analysis emphasizes the representations of the different territorial actors and describes the various interactions that bind them in order to confront these representations with the practices and strategies from which they are derived and that they constantly change (see Figure 1).

3. A dynamic perspective on the appropriation of high-speed rail

The analysis of the territorialization of high-speed rail in terms of appropriation encourages researchers to highlight the temporal depth of the process. Indeed, appropriation is a long-term evolutionary process which has started long before the implementation of the new transport infrastructure and has continued even after the trivialization of its uses (de Vaujany, 2003). Therefore, if the choice of location and the opening of stations are highlights of territorialization process, insofar as they confer a tangible reality to the HSR project, their appropriation has taken shape since the first reflections on the emergence of the high-speed line project. Then it has gradually developed and changed during the various stages of the project implementation. Taking this diachronic dimension into account is fundamental. On the one hand, it allows me to understand how the appropriation modes of the project have influenced the choice of the location of stations and the strategies developed to promote the territorial integration of high-speed rail. On the other hand, it enables me to specify how these strategies may modify the stakeholders' practices and representations in return.

3.1 An approach adapted to the temporality of high-speed line projects

Several authors have attempted to deconstruct the chronology of the appropriation process. Among them, Brunel and Roux, inspired by Sartre's work on desire and possession, have constructed a comprehensive analytical grid of appropriative acts in the field of marketing (see Tab.1). The intention of their study was to grasp the dialogical and conflictual relationship between demand and supply in order to understand how the purchase and the consumption of any product participate in the individual's identity building. Thus, they have identified four strategies of appropriation (the contamination, the knowledge, the creation and the control) which come in a specific way according to the different stages of consumption act (Brunel and Roux,2006).

Tab. 1: Comprehensive analytical grid of appropriation

	Contamination	Knowledge	Creation	Control
Pre-appropriation	Intrusion	Impregnation	Preconception	Will to vanquish
Pre-acquisition appropriation	Identification	Researching information	Ressource allocation	Takeover
Appropriation during acquisition	Transfer	Choice	Personalization	Taking possession
Pre-consumption appropriation	Internalization	Discovery	Transformation	Possession
Appropriation during consumption	Incorporation	Learning	Self-fulfilment	Domination
Post-consumption appropriation	Passing on	Dissemination / Withholding	Transformation of self and society	Enjoyment

Their chronological approach appears relevant to examine how the territorial appropriation of high-speed rail changes throughout the three main stages of the HSR projects (see figure 2):

Over the two or three decades which have elapsed between the first evocations of the project and the conclusions of the public debate, appropriation has built up gradually from the numerous and often contradictory representations which condition the territorial identification of the HSR project and the ability of local actors to collaborate and to implement development projects. During this gestation phase, numerous studies from the transport operator and the institutional and socio-economic actors have helped fuel the debate. Although at this stage nothing has been decided yet, the mobilizations against or in favor of the infrastructure project, lobbying actions, the first technical and economic feasibility studies – now widely co-financed by local actors - then the consultation organized for the public debate have given a virtual reality to the project.

Then, the project gets into an active stage of development which constitutes a turning-point in the spatial integration of infrastructure. Reports and consultations preceding the Declaration of Public Utility (DUP) allow to refine the technical and spatial characteristics of the project, to evaluate its socio-economic and environmental impacts and to consider its financing terms. Preliminary engineering studies and public inquiries gradually give substance to the HSR project, reducing the range of possibilities before the DUP initiates its concrete realisation. From there, preliminary project studies, land acquisitions, financial negotiations, the construction site and the definition of railway services replace one another and materialize the *"désir de gare"* (desire for a rail station) (Troin, 2010). The new HSR station becomes a valuable potential resource and gives rise to anticipation strategies that are expressed through development projects and an intense territorial marketing campaign.

The official opening of the high-speed line renews the forms of appropriation. During the first years of operation, new travel practices have accompanied the adjustments of transport supply.

Finally, with the gradual trivialization of high-speed rail, the new mobility practices associated with the gain in accessibility go hand in hand with the slow implementation of the economic and urban projects linked to the HSR station and the territorial integration of the new transport supply.

During these three phases, appropriation has evolved; the conflictual, dialogical and identity facets of the process get organized into a different hierarchy according to the temporalities of each project and the specificities of each territory. The conflictual dimension, often predominant during the gestation of the project, is gradually replaced by the dialogic facet during its implementation, and then gives way to the identity dimension once the commissioning of the high-speed line is completed. Nevertheless, these three components of appropriation occur to varying degrees of intensity depending on the geographical context. The methodological approach that I have chosen aims to identify and to explain these different forms of territorialization.

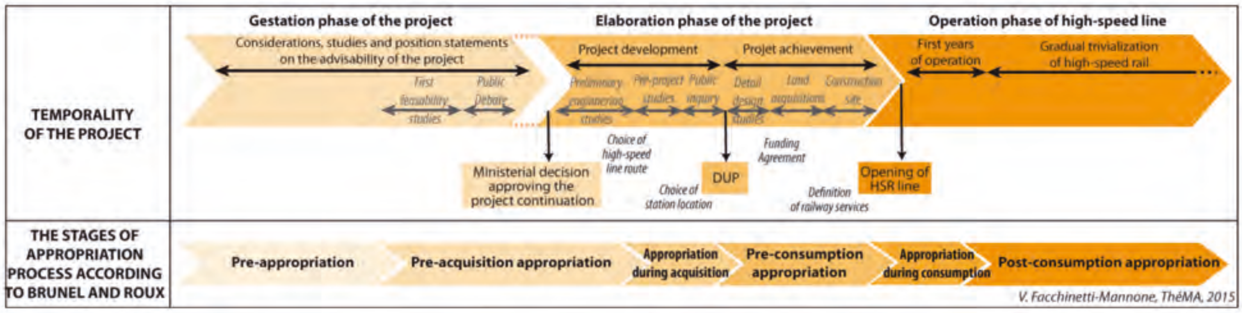

Fig. 2: Evolution of appropriation according to the different stages of the HSR project

3.2 Evolution of the appropriation mechanisms of high-speed rail stations

Because the analysis grid designed by Brunel and Roux emphasizes the recursive dimension of the process, it seems to be relevant to understand how the appropriation of high-speed rail has developed (see **fig. 2**).

The first mentions and the slow emergence of the HSR project correspond to a pre-appropriation phase when imagination construes reality and elaborates desire (Brunel and Roux, 2006). Faced with the possibility of a high-speed rail service, some territorial actors inquire about the project and become imbued with it. They start to interpret the potential renewal of accessibility that may be brought by high-speed rail system, in various ways according to their expectations or fears. By a kind of symbolic deciphering (Brunel and Roux, 2006), pre-appropriation participates in the formalization of the desire for a railway station: the territorial actors begin to consider the most favorable location of the station to realize their aspirations. During the slow maturation of the project, the multiplication of studies and consultations marks the gradual transition to the pre-acquisition appropriation stage which contributes to the recognition and identification of the Object of Desire (Brunel and Roux, 2006). Until the layout of the high-speed line has been chosen, the successive studies which confront the project with the territorial specificities allow to improve the knowledge of the project. Appropriation becomes learning, thus contributes to the gradual identification of the project with the territory. The desire for a HSR station is transformed into a particular project, and high-speed rail is gradually integrated into the territorial development project.

Established by the Bianco circular, the public debate, which offers local actors the opportunity to express their opinions about the project imagined by the transport operator, is today a highlight of this pre-acquisition stage. The balances of power between proponents and opponents of the project and/or between competing territories, reflect the conflictual dimension of appropriation in a quest for a progressive coherence between local actors' expectations and the transport operator's logic. As the "Cours des Comptes" has pointed out in a recent report (2014) devoted to high-speed rail, these initial consultations contribute to fixing the project into local reality, as it is shown by the beginning of the considerations on the strategies to be implemented to take advantage of the real or alleged opportunities of the arrival of high-speed rail.

From the choice of the HSR route to the Declaration of Public Utility, a phase during which the technical and spatial characteristics of the project are defined together with the stakeholders concerned, appropriation changes its nature, getting closer to the sequence of "appropriation during acquisition" that Brunel and Roux have defined as a phase of choice of conditions the most appropriate to the realization of the desire. If the choices of the HSR route and location of stations reduce the scope of possibilities they give a symbolic weight to the project which becomes identified with the served territory. During this stage, the territorial agents negotiate the best conditions to give concrete expressions to their expectations with the infrastructure operator and they conceive the development strategies to convert the improvement of accessibility into attractiveness.

From the Declaration of Public Utility to the completion of the infrastructure works, « *l'appropriation pré-consommation constitue une phase intermédiaire où l'objet n'est pas encore consommé et incorporé, mais préparé et intégré dans une mise en scène préalable à sa consommation»*[3] (Brunel et Roux, 2006). During this particularly active phase of mutual adjustments between representations and expectations, territorial actors take hold of the project and give it a meaning by adopting the first accompanying measures, initiating the negotiations on HSR services and elaborating territorial marketing campaigns.

The opening of the HSR line marks the transition to the stage of appropriation while consuming. The expectations created by the new transportation supply among the different categories of actors are submitted to reality and lead to positive or negative evaluations (Brunel and Roux, 2006). This appropriation by use, which marks the gradual integration of the new transport supply into users' and economic actors' travel practices and territorial development strategies, indicates successive adjustments between the territory and the new transport system. Finally, the post-consumption appropriation, that accompanies the trivialization of the transport supply, refers to what the territory retains from its experience according to the expectations created by the project. Becoming an integral part of the territorial identity, high-speed rail is, at this stage, integrated into territorial actors' everyday life, contributing, through the story-telling of the project, to the orientation of attitudes and beliefs in future situations of choice (Brunel and Roux, 2006).

Although the complete grid proposed by Brunel and Roux to analyse individuals' appropriation acts in a context of food consumption could easily be applied to the various stages of an HSR project for understanding the territorialization of stations, its transposition nevertheless raises a few remarks which require further clarification. Even if HSR gives access to new destinations and alters the image of served territories, it is not an ordinary consumer product. Thus, it will be necessary to re-examine the appropriative dimension of HSR stations in the light of the relations that the various actors maintain with these places and the forms of territorial appropriation that they may generate. The transposition of analytical methods designed to describe individuals' appropriate actions to the questions posed by the territorialization of high-speed rail also requires caution and circumspection. Indeed, even if individual appropriation remains a collective process (Taddei and Staii, 2008), territorial appropriation cannot be reduced to the aggregation of forms of individual appropriations but is built through the interactions of the appropriation logics of the various categories of actors.

3 *[Translation: " pre-consumption appropriation constitutes an intermediate stage during which the object is not yet consumed and incorporated, but prepared and integrated into a staging prior to its consumption"]*

4. Methods of analysis of the territorial appropriation of high-speed rail

4.1 Reconstitution of the trajectories of high-speed rail appropriation

According to the proposed framework, the adopted diachronic approach allows to understand the progressive construction of appropriation during the different stages of the project. As the research devoted to the sociology of uses has emphasized (Flichy, 1995 ; Jouet, 2000 ; Chambat, 1994), new uses do not come out of nowhere but they prolong previous practices incorporating the reproduction of existing configurations into the progressive construction of new social or spatial structures. Thus, different methodological approaches, specific to each sequence previously identified, are suggested to understand the diversity of the trajectories of the appropriation of the new transport supply. The objectives are to show, on the one hand, how the appropriation forms that have been developed during the genesis of the project have had repercussions on strategies and practices observed later on and to explain, on the other hand, how the interrelations between the different stakeholders' actions stimulate the territorial appropriation of high-speed rail. Therefore, my presentation envisages three types of analysis, modelled on the stages of the realization of a high-speed line (see figure 3):

- Focused on the political logics that occur during the territorialization process of high-speed rail, the first analysis suggests a geopolitical interpretation of actions, negotiations, compromises and possible conflicts that have led to the choice of the high-speed line and the location of stations. It will be necessary to identify the actors involved in the decision-making process according to their scale of intervention and their degree of mobilization. While the genesis of the project mainly involves political and institutional actors beside transport operators, the other categories of actors -through the associations and consular structures that represent them- are not absent from the debates. The analysis of their actions, in relation to the positions expressed and the arguments developed by each of them during the consultation phase, will allow me to clarify their respective roles in the decision-making process. The identification of the nature, the intensity and the evolution of the relationships that have been established between the different stakeholders will help characterize the actors' interactions and to specify their influence on the spatial integration of stations according to the geographical, historical and political contexts of the implementation of the HSR projects.

Several types of data will be collected to reduce the pitfalls involved in the retrospective reconstruction of facts and decisions that have marked out the different stages of the projects. Reports and studies produced during the preparation of the HSR project, press articles and interviews with the various actors involved in the choice of the location of stations, lend themselves to a geopolitical rereading of the actors' interactions during the territorialization process. The adopted approach also allows me to analyze the documentary resources produced during the consultations which punctuated the implementation of the project. The deliberations taken by the various local authorities, the documents resulting from the public inquiries and, for more recent projects, the reports and working papers of the public debate provide rich research materials which have not been much exploited up to now. An exploratory study of the documents resulting from the public debate questioning the opportunity of the high-speed line *Paris-Orléans-Clermont-Ferrand-Lyon* and particularly a qualitative study of the fears and expectations expressed in the contributions dedicated to the territorial development, (Maréchal, 2014) revealed the diversity of the "pre-appropriation" and "pre-acquisition" logics aroused by the project according to actors'political and spatial affiliation.

Centred on a systemic approach, the second analysis meant to assess the coherence and complementarity of the strategies and actions accompanying the project will allow me to re-examine the co-constructed dimension of appropriation in connection with the exogenous dynamics that affect the functioning of the territorial system. In this second phase, appropriation evolves and takes specific forms according to the categories of actors. From the political and institutional actors' sides, the negotiations on the choice of rail services, the spatial planning intended to encourage the integration of stations and the strategies to promote and to enhance high-speed rail, shed light on the territorial appropriation of the new transport infrastructure. From the users' and economic actors' sides, the appropriation of the new transport supply appears at this stage through the way they adapt their travel practices to the changes introduced by high speed rail. The joint analysis of these different appropriative logics thus makes it possible to assess the coherence of the implemented development strategies by relating them to the appropriation forms that have accompanied the preparation of the HSR project. The example of small-sized French and Spanish cities (Facchinetti-Mannone, et al., 2013) has thus clearly emphasized that the strategies developed to facilitate the expansion of new metropolitan functions near the peripheral HSR stations corresponded neither to the expectations of companies which, in their great majority, have not regarded HSR as a factor of location, nor to the strengthening of the polarization of large cities revealed by railway customers' travel practices.

- Most high-speed lines in operation today offer the necessary perspective to analyze the "post-consumption appropriation" stage. The follow up of valorisation strategies and complementary surveys to those already carried out will help to improve the understanding of the forms of appropriation that accompany the trivialization of the transport service. If the reorientations of development strategies highlight the evolution of the appropriation logics, the follow-up of these strategies will be more specifically put into perspective with the way in which the renewal of rail accessibility and the development projects created by HSR have been integrated into the territorial projects. The latter will be approached through an analysis of the "Schéma de Cohérence Territoriale" (SCOT)[4]. The general and transversal nature of these planning documents, intended to reinforce the link between spatial planning and travel management policy makes it possible to objectively apprehend the role devoted to high-speed rail in the territory project, the degree of the integration of stations into territorial development strategies as well as their degree of appropriation by institutional actors.

For instance, the comparison between the territorial coherence plans of "*Pays Barrois*"(served by the Meuse TGV station) (Pays Barrois, 2014), Great Besançon (served by the Besançon Franche-Comté TGV station) (Syndicat Mixte du Schéma de Cohérence Territoriale, 2014), and Great Rovaltain (served by the Valence TGV station) (Syndicat Mixte du SCOT du Grand Rovaltain-Ardèche-Drôme, 2014), all served by new HSR stations built on the outskirts of cities, underlines the very different roles played by high speed rail in the territorial project. Despite a similar spatial distribution of train stations, the three territorial planning documents point out distinct modes of appropriation of high-speed rail by local political actors. Thus, high-speed rail occupies a marginal place in the territorial project of *the Pays Barrois.* This low appropriation contrasts with the strong willingness to transform the new transport supply into a vector of European openness and economic development of Greater Besançon, or into a **ferment** of coherence and territorial identity in the case of Rovaltain.

The modalities of appropriation identified through these planning documents will have to be compared with those of the other categories of actors and more specifically with the way in which railway users and economic players adapt the new transportation supply to their daily lives and functioning. Early business surveys revealed that high speed rail, whatever its use and degree of influence in firms' location decisions, has introduced a number of changes in their functioning. Some of them have taken advantage of the land available in the vicinity of the stations to gather activities formerly scattered over several national or regional sites in a single place. Others have taken the opportunity offered by the improvement of accessibility to acquire new markets, expand their recruitment area or develop new economic partnerships. Beyond

4 *Territorial Coherence Plan established on the metropolitan area scale.*

their spatial implications, these functional changes reflect specific forms of appropriation that need to be identified in order to better understand the diversity of territorial impacts of high-speed rail.

The various approaches proposed to analyse the co-construction of the appropriation process, from the emergence of the HSR project to the trivialization of its uses, aim at reconstructing appropriative trajectories to identify, in the long run, the relations that these trajectories maintain with the location and territorial integration of stations. Even if it is difficult to compare HSR projects designed at different times, this long-term follow-up allows to specify the influence of the decision-making context on the appropriation process, in relation with the spatial representations intrinsically linked to the travel practices and the uses of high-speed rail stations. Indeed, these places are invested with meanings and values that participate in their appropriation. This necessary confrontation between practices (concrete appropriation) and representations (abstract appropriation) involves an exploration of the imaginary dimension of stations in order to relate it to the individual and collective strategies created by high speed rail.

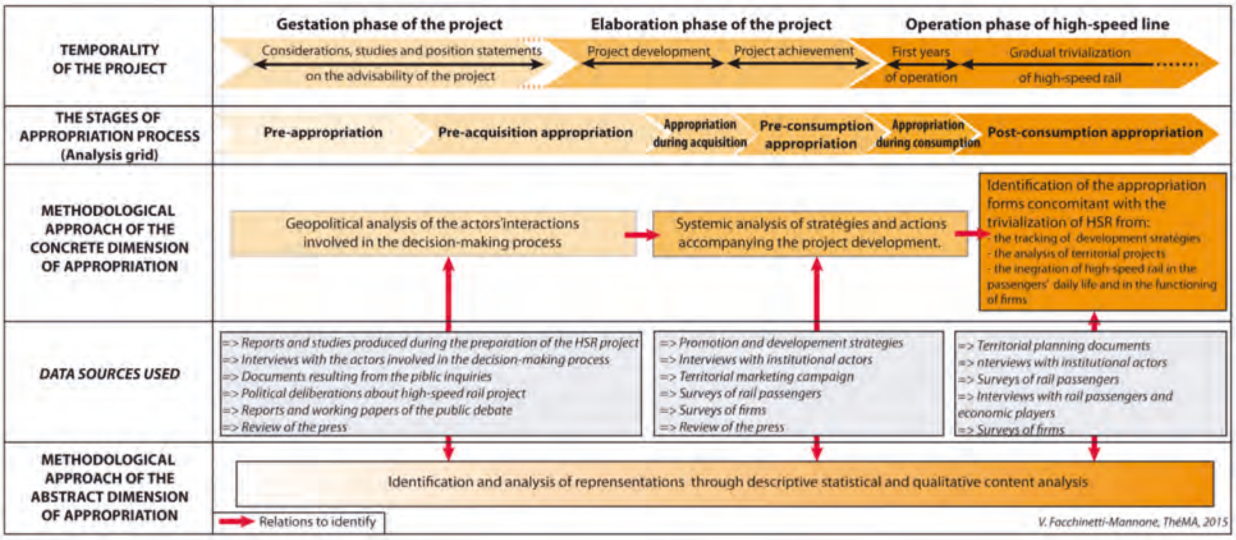

Fig. 3: Synthesis table of the proposed methodological approach

4.2 A semantic exploration of high-speed rail imaginary representations

High-speed rail, synonymous with renewal of accessibility and symbol of modernity, has largely enhanced the image of regions with high speed train services. Vectors of this “image” effect, the renewal of the architecture of railway stations, the redevelopment of the station area and territorial marketing campaigns promoting the attractiveness of newly destinations, participate, each in their own way, in increasing the legibility and the reputation of the areas served by HSR (the image they give of themselves) and in the construction of territorial identity (the image that they have of themselves).

Neglected for a long time by geographers, spatial representations, under the influence of social geography, have completely become objects of research whose heuristic interest is no longer to be demonstrated. As Bailly and Ferras (1997) have pointed out, geography draws its richness from the analysis of a permanent mixture of the real and the imaginary. By analogy with the *Image of the City* studied by K. Lynch (1960) or Y. Chalas (2003), the image of train stations refers to the representations they produce, the expectations and fears they feed, the values they convey and the myths they help to forge. By mixing perception of reality, social values and affective relationships with places, these representations fully participate in the production of space. In relation with the practices and strategies they influence, they show how territorial actors appropriate space and transform it into territory.

Just like the material characteristics of spatial organization, these ideal representations, that are constructed from the way in which territorial actors perceive and interpret the changes introduced by high-speed rail, influence and guide individuals' daily practices and the policies implemented to facilitate the territorial integration of the new transport supply. The identification of the social values attached to high speed rail, the understanding of how these values have been constructed and sometimes exploited, are essential for analyzing spatial practices and implemented strategies.

In order to explore these representations, the speeches of the various actors involved in the project have been submitted to a semantic analysis which mobilizes the tools and methods of the content analysis. The different textual and oral sources gathered to study the spatial practices and strategies linked to the arrival of high-speed rail constitute a relevant material to apprehend the representations (see figure 3). The words used to describe a project or an object refer to a mental representation of the real object (Hernandez, 2003). They enlighten the understanding of spatial practices and the construction of the process of appropriation. Studied from a quantitative and qualitative approach, the transposition into words and pictures of high-speed rail during the process reveals distinct forms of appropriation depending on the actors and the territories served by HSR. The challenge is then to identify how individual and collective representations affect spatial practices but also to better understand the reciprocal influence that the different speeches have on each other throughout the temporality of the appropriation process.

At this stage, the approach does not exclude any of the speeches and texts collected in connection with the reconstruction of the appropriative trajectories (see figure 3). These corpuses, each in their own ways, make it possible to understand the expectations and fears created by high-speed rail projects, the multiple representations attached to the location of HSR stations and the strategies used to develop railroad sites and the added values of the improvement of accessibility. To decipher these language games, the different textual data will be the object of a semiological and lexical analysis by mobilizing the tools and methods of the content analysis (Bardin, 2013 ; Lebart and Salem, 1994, Maingueneau, 1987) that Berelson defined as *"a research technique for the objective, systematic and quantitative description of the manifest content of communications, with the aim of interpreting them"* (Berelson, 1952). First of all, it will be necessary to analyze the enunciative context of the textual data studied, not only to situate them in relation to the temporality of HSR projects but also to clearly identify the elements that influence representations. Indeed, while some of the analyzed speeches are limited to a restricted circle, others, by their wide diffusion, contribute to the construction of social norms. This contextual study is based on an identification of the authors of the textual data and of the people to whom they are addressed, specifying their sphere of influence, their spatial scale of intervention and their position in the decision-making process. This approach also needs to determine the motivations of speeches which can take on very distinct tonalities depending on whether they are required to relate facts, to provide information, to explain a decision, to convince an audience or to promote a territory. Finally, the concomitant events associated with their enunciation must not be neglected insofar as they are likely to influence the individual and collective representations of the territorial actors.

Speeches and texts produced during the different phases of the HSR project will be subjected to a first quantitative lexicometry analysis. Based on the occurrence of the terms used, the frequency of co-occurrences, the relations established between the identified themes and the connotations attached to them, the analysis allows to obtain a first classification of the representation systems produced by high-speed rail. Then, the representations identified by these statistical treatments will be the subject of a more in-depth qualitative analysis which will be aimed at understanding the logics that have structured the representation systems, taking the contextual elements previously highlighted, the modalities of speech articulation, the allusive references and the stylistic registers into account. into account

The analysis of the image of high speed rail conveyed by Territorial Coherence Plans confirms the unequal role of the new transport supply (see figure 4). Thus, high-speed rail and HSR stations are mentioned only 13 times, usually laconically, in the SCOT of Pays Barrois, in which the first mention of high speed rail, appearing very late compared to other SCOTs, refers to the noise pollution caused by the rail traffic. Presented in the very first pages of territorial diagnosis, high-speed rail is the subject of more numerous references in the presentation reports of Great Besançon (28 references) and Great Rovaltain (39 references), most often under the form of extensively argued paragraphs.

A first quantitative analysis of the words associated with stations and high speed rail also reveals distinct representations of the traditionally established link between railway accessibility and territorial attractiveness. Thus, while the SCOT of Pays Barrois conveys a rather negative image of high speed rail, that of Great Besançon highlights the link between a widely idealized European openness and the economic development of the urban area with numerous hyperboles. For the SCOT of Great Rovaltain, the HSR station and the economic activity zone to which it is systematically associated are major vectors of European reach, development and territorial cohesion.

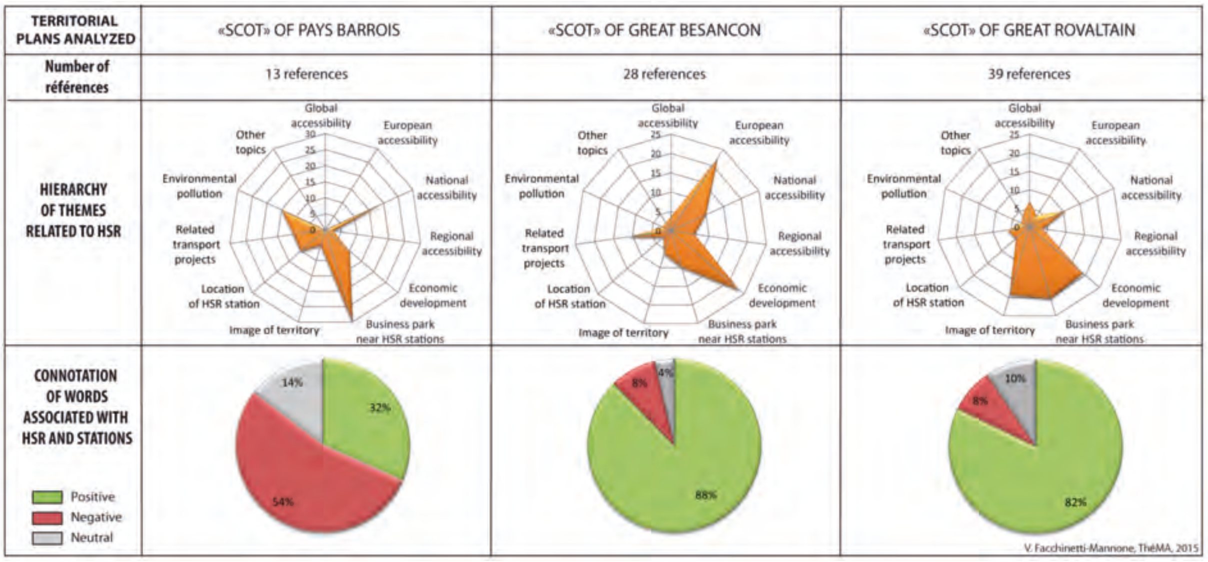

Fig.4: Hierarchy and connotation of the words associated with high-speed rail

The joint analysis of the role devoted to HSR stations in the territorial project and that of their symbolic representations reveals the unequal appropriation of high speed rail by local actors. Beyond the specificities of the served regions, this unequal appropriation reflects the degree of local actors' involvement in the choice of the location of stations. When, as in Besançon or Valence, local actors played an active role in the negotiations leading up to the implementation of stations, the territorialization of high speed rail is based on the adoption of development strategies that are largely integrated into the territorial project. It is also based on the construction of representations which exploit the mythical link between accessibility and attractiveness to serve the achievement of this project. Reflecting institutional actors' expectations, these imaginary constructions play an essential role in the territorialization of high-speed rail because they influence the measures and policies adopted to enhance the spatial integration of stations. In the Pays Barrois where the appropriation of HSR is governed by an "intrusive logic", the SCOT describes the station as a foreign object, over-imposed on territory, whereas the SCOT of Great Rovaltain has made the new HSR station a real local symbol (Lussault, 2007) and a strong element of territorial identity at the service of its economic development.

The exploration of the imaginary dimension of HSR stations from the representations conveyed by the speeches of the actors involved in their territorialisation is a useful complement to the reconstitution of appropriative trajectories. A comparative analysis of the representations and values of HSR stations will help to clarify how this imaginary dimension contributes to the appropriation of high-speed rail. A dual comparison will be implemented. First of all, for each project, the comparison of the representations of different categories of actors will allow to understand how their mutual influence boosts the territorial appropriation of high-speed rail. Through their interactions, the various individual representations thus identified contribute to build a collective image of high-speed rail which is much more than the aggregation of the multitude of individual representations according to the principles of systemic thinking. Secondly, putting the different analyzed cases into perspective will allow to interpret the spatial fluctuations of these representations in relation with the different choices of the location of stations and the measures implemented to enhance their integration.

5. Conclusion

By focussing the analysis on the many relations between the practices and representations of local actors involved in the territorialization process, the challenge is to grasp appropriation in its multiple components in order to understand the interactions between the location, the integration and the appropriation of HSR stations according to the various contexts of HSR projects implementations. Analyzing the logics of HSR appropriation suggests new research perspectives in order to examine the diverse forms of territorialization of high-speed rail. By mobilizing various data and observation angles (see fig. 3), the methodological approach considered in this paper makes it possible to understand how spatial representations and practices feed each other and to specify the mutual influence of the appropriative logics of territorial actors during the successive stages of the territorialization process. The initial exploratory analyses thus reveal the emergence of different forms of appropriation which emphasize that the territorialization of high-speed rail and HSR stations is ultimately the result of the overlapping of multiple territorialities which could be identified by the joint study of spatial practices and representations. By considering representations induced by high speed rail, my study allows to shed light on the actors' interactions involved in the territorialization of the new transport supply, integrating the symbolic and imaginary dimensions that guide spatial strategies and practices throughout the temporality of the HSR project.

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The configurations of Chinese national urban systems in both high-speed railway and airline networks

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Abstract

Although entering the transportation market at a later stage in 2003, Chinese HSR networks have become the largest in the world and are even growing faster than airline networks. Using 2013 origin/destination (O/D) passenger flow data, we compare the spatial configurations of Chinese urban systems in both high-speed railway and airline networks at the national scale. The outcome shows that, HSR dominant cities and links are mainly centralized in the middle and eastern parts of China offering regional connections, whereas air dominant cities and links are evenly distributed in the whole China offering interregional connections. That is mainly a result of that compared to airline networks, the strength of cities in HSR networks is more sensitive to socio-economic performance of cities, while the strength of links in HSR networks is more sensitive to the geographical distance between linked cities. Furthermore, HSR networks promote agglomeration economies of urban systems along the trunk lines in specific regions, whereas air networks relatively contribute to a more balanced urban development in China.

Keywords: High Speed Railways (HSR), airlines, passenger flows, China, urban systems

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1. Introduction

Urban systems are made up of city nodes and of various kind of (social, economic and political) interactions that materialize to some extent through transportation and information flows (Meijers 2005; Devriendt et al. 2010). Even though Information and Communication Technologies (ICTs) overwhelmingly facilitates instant communication, face to face interactions are still important in the contemporary world (Bertolini and Dijst, 2003). High-speed physical transportations such as airlines and high-speed railways (HSR) which can dramatically decrease geographic and temporal constraints of moving people for business transactions, tourism, post-migratory travels for keeping social links with friends and relatives, academic collaborations and political activities, are still crucial for facilitating the formation of functional urban systems (Hall and Pain, 2006).

Seen the important role of high-speed transportation networks on linking urban areas, the development of airlines and HSR has been supported with substantial capital and infrastructure investments in China to stimulate integration of the national urban network (Ng and Wang, 2012) and its future integration with Euro-Asian urban systems by the Belt and Road Initiatives (Chen and Zhang, 2015). Regarding airline transportation networks, China's ranking in scheduled seats was merely 37th in the world in 1978, but rose to 2nd after 2005. The number of airports (civil certificated schedule airport) in mainland China increased from 94 in 1990 to 216 in 2016, and is expected to reach 260 in 2020 according to the 13th five-year plan of China's contemporary and comprehensive transportation system (Fu et al., 2012; NDRC, 2016). Although entering the transportation market at a later stage in 2003, Chinese HSR networks (Figure 1) have become the largest in the world and are even growing faster than airline networks, even though HSR length per capita is less spectacular (Delaplace and Dobruszkes, 2016). Until to the end of 2015, Chinese HSR networks have reached a total of 19,000km accounting for over 60% of the global level, and can cover more than 70% of the population and 80% of the GDP (Wang et al., 2015; NDRC, 2016).

Figure 1 The HSR planning in China until 2020 (made by authors)

Up to now, a great deal of the existing literature have been focused on functional relationships of urban systems by using schedule seat airline flow data across the world (Smith & Timberlake 2001; Derudder & Witlox 2005; Derudder & Witlox 2009; Van Nuffel et al. 2010). However, HSR travel has received less attention and the few available studies on the functional relationships of urban systems in Europe (Hall and Pain, 2006) and China (Zhang et al., 2016) at the regional or sub-regional scales are based on time schedule HSR data. Like airline travel, HSR has been considered alone instead of jointly with other longdistance transportation modes. The only exception is the study of Xiao et al. (2013) who used passenger data of conventional railways and airlines to estimate a reversed gravity model to identify attractions of a limited number of cities in China. To the best of our knowledge, no study is available on the comparisons of urban systems in both two high-speed transportation networks at the same national scale and by using the same type of passenger flow data. Our research tries to fill these gaps. Thus, the key research question in this paper is how the use of both networks articulates the configuration of national urban systems using the actual HSR and air passenger flows. This is of particular interest for two reasons. First, as we will argue in the next section, the functional relationships of urban systems at a larger spatial scale would be better reflected by passenger flows travelling (i.e. the demand side) than by the provision of rail or air services (i.e. the supply side) (Yang et al., 2017). Second, both HSR and airline networks in China mainly carry people from the middle to upper-middle classes, that is, social groups that have stronger travel demands for functional activities such as high-end business, advanced producer services and tourism (Delaplace and Dobruszkes, 2016; Liu and Kesteloot, 2015). The relevant functional relationships of urban systems might differ in both high-speed transportation networks with their different network properties. Consequentially, the comparisons of the configurations of urban systems in both transportation networks could provide an insight into the future high-speed transportation and urban system planning.

This paper is structured as follows. Section 2 presents the literature review. Section 3 explains our analytical framework, after which we introduce both HSR and airline O/D flow data. In Section 4, the results of our analyses are discussed, which consist of a general overview of HSR and airline passenger flows at the national scale. This section is followed by a comparison between them. The final section comprises the conclusions of the paper and an outlook on some future research issues.

2. Literature review

For understanding the functional relationships between cities, studies on transport networks have taken a prominent role in the space of flows at different spatial scales. The traditional internal “space of places” has given way to the external “space of flows” proposed by Castells (1996), which emphasizes functional relationships between cities. In the theory of “space of flows”, there are three layers determining the flows of information, people, and capital. The first layer is the infrastructure layer of the material support for the flows. The second layer contains different nodes and hubs which are connected and organized by the infrastructure layer. The third layer is that people exercise the directional functions (Derudder & Taylor 2005).

As to the three layers, two types of popular empirical approaches emerged to assess the external flows among cities. The first approach is based on the derived flows of advanced tele-information contacts (Devriendt et al., 2010), advanced producer services (APS) (Zhao et al., 2015), and business elite contacts (Beaverstock, 2004) within the three layers. However, strong criticisms exist on the ‘derived flow approach’. The main argument is that it cannot reflect the extent to which the internal characteristics of nodes can be translated into the external interaction (Robinson, 2005), which means the derived linkages of people, information, and service from node attributes cannot reflect in which direction and to what extent flows are actually produced by people (Neal, 2010). Therefore, a better alternative approach is based on actual corporeal flows in the first transport infrastructure layer by means of either schedule data (the supply side) or actual passenger data (the demand side).. Airline scheduled seats have been used to investigate the structure of world cities at the global scale (e.g., Smith & Timberlake 2001; Choi et al. 2006; Derudder & Witlox 2005) and inter-regional airline transport linkages in Europe (Derudder and Witlox, 2009; Van Nuffel et al., 2010), the USA (Derudder et al., 2013) and China (Lao et al., 2016; Ma and Timberlake, 2008). In contrast, only a few scholars have considered HSR travel to investigate interactions between cities. For instance, Zhang et al. (2016) used the HSR time schedule data to approximate the actual passenger flows to uncover the relationships of cities in the Yangzi River Delta (YRD) region in China and Hall & Pain (2006) used the scheduled train flows to identify the polycentric urban regions in Europe.

However, both airline and HSR data raise several issues. First, it is common to consider supply-related data (typically the number of seats offered between two cities, or sometimes train frequencies or seatkm's). The rationale for supply-side data relies on the fact it says something about carriers' strategies that are expected to draw networks according to existing and potential interactions between places served. However, the supply is by definition larger or equal to the demand, so at best it can be considered as a proxy for actual flows of people (Neal, 2014). Second, supply or demand data are usually given at the individual legs of trips rather than the trip as a whole. For instance, if air or rail passengers travel from A to B where they connect to C, usual figures would count the number of (airline or HSR) seats or passengers between A and B and between B and C but not between A and C via B. As a result, transfers distort the picture of actual intercity relationships (Derudder et al., 2010; Derudder and Witlox, 2008, 2005). As far as air travel is concerned, some researchers have addressed this issue by using the so-called MIDT dataset, which is based on actual origins/destinations air travellers flew from/to (Derudder et al., 2007). However, information is based on bookings made through global distribution systems (GDS). It means that those travellers who directly book on airlines' websites are not included. This could arguably lead to biases, for instance, an underestimation of people flying by low-cost airlines[1].

Finally, HSR timetables are difficult to convert into the number of seats for two reasons. First, many HSR routes are served by heterogeneous rolling stock (e.g., shorter vs. longer trains or single- vs. double-deck trains). This means that if a train operator would pursue a high-frequency strategy (that is, the operation of frequent services but with likely less capacity per train), the alleged interactions between cities derived from HSR frequency would be biased. Second, provided the number of HSR seats is nevertheless available (e.g., from the train operator or thanks to homogeneous rolling stock), one still needs to consider that most high-speed trains (HSTs) call at several intermediate stations. This involves uncertainties on how seats are split between the various city-pairs thus served. For instance, if a Beijing (A) to Shanghai (D) HSR service calls at Jinan (B) and Nanjing (C), then seats are potentially sold for A-B, A-C, A-D, B-C, B-D and C-D city-pairs. Either the train operator pre-allocates seats to all pairs or the actual bookings make the split change in real time. But in both cases, this information is usually not available to researchers. It is thus not surprising that Yang et al. (2017) found that the scheduled train flows actually

1 *In Europe for instance, European low-cost airlines have long kept out of GDS to avoid extra costs.*

can to a large extent underestimate the positions of major cities in the urban system, especially in China with a larger-than-average capacity in the trains running from and to these major tier cities to satisfy the demands of passenger travel.

As a result of all these limitations, there is a strong rationale for investigating urban systems (1) through demand-related data, which (2) are based on true origins and destinations (Neal, 2014). Of course, such data are usually not fully available (or even not available at all) for scholars. Commercial privacy and confidentiality dominate academic purposes, even in the strictly controlled railway sector in China (Liu et al., 2015).

In sum, the literature review above indicates that currently the research on both airline and HSR network research is largely based on time schedule data instead of the actual number of passengers carried by transportation networks between cities, which can lead to some misunderstanding of the functional urban system. Furthermore, world city research using airline data and the regional urban system research using HSR data only include a limited number of cities at the global and regional scale, respectively. There is no comparison between the roles of high-speed railway and airlines on the configuration of urban systems with a large number of cities at the same spatial level. Our research tries to fill the gaps by the applications of both HSR and airline O/D passenger flows to compare the configurations of urban systems in the two high-speed transportation networks at the national scale in China.

3. Methodology

3.1 Data description

In this study, cities are the nodes in the networks. The relationship between nodes is operationalized as the number of actual number of HSR and airline passengers travelling between cities. In China, there are four types of cities: municipalities, sub-provincial and provincial capital cities, prefecture-level cities and county-level cities (Ma, 2005). Country-level cities are merged with the prefecture-level cities since most cities do not have airports and HSR stations and are under the administration of relevant prefecture-level cities. If there are cities with multiple HSR stations and airports, those terminals have been merged into one node. For example, if node *i* is Beijing and node *j* is Shanghai, a_{ij} represents the HSR or airline passenger flows between the two urban areas. The HSR passenger matrix was collected by the Transportation Bureau of the China Railway Corporation, including the total actual numbers of aggregated HSR O/D passengers travelling between pairs of cities[2]. The data cover the 105 existing HSR cities (Figure 2) (4 municipality-level, 21 sub-provincial/provincial capital level and 80 prefecture-level cities) and 1675 city links (passenger volume larger than 0) in China in 2013 (over 436 million passengers). The airline passenger matrix was collected by the Civil Aviation Administration of China and includes a total actual number of O/D air passengers travelling between pairs of cities. The data cover the 168 existing airport cities (Figure 2) (4 municipality-level, 32 sub-provincial/provincial capital level and 132 prefecture-level cities) and 1467 links (passenger volume larger than 0) in China in 2013 (over 306 million passengers). In the end, we obtained 51 cities with both HSR and airport terminals and 144 city pairs with both HSR and airline connections in 2013.[3]

2 According to China classification of HSR services, these are D and G trains.

3 Due to the fact that HSR passenger flow data are rarely accessible for researchers especially at the national scale in China, we could only compare both HSR and airline passenger flow data in 2013 instead of the up-to-date data in 2016.

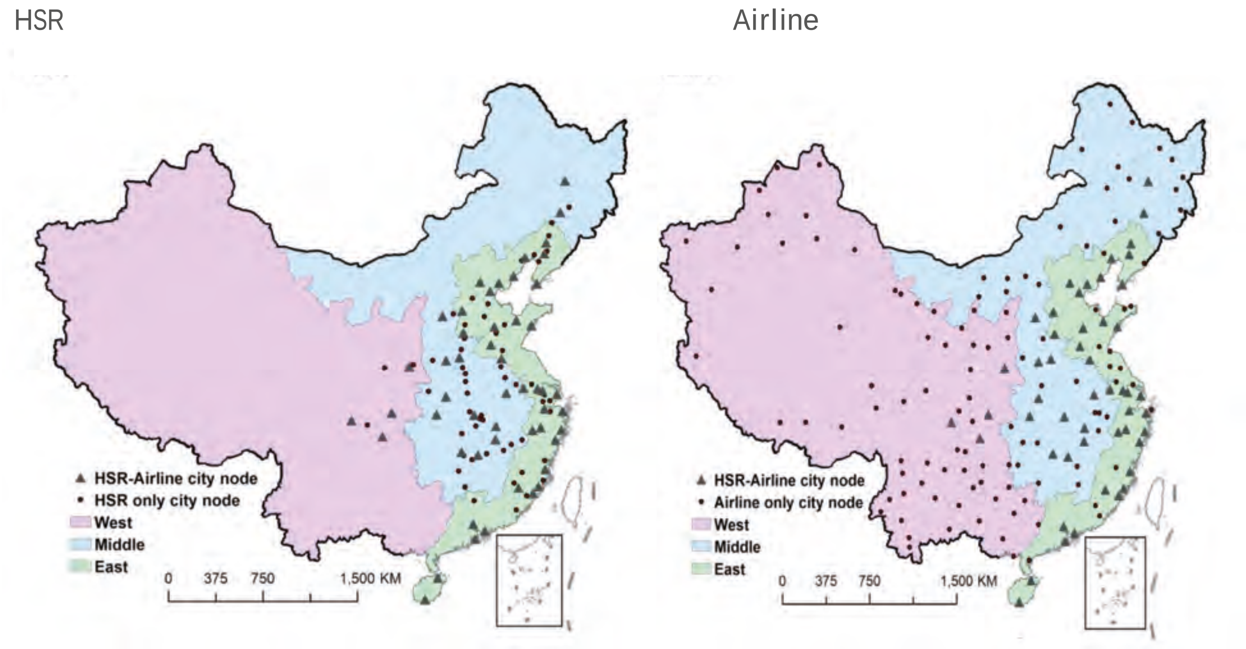


Figure 2. The distribution of HSR and airline cities[4]

It is worth noting that airline and HSR travel is arguably not representative of all medium- and longdistance travel within China. Indeed, there is clear evidence that the poor and even a part of the middle class have much less access to airlines and HSRs due to relative high monetary travel cost than conventional railways (Delaplace and Dobruszkes, 2015; Wang et al., 2013). For instance, migrants living in cities favour conventional (lower-speed) trains to visit other cities notably because it is much cheaper (Liu and Kesteloot, 2015). In addition, various cities are neither served by HSR services nor by air services. Therefore, our research does not capture the full set of functional interactions between cities. Instead, our research is focused on urban systems as reflected by both HSR and air passenger flows, which favour mobilities of the upper social-occupational groups (business activities, government officials, premium tourism or VFR (visiting friends and relatives) travel, etc).

3.2 Analytical framework

3.2.1 Measures of the city centrality and link connectivity

To identify the structural characteristics of the urban system as manifested by airline and HSR passenger flows, it is necessary to understand the urban hierarchical structure based on city centrality and connectivity rankings in the transportation network. We measure configuration of the urban systems by adapting the framework presented in Limtanakool et al. (2007) and Van Nuffel et al. (2010) in which two strength indices (namely, city strength and link strength) are used to measure the city centrality and link connectivity.

$$DIT_i = \frac{T_i}{(\sum_{j=1}^{J} T_j / J)} \qquad (1)$$

4 *The division between the west, middle and east is based on NBSC (2011).*

Where we define DIT_i as the city centrality, indicating the relative strength of city i in the national transportation network. T_i is the total number of passenger volumes associated with city i, and i≠j. Cities with DIT_i values above 1 are considered dominant because they are more important than the average of the other cities in the network. To compare the different positions of cities in the two transportation networks, we further categorized 3 classes of dominant cities (the first class with a DIT value larger than 10 as national dominant cities, the second class with a DIT value between 5 and 10 as regional dominant cities, and the third class with a DIT value between 1 and 5 as local dominant cities (Wang and Jing, 2017).

$$RSL_{ij} = \frac{t_{ij}}{\sum_{i=1}^{I} \sum_{j=1}^{J} t_{ij}} \qquad (2)$$

Where we define RSL_{ij} as the connectivity of a city pair, indicating the relative strength of a link connected by the national transportation network. t_{ij} is the total number of passengers travelling between cities i and j, and i≠j. RSL_{ij} is the value for all links in the network sum to unity, while individual values range from 0 to 1. A value of 1 represents the highest strength of a link. Since some RSL values will be rather small, to clear understand their strength values, the RSL value is multiplied by 1000 (Derudder and Witlox, 2009). According to the multiplied value of link strength, we categorized 5 classes of dominant city links (the first class with a RSL value larger than 20, the second class with a RSL value between 10 and 20, and the third class with a between 5 and 10, the fourth class between 1 and 5.

We further perform a multiple linear regression to investigate the differential impacts of attributes of urban systems on the city and link strength in both transportation networks. Following the existing literature, in Table 1 we considered a mix of geographic, social, economic and political attributes related to cities as potential covariates.

Table 1. Independent variables for regression analysis

Variables	Information	Source	Mean_HSR	SD_HSR	Mean_Airline	SD_Airline
	City strength					
GDP per (million yuan)	Gross domestic product per capita for a city	Chinese urban statistical yearbooks 2014	3712.4	3989.6	2549.6	3431.5
Population (inhabitants)	Population for a city		578.5	428.7	452.2	402.9
Average distance (km)	The average distance of one city to other cities connected by HSR or airline networks	Calculated by authors from GIS	551.4	175.2	914.2	320.8
Administrative level	Hierarchical administrative level (scored)	(Ma, 2005)	2.7	0.5	2.8	0.5
	3=Municipality level city 2= Sub-provincial/ regional capital level city 1 = Prefecture city					
	Link strength					
Summed GDP per (million yuan)	Summed gross domestic product per capita for each city pair of origin and destination	Calculated by authors	9361.4	6604.1	12145.1	6923.8
Summed population (inhabitants)	Summed population for each city pair of origin and destination		1264.0	607.5	1489.3	854.0
Distance (km)	The geographical distance between a city pair		605.3	363.3	1086.2	583.1
Summed administrative level	Summed administrative level for each city pair of origin and destination		5.3	0.8	4.5	0.7

3.2.2 Hierarchical cluster analysis (HCA)

It should be noticed that each transportation network could be composed of multiple clusters and multiple subgroups as community networks. Community networks refer to city nodes that are gathered into several groups in which there is a higher density of city-pair connections within groups than among groups. HCA is a community detection algorithm based on modularity proposed by Newman and Girvan, (2004). The basic concept of the HCA algorithm is to evaluate the result of the network partitioning, which computes the difference between the number of links within communities and the expected number.

$$Q = \sum_{m=1}^{n} \left[\frac{l_m}{L} - \left(\frac{d_m}{2L}\right)^2 \right] \quad (3)$$

We define Q as the modularity value; the higher the value of Q, the better the community structure is. n denotes the total number of communities in the network, L is the total number of passengers in the transportation networks, l_m is the total number of passengers in the community m, d_m is the total number of cities in community m.

4. Results

4.1 The comparison of city strength between HSR and airline networks

4.1.1 City strength

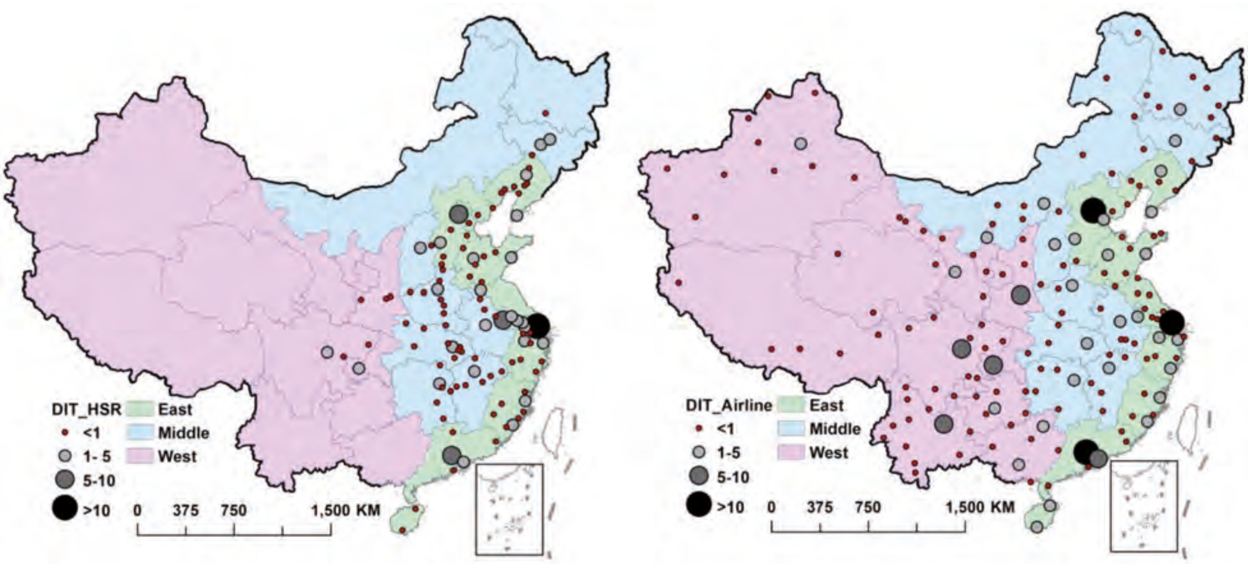


Figure 3 The city strength of HSR (left) and airline (right) networks.

As shown in Figure 3, 29 of 105 HSR cities and 37 of 168 airline cities are dominant (that is, DIT ≥1), and 76 and 130 non-dominant, respectively (DIT <1). Regarding the dominant cities, Beijing, Shanghai and Guangzhou in the east are the top three cities in China but belong to different city classes in both networks. Although the three cities as national cores have the similar socio-economic performance in China, Beijing and Guangzhou are only in the first class of airline networks but Shanghai in the first class of both airline and HSR networks. This can be explained by two reasons:

Firstly, Beijing and Guangzhou's average distances to other cities (828 km and 1034 km) are larger than Shanghai's (723 km) in HSR networks, making air travel more attractive than HSR travel due to a shorter travel time.

Secondly, HSR networks in the densely populated YRD are much more developed (e.g. higher density and frequency of HSR networks) than in the Bohai Rim and the PRD, leading to more functional interactions of cities with Shanghai in the YRD than that with Beijing in the Bohai Rim and Guangzhou in the PRD by HSR networks.

Meanwhile, regarding the geographical location of Nanjing in the YRD region with completely developed HSR networks and its role of being a regional socio-economic core rather than a national one, it is not surprising to find that Nanjing is in the second class of HSR networks but the third class of air networks. Except to Shenzhen as a sub-provincial city in the east, Chongqing as a municipality city, Chengdu, Kunming, and Xi'an as provincial capitals in the west are in the second class of air networks, which reflects that major cities being as regional socio-economic cores in the west are competitive for the air travel than in the east.

In the third class of dominant cities, there are 25 HSR cities most of which are mainly regional capitals and economic centers in the middle and the east (i.g. Wuhan in Hubei province and Hangzhou in Zhejiang province) of the country. Only Chengdu and Chongqing are located in the west of China offering only connections between each other and not with the rest of the country. In the third class of dominant cities we also find 30 airline cities most of which are provincial capitals and economic centers in the middle and east, but include in comparison with HSR cities more provincial capital cities in the west, such as Urumchi, Guiyang, Nanning, Lanzhou and Yinchuan and typical tourism cities such as Sanya and Guilin.

In order to identify the different positions of a city in HSR and airline networks, we further identified the HSR and airline advantage cities by comparing the differences of city strength values (DIT) between HSR and airline networks among the 51 HSR-Airline cities. If one city's DIT value of HSR networks is larger than that of airline networks, it is considered as a HSR advantage city or otherwise an airline advantage city in Figure 4. Furthermore, Pearson's r (city strength correlation coefficient) and Spearman' rho (city rank correlation coefficient) test are used to identifying whether there is a direct correlation for 51 HSRAirline cities between HSR and airline networks.

The associations between the two networks for HSRAirline cities by the values of city strength and related rankings are statistically significant: Pearson's correlation coefficient is 0.871 ($p < 0.01$) and Spearman's rho is 0.788 ($p < 0.01$). This means that a city is dominant and highly ranked in one network should be the same in another network, thus it is necessary to not only take into account the large absolute value (DIT_HSR minus DIT_Airline >1 or DIT_Airline minus DIT_HSR>1) but more importantly the class changes to identify those outlier cities between two transportation networks.

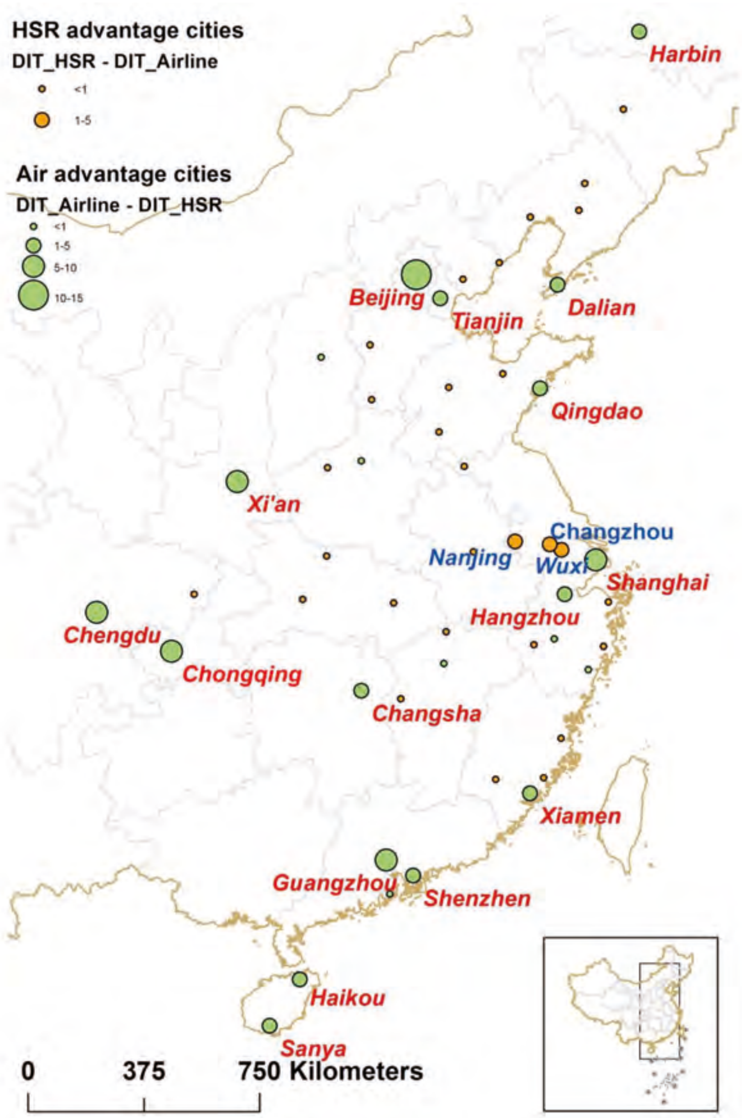


Figure 4. The comparison between HSR and Airline advantage cities.

With the difference value larger than 1, there are three HSR advantage cities (Nanjing, Wuxi and Changzhou) and 16 airline advantage cities (Beijing, Chengdu, Shanghai, Guangzhou, Xi'an, Chongqing, Shenzhen, Sanya, Haikou, Xiamen, Qingdao, Harbin, Dalian, Tianjin, Changsha, Hangzhou) in China. As to HSR advantage cities, Nanjing was upgraded from the third class of airline networks to the second class of HSR networks, Wuxi, Changzhou are from the fourth class to the third class. The three HSR advantage cities with more than 60 HSR connections to other cities are all major cities with a high number of GDP and populations, interacting strongly with each other within Jiangsu province by the Nanjing-Shanghai HSR route and with other cities out of Jiangsu province through the Shanghai-Hangzhou HSR route. Their HSR dominant positions not only reflect their important roles of serving as regional HSR hubs for short and medium distance travel, but also the intense interactions between them and adjacent cities which are facilitated by relatively more completed HSR networks in the YRD than any other regions.

In terms of airline advantage cities, except to Sanya and Haikou which are tourism cities in Hainan province[5], they are the major cities with high socio-economic performance and administrative levels mainly in the east and a few in the west. Among them, although there exist large differences between the city strength values in two transportation networks, Shanghai, Xiamen, Dalian, Changsha and Hangzhou did not have the class change. They are typical transport hub cities in specific regions with well-connected both HSR and airline networks, functionally interacting not only with distant cities far away but also adjacent cities within the regions to a certain extent. Therefore, in this case, although those cities are in the same class of both networks, their city strength is larger in airline networks than HSR networks because of some inbound airline passengers (or outbound airline passengers) transiting to/from other cities by HSR within the specific regions. For instance, despite some operational and administrative obstacles for the airline-HSR integration in Shanghai's Hongqiao Terminal (the best integrated transport hub in China), there are still a large amount of airline passengers transferring in Shanghai by HSR to adjacent cities in the YRD region (Givoni and Chen, 2017). This is also confirmed by aforementioned three HSR advantage cities within less than one hour HSR travel time with Shanghai. Different from those airline advantage cities without the class change, Beijing was upgraded from the second class of HSR networks to the first class of airline networks; Guangzhou and Shenzhen as the other two southern economic cores in Guangdong province were upgraded from the second and third class of HSR networks up to the first and second class of airline networks, respectively.

As mentioned before, due to its geographical location in the north with a larger average distance to other cities, being a national capital with the most airline connections, Beijing still heavily relies on the airline network for the interaction with other distant cities, which is also the case for Guangzhou and Shenzhen in the south. Chengdu and Chongqing in the south-west were upgraded from the third dominant class of HSR cities to the second dominant class of airline cities. However, different from the cases of Beijing, Guangzhou and Shenzhen, the weaker roles of Chengdu and Chongqing with fewer than three HSR connections to other cities are mainly a result of the uncompleted HSR construction between the middle and the west. Thus, their functional interactions with cities in the middle and even further to the east could be only facilitated by air networks.

Interestingly, Haikou and Sanya in Hainan province, and Harbin, and Tianjin in the north increase from the non-dominant class of HSR networks to the third dominant class of airline networks and Xi'an from the non-dominant class of HSR networks even to the second class of airline networks. Typically, Sanya and Haikou as two tourism cities in Hainan province are only served by the Sanya-Haikou HSR route; therefore, due to their isolated geographical locations in an island without direct ground transportation connections to the mainland of China, they have to resort to the airline transportation for carrying passengers to/from Hainan province, especially for leisure travel.

It is surprising that Tianjin as a municipality-level city, and Haerbin and Xi'an as sub-provincial and regional capital cities with large GDP and populations, are only dominant in airline rather than HSR networks. It could be that their regional integrations with adjacent cities are not as good as their interregional integrations with distant cities, which is reflected by both types of passenger flows from demand side. For instance, Tianjin's economic structures are less cooperative with other adjacent cities in the Bohai Rim (Yang, et al 2017). Therefore, it has to resort to the airline travel instead of HSR travel for the economic cooperation with other distant cities out of the Bohai Rim.

5 *Hainan province is an island separated from Mainland China by the Qiongzhou Strait with an average 30km width.*

4.1.2 Link strength

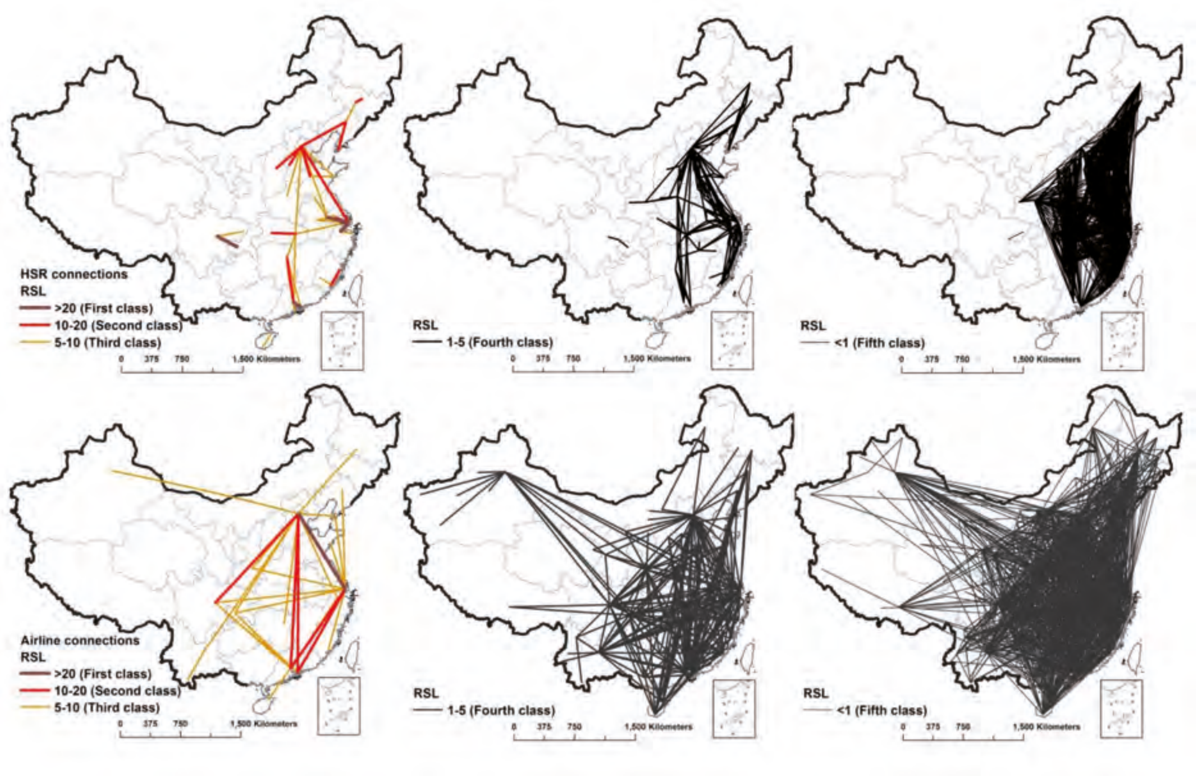


Figure 5. The geographical distribution of HSR and airline links.

Figure 5 shows the five classes of links in the HSR and airline networks. Regarding the first class, only the link Beijing-Shanghai connecting the Bohai Rim and the YRD region is in airline networks, while the links Guangzhou-Shenzhen in Guangdong province, Hangzhou-Shanghai, Suzhou-Shanghai, and NanjingShanghai in the YRD region, and Chengdu-Chongqing in the south-west are in HSR networks. It can be found that city ends in the first class are all national or regional socio-econoimic cores with quite high GDPs and populations. However, airline networks facilitated the interregional interaction between the national economic cores such as Beijing and Shanghai with a long geographical distance (1,092 km). In contrast HSR networks facilitate the regional interactions between regional economic cores with an average short distance (178 km), which can be understood as a consequence of the dense urban network in Eastern China. This typically reflects the primarily dominant position of each type of network for the inter-city connection at the national or regional scale, respectively.

In terms of the second class, besides to a few interregional links such as Beijing-Shanghai, GuangzhouChangsha and Beijing-Shenyang whose city ends are economic cores in different regions, there are more regional connections in HSR networks such as the links connecting Beijing to Shijiazhuang, Jinan and Taiyuan in the Bohai Rim and Shanghai to Wuxi and Changzhou in the YRD region; meanwhile, there are still only interregional connections for long distance travel in airline networks such as the links connecting Beijing to Guangzhou, Shenzhen and Chengdu, and the links connecting Shanghai to Guangzhou and Shenzhen. The Beijing-Shanghai link in the second class of HSR networks reflects that for interregional travel within a certain distance, HSR connections can compete with airline connections for the major city links.

As to the third class, HSR networks start to cover largely the inter-regional connections between capital cities within their respective regions such as Beijing-Nanjing and Guangzhou-Wuhan, while airline networks start to connect the national capital cities with high socio-economic performance and other regional capital cities with relatively low socio-economic performance such as the link Beijing-Urumchi, and further provide connection services between major and tourism cities within specific regions such as the link Kunming-Xishuangbanna in Yunan province. With regard to the fourth class, there are 219 links accounting for 14.9% of the total links in HSR networks in which the interactions between the middle and the east have increased to a large extent by HSR travel. Meanwhile, there are 155 links accounting for 16.9% of the total links in airline networks in which interactions between the west, the middle and the east parts of China have increased; the connections to cities in Xinjiang, Yunnan and Xizang provinces are only covered by airline networks. In the fifth (non-dominant) class, the airline connections have already covered the whole parts of China but with weaker intra-connections in the west than the middle and east, whereas the HSR connections still only cover the middle and east parts of China. This is likely a typical reflection of the core-periphery urban system in China where cities where cities in the middle and west are much reliable on the functional interactions with cities in the east by HSR and airline travel, respectively.

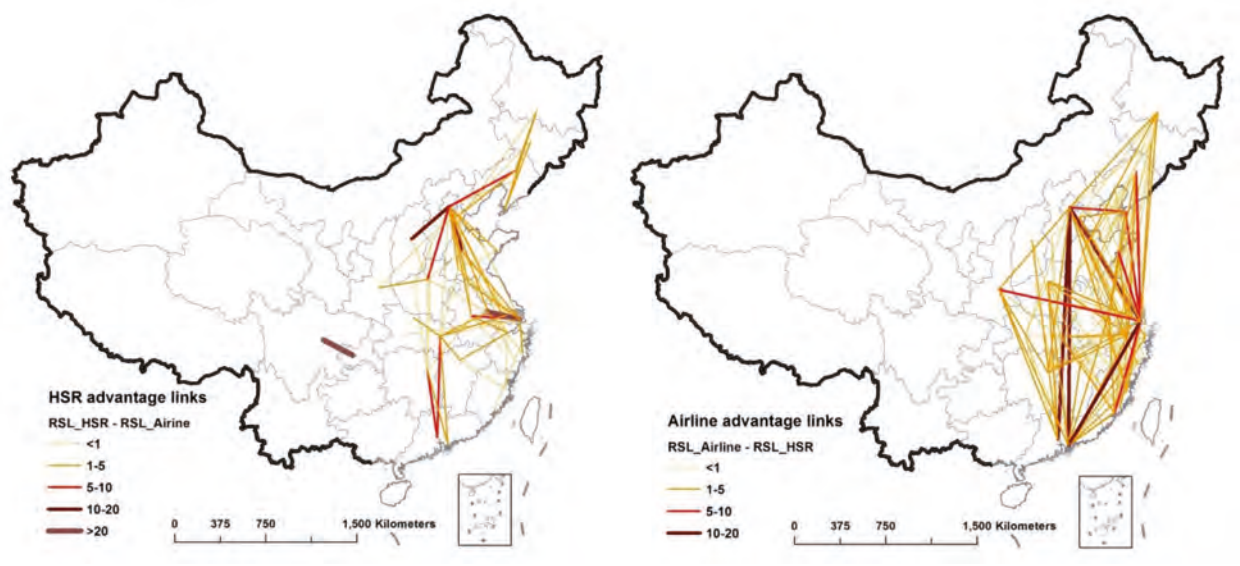


Figure 6. The comparison between HSR and airline advantage links.

We further identified the HSR and airline advantage links by comparing the differences of link strength values (RSL) between the HSR and airline network among 144 HSR-Airline city links. If one link's RSL value of HSR networks is larger than that of airline network, it is considered as a HSR advantage link or otherwise an airline advantage link in Figure 6. The associations between the two networks by the values of link strength and related rankings are statistically non-significant: Pearson's correlation coefficient is 0.167 ($p > 0.01$), and Spearman's rho is 0.123 ($p > 0.01$). This means that a city link with both HSR and airline connections, which is dominant in one transportation network, will be not dominant in another one. In Figure 8, it clearly shows that HSR advantage links normally connect the major cities with large populations and GDP in the specific region with a short travel distance. In contrast, airline advantage links connect the major cities with large populations and GDPs in different regions with a long travel distance. For example, both Chongqing-Chengdu and Shanghai-Nanjing were downgraded from the first class in the HSR networks to the fifth class in the airline networks, while Beijing-Shenzhen and ShanghaiShenzhen upgraded from the fifth class in HSR networks to the second class in airline networks. Therefore, it can be found that although for the city links with both HSR and airline connections, end nodes of links are mainly the major cities or hubs, whether they are dominant on HSR or airline networks are largely based on their geographical distances between the city ends.

4.1.3 City and link strength vs. attributes of urban systems

To interpret aforementioned results, we performed a multiple linear regression to investigate potential factors of both city and link strength

Table 2. Multiple regression on city strength

	DIT_HSR[a]	DIT_Airline[a]
	Standardized coefficients	Standardized coefficients
GDP per capita[a]	0.576***	0.184***
Average distance[a]	0.022	0.299***
Population[a]	0.414***	0.141***
Administrative level	0.185**	0.502***
Observations	105	168
Adjusted R-squared	0.689	0.665
* p<0.1 ** p<0.05 *** p<0.01		

[a]*Ln transformation.*

Table 2 shows results at the city level, it appears that GDP per capita and population of cities are the first and second most significant indicators for the city strength in HSR networks, compared to the administrative level of cities and the average distance to others in airline networks. Cities in HSR networks show higher elasticities of GDP per capita and population to the city strength than in airline networks, meaning that compared to airline travel, HSR travel is still mainly concerned about the connections to cities with higher socio-economic performance. The positive sign of the average distance to other cities in airline networks rather than in HSR networks indicates if one city is far away from others, the airline travel becomes a more suitable transportation alternative than the HSR travel for middle and long haul travel. Furthermore, the negative coefficients of the administrative level in both transportation networks indicate that in general the higher the city's position in the administrative hierarchy, the more likely passengers need to travel either to/from other cities. However, city strength is much sensitive to the administrative level in the airline network than in the HSR network. Therefore, it could expect both distance and administrative hierarchy more affect the city strength in airline than HSR networks.

Table 3. Multiple regression on link strength

	RSL_HSR[a]	RSL_Airline[a]
	Standardized coefficients	Standardized coefficients
Summed GDP per capital[a]	0.171***	0.198***
Summed population[a]	0.254***	0.027
Distance[a]	-0.571***	-0.081***
Summed administrative level	0.287***	0.457***
Observations	1675	1466
Adjusted R-squared	0.508	0.265
* p<.1 ** p<0.05 *** p<0.01"		

[a]*Ln transformation.*

Distance and summed administrative level are the most significant factors to the link strength in HSR and airline networks, respectively (Table 3).

It can be observed that the link strength has a much higher negative elasticity compared to the distance in HSR than in airline networks. This makes sense considering that with all other things being equal, the attractiveness of HSR services decreases when travel time increases (Givoni and Dobruszkes, 2013). If we eliminated the distance factor that can be considered as not being an attribute of cities, the model describes 19.7% and 25.9% of the variation in link strength in the HSR network and the airline network, respectively. This means that the geographical distance between cities in HSR networks has a larger impact on the link strength of city pairs than in airline networks. The reason could be that link strength is much more sensitive to the distance decay effect in HSR rather than airline networks and that the HSR travel is heavily restricted by the geographic condition of terrains. Furthermore, the negative sign of summed administrative level reflects that nodes of city links with a lower administrative level show low travel demand in between. However, the summed administrative level is much more elastic to the link strength in airline networks and thus proves that city nodes with a higher administrative level and being far away from each other tend to be served by airline travel. That indicates that public service obligations or any other governmental mechanism guarantees some decent level of airline service between distance cities.

4.2 Community structure

According to the HCA analysis, we visualized the communities of the HSR and airline network, respectively in Figure 7. The dendrograms of HCA of HSR and airline networks, which are presented in Appendix (A), can reflect the extent to which city nodes are bonded within each community. A shorter bracket and a lower position in the dendrogram trees mean a stronger relationship between a pair of cities in the subgroup.

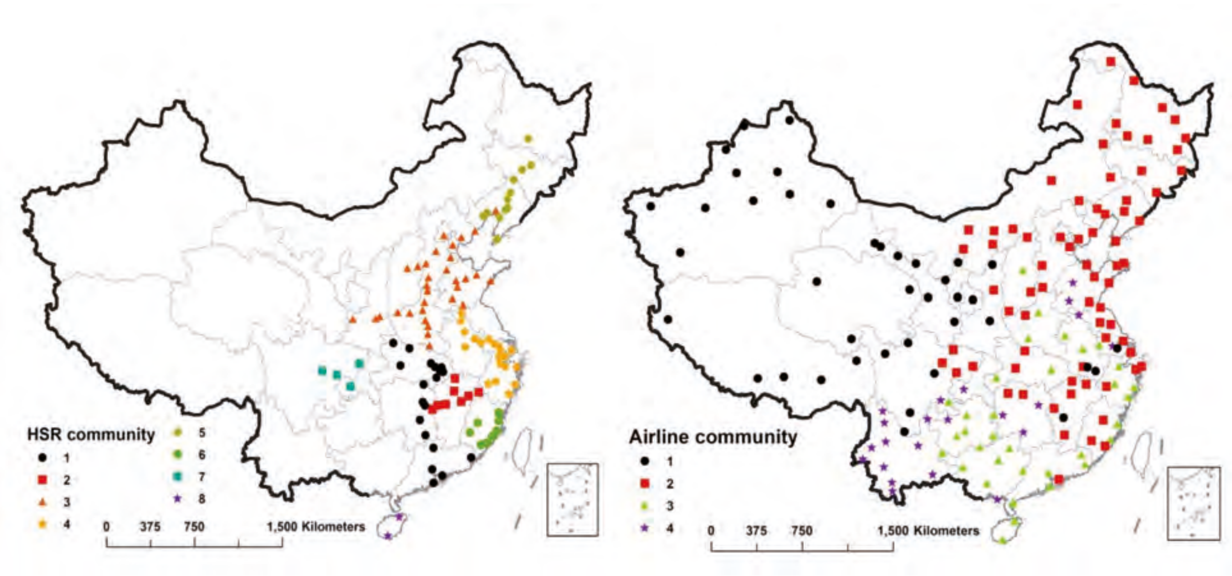


Figure 7. The spatial distribution of communities

In the HSR network, the modularity value is 0.58, and there exist eight subgroups with typical characteristics of geographical distributions in China, reflecting that the geographical proximity matters most in intercity relationships. For instance, in the YRD region, Shanghai services as the core and form the strongest bonds with Hangzhou along the Jinghu and the Shanghai-Hangzhou HSR routes. In the north-east with Liaoning, Jilin and Heilongjiang provinces, Jilin-Changchun and Dalian-Shenyang form strong bonds along the Jingha HSR routes covering the north-east regions. Besides, in Jiangxi and Fujian provinces, there are strong agglomeration effects within each province where Nanchang-Jiujiang and Fuzhou-Xiamen form the strongest bond, and then other peripheral prefecture-level cities are connected by parts of the Hukun HSR route and the southeast coastal HSR route within each province, respectively. Along the Wuhan-Guangzhou route connecting the middle and the southeast, cities are also clustered. Furthermore, two clusters are formed mainly due to the geographical isolation and less developed HSR network connections: Sanya and Haikou as mentioned before are isolated from the mainland of China. There is no direct HSR channel connecting the Hainan island to the mainland of China, which forces them to be a cluster connected by the Hainan HSR route. There exists another cluster in the southwest where Chengdu and Chongqing serve as the cores with limited connections with adjacent cities by parts of the Huhangrong HSR route due to a rather slow development of HSR networks up to 2013 in the southwest. In sum, HSR cities in the specific regions tend to be clustered with adjacent cities along the HSR routes.

In contrast, in the airline network, the modularity value is only 0.12 and accordingly there are four subgroups in the airline network without the obvious characteristics of the geographical cluster distribution in specific regions. For instance, in the airline transportation network, Shanghai and Shenzhen in the middle-east and the south-east forms the strongest bond and starts the first subgroup, and this subgroup grows with the addition of Xiamen and Tianjin. Then loosely connected cities in different parts of China then are added to enlarge the original group. Despite four subgroups in the dendrogram, they have not formed any major geographical clusters separately in specific regions due to the overlapping wide influence scopes of aviation centers.

5. Conclusions and discussions

This paper contributes to the current state of research, as it clearly reveals differential China's spatial structures of urban systems connected by its two high-speed transportation networks (HSR and airlines). To the best of our knowledge, this paper is the first study to use the actual O/D passenger flow data and compares the resulting configuration of the Chinese urban systems in tow type of high-speed transportation networks at the national scale. These urban systems are likely those of upper socialoccupational groups given the social filter that shapes the use of fast, long-distance transportation modes.

First, in terms of city strength, HSR dominant cities are mainly centralized in the middle and eastern parts of China, whereas airline dominant cities are evenly distributed over the whole China. This difference can be partly explained by the Chinese physical geography of the country: many cities are located far away from each other in the non-densely populated mountain areas of the west region that cannot be easily reached by surface HSR transportation, in contrast to the cities located in the densely populated plain areas of the east region. Movover, that difference can be further explained by that although both HSR and air passenger flows are constrained by the socio-economic performance of cities, the city strength in HSR networks tends to be more sensitive to socio-economic performance but less sensitive to administrative level of cities compared to air networks. This is largely a consequence of the relatively expensive investments in HSR networks that are socially and economically justifiable in high-density passenger volume areas compared to airline networks. In other words, not only HSR networks are not suitable for long-distance travel at the national scale, but also not viable for low-density passenger volume corridors, even though central governments can decide differently due to political reasons (de Rus and Nombela, 2007; Dobruszkes et al., 2017). Typically, in this case, remoter but higher ranked cities in the west part of China in 2013 are usually served by airline instead of HSR at the national scale, at least for the needs of the public authority's interactions between them and other dominant cities in the east from an administrative and governance perspective. Therefore, cities with high GDP and populations in the east are normally the core cities in both transportation networks, reflecting the inequitable development of urban systems. For instance, Beijing, Shanghai and Guangzhou as the top three cities in both HSR and airline networks reflect their national socio-economic importance in China's urban systems, which is similar to the finding of scheduled data in airline networks (Lin, 2012; Ma and Timberlake, 2008) but different from that in HSR networks (Jiao et al., 2017) where Nanjing instead of Guangzhou is in the top three. Regarding a much better socio-economic position of Guangzhou than Nanjing in China, logically Guangzhou should be more dominant than Nanjing at least in HSR networks from the perspective of demand side.

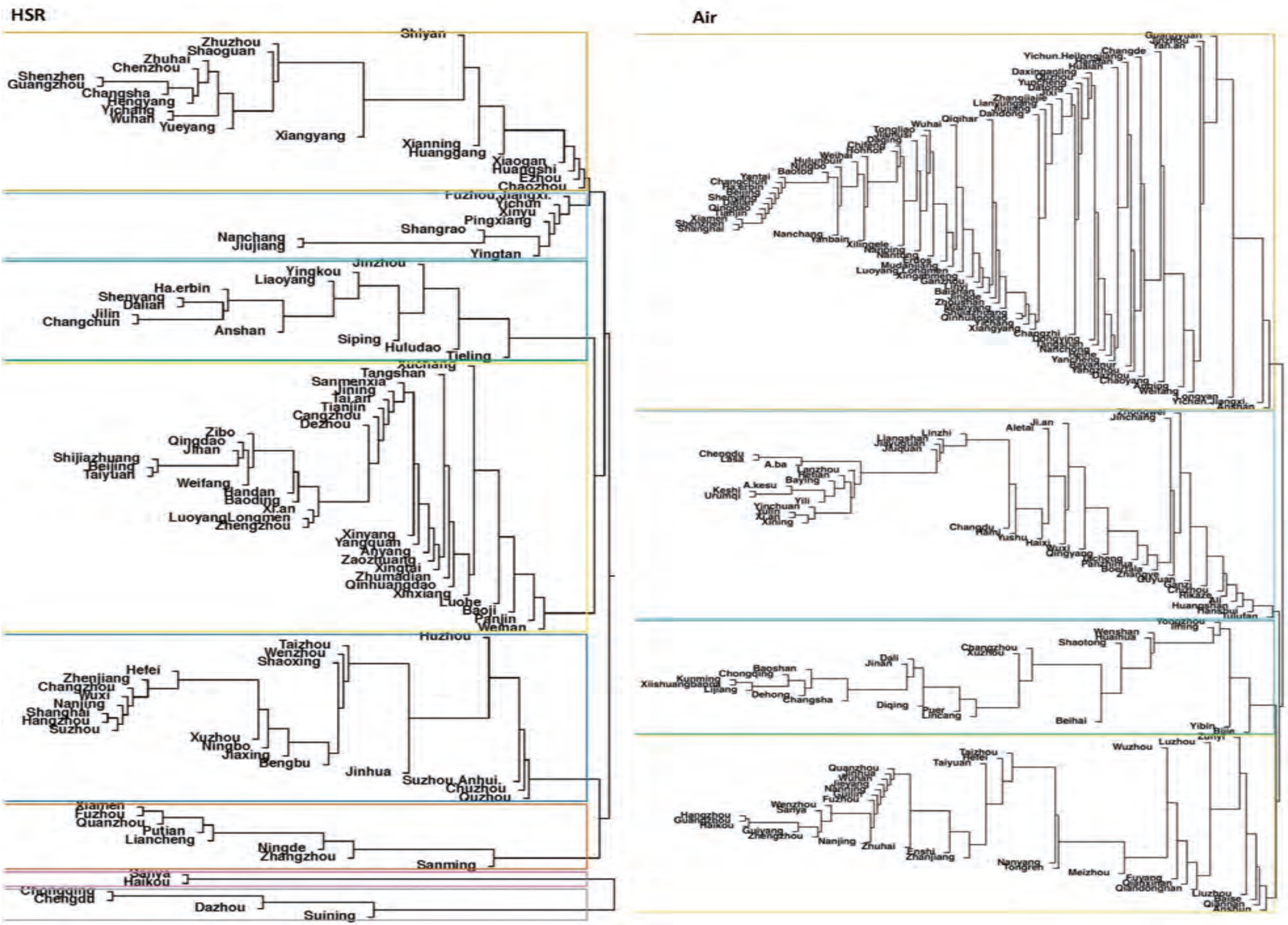
Second, in line with the former observation and explanation, the findings from the perspective of link strength further confirm that the regional connections between the middle and the east part have been largely facilitated by the HSR travel, but the interregional connections between the west and the east part still largely rely on the airline travel, consolidating a typical "flyover" effect in China as mentioned by (Jin et al., 2004). This is partly a reason that HSR travel is competitive for short and medium distance travel but airline travel competitive for medium and long distance travel, which is similar to the finding from World Bank (Zheng and Kahn, 2013). Moreover, although city nodes of links with better socioeconomic performance still induce a certain level of travel demand between both HSR and airline networks, the link strength in HSR networks is compared to airline networks highly sensitive to the geographical distance due to a severe distance decay effect, but less sensitive to administrative levels. Therefore, there exist stronger connections for city ends with a rather high administrative level and long distance in airline networks.

Third, in terms of community structure, compared to airline networks without an obvious pattern of clusters in specific regions, cities with dense populations and developed economies along with trunk HSR lines tend to be clustered in specific regions. Therefore, it is worth noting that agglomeration economies of urban systems could be facilitated by HSR networks, whereas airline networks relatively contribute to a more balanced urban development by increasing interactions especially between cities with lower socio-economic performance in the west and ones with higher socio-economic performance in the east.

This paper opens several research perspectives. First, because long-distance transport networks evolve over time and shape the demand to some extent, it will be of interest to replicate our analyses for several years. Indeed, the total HSR length will extend from 19,100 km in 2016 to 30,000 km in 2020 in comparison to the total number of airports from 216 to 260 (NDRC, 2016), which means that the HSR development will be in a faster growth rate especially in the western part of China after 2013. On the airline side, the expansion of low-cost airlines in China (Jiang et al., 2017), even though at a controlled rate, could also affect the pattern of domestic intercity travel. Future research after a fully complete construction of the HSR and mature airline networks could thus shed light on updated China's urban systems, especially regarding that new HSR developments in western China could play an important role in bridging China and Euro-Asian urban systems by the Belt and Road Initiatives. In addition, future research could better consider that HSR and airline networks are highly related to the economic process of cities nodes. Therefore, comparisons of HSR and airline passenger flows with other socio-economic intercity flows could more clearly illustrate the relationship between the economic networks and highspeed transportation networks. Finally, since HSR and airline travel are mostly due to upper socialoccupational groups, it is of interest to expand our work with intercity travel made by traditional rail services and by road. This would arguably diversify travelers' social –and thus spatial– patterns. The resulting urban system would thus be more comprehensive, and comparison of urban systems rendered by traditional/slower vs. modern/faster transportation modes would be full of lessons to be learnt.

6. Appendix

A. Dendrogram trees for the HSR and airline networks.



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Territorial and enviromental impacts

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Sustainability of HSR as a mass transportation mode in terms of efficient use of natural resources

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Abstract

The global economic system depends on the sustainable use of natural resources some of which are renewable whilst the others are finite and non-renewable. There has been an increasing need to reduce the use of non-renewable resources particularly within the transportation sector, which is the major consumer of fossil fuels and thus responsible for most of the carbon dioxide emissions and pollution worldwide. High-Speed Rail (HSR) can provide a more sustainable and efficient use of energy and land whilst reducing emissions and pollution compared with road transport and other modes of transport.

The reported research takes the form of an investigation and critical evaluation of key existing factors that influence the sustainability of HSR in terms of the efficient use of natural resources. From the evidence that has been gathered from different resources and related critical evaluation, conclusions can be made to show that the development of HSR systems will improve the sustainability of transport in general and reduces the amount of non-renewable natural resources used by the transport industry. The secondary data methodology has been used in this research supported by empirical evidences. Most of the data was gathered from the internet including in depth research of HSR in selected countries, available railway statistics and relevant European and Institutional publications.

The main findings are that in many cases, HSR can bring a benefit for society by contributing to the reduction of carbon dioxide emissions produced by the transport industry, reduces the consumption of raw materials, and increases the use of sustainable energy. The expected outcomes of this research will contribute to the development and advances of more sustainable HSR systems that can meet the growing demand for travel due to the continuing growth of the world population and the increasing activities related to business, leisure, and social needs.

Keywords: High speed rail, sustainability, natural resources.

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1. Introduction

Increased globalization has large impacts on the transport system. Traffic growth is largely the result of economic growth in a such a way that when a country's gross national product goes up, personal travel increases by a factor of 1.5 in relation to the GDP. It was estimated that the average growth rate of passenger kilometres increases by 4.6% every year (Whitelee & Haq, 2003a). The role of railway transport tends to increase and is becoming an important mode of transportation because it offers many advantages over other modes of transport. The transport system is considered sustainable if it satisfies three conditions, namely; its rates of use of renewable resources do not exceed their rates of regeneration, the use of non-renewable resources do not exceed the rate at which sustainable renewables are developed, and its rates of pollution do not exceed the assimilative capacity of the environment (Hoyle & Knowles, 1998).

Reducing the energy that is consumed by railways and reducing the amount of raw materials that is used by railways can sufficiently reduce the environmental impact of railway and improve its economical sustainability. The Carbon footprint that a train may accommodate over its lifecycle can be 55 to 85% due to energy consumption whilst the rest is related to the use of raw materials (Andries, 2016). HSR is comparatively the most sustainable transportation mode because it is powered by electricity that may come from renewable energy sources such as hydro, solar, wind and other environmentally friendly forms of energy, uses less non-renewable natural resources than any other transportation mode. HSR contributes to the growth of circular economy.

2. Resource Efficiency

The global economic system depends on how the natural resources are used. All-natural resources are divided into renewable resources and non-renewables such as raw materials, land and fossil fuels. At the present time, the transport sector is the major consumer of fossil fuels and is responsible for most of the emissions of CO_2. It is stated that the UK transport sector in 2014 consumed 54.2 million tons of oil (38% of the total consumption of oil) with an increase of 1.1% from that of 2013. Considering that transport is responsible for 74% of the total transport energy consumption, air transport is responsible for 23%, the rail transport is responsible for a percentage of 1.9% including high speed trains (Waters, 2015).

The growth of population may mean a growth in the consumption of raw materials whilst the world energy reserves and raw materials are finite. It was forecasted that oil reserves in the world would run out around the year 2040. This is only approximate, but it must be realised that oil reserves are limited. Modern transport depends 95% on fuel oil, and HSR can reduce dependency on this energy resource.

In the European Union railway transport carried 11% of goods and 8% of passengers and was responsible for only 0.6% of the emission of greenhouse gases and consumed only 2% of the total energy consumption in transport (Jehanno, et.al., 2011a). The railway network can accommodate more passengers and freight in the future. Resource efficiency for HSR means that there is a need to minimise emissions from the construction or upgrading of the railway infrastructures, increase recyclability of train components and parts of infrastructure, and sensitively use the land resources. Reducing the weight of rolling stock will reduce the amount of raw materials that are needed for their production.

Better use of insulating materials in the construction of rolling stock can reduce the energy output. Modernisation of existing high-speed trains instead of building new ones, can give sufficient savings in energy and raw materials. When the first generation of ICE was modernised, it gave savings of 16,000 tons of steel and 1,200 tons of copper (Jehanno, et.al.,2011b). Further weight reductions can be achieved by replacing conventional stock by articulated rolling stock and increasing the use of aluminium and light alloy construction.

Due to the high rate of scrapped cars around the world, transport is responsible for a large proportion of solid waste. Regarding the railway transport, there are abandoned lines, equipment and rolling stock. Improving recyclability by 10% in the European railway sector can produce an economic benefit of around 170 Million Euros per year (Garcia, 2010).

Regarding the car industry, in the UK in 2014 there were 2.47 million new cars sold, and it was estimated that more than one million of old cars and more than 40 million tyres were scrapped (www.bra.co.uk). Also, old batteries and other semi-hazard materials from motor vehicle production needed to be disposed. These millions of scrapped cars annually result in millions of tonnes of waste material. Such waste materials required recycling, reclamation and disposal. With an increasing amount of plastic in the production of cars there are not enough technologies that have been developed to recycle all the different types of plastic. Furthermore, the construction of one kilometre of three-lane motorway requires around 80,000 tons of aggregate and that gives a clear picture of the scale of the related damage to the natural habitat and landscape. For example, approximately 90 million tonnes of aggregates are used in the UK every year in the construction and repair of roads (Hoyle & Knowles, 1998).

Existing cars are not efficient and unsustainable when considering the overall cost and benefit as they incur very large expenditure of materials, energy, and effort to deliver a comparatively small benefit.

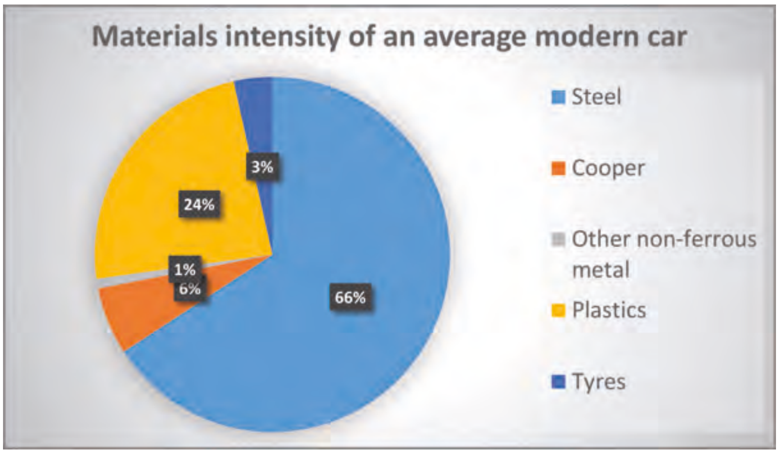

Figure 2.1 Materials intensity of an average modern car

Figure 2.1 shows the percentage of resources that are used to produce one car. An average modern car consists of 0.75 ton of steel, 0.07 ton of cooper, 0.01 tons of other non-ferrous materials, 0.27 tons of plastic and 0.04 tons of tyres. On average, the total weight of a car is 1.14 ton (Whitelee & Haq, 2003b). All these raw materials must be extracted and processed to manufacture the car and that requires energy and produces waste in the range of 25 tons which may pollute air, land and water.

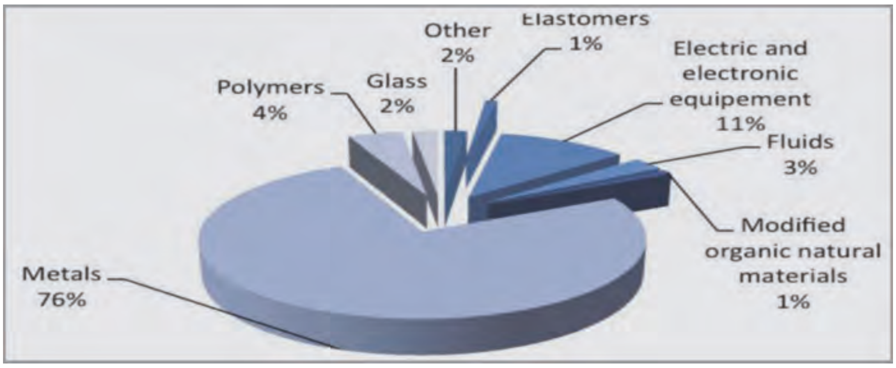

Figure 2.2 Typical train material content (Source: www.uic-environment.org, 2016)

The percentages of resources that are used to produce a typical train car are depicted in Figure

Figure 2.2. On average, the production of a single train vehicle requires more metal and less plastics than that used to produce a road car. In most countries, recently designed trains have around 40 years of service life and this long life supports the resource efficiency. In order to ensure that railway transport is fully competitive it is important to consider at all stages of the life cycle of the railway transport from the design and building stages to the operation and maintenance and eventually the disposal.

At the design stage of a new rolling stock, there is a need to minimise the amount of generated waste and to avoid potentially hazardous materials such as asbestos-containing materials or substances that may contribute to the damage of the Ozone layer and accelerate climate change. For example, at the production stage, there is a need to re-use parts and components of the rolling stock whilst at the disposal stage of the rolling stock there is a need to recycle the greatest possible amount of used materials. Bombardier's vision is to achieve 100% product recyclability and to use 100% recycled materials. At the current time, Bombardier has an average recovery rate for all manufactured rolling stock of 95%. The French high speed train AGV has 98% recyclability (Jehanno, et.al.,2011c). The proper disposal of the end-of-life rolling stock and components of railway infrastructure can reduce the negative impact on the environment.

When comparing the number of vehicles and carriages needed to be disposed, the amount of carriages is not sufficient compared to the number of vehicles, but waste generated by one carriage is greater than waste generated by one vehicle. It was found that disposal of one freight carriage generated is the same amount of waste as 16-20 passenger road cars. The waste of the disposal of one railway passenger carriage is equivalent to the waste of disposing 48-57 road passenger cars whilst the disposal of 3-part electric multiple unit will generate waste of 126-156 road passenger cars.

Some rail carriages are easier to recycle than others, for example, freight rail carriages are easy to recycle, as 60 to 80% of their mass is steel and cast iron and it is known that metals have the highest recyclability rate (www.unife.org, 2013a). Passenger rail carriages, particularly electric multiple units are more difficult and labour intensive to recycle. At the present time, there is a lack of technology for recycling polymer and plastics, but it is easy and cheap to produce them. Different types of plastics have different chemical components and this makes it difficult to dispose them.

The disposal of rolling stock is similar to the disposal of road cars, and this includes the following stages; send the vehicle to a recycling site, pre-treatment, dismantling, shredding and treatments of recovered materials and parts. Newport in the UK has the largest shredder in the world and can shred 450 cars per hour (www.weg.net.,2009). One of the most difficult issues of recycling of rolling stock is getting a rail carriage to the recycling site, as many of them in their current condition are not suitable for transportation on the main line. The scrap value of a carriages is around £11,500 but to get it to a recycling site will cost approximately £5,000 (www.unife.org., 2013b). There is little economic benefit for the railway industry to encourage it to recycle the rolling stock. For this particular reason, there is need for governments to support the railway industry in recycling the rolling stock and parts of railway infrastructure. Suitability for recycling or recovering is measured through Material Recovery Factor and Energy Recovery Factor. Material Recovery Factor represents the availability of recycling and inefficiency of the recycling processes. Energy Recovery Factor represents the suitability of the material concerned to be recovered as energy. Values of Energy Recovery Factor and Material Recovery Factor need always to consider the concept of valuating the efficiency of recycling. If materials do not have recyclability or energy recovery potential then these factors will be equal to zero (www.unife.org., 2013c).

Recycling needs to be considered in the design stage, in order to be able to make dismantling quick, cheap and easy. Internal panels should be easy to remove within only a few hours work. Recycling could be made easier if body shells were produced from as few materials as possible. This will reduce time for material sorting. Resources efficiency means using the Earth's limited resources in a sustainable manner whilst minimising possible impact on the environment. It allows creating more for less and to deliver greater value with less input (www.ec.europe.eu, 2017). The railway industry is working to reduce the waste and to re-use recycled materials in addition to reducing spending on raw materials and energy usage in order to be greener and more sustainable.

The strongest manufacturing industries producing rolling stock for HSR are; Germany, Spain, Japan and China. The rolling stock industries heavily depend on strong domestic market that has demand for this product. One example of influence on the domestic market on rolling stock industry can be the UK. In the middle of 1960s, large parts of the railway network in the UK was closed and that in turn affected the railway rolling stock industry in UK quite badly. With the creation of the EU and the single market, some changes in the rolling stock industry occurred. Railway stock manufacturers moved over the national boundaries and became international companies. As a result of the economic growth around the world, the railway networks started expanding. The International Union of Railways predicted that by 2025 HSR network will increase to 41,997km. Europe and Asia will have the biggest expansion and by 2025 will reach 17789km in Europe and 21460km in Asia (Jehanno, et.al., 2011d). High demand for new rolling stock is observed in China and South-East Asia. China is the largest producer of rolling stock in the world. Countries that have a developed railway network also manufacture and export rolling stock to other countries with less advanced railway technology. In 2012-13, the top 10 manufactures of rolling stock had 65% of the global market (Briginshaw, 2017). The two biggest manufactures of rolling stock in China are CNR and CSR.

Table 2.1 The Ten Biggest Manufactures of Rolling Stock

Rollin Stock Manufacture	Country	Place in the World in 2013
CNP	China	1
CSR	China	2
Bombardier	Canada	3
Alstom	France	4
Transmashholding	Russia	5
Stadler	Switzerland	6
Siemens	Germany	7
GE Transportation	UK	8
Uralvagonzavod	Russia	9
Trinity Industries Inc	USA	10

(Data taken from several sources)

Table 2.1 shows the ten biggest manufactures of rolling stock in the world. The biggest Japanese manufactures of rolling stock is not presented in the top ten. One of the explanations of this can be that the rolling stock produced by Hyundai-Rotem and Kawasaki has so high technology that it does not match the existing infrastructure outside Japan. Also, not presented in the top 10 is the Spanish manufacture CAF.

High speed trains that are presented in Table 2.2 have a large variety in terms of axle loading;

from 11.4t Hitachi Train to 23t Bombardier. Such large difference can be explained by the type of railway that uses this rolling stock. Shinkansen line that employs Shinkansen-Series 700 is HSR with fences and screens that secure the entire length of the track. In contrast, the Acela Express operated on upgraded infrastructure with level crossings equipped with anti-collision structure to meet USA crash standards.

Zefiro high speed train, which has 16.5t axle loading and manufactured by Bombardier, is one of the most economical and environmentally friendly trains in the world. With optimizing the energy use, minimising waste and lowering the carbon footprint from the total life-cycle, the efficiency of trains increased by around 50%. Resources efficiency with different constructors of rolling stock for HSR is different and it depends on raw material intensity that was used to produce the modern rolling stock. This may mean reducing the axle load and decreasing the amount of raw materials used to produce the rolling stock. Another important feature is the power system of HSR. With a centralized power system train that has a heavy locomotive engine, the subgrade and foundation must be stronger and a stronger rail must be used. This involves more raw-materials to build the high-speed railway lines. The distributed power system is more advanced in term of using fewer raw materials.

Table 2.2. Comparison of different types of high speed trains in terms of power systems, axle loading, and car body materials

Country	Main Constructor	Train	Power system	Axel Loads	Car Body
France	Alstom	AGV	Centralized	17t	Aluminium with carbon
Japan	Hitachi	Shinkansen-Series 0	Distributed	16t	Carbon steel
Japan	Hitachi	Shinkansen-Series 700	Distributed	11.4t	Aluminum alloy
Spain	Talgo	Talgo 350	Centralized	17t	Aluminium
Italy	Hitachi Rail Italy	Frecciarossa	Distributed	17t	Aluminum alloy
Germany	Siemens	ICE1	Centralized	19.5	Aluminium-silicon alloy
Germany	Siemens	ICE2	Centralized	19.5t	Aluminium-silicon alloy
Germany	Siemens	ICE3	Distributed	15t	Aluminium
Sweden	Bombardier	SJ X2	Centralized	17.5t	Stainless steel
USA	Bombardier	Acela Express	Centralized	23t	Stainless steel
China	Bombardier	CRH1	Distributed	15t	Stainless steel
China	Siemens	CRH3C	Distributed	17t	Aluminium
Canada	Bombardier	Zefiro	Distributed	16.5t	Aluminium

(Data taken from several sources)

Aluminium car bodies may give a raw-material saving and reduce energy consumption to operate trains in addition to reducing the wear of bodies and rail. However, aluminium car bodies have some disadvantages particularly the increase in maintenance costs. For example, in the event of an accident the steel car body is easier to repair. Another disadvantage will be the need to consider the insulation properties as they can be less effective compared with the situation when a steel car body is used. All new high-speed trains have an aluminium body but in the future, there is a big potential to use fibre-reinforced polymers for train car bodies. Replacing steel by aluminium can achieve weight reduction of the car body of a train between 20-30%. There is also a need to take into consideration the recycling rate which is high for aluminium car bodies. A typical high-speed train consist of 400,000 different parts (www.plmautomation.siemens.com, 2012).

3. Land Use

Land is one of the natural resources and as it is not infinite it must be taken seriously as an index of sustainable society. There is a reason to believe that in the future the land use would be a major barrier to the development of new transportation systems. There is a strong opposition for airport expansions and locating new airports in local communities such as the proposed expansion of Heathrow airport. Also, some motorway projects have been stopped in urban areas by concerned local communities. HSR is environmentally less polluting and consumes less land than motorways or airports whilst some of HSR routes for long distances run in tunnels. It was reported that approximately 90% of the route of the HSR in Taiwan (THSR) was paced in tunnels or on raised viaducts (Watson, et.al., 2017).

In the European Union, around 1.3% of the total land has been taken to build roads. In the UK, it was estimated that roads occupy around 1.5% of the land. The railways occupy substantially less, at around 0.2% (Hoyle & Knowles, 1998b). Allocating land for transport means that land is taking away from agriculture and causing biodiversity damage and fragmentation of the local community. It is inefficient use of land, as on average cars are used for 2.8% of the time and very often just with one person. The total amount of land that has been taken by road transport use in the UK is over 3,500km^2. The total length of roads in UK in 2016 was 396,719km compared with a total length of railways of 15,799km (www.gov.uk., 2013).

3.1 The railway is one of the most environmentally friendly modes of transport.

Railway infrastructure is less damaging in its use of space than road transport. A double track railway line takes only 25 metres in width but a dual 3-lane motorway occupies 75 metres in width (www.gov.uk, 2014a). One kilometre of road takes 13.729 hectares of land. Also, a road may transport only 225 passengers per metre width per hour based on the assumption of 1.5 people per car, but a railway can transport approximately 8700 passengers per metre width per one hour (Hoyle & Knowles, 1998c). Roads require much more land to transport the same volume of passengers and freight than railways. It was estimated that rail is potentially 60 times more efficient in terms of land use.

The transport infrastructures are the major land consumers. The amount of space occupied by railways is relatively small compared with road transport. For example, in Germany, the average overall land-take per kilometre of length of motorways is around 9ha compared with 3.5ha for the new build railway lines. The total amount of land in Germany given for roads is greater than that taken by general buildings and houses. In Germany, public highways occupy approximately 3 000^2 km or 1.23 % of the country’s area (Transport policy and the environment, 1990). Furthermore, in Bangkok and Calcutta 7-11% of urban space is devoted to transport activities compared with 20-25% in European cities and over 30% in Manhattan (Banister, 2005).

In the UK, approximately 1.2-1.5% of the total amount of land is occupied by roads (Whitelee

& Haq, 2003c). It was estimated that each car takes 200m² of land. Similar data comes from Switzerland, where it is estimated that the average of land taken by each vehicle is 113m², but the land allocated for housing and gardening is only 20-25m² per person. Land covered by asphalt is lost to nature, it has affected the behaviour of groundwater and it breaks down ecological relationships with impact on fauna and flora.

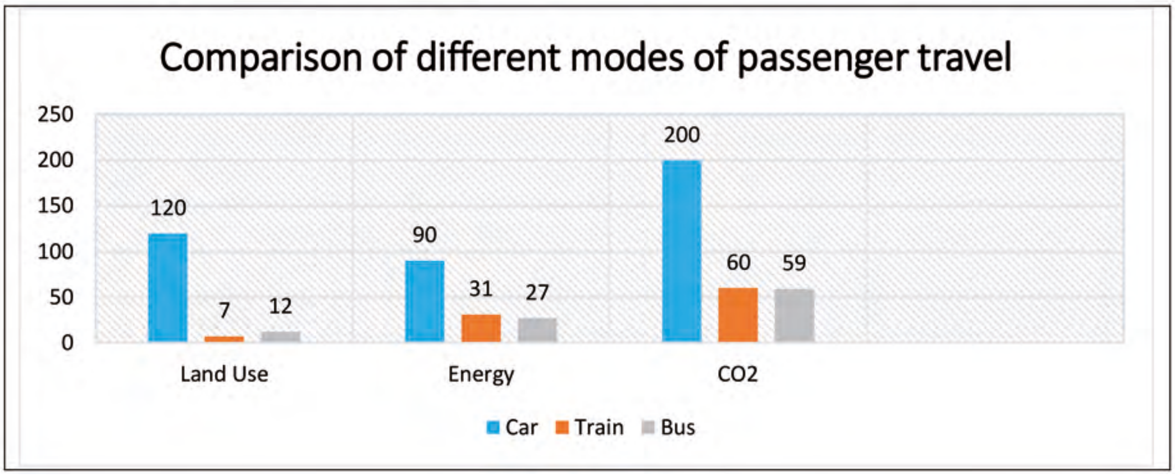

Figure 3.1. Comparison of different modes of passenger travel (Source: Adapted from (Whitelee & Haq, 2003d), where: Land use is measured in m²/person, Energy- in grams of coal/pass.km, CO_2-grams/pass.km

It was calculated that lorries require around three time more space than trains to do the same work. Each passenger travelling by car uses 120m² land, by trains 7m² land, and by bus 12m² land. The amount of land that has been taken depends on which mode of transport is used. Also, there is a need to consider the secondary land taking. This means that in addition to the land allocated for railways there is a need to add areas that provide the raw materials needed to build railways and rail infrastructure, and manufacturing areas to produce steel and concrete.

In 2014, in the UK 35.6 million cars have been registered (www.gov.uk, 2015), and with the increasing number of cars on roads and the increasing number of trips, the total amount of land taken by cars will also increase. Between 1990 and 1996, around 10ha of land each day was taken to build new motorways in the EU. Roads are the biggest land consumer in EU (EEA, 2016a).

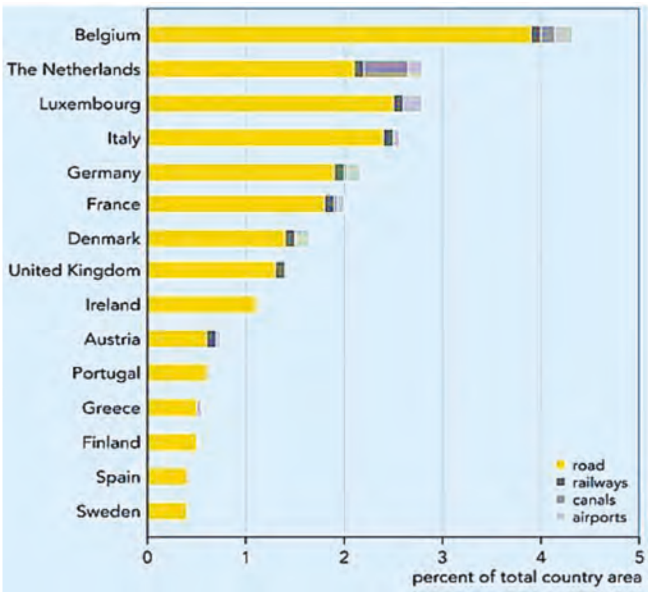

Figure 3.2 Total land-use by transport infrastructure in selected countries in 1996 (Source: EEA, 2016b)

Figure 3.2 shows that the road network takes most of the total land used by transport infrastructure, and it occupies 93% of the total land used by transport infrastructure when railways occupies around 4% and the rest is occupied by airports and inland water transport. With the increasing population and growth in global mobility, it was predicted that by 2050 there will be a need to build around 25 million lane-kilometres roads and 335 000 rail track kilometres. It will increase the built surface area between 250 000 km² and 350 00 km². It is approximately the size of Germany and UK combined that will be needed to build the new transport infrastructures (Dulac, 2013).

The shift of travel from roads to railways can reduce the amount of land that is needed to build new transport infrastructures. The network of HSR in the next 10 years will increase slightly, and most of it will be in countries that have developed HSR network already. There was a plan to build 14 000km of HSR in countries such as Iran, Morocco, Turkey, Argentina, and USA. However, with the present political and economic circumstances, it is questionable that these countries will build HSR.

HSR in France, LGV Bretagne Pays de la Loire are responsible for 2,300ha of taken land but Paris CDG airport had taken 3,200ha of land. When comparing the land that has been taken by HSR and airports, there is a need to bear in mind the indirect amount of land that has been taken by aviation and this number is very significant (Jehanno, et.al., 2011e). For example, Schiphol airport in Nederland has 26.8 km² land in direct use and 222.8 km² for indirect uses (Koetse, et.al., 2001). HSR can carry 12,000 passengers per hour per track, whereas a single line highway carries 2,250 passenger cars per hour and HSR is approximately 5-6 times more efficient than road transport in terms of land use (Agarwal, 2011). Building HSR will need more land take than that required to build conventional line as HSR needs to allow greater distances between the railway tracks. The reason for this is the pressure caused when two trains pass each other with a speed of 250-350 km/h. Also, HSR requires larger radius curves than conventional rail.

Table 3.1 Comparison of land-use for different types of transport infrastructure

Means of transport	Type	Average width	Surface occupied in ha
Railway	Conventional 2 tracks	26 m	2.6 ha
	Upgraded TGV line	32 m	3.2 ha
	New TGV line	35 m	3.5 ha
Road	Motorway 2x2 lanes	54 m	5.4 ha
	Motorway 2x3 lanes	60 m	6.0 ha
	Motorway 2x4 lanes	72 m	7.2 ha

Source: *(Publications.naturalengland.org.uk, 2011)*

Table 3.1 represents the difference in land occupied by different transport infrastructures. Land-use policies can be an effective tool to encourage shift to a more environmentally friendly mode of transport and can influence traffic volumes and behaviour. By building new residential areas close to railway stations or by building new stations close to residential areas, there can be an increase use of public transport. Urbanisation will make closer places to work, live and relax. Land-use policies can contribute to conservation of open spaces for further generations. "Reducing the land requirements for road transport is central to the achievement of sustainability and quality of life", (Whitelegg 1994).

Table 3.2 Comparison of different corridors for HSR in terms of minimum radii of curve

Country	Corridor	Length km	Track	Type of Line	Radii of Curve m	Track Gauge m
Japan	Tokyo -Osaka	515.4	Double	Dedicated	Minimum 2500	1,435
France	Paris-Lyon	425.0	Double	Dedicated	Minimum 4000	1,435
Spain	Madrid-Barcelona	620.9	Double	Dedicated	Minimum 7000	1,435
Italy	Rome-Florence	254.0	Double	Dedicated	Minimum 3000	1,435
Germany	Cologne-Frankfurt	177.0	Double	Dedicated	Minimum 3,350	1,435
Sweden	Stockholm- Gutenberg	455.0	Double	Mixed Line	n/a	1,435
USA	Washington C.D. -Boston	729.5	Double	Mixed Line	Absolut minimum 76	1,435
China	Beijing-Shanghai	1,318.0	Double	Dedicated	Minimum 7000	1,435

Source: Data taken from several sources

Horizontal and vertical curves are important parts of the railway alignment. Minimum radii of curves depend on the maximum speed of the rolling stock, technical characteristics of the rolling stock, topography of corridor, safety standards, and constructional and operating costs. Large radii of curves are more comfortable for passengers to travel. New HSR lines built with a minimum curve radius of 7000 m will allow railway speed of up to 350-400 km/h. The amount of land needed to construct HSR depends on the geographic region and specific needs of the project. Also, there is a need to strike a good balance between the needs of the project and the local communities. The amount of land taken by a HSR depends on certain factors, such as; is it a new railway line or upgraded one, is it a single or double track line, what is the maximum speed, size of embankments, radii of curves, etc. The amount of cutting and embankments can influence the amount of land that is needed to build HSR. Embankments reduce the noise level, but the negative impact is that it reinforces the separation effect and it reduces the available living space.

For example, in the proposed project of HS2 in the UK, for deep cuttings and higher embankments of 16m, a safeguarding corridor of 70m from the central line was suggested. Therefore, the land needed to build a HSR would increase from 5 m to 67.5m from the centre of the outer tracks. The safeguarding boundaries can be wider for more deeper cuttings and higher embankments (www.gov.uk, 2014b).

Newly constructed high-speed lines are designed with a minimum of 7000m curve radius but in some cases the radius would need to be 10000m in order to accommodate higher future speeds and to improve the passenger comfort (Revolvy, 2017). Higher speed means more needed land and more distance between centres of the main tracks such as the case of 4.2 m used in Tokyo-Osaka lin. For a speed above 300 km/h, the UIC recommended a minimum value of 4.5 metres distance between track centres (www.uic.org). However, land-use and environmental impacts can be minimised by placing railways in tunnels and on viaducts.

4. Energy Consumption

It is widely accepted that oil production has now peaked and that in future it will become both costlier and more difficult to produce. Economic dependence on oil translates into political dependency on oil-exporting states. The oil reserves are concentrated in a very specific location.

Security of supply becomes a matter of political priority, which in turn leads to conflicts. World oil demand increased by 38% between 1983 and 2006, and with the increase in demand comes increases in global geopolitical instability (Cox, 2010). There are potential security threats to many higher motorised economies. Liquid fuels will be running out in about forty years, gaseous fuels in about sixty years and even coal has only around two hundred and fifty years of practical extraction (The Railways, Challenges to Science and Technology, 1995). The way forward is to develop and use advanced technology to cut fuel consumption and to produce less polluting vehicles coupled with effective measures to promote the shift of traffic from road to railways. However, transport is almost totally dependent on oil for energy as 95% of the total amount of transport around the world depends on fossil fuels (Watson, et.al., 2016) and it seems that there is little prospect for a major change even if oil prices rise substantially. HSR is a good alternative to road transport as it is powered by electricity and the proportion of renewable energy increases year by year. Some of HSR systems such as in Sweden is powered by 100% renewable energy.

Railways have the significant advantage over road and air transport, as electrified railways can use different types of energy; nuclear, wind, solar, water, oil. With the increasing use of renewable energy sources, railways are getting more environmentally friendly. It was estimated that using an airline will take 3 hours 50 minutes to get from Los Angeles city centre to San Francisco city centre but using a train will take 3 hours 2 minutes. The fuel consumption difference will be more dramatical. One passenger uses 10.56 gallons of aviation fuel flying but travelling by train requires only 0.74 gallon of fuel (www.1001-home-efficiency-tips.com.l). Fuel consumption difference is more than 14 times in favour of a train.

The energy consumption of a high-speed train depends on a number of factors including technical characteristics of train, layout of line and number of stops. The number of curves and their radii and length, the gradients of line and other factors can affect the train energy consumption. Reducing the number of curves can increase the speed of a train and in its turn a train uses less energy. Using regenerative brakes, high speed trains can recover some of the energy dissipated by braking and this energy can be used by other trains or can be returned to the power network. Improving the aerodynamics of trains can sufficiently reduce energy consumption. There is an energy loss during the transmission and transformation from the power station to the train, but there is a big difference in the losses for high speed lines electrified at 25kV and at 3kV as the loss for a line voltage of 25kV is lower than that 3kV. There is a need to provide 8.8% more electricity through a pantograph to operate a train at 25kV compared with 22.6% to operate a train at 3kV (Garcia, 2010).

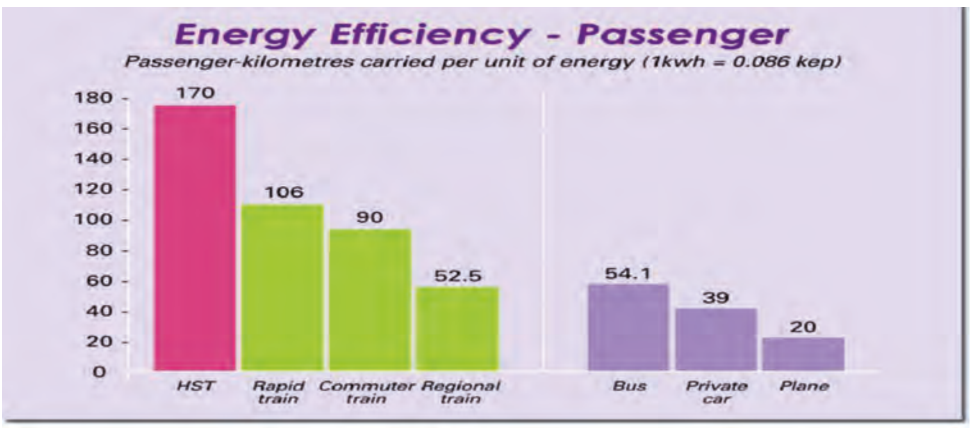

Figure 4.1 Passenger-kilometres carried per unit of energy by different transportation modes (Source: www.ushsr.com)

Consider Figure 4.1. there are clear differences in energy efficiency for different modes of transportation, but the HSR seems to be the most efficient mode of transportation. HSR loses its energy consumption benefit in comparison with air transport at speeds between 300 and 400 km/h, as the actual value depends on which route is considered and on the efficiency and aerodynamics of trains and airplanes. Two main factors determine a train energy consumption; namely, acceleration and overcoming rolling resistance. HSR is the more efficient transport mode, even when compared with conventional railway. New high-speed trains have improved design to reduce drag, increases capacity, and uses lighter materials that reduce the weight of the train. The new articulated high-speed train AGV from Alstom has a reduced weight and needs 15% less energy than that of TGV and has 98% recyclability (www.bombardier.com.). Power output for high speed trains depends also on a train formation. Trains can have different formations from 16 or eight cars as has Shinkansen Series 500 and Shinkansen Series 700 or the 8 cars that Frecciarossa has. Some trains are more flexible in formation as AGV can be formed from seven, eight, 10, 11 or 14 cars. Reducing the axle load is the most critical factor to increase the speed of trains and reduce the energy consumption. This can be achieved by introducing the articulated railcars, and using a new more lighter material. For TGV, Duplex car bodies, aluminium was used which is easy to recycle and it does not lose its quality after recycling. In order to increase the passenger-kilometres carried per unit of energy, there is a need to consider the train length, so that instead of having locomotive and passenger cars, these can be replaced by electric multi units.

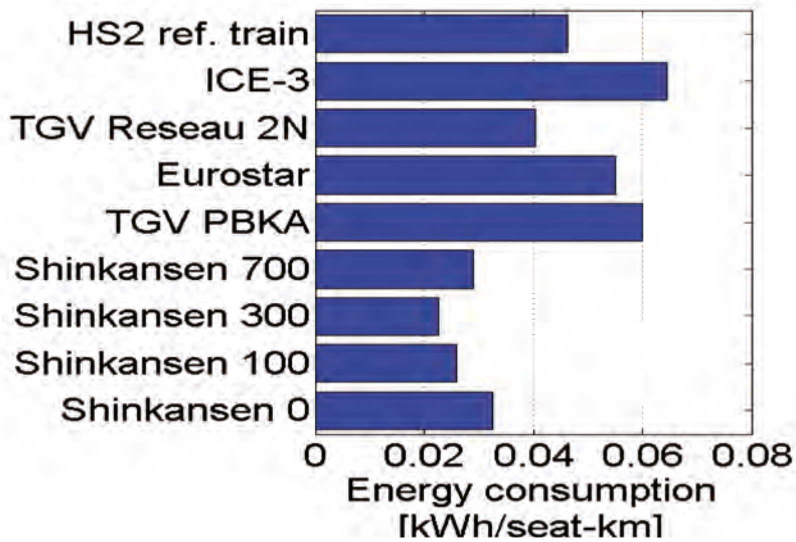

Figure 4.2 Comparison of the net energy drawn from the line by the HS2 reference trail output for the London-Birmingham baseline simulation with data for other high-speed trains (Watson R., 2012)

Figure 4.2 demonstrates that the lowest energy consumption belongs to Shinkansen rolling stock. One explanation for this is that in Japan rolling stock is renewed to a more efficient type every 15-20 year. Newer high-speed rolling stock has improved the design, reduced drag, increased capacity, reduced axel load, improved energy efficiency and upgraded passenger comfort to meet changing customer expectation considering the fact that trains in Europe are designed for 30-40 years' service life.

Table 4.1 Comparisons of different high-speed rolling stock in term of speed, power output and type of trains. Data taken from several sources.

Train	Maximum Speed Km/h	Power output	Type of train
AGV	360	5,760 kW	Electric multiple unit
Shinkansen-Series 500	300	18,240 kW	Electric multiple unit
Shinkansen-Series 700	270	13,200 kW	Electric multiple unit
Talgo 350	330	8,000 kW	Two Power Cars
Frecciarossa	300	9,800 kW	Electric multiple unit
ICE1	280	9,600 kW	Two Power Cars
ICE2	280	4,800 kW	One Power Car
ICE3	330	8,000 kW	Two Power Cars
SJ X2	200	3,260 kW	One Power Car
Acela Express	240	9,200 kW	Two Power Cars
CRH1	200	5,300 kW	Electric multiple unit
CRH3C	350	8,800 kW	Electric multiple unit
Zefiro 300	360	9,800 kW	Electric multiple unit

Table 4.1 shows selected high speed trains and what power output is required. With the introduction of the SJ X2 long distance trains in Sweden, the average speed increased by 44%, travel time was reduced by 30% from 4-hour 25 min to 3-hour 5 min and the energy consumption was reduced by 29% (Lukaszewicz & Andersson, 2008a). This shows that using more advanced rolling stock can increase speed and reduces energy consumption.

5. Conclusions

The demand for road transport continues to increase despite the fact that it mostly uses non-renewable natural resources. The railway transport is a strong alternative to road transport. Railway transport uses less energy, needs less land and uses less non-renewable natural resources. The railway industry increase to use environmentally friendly materials in its vehicles and rail installations. However, there is a considerable growth in the use of plastics that are not always recyclable which shows that there is an urgent need to develop new technologies for recycling different types of plastic.

There are many ways to achieve the targets for sustainable mobility. Such achievements can be made possible through a greater technological improvement. The HSR and railway industry are working to improve the efficiency, reduce the weight of vehicles, and develop new technologies to reduce the power needs for the industry. Despite the increasing speed of modern trains, energy consumption is reduced by 25-45% (Lukaszewicz & Andersson, 2008b). The assessment of transport efficiency in the future must be related to the total energy life-cycle, from the extraction of the minerals to their final return to earth as waste. For example, on average, the Alstom train is 93.3% recyclable and 98.5% recoverable and there is a future need to increase the recyclability closer to 100%.

In order to reduce the amount of raw materials used in the railway industry, manufactures are continuously working to minimise waste and to increase recycling and energy recovery. This can be achieved by improving the recyclability of the rolling stock and infrastructure and by increasing the use of the amount of materials that is being recycled. For instance, the recoverability of TGV Euroduplex is 97-98% (Andries, 2016).

There has been a growing understanding that the ever-increasing number motor vehicles will soon reach the environmental and social limit. Climate change, which is believed to be caused by the rising greenhouse gas emissions, threatens the world stability and life in general. The increasing global temperature could lead to a damage equivalent to 5-20% of GDP (Stern, 2006). These issues necessitate urgent and effective worldwide actions to improve the energy efficiency and to shift transportation from roads to a more sustainable mode of transport such as railways.

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Territorial and enviromental impacts

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Impactos del AVE en la cohesión territorial: Un análisis de los cambios en la accesibilidad en el periodo 1990-2015

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Resumen

La red de alta velocidad ferroviaria española (AVE) acaba de cumplir los 25 años en funcionamiento, y cuenta en la actualidad con una longitud de unos 3.200 km. En este período, los niveles de accesibilidad se han incrementado progresivamente en todo el territorio español, siendo las ciudades con estaciones de AVE las más beneficiadas. Junto con estos beneficios, los cambios en la distribución espacial de la accesibilidad pueden conducir a patrones de desarrollo espacial más polarizados y producir mayores diferencias, con efectos negativos sobre la equidad territorial, impactos que deben ser evaluados en las diferentes etapas del proceso de planificación.

Este artículo presenta una metodología para evaluar este riesgo de polarización espacial, que actualmente constituye un reto en la planificación estratégica de grandes infraestructuras de transporte. Para ello, se evalúan los impactos sobre la cohesión territorial causados por las actuaciones en la red de AVE en España en el período comprendido entre 1990 y 2015. Los valores de accesibilidad se calculan con el soporte de un Sistema de Información Geográfica (SIG) y la cohesión territorial se evalúa en función de los cambios en la distribución espacial de dichos niveles de accesibilidad.

Los resultados muestran que las nuevas líneas de AVE han aumentado significativamente los niveles de accesibilidad de la población española peninsular. Las ganancias se concentran en los corredores de las nuevas líneas de AVE y en las ciudades con estaciones. En resumen, los valores medios de accesibilidad han mejorado en el período 1990-2015 en un 48,6%, siendo estas mejoras muy significativas en los principales nodos de la red, como Madrid (39%), Sevilla (75%), Zaragoza (76 %) o Valencia (48%). Asimismo, los resultados indican que el desarrollo de la red de AVE ha supuesto un impacto positivo en la cohesión territorial, con una reducción de las disparidades de aproximadamente un 15% en el periodo 1990-2015.

Palabras clave: alta velocidad española (AVE), accesibilidad, cohesión territorial, Sistemas de Información Geográfica (SIG)

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1. Introducción

El desarrollo de la red de alta velocidad ferroviaria española (AVE) ha sido y es uno de los principales objetivos la política de transporte, para hacer más competitivo al ferrocarril, con efectos a nivel local y nacional, e incluso de conectividad a nivel internacional. Desde la inauguración del primer tramo Madrid-Sevilla, en 1992, la red de AVE ha ido creciendo y desarrollándose en diferentes corredores radiales centrados en Madrid (García, 2011; Palacio & Mesa, 2016), crecimiento que continúa a fecha de hoy, y cuyos desarrollos futuros están planteados en el vigente Plan de Infraestructuras, Transporte y Vivienda (PITVI) 2012 – 2024 del Ministerio de Fomento.

Tradicionalmente, la construcción de la red de AVE ha estado justificada, por un lado, como un instrumento de desarrollo regional, de mejora de la competitividad, y de vertebración del territorio, cuestiones que son aún objeto de investigación (Banister & Berechman, 2003; Barrón et al., 2012; Givoni & Banister, 2012; Vickerman, 2015a). Por otro lado, las inversiones en alta velocidad pretenden alcanzar un mayor equilibrio modal; fomentando un trasvase de demanda desde la carretera o el avión hacia el ferrocarril (Jaro, 2011), y contribuyendo así a la mejora de la sostenibilidad del sistema de transporte (European Union, 2011; López & Monzón, 2010). En este proceso de planificación de la red de AVE se plantea una disyuntiva difícil de resolver entre dos objetivos clave: por un lado, el de mejora de la eficiencia de la red y, por el otro, el de contribuir a una mayor *cohesión territorial* (Gutiérrez, 2004; López, Ortega, & Condeço-Melhorado, 2009; Monzón, Ortega, & López, 2013).

En efecto, el desarrollo de los nuevos corredores de AVE ha generado, por un lado, una mejora de la eficiencia de la red, entendida como una reducción en los tiempos de viaje entre las principales ciudades de la España peninsular. Pero, simultáneamente, las actuaciones en ejes radiales pueden haber ejercido un efecto polarizador del territorio, aumentando los desequilibrios territoriales. En este sentido, es frecuente que -por el efecto de aglomeración- se generen desarrollos centro-periferia en el entorno de las estaciones, mientras que las ciudades intermedias de los nuevos corredores pueden quedar “relativamente” aisladas, en lo que se ha denominado el “efecto túnel” (Gutiérrez, 2004) de los corredores de la alta velocidad ferroviaria, efecto no exento de controversia (Garmendia, Ribalaygua, & Ureña, 2012; Garmendia, Ureña, & Coronado, 2011; Martínez Sanchez-Mateos & Givoni, 2012; Melero & Magallón-Rezusta, 2012; Ureña, Menerault, & Garmendia, 2009; Vickerman, 2015b).

Obviamente, cualquier red ferroviaria de alta velocidad es una infraestructura de transporte con un marcado carácter discontinuo a nivel territorial, discontinuidad derivada de la necesaria distancia entre estaciones. Así, el entorno de las estaciones de AVE gana (relativamente) más que otras zonas, que se ven (relativamente) desfavorecidas, al no contar con estación. Algo similar ocurre en ciudades intermedias de los nuevos corredores de AVE; se trata de ciudades sin estación, que pueden verse afectadas negativamente por la proximidad de una estación que actúa de polo de atracción de la región (Bellet, 2016; Brons, Givoni, & Rietveld, 2009; Garmendia et al., 2012; Melero & Magallón-Rezusta, 2012; Monzón et al., 2013; Ureña et al., 2009).

Estos riesgos polarizadores acentúan la necesidad de políticas que reduzcan los desequilibrios territoriales, para lo que es clave garantizar una adecuada conectividad de las ciudades intermedias con las estaciones de AVE (González-González & Nogués, 2016; Gutiérrez, 2004; Monzón et al., 2013), bien sea con redes secundarias de carreteras o manteniendo, en la medida en que sea viable, los servicios de la red convencional de ferrocarril. Se trata de desarrollar políticas que fomenten el desarrollo de las ciudades intermedias y/o de los entornos rurales susceptibles de verse negativamente afectados por la construcción de nuevos ejes.

La evaluación de los citados efectos territoriales de la alta velocidad cuenta con una importante herramienta de análisis espacial: los indicadores de accesibilidad (Gutiérrez, 2001; Gutiérrez, González, Gómez, 1996; López et al., 2009; Martínez Sanchez-Mateos & Givoni, 2012; Monzón, Gutiérrez, López, Madrigal, & Gómez, 2005; Monzón et al., 2013). El concepto de accesibilidad es complejo, contándose con numerosas formulaciones para el cálculo de indicadores (Geurs & van Wee, 2004; Páez, Scott, & Morency, 2012; Reggiani, 2012). En este artículo entenderemos la accesibilidad como una característica de una determinada localización, que guarda relación con la facilidad con la que la red de transporte permite, desde esa localización, acceder a determinados destinos.

Uno de los primeros estudios sobre los efectos sobre la cohesión territorial que empleó indicadores de accesibilidad fue el de Gutiérrez (2001), quien evaluó los impactos sobre la distribución territorial de los niveles de accesibilidad de la línea Madrid-Barcelona-frontera francesa. Sus resultados arrojaron impactos negativos sobre la cohesión territorial a nivel nacional, a la vez que mejoras en la misma en el acceso a nivel europeo y de corredor. Esta misma línea, utilizando indicadores de accesibilidad, se ha seguido en recientes trabajos. Es el caso de Ortega, López y Monzón (2012, 2014) quienes evaluaron la influencia del nivel de planificación y del tipo de zonificación con los que se realiza el estudio en los resultados sobre la cohesión territorial. En estos trabajos se evaluaron los efectos sobre la cohesión territorial de la construcción del corredor de AVE noroeste (gallego), de 670 km, tal como estaba incluido en el Plan Estratégico de Infraestructuras y Transporte (PEIT) 2005-2020. Utilizando un indicador de accesibilidad de tipo potencial, se evaluaron los efectos sobre la cohesión territorial utilizando diferentes sistemas de zonificación, encontrando diferencias significativas en los resultados. Asimismo, se evaluaron los efectos sobre la cohesión a nivel provincial, de corredor, y nacional, encontrando que los efectos eran positivos a nivel nacional y de corredor, mientras que a nivel provincial aparecían efectos polarizadores en algunas de las provincias del corredor gallego. Los resultados obtenidos se explican a través de la combinación de diferentes variables, principalmente la distribución de la población, la localización de las nuevas estaciones, y la accesibilidad de partida en esas provincias.

Este artículo continúa la línea de investigación sobre el estudio de los efectos de la alta velocidad ferroviaria en la cohesión territorial. La metodología utilizada se explica en el siguiente apartado.

2. Metodología

La metodología se basa en el cálculo de indicadores de accesibilidad y la evaluación de los cambios en la distribución territorial de los mismos, siguiendo procedimientos explicados con detalle en publicaciones anteriores del equipo investigador (Monzón et al., 2013; Ortega et al., 2012, 2014). Para ello se evalúan los cambios en dos tipos de indicadores -accesibilidad y cohesión territorial- en el periodo 1990-2015.

2.1 Cálculo de indicadores de accesibilidad

El primer paso en los cálculos de accesibilidad es la implementación los datos de las redes de transporte por carretera y ferrocarril en un SIG. Las bases de datos SIG necesarias son: (i) red de carreteras con atributos que contienen tipología y velocidad; (ii) red ferroviaria con atributos de tipología, velocidad y penalizaciones; y (iii) la ubicación de los orígenes y destinos con información sobre su población. El indicador de accesibilidad considera el tiempo de viaje en tres etapas: acceso por carretera a la estación de AVE más cercana, tiempo en AVE, y tiempo desde la estación de destino hasta el destino final, por carretera. Los enlaces por carretera hasta la estación más cercana se realizan principalmente por carreteras locales / regionales sin grandes cambios en el nivel de servicio durante el período de análisis.

El indicador de accesibilidad seleccionado es el *indicador de potencial*, cuya formulación se incluye en la Ecuación 1. Este indicador se ha utilizado previamente en estudios similares (Gutiérrez, Condeço-Melhorado, López, & Monzón, 2011; Monzón et al., 2013; Ortega et al., 2012, 2014).

Indicador de Potencial: $$PA_i = \sum_j \frac{P_j}{I_{ij}} \qquad (1)$$

Donde PA_i indica la accesibilidad de cada origen i a los j destinos potenciales j, P_j es la variable población del destino, e Iij es el tiempo de viaje entre ambos, de acuerdo con la Ecuación 2:

$$I_{ij} = TT_R(i, E_i) + TT_F(E_i, E_j) + TT_R(E_j, j) + \theta_F \qquad (2)$$

El tiempo de viaje se calcula como la suma de tres términos: (1) el tiempo de viaje por carretera desde el origen hasta la estación más cercana $(TT_R\ (i,E_i))$, siendo Ei la estación más cercana al origen; (2) el tiempo utilizando la red ferroviaria $(TT_F\ (i,j))$, y (3) el tiempo desde la estación más cercana al destino (Ej) hasta el destino final, utilizando la red de carreteras (TT_R (E_j,j)). También se tienen en cuenta una serie de penalizaciones (ϑ_F) relacionadas con el cambio de ancho de vía y tiempos de espera. Todos los cálculos han sido realizados con ayuda de un SIG y programados en código Arc Macro Language (AML). La descripción detallada de todo el proceso de cálculo puede ser consultada en Ortega, Mancebo & Otero (2011).

El valor agregado de accesibilidad potencial en cada horizonte temporal (Hx) se calcula como:

Indicador de Potencial Agregado:

Indicador de Potencial Agregado: $$PA^{Hx} = \frac{PA_i^{Hx} \cdot P_i^{Hx}}{\sum P_i^{Hx}} \qquad (3)$$

Donde PA^{Hx} es el valor de accesibilidad agregado en el horizonte temporal Hx; PA_i^{Hx} es el valor de accesibilidad en el origen I, y P_i^{Hx} es la población en el origen i, ambos para el horizonte temporal H_x.

Los cambios en los valores de accesibilidad entre dos años horizonte permiten evaluar los efectos de los proyectos de AVE implementados en el período correspondiente. La diferencia en niveles de accesibilidad mide el impacto y se calcula como un porcentaje del cambio de accesibilidad. Los cambios entre dos años horizonte serán los siguientes (ecuación 4):

Impacto entre horizontes: $$PAC^{Hx-Hy} = \frac{PA^{Hx} - PA^{Hy}}{PA^{Hx}} * 100 \qquad (4)$$

Donde PAC^{Hx-Hy} representa el cambio porcentual en los valores de accesibilidad potencial entre los dos horizontes temporales H_x y H_y.

Cálculo de indicadores de cohesión territorial

Los impactos sobre la cohesión territorial se miden a través del cálculo del *índice de dispersión* en la accesibilidad potencial *(PAD)* (Ortega et al., 2012), basado en el coeficiente de variación, (López, Gutiérrez, & Gómez, 2008; López & Monzón, 2010), de acuerdo con la Ecuación 5:

$$\textit{Dispersión Accesibilidad Potencial}: PAD^{Hx} = \frac{\sigma^{Hx}}{\frac{\sum PA_i^{Hx} \cdot P_i^{Hx}}{\sum P_i^{Hx}}} \qquad (5)$$

Donde PAD^{Hx} es el coeficiente de variación en el horizonte temporal H_x, y σ^{Hx} es la desviación estándar en los valores de PA_i^{Hx},, ponderadas por la población - P_i^{Hx}-. Los valores más altos en *PAD* corresponden a las distribuciones de accesibilidad más polarizadas, o, en otras palabras, con menor cohesión territorial. Por último, el cambio en la cohesión territorial entre horizontes temporales se calcula a través del *índice de cohesión territorial* (*TC*) (Ortega et al., 2012), tal como se indica en la Ecuación 6:

$$\textit{Cohesión territorial}: TC^{Hx-Hy} = \frac{PAD^{Hx} - PAD^{Hy}}{PAD^{Hx}} * 100 \qquad (6)$$

Donde *TC* es el cambio porcentual en la cohesión territorial entre dos horizontes temporales: H_x and H_y. Un valor positivo de *TC* se interpreta como una mejora en la cohesión territorial en el periodo entre los dos horizontes temporales correspondientes.

3. Análisis de los cambios en la cohesión territorial en el periodo 1990-2015

En la Figura 1 se ha representado la red de AVE correspondiente a 2015, con la ubicación de las estaciones. El área de estudio comprende el territorio peninsular español a nivel municipal, que incluye un total de 8,100 municipios, cuyos centroides actúan como orígenes y destinos de los viajes. Los 278 concelhos portugueses y los 19 distritos franceses también se consideran destinos potenciales.

Para calcular los valores de accesibilidad, se utilizó un SIG vectorial, en el que las redes de carreteras y ferrocarriles se modelizaron de forma independiente. La red de carreteras es necesaria como complemento de la red ferroviaria desde el origen del viaje hasta la estación más cercana, y desde la estación destino, al destino final del viaje. En la base de datos SIG se incluye también la longitud y la velocidad estimada según el tipo de infraestructura, junto con los datos socioeconómicos (población) a nivel municipal.

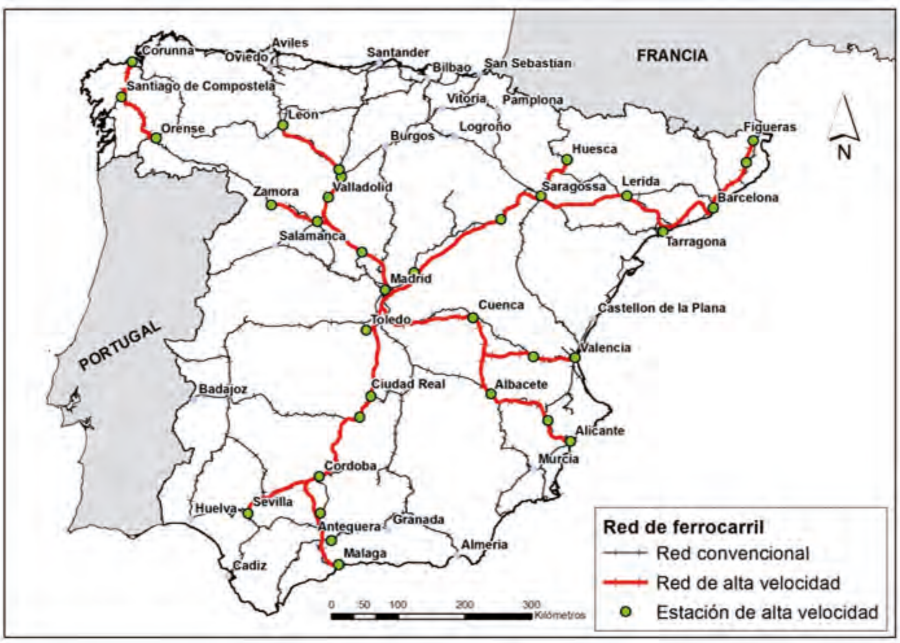

Figura 1: Red de AVE en 2015

La red ferroviaria también incluye información sobre datos de ancho de vía (Ibérico / UIC), la ubicación de las estaciones y la frecuencia del servicio, con objeto de calcular los tiempos de viaje, tal como se describe en López et al. (2009) y López & Monzón (2010).

3.1 Diferencias en niveles de accesibilidad 1990-2015

Una vez que se han creado las bases de datos SIG, es necesario calcular el tiempo de viaje entre cada origen-destino. Los resultados y los datos de población de destino se introducen posteriormente en la ecuación 1 para obtener el valor potencial de accesibilidad (PAi) de cada municipio. La accesibilidad se calculó utilizando la herramienta TITIM-GIStool (Ortega, Otero & Mancebo, 2014). Los mapas de accesibilidad para todo el territorio se construyen utilizando una técnica de interpolación implementada en el SIG, a partir de los valores de los municipios.

La Tabla 1 muestra los resultados de accesibilidad (PA) en 1990 y 2015 (expresado en miles) y los cambios porcentuales en la accesibilidad (PAC) en dicho periodo, tanto en valores medios nacionales, como en una selección de ciudades. Estos valores están representados gráficamente en las Figuras 2, 3 y 4: las Figura 2 y 3 muestran los valores de accesibilidad (PA) en 1990 y 2015, respectivamente, mientras que la Figura 4 muestra el porcentaje de cambio en la accesibilidad (PAC) en el periodo 1990-2015.

Tabla 1. Valores de accesibilidad (en miles) y cambios (en %): media nacional y selección de ciudades

Area/Año	Accesibilidad (PA) (miles)		Cambios (PAC) (%)
	1990	2015	1990-2015
MEDIA NACIONAL	**128**	**190**	**48,6**
Albacete	132	212	60,8
Badajoz	91	123	35,9
Barcelona	210	263	25,5
Bilbao	117	134	14,2
Granada	98	142	44,7
La Coruña	82	128	55,8
Madrid	282	393	39,3
Málaga	105	198	88,3
Santander	87	128	47,2
Sevilla	123	215	74,5
Valencia	172	255	47,8
Valladolid	122	236	93,9
Vitoria	110	148	34,3
Zaragoza	134	237	76,3

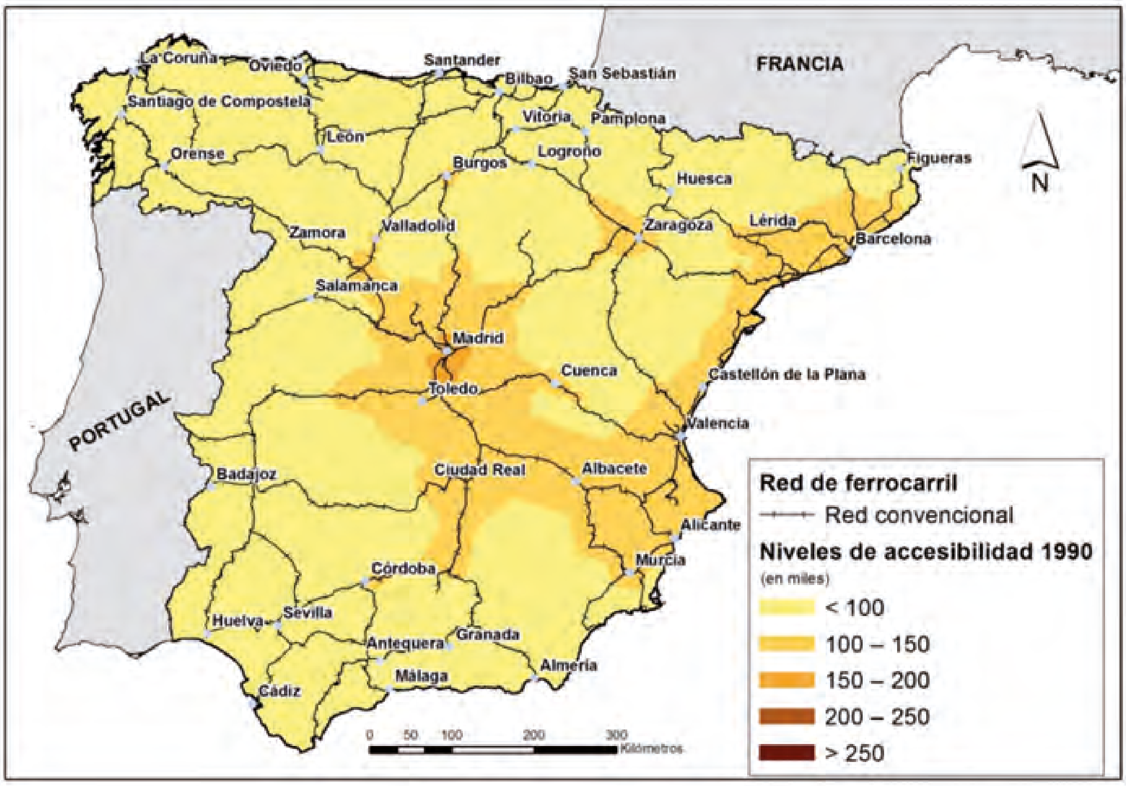

Figura 2: Niveles de accesibilidad (1990)

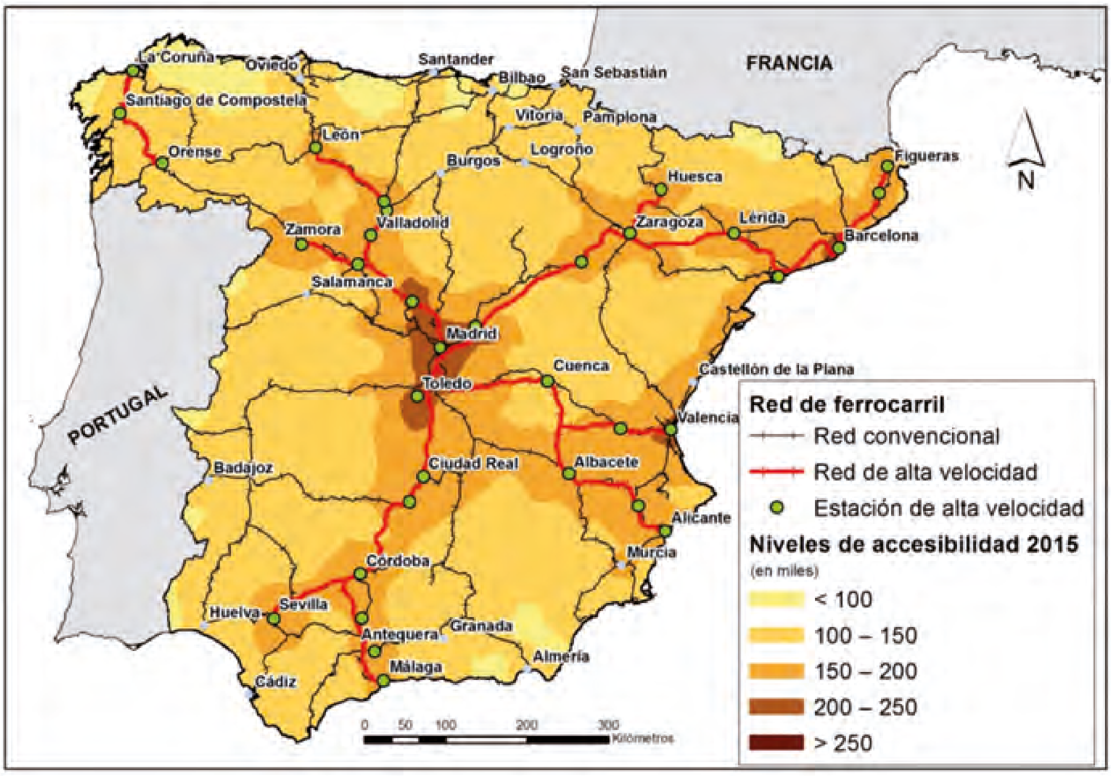

Figura 3: Niveles de accesibilidad (2015)

Como se puede observar en la Figura 2, en 1990, las áreas con mayores niveles de accesibilidad se ubicaban principalmente en los corredores Madrid-Toledo-Ciudad Real, Madrid-Valencia y parte del corredor mediterráneo. Se trata de corredores que gozaban de cierta calidad en sus líneas ferroviarias convencionales, con ciudades como Madrid, Barcelona y Valencia que mostraban niveles de accesibilidad significativamente superiores a la media nacional en 1990 (ver Tabla 1). La accesibilidad ferroviaria del resto del territorio peninsular presenta niveles significativamente bajos. La situación mejora significativamente en 2015 (ver Figura 3), encontrándonos con cambios importantes en los niveles de accesibilidad en gran parte del territorio.

Las actuaciones en la red de AVE consiguen que en 2015 surjan varios corredores con niveles de accesibilidad sensiblemente mejores: se trata de un conjunto de ejes radiales que, partiendo de Madrid, la conectan con ciudades como Sevilla, Málaga, Valencia, Alicante, Zaragoza-Barcelona-Figueres, Zamora o León. Las zonas con niveles de accesibilidad más bajos (ver Figura 3) se concentran en algunas regiones del norte peninsular, -ciertas áreas de Galicia, Asturias y Cantabria y País Vasco-, junto con algunas zonas cercanas a la frontera francesa, ciertas áreas cercanas a la frontera portuguesa y algunas zonas de Andalucía Oriental. La aparición de estas "islas" con niveles de accesibilidad tan reducidos se debe a una combinación de factores, entre los que destaca la ausencia de estaciones de AVE cercanas, junto con su localización geográfica y la distribución de la población en su entorno. La cercanía a una frontera administrativa (francesa o portuguesa), o geográfica (zonas costeras) también ejerce un "efecto borde" que, dependiendo de los casos, supone un efecto importante sobre la accesibilidad de dichas zonas.

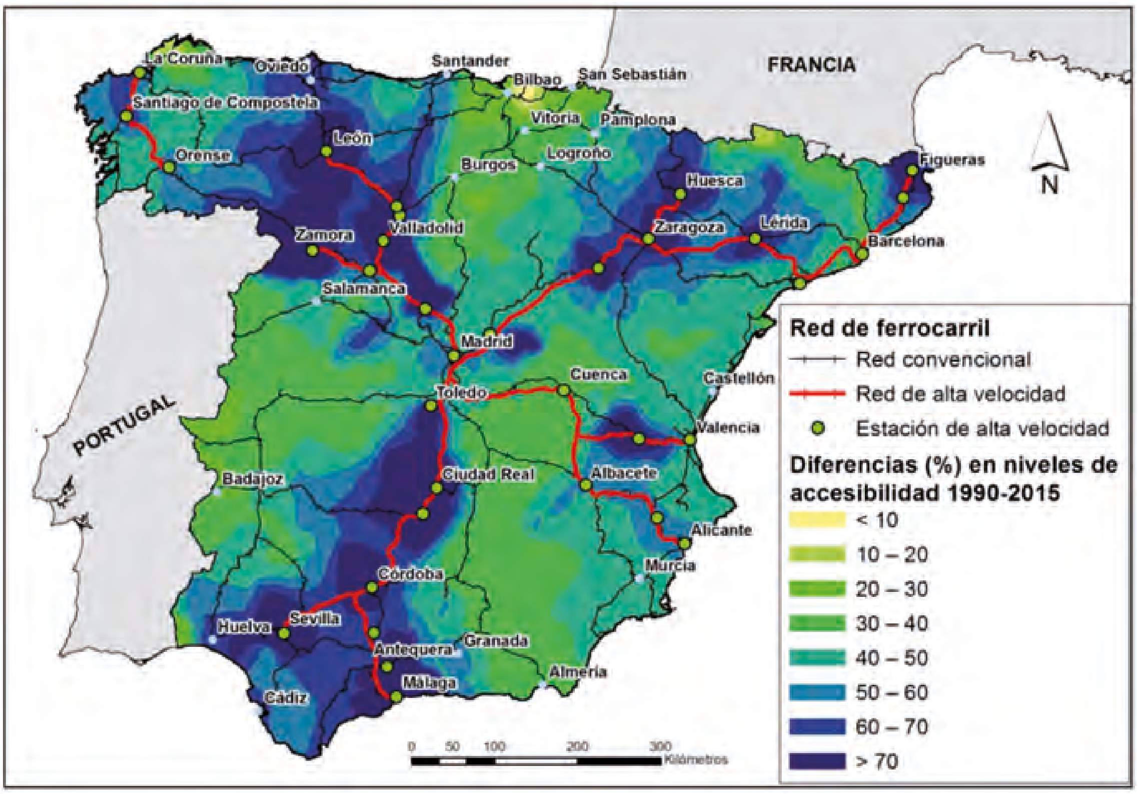

Figura 4: Diferencias (%) en niveles de accesibilidad 1990-2015

En la Figura 4 se ha representado la distribución territorial de los cambios que se han producido en el periodo 1990-2015. En general, se observa también un patrón radial en la distribución de las mejoras, coherente con el desarrollo de los correspondientes corredores de AVE. Asimismo, puede observarse cómo las mejoras se concentran en el entorno de las estaciones, apareciendo zonas intermedias en los corredores que no resultan tan beneficiadas -lo que se ha venido a denominar “efecto túnel” (Gutiérrez, 2004)-. Tal como se indica en la Tabla 1, el valor promedio de mejora muy significativo, - del 48,6%-. En las principales ciudades se alcanzan valores de mejora elevados, como en Madrid (39,3%) o Barcelona (25,5%), que en algunos casos llegan a ser especialmente destacados en ciudades como Málaga (con un 88.3% de mejora), Valladolid (93,9%), o Sevilla (74,5%).

3.2 Impactos sobre la cohesión territorial 1990-2015

La Tabla 2 muestra los valores del índice de dispersión en la accesibilidad potencial (PAD) para los años 1990, 2015, y las diferencias relativas en la cohesión territorial (en %) en el periodo 1990-2015 (índice TC), siguiendo las ecuaciones 5 y 6, respectivamente. Se puede observar que el valor del PAD ha disminuido de 1990 a 2015, lo que implica un incremento en la cohesión territorial en España. En términos de cambio porcentual en la cohesión territorial, tal como mide el índice TC, la mejora ha sido del 14,5%. Este resultado indica que las actuaciones en la red de AVE en este periodo han resultado en una distribución territorial de la accesibilidad más equitativa.

Tabla 2: Índice de dispersión de la accesibilidad potencial (PAD): valores en 1990, 2015, y diferencias en cohesión territorial (TC) (%)

Año	1990	2015
PAD	0,46	0,39
TC (%)	14,5	

4. Discusión

Los resultados muestran que el desarrollo de la red de AVE en el periodo 1990-2015 ha tenido impactos claramente positivos en la accesibilidad y cohesión territoriales. Los niveles de accesibilidad han mejorado, de media, cerca de un 49% en el territorio peninsular en el periodo 1990-2015, y la cohesión territorial ha mejorado cerca de un 15%. Estos resultados corroboran que la red de AVE ha contribuido a una mayor vertebración territorial, tanto por la mejora de la eficiencia de la red y las consiguientes reducciones en los tiempos de viaje, como por la reducción de los desequilibrios entre las regiones más y menos accesibles. Todo ello contribuye a una mayor integración territorial (Givoni, 2006; Guirao, 2013; Ortega et al., 2012) y atenúa los efectos polarizadores de los procesos de aglomeración que suelen acompañar a los desarrollos de nuevos corredores de AVE.

Ante esta situación, y de cara a futuras actuaciones, el reto consiste en continuar desarrollando una planificación que siga mejorando la eficiencia de la red, a la vez que tenga en cuenta la situación de las regiones más desfavorecidas en términos de accesibilidad. Para lograr estos objetivos es necesaria la integración de los agentes implicados en las diferentes administraciones implicadas, desde la local hasta la nacional, con objeto de facilitar el acceso a las nuevas infraestructuras en condiciones de accesibilidad adecuadas. En este sentido, es clave que las estaciones cuenten con una adecuada localización, que permita que los tiempos de acceso y dispersión se minimicen (Monzón et al., 2013, 2016), así como contar con buenas conexiones de la red de AVE con la red ferroviaria convencional y de carreteras secundarias (Melero & Magallón-Rezusta, 2012; Monzón et al., 2013; Ureña et al., 2009). Es necesario, por tanto, dedicar esfuerzos a una adecuada labor de planificación en las primeras etapas de diseño de la red, tanto en términos de dotación de infraestructuras como en el de la oferta de servicios de transporte.

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General and network aspects of HSR

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Universidad de Castilla-La Mancha

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"LOS ANGELES-BOSTON: 20h on High Speed"

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Abstract

This paper describes a Spanish proposal of possible collaboration with the Federal Railway Administration of the USA Transport Department for the operating in a term of 15 years of the HSR way Los Angeles (CA)-Boston (MA), 3.626 mile (5.834 km) length, that vertebrate the USA High Speed Railway System "USHSRS", 17.000 mile (more of 27.000 km) length, launched in 2009 by the President Obama, and to date, only in execution some sections of the CHSRA (California High–Speed Railway Authority), 200 km hardly, in the Californian Central Valley, around Fresno. In the construction of these sections take part Spanish companies of high level in wined bids provided the Spain's privileged international consideration for the development and high technology of its high-speed railway network (AVE), the second in the world by length, after China.

This itinerary is integrated by the Structural Units: "Ia:- Pacific Coastal Corridor", "II: Intercoasts Way" and "Ib:– Atlantic Coastal Corridor", as collect in the Table "Taking off & Summary" about Characteristic figures: morphological, structural and budgetary, from predesigned HSR Lines by the authors of this paper in the "Farwest", "Canevar", "Nevut", "Utconmar", "Interplains", "Ohio-Potomac" and "Chesa-Hudsanan-Charles" Projects. The Construction Budget is 112.175 M$, with an unit cost of 19,30 M$/km.

Finally is summarized an operation study of this itinerary with fourteen stations and the two Terminals, from which would depart trains each forty minutes (18h/day) by direction, respectively, with twenty carriages (eleven sitting cars and nine sleeping cars) in a similar composition to the used in the Berlin-Moscow express railway since 2016 December 17. In a graph is summarized also the distances between stations, times of travel (with stops between) and foreseen ticket rates with loans at 6% for a total investment financing (infrastructure, superstructure, equipments, signaling and rolling stock).

Keywords: High-Speed Railway, USHSRS, Los Angeles-Boston Itinerary, ...

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1. Introduction

The news in the press in December 2016: "Opening of the new Moscow-Berlin night train service", a few days before the announcement of the International High Speed Congress in Ciudad Real (October 2017), motivated the proposal of this Conference with The "abstract" sent at the end of January 2017.

The authors of this paper have pre-designed a large part of the US High Speed Network "USHSRS" in Preprojects registered at the Colegio de Ingenieros de Caminos of Madrid, and described in articles published in the "Vía Libre" and "Alta Velocidad" of the Fundación de los Ferrocarriles Españoles, "Ingeniería Civil" and "Fomento" of the Ministerio de Fomento and "Revista de Obras Públicas""ROP" of the Colegio de Ingenieros de Caminos.

At the 1st International Congress of Civil Engineering, held at the Colegio de Ingenieros de Caminos in Madrid on March 2 and 3, 2016, under the motto "Routes joining the world", the authors presented a communication, based on the positioning of Spain as a world reference in the field of High Speed Rail, so that it could serve as the starting point for a possible coordinated collaboration between the governments of Spain and the United States. Figure 1 reproduces the planning presented for the development of the Plan, considering eight structural units. For the purposes of the present paper, we focus on units I, II and VI.

Unit I, "Coastal Corridors", consists of the Pacific Coast Corridor (I1) and the Atlantic Coast Corridor (I2). This unit is the one with the greatest profitability foreseeable in its exploitation, when communicating large urban conglomerates: (I1: Los Angeles-San Francisco Bay) and (I2: Washington D.C.-New York-Boston).

Unit II, "Intercoasts Way: San Francisco-Washington DC", communicates the two corridors of the first Unit and vertebra the network, allowing its execution a progressive advance of the communication between the different States of the country, taking into account the difference Time between the two coasts and the possibility of taking advantage of the night time for the trips, favors a progressive, comfortable, flexible and efficient exchange of relations between the most important centers of activity of the nation, in a similar way, although on a much larger scale, to the service of the night train Moscow-Berlin, inspiring of the Conference.

Unit VI, "Missouri-Illinois-Indiana-Ohio Connection (VI 1-3)". This connection: Saint LouisSpringfield-Chicago / Gary-Indianapolis-Cincinnati allows, alternatively, in a part of sub-unit II3 "Saint Louis-Louisville-Cincinnati Route, to realize it" via Chicago "or" via Louisville ", giving So high-speed access to the third urban agglomeration of the United States.

2. State of the art (Exposition)

The proposed commissioning of the Los Angeles (CA) -Boston (MA) itinerary requires at least the construction of 5,876 km (5834 + 42 km state of the branch to Carson (NV)), and an investment of 112,175 M $, with itinerary integrated only by Structural Units I and II, connecting a population of 32.5 Mhab. in every sense.

If in this itinerary, the Saint Louis-Cincinnati route "via Louisville" is replaced by "Chicago route", the total length to be built is 6,170 km (5979 + 191 km state) of the branches to Carson (NV), Jefferson (MO) and Mount Vernon (TN)), with an investment of 116,917 M $ and a connected population of 36,5 Mhab. in every sense.

This second option has the objective advantage that, with a 4% increase in investment, the population connected to a large distance is increased by 14%, with no appreciable difference in travel times. References to the Los Angeles-Boston route, are made considering it "via Chicago".

This itinerary, which is part of the United States High Speed Network "USHSRS", can be carried out, according to the Approach planned for its development in four five-year (20 years) stages, by the USHSRS Association, within fifteen years, taking the initial proposal of the authors (Ref. 11), to construct the more than 27,000 km of estimated total length of the network from ten major poles of action, dedicating six of them for the direction and coordination of the execution of this itinerary (San Francisco, Denver, Chicago, Pittsburgh, New York and Boston).

The other four large poles would occupy in this same period of construction of the "injection" to the vertebral route of the network, another 20 Mhab. In each direction: 2.5 Mhab. from the Seattle Polo (Salt Lake City Connection); 8.0 Mhab. from the Dallas Pole (Kansas City Connection); 3.0 Mhab from Atlanta´s Polo (Connection Saint Louis) and 6.5 Mhab. from the Miami Polo (Washington DC Connection)

In the following five years, from the ten poles, the planned network could be completed, but with more than 50% of the urban working population already connected with traveling times of less than 20 hours, with an investment of less than 25%, overall.

2.1 LA-BO Itinerary Description

A detailed description of the route with the HSR lines that form it is found in the preliminary projects whose characteristic, morphometric, constructive and budgetary figures are summarized in the attached Tables

The following is a summary of the length of each line, the number of LT "Long Tunnels", the longest and total length of them, as well as the number of SB "Suspension Bridges" and their total length .

		LT			SB	
Line	**L (km)**	**nb**	**ΣL(km)**	**Lmax (km)**	**nb**	**ΣL(km)**
1: LA-SF	598	5	95,7	27,5	1	1,6
2: SF-Sac	167	1	14,0	14,0	8	12,8
3: Sac-Reno	162	4	56,5	16,0	1	1,6
4: Reno-SLC	680	2	70,0	35,0	7	11,2
5: SLC-Denver	660	18	204,5	22,0	3	4,8
6: Denver-KsC	896	0	0,0	---	4	6,4
7: KsC-SL	415	0	0,0	---	2	3,2
8: SL-Chicago/G	420	0	0,0	---	2	3,2
9: Chicago/G-Cin	450	1	6,0	6,0	1	1,6
10: Cin/H-Colum	60	0	0,0	---	2	3,2
11: Colum-Pittsb	253	0	0,0	---	2	3,2
12: Pittsb-Wash	371	2	17,0	10,0	3	4,8
13: Wash-NY	460	2	12,0	6,0	5	8,0
14: NY-BO	387	0	0,0	---	5	8,0
1-14: LA-BO	**5.979**	**35**	**475,0**	**35,0**	**46**	**73,6**

2.2 Summary of the previous exploitation study of the LA-BO itinerary

The Sustainable Approach to the California High Speed Network (CHSRS) (Ref.15) was premised on its functional integration into the United States federal grid, as anticipated by the USHSRS Network Phasing Plan) which includes, among others:

- Direct communication between the city of San Francisco and the capital of the State of California, Sacramento, crossing the Bay of San Francisco
- Direct communication of the "Central Valley" with downtown Los Angeles through "Tehachapi Mountains"
- The North HSR connection of the States of California and Nevada by the "Tahoe Line"

From a general point of view, the planning of the construction and operation of the network as a whole is based on the criterion of "prompt profitability" of the operation, linked to competitive rates with other means of transport (car, airplane) An operating income that allows the self-financing of the construction and operation of the same, providing its cashflow, from an initial funding contribution of approximately 20% of the total investment, an internal rate of return similar to Interest rate of the financial market for long-term operations (≈ 6%).

As a summary of the economic-financial analysis carried out for the LA-BO itinerary, some data are highlighted in the following sections.

a) Operating revenue

The average occupancy of the itinerary, of 5,979 km, is 8.83 Mp / y, which means an average operating revenue of 13,990 M $ / y.

At the age of ten it could be in service from Los Angeles (CA) to Reno / Carson (NV) (927 km with demand of 18.6 Mp / y), on the other hand, from Denver (CO) to Columbus (OH) (via Chicago / Gary) (2,241 km with 5.4 Mp/y) and on the other hand, from Washington DC To Boston (MA) (847 km with 14.9 Mp / y). That is, 3,715 km, with an average operating revenue of 11,125 M $ / y.

b) Rolling stock required for the operation

The following mobile material (for circulation and minimum reserve), both for service (TAV), and for assistance and rescue (VAL), is foreseen:

- Years 9 to 14: 50 TAV of 540 seats (348 seats and 192 beds / berths) and 26 VAL
- Years 15 to 50: 80 TAV of 540 seats (348 seats and 192 beds / berths) and 84 VAL

c) Operating costs

Annual operating costs are the sum of hourly costs (ch), linked to driving hours and kilometer costs, multiplied by a factor (F) of annual hours of service.

The unit costs, updated to 2017, of the US Bureau of Labor Statistics, are: cu h = 37 $ / h and cekm = 2.57 $ / km   F = 365 * (15 or 21). n = number of trains

Operating costs will therefore be:

≈ 300 M$/y (years 9 to 14)

≈ 765 M&/y (years15 to 50)

d) Construction Budgets

Los Angeles-San Francisco	15.312 M$	Preliminary design Farwest
San Francisco-Sacramento	6.910 M$	Preliminary design Farwest
Sacramento-Reno/Carson	6.806 M$	Preliminary design Canevar
Reno-Salt Lake City	13.686 M$	Preliminary design Nevut
Salt Lake City-Denver	19.905 M$	Preliminary design Utconmar
Denver-Kansas City	8.825 M$	Preliminary design Interplains
Kansas City-Jefferson/Saint Louis	4.345 M$	Preliminary design Interplains
Saint Louis-Springfield-Chicago/Gary	6.183 M$	Preliminary design Misilinoh
Chicago/Gary-Indianapolis-Cincinnati/H	5.088 M$	Preliminary design Misilinoh
Cincinnati/Hamilton-Columbus	1.957 M$	Prelimin. design Ohio/Potomac
Columbus-Pittsburgh	2.429 M$	Prelimin. design Ohio/Potomac
Pittsburgh-Washington D.C.	5.587 M$	Prelimin. design Ohio/Potomac
Washington/Dulles-New York	10.510 M$	Prelimin. design ChesananCharles
New York-Boston	9.374 M$	Prelimin. design ChesananCharles
Itinerary Los Angeles-Boston	**116.917 M$**	**(Chicago way)**

Tabla 2 (Desglose y Resumen)

USHSRS :LOS ANGELES-SAN FRANCISCO+ INTERCOASTS WAY (TRAYECTO INTERCOSTAS SAN FRANCISCO-WASHINGTON (Via Chicago)) + WASHINGTON-NEW YORK-BOSTON

Líneas	PACIFIC SIDE	CENTRAL SIDE	APPALACHIAN SIDE Chicago Connection	PACIFIC COASTAL CORRIDOR	ATLANTIC COASTAL CORRIDOR	LOS ANGELES-BOSTON
	FARWEST/CANEVAR/NEVUT PROJECTS USHSRS: INTERCOASTS I (San Francisco-Salt Lake City)	UTCONMAR/INTERPLAINS I y II PROJECTS USHSRS: INTERCOASTS II (Salt Lake City-Saint Louis)	OHIO/POTOMAC PROJECT & MISILINOH PROJECT USHSRS: INTERCOASTS III (Saint Louis-Washington via Chicago)	FARWEST PROJECT CHSRS: MISSIONS TRAIL HSL (Los Angeles-San Francisco)	CHESA/HUDSANAN/CHARLES PROJECT USHSRS: LIBERTY&TRIMOUNTAINE HSLs (Washington-New York-Boston)	FARWEST/CANEVAR/NEVUT/UTCONMAR/ INTERPLAINS I y II /OHIO-POTOMAC/MISILINOH/ CHESAHUDSANANCHARLES PROJECTS USHSRS:INTERCOASTS+CORRIDORS(Los Angeles Boston)
Longitud Total (km, miles)	1052,0 (654mile)	1971,0 (1225mile)	1703,0 (1059mile)	597,0 (371mile)	847,0 (527mile)	6.170 (3835mile)
Desmontes / áreas de relleno (km) (%)	795,0 (75,97%)	1682,0 (85,31%)	1601,0 (94,02%)	359,0 (60,14%)	778,0 (91,83%)	5.315 (84,52%)
Longitud Total de Túneles (km)	194,0 (18,44%)	219,5 (11,14%)	55,5 (3,26%)	199,0 (33,33%)	32,5 (3,84%)	700,0 (11,35%)
Longitud Total de Viaductos (km)	63,0 (5,99%)	70,0 (3,55%)	46,4 (2,72%)	39,0 (6,53%)	36,5 (4,31%)	235,0 (4,13%)
Estaciones Principales	VALLEJO-RENO/CARSON-BONNEVILLE	Duchesne-Meeker-DENVER-Goodland-Salina-TOPEKA-KANSAS CITY-Marshall-COLUMBIA/JEFFERSON CITY	SPRINGFIELD-BLOOMINGTON-JOLIETCHICAGO/GARY-WEST LAFAYETTE-INDIANAPOLIS-RUSHVILLE-CINCINNATI/HAMILTON-COLUMBUS-Wheeling-PITTSBURGH-HAGERSTOWN-LEESBURG-WASHINGTON Dulles Airport-CENTREVILLE	LOS ANGELES-BAKERSFIELD-FRESNO-GILROY-SAN JOSE-SAN FRANCISCO	WASHINGTON D.C.-BALTIMORE-PHILADELPHIA-TRENTON-NEW YORK-NEW HAVEN-HARTFORD-PROVIDENCE-BOSTON	LOS ANGELES-SAN FRANCISCO-SACRAMENTO-RENO/CARSON-SALT LAKE CITY-DENVER-KANSAS/TOPEKA-SAINT LOUIS/JEFFERSON-SPRINGFIELD-CHICAGO/GARY-INDIANAPOLIS-CINCINNATI/HAMILTON-COLUMBUS-PITTSBURGH-WASHINGTON/BALTIMORE-PHILADELPHIA-TRENTON-NEW YORK-PROVIDENCE-BOSTON
TSAP's/PAET's número (Línea+Estaciones)	22 (17+5)	31 (22+9)	41 (23+18)	17 (8+9)	31 (21+10)	142 (91+51)
Velocidad media (km/h)	306	319	306	281	322	309
Total Movimiento de Tierras (Mm³)	896,95	380,23	245,43	128,98	333,42	1985,01
Túneles Largos (≥6 Km) (ud. Km Totales)	10 (151,24)	12 (168,50)	5 (36,70)	14 (181,10)	3 (22,00)	44 (559,54)
Viaductos principales (>400 m luz) (ud ; Km Totales)	5 25,68	14 28,40	14 22,40	3 5,00	10 16,00	46 97,48
Presupuesto (A+B+C+D+E+F) (M$)	27.402	33.075	21.244	15.312	19.384	116.917
Movimiento de Tierras (a) (M$)	8815	7351	4961	1757	9324	32.208
Túneles (b) (M$)	7060	7339	1553	7320	1103	24.375
Estructuras (c) (M$)	4369	3703	3465	1971	3469	40.746
A - Infraestructura (a+b+c) (M$)	20244	18393	4979	10856	13896	73.368
B - Superestructura (M$)	2304	5946	5348	1329	2943	17.770
C - Equipamento (M$)	2991	8889	4457	1731	1754	17.822
D - Protección ambiental (M$)	453	553	356	177	348	1.887
E - Proyecto,Garantía de Calidad y Dirección de obra (M$)	651	796	511	348	518	2.824
F - Suplemento por Estaciones y PAETs (M$)	759	498	593	558	414	2.822
Coste Unitario (incluidas Estaciones) (M$/km)	25,39 (26,05)	16,80 (17,05)	12,13 (12,48)	25,39 (25,85)	22,99 (23,49)	18,49 (18,95)
Inversión prevista de los Estados (M$)	10.200 CALIFORNIA 12.875 NEVADA 4.327 UTAH	8.595 UTAH 13.605 COLORADO 6.530 KANSAS 4.345 MISSOURI	6.801 ILLINOIS 3.882 INDIANA 294 MISSOURI 4.200 OHIO 4.139 PENNSYLVANIA 738 MARYLAND 1.190 VIRGINIA	15.312 CALIFORNIA	389 VIRGINIA 4.505 MARYLAND 1.589 PENNSYLVANIA 3.020 NEW JERSEY 2.291 NEW YORK 5.258 CONNECTICUT 920 RHODE ISLAND 1.914 MASSACHUSSETS	25.512 CALIFORNIA 12.875 NEVADA 12.922 UTAH 13.605 COLORADO 6.530 KANSAS 4.639 MISSOURI 6.801 ILLINOIS 3.882 INDIANA 4.200 OHIO 5.728 PENNSYLVANIA 5.243 MARYLAND 1.579 VIRGINIA 3.029 NEW JERSEY 2.291 NEW YORK 5.258 CONNECTICUT 920 RHODE ISLAND 1.914 MASSACHUSSETS

e) Estimation of the number of passengers/year (Demand)

The total demand initially envisaged in the LA-BO route, once put into service within 15 years, according to the attached list, is 128.70 Mp / y (passenger / year), and 143 Mp/y when the connections with the Poles of Seattle (in Salt Lake City), Dallas (in Kansas City), Atlanta (in Saint Louis) and Miami (in Washington DC) were put into service.

Section (HSL)	Population (Mhab)	Passenger/y(1) (Mp/y)	Travel time	Operation term (years)
LA-SF	8,111	22,25	2h 28'	8
SF-Sac	4,385	20,43	0h 36'	8
Sac-Ren	0,700	3,31	0h 34'	7
Ren-SLC	1,500	*2,87	2h 10'	15
SLC-Denv	2,500	**3,92	1h 57'	15
Denv-Ks.C	2,500	***1,62	2h 56'	9
Ks.C-SL	3,750	2,23	1h 19'	6
SL-Chic/G	7,330	8,02	1h 22'	10
Chic/G-Cin-Col	6,160	12,26	1h 43'	10
Col-Pittsb	3,100	10,76	0h 48'	15
Pittsb-Wash	5,400	9,94	1h 19'	15
Wash-NY	12,777	7,78	1h 24'	10
NY-Boston	**14,401**	**23,31**	**1h 14'**	**10**
LA-BO	**72,614**	**8,83**	**19h 50'**	**15**

(1): z=(20,000-0,039682L) (0,34854 P)

*: Lv=(200/315)L

**: Lv=(200/338)L

***: Lv=(200/350)L

Average daily occupation: 8.83 * 106/2/365 = 12096 p / d ->≈20 daily compositions of 600 passengers, distributed in seated places, berths and beds, as specified in the attached tables by routes and directions: HST LABO And HST BOLA

LOS ANGELES - BOSTON HIGH - SPEED TRAINS ("HS LABO") TIME TABLE

Time Zones	Pacific Time (-3)				Mountains Time (-2)		Central Time (-1)			Eastern Time (0)								Δ= 3'
Travel Times	2h 29m	34m	32 m	2h 06m	1h 57m	2h 50m	1h 15m	1h 17m	0h 54m	0h 30m	0h 40m	0h 48m	1h 12m	0h 46m	0h 38m	1h 12m		Σ=19h 40m
Stop Times	5m	2m	2m	2m	5m	2m	2m	5m	2m	2m	5m	5m	5m	5m	5m			Σ= 0h 54m

Block	HS TRAINS \ CITIES	LOS ANGELES (CA)	SAN FRANCISCO (CA)	SACRAMENTO (CA)	RENO (NV)	SALT LAKE CITY (UT)	DENVER (CO)	KANSAS CITY (KS+MO)	SANT LOUIS (MO)	CHICAGO/GARY (IN)	INDIANAPOLIS (IN)	CINCINNATI (OH)	COLUMBUS (OH)	PITTSBURGH (PA)	WASHINGTON D.C.	PHILADELPHIA (PA)	NEW YORK (NY)	BOSTON (MA)
Morning Block	HSLABO M1	09h 00m	11h 29m	12h 08m	12h 42m	15h 50m	17h 49m	21h 44m	23h 01m	00h 20m	02h 19m	02h 51m	03h 33m	04h 26m	05h 45m	06h 34m	07h 17m	08h 34m
	HSLABO M2	09h 15m	11h 44m	12h 23m	12h 56m	16h 05m	18h 04m	21h 59m	23h 16m	00h 35m	02h 34m	03h 06m	03h 48m	04h 41m	05h 58m	06h 49m	07h 32m	08h 49m
	HSLABO M3	09h 30m	11h 59m	12h 38m	13h 11m	16h 20m	18h 19m	22h 14m	23h 31m	00h 50m	02h 49m	03h 21m	04h 03m	04h 56m	06h 13m	07h 04m	07h 47m	09h 04m
	HSLABO M4	09h 45m	12h 14m	12h 53m	13h 26m	16h 35m	18h 34m	22h 29m	23h 46m	01h 05m	03h 04m	03h 36m	04h 18m	05h 11m	06h 28m	07h 19m	08h 02m	09h 19m
	HSLABO M5	10h 00m	12h 29m	13h 08m	13h 42m	16h 50m	18h 49m	22h 44m	00h 00m	01h 20m	03h 19m	03h 50m	04h 33m	05h 26m	06h 43m	07h 34m	08h 17m	09h 34m
Noon Block	HSLABO N1	15h 00m	17h 29m	18h 08m	18h 42m	21h 50m	23h 49m	03h 44m	05h 00m	06h 20m	08h 19m	08h 50m	09h 33m	10h 26m	11h 43m	12h 34m	13h 17m	14h 34m
	HSLABO N2	15h 15m	17h 44m	18h 23m	18h 56m	22h 05m	00h 04m	03h 59m	05h 16m	06h 35m	08h 34m	09h 06m	09h 48m	10h 41m	11h 58m	12h 49m	13h 32m	14h 49m
	HSLABO N3	15h 30m	17h 59m	18h 38m	19h 11m	22h 20m	00h 19m	04h 14m	05h 31m	06h 50m	08h 49m	09h 21m	10h 03m	10h 56m	12h 13m	13h 04m	13h 47m	15h 04m
	HSLABO N4	15h 45m	18h 14m	18h 53m	19h 26m	22h 35m	00h 34m	04h 29m	05h 46m	07h 05m	09h 04m	09h 36m	10h 18m	11h 11m	12h 28m	13h 19m	14h 02m	15h 19m
	HSLABO N5	16h 00m	18h 29m	19h 08m	19h 41m	22h 50m	00h 49m	05h 44m	06h 01m	07h 20m	09h 19m	09h 51m	10h 33m	11h 26m	12h 43m	13h 34m	14h 17m	15h 34m
Afternoon Block	HSLABO A1	16h 15m	18h 04m	19h 23m	19h 56m	23h 05m	01h 04m	05h 59m	06h 16m	07h 35m	09h 34m	10h 06m	10h 48m	11h 41m	12h 58m	13h 49m	14h 32m	15h 49m
	HSLABO A2	16h 30m	18h 59m	19h 38m	20h 11m	23h 20m	01h 19m	06h 14m	06h 31m	07h 50m	09h 49m	10h 21m	11h 03m	11h 56m	13h 13m	14h 04m	14h 47m	16h 04m
	HSLABO A3	16h 45m	19h 14m	19h 53m	20h 26m	23h 35m	01h 34m	06h 29m	06h 46m	08h 05m	10h 04m	10h 36m	11h 18m	12h 11m	13h 28m	14h 19m	15h 02m	16h 19m
	HSLABO A4	17h 00m	19h 29m	20h 08m	20h 41m	23h 50m	01h 49m	06h 44m	07h 01m	08h 20m	10h 19m	10h 51m	11h 33m	12h 26m	13h 43m	14h 34m	15h 17m	16h 34m
	HSLABO A5	17h 15m	19h 44m	20h 23m	20h 56m	00h 05m	02h 04m	06h 59m	07h 16m	08h 35m	10h 34m	11h 06m	11h 48m	12h 41m	13h 58m	14h 49m	15h 52m	16h 49m
Evening Block	HSLABO E1	17h 30m	19h 59m	20h 38m	21h 11m	00h 20m	02h 19m	07h 14m	07h 31m	08h 50m	10h 49m	11h 21m	12h 03m	12h 56m	14h 13m	16h 04m	15h 47m	17h 04m
	HSLABO E2	17h 45m	20h 14m	20h 53m	21h 26m	00h 35m	02h 34m	07h 29m	07h 46m	09h 05m	11h 04m	11h 36m	12h 18m	13h 11m	14h 28m	15h 19m	16h 02m	17h 19m
	HSLABO E3	18h 00m	20h 29m	21h 08m	21h 41m	00h 50m	02h 49m	07h 44m	08h 01m	09h 20m	11h 19m	11h 51m	12h 33m	13h 26m	14h 43m	15h 34m	16h 17m	17h 34m
	HSLABO E4	18h 15m	20h 44m	21h 23m	21h 56m	01h 05m	03h 04m	07h 49m	08h 16m	09h 35m	11h 34m	12h 06m	12h 48m	13h 41m	14h 58m	15h 49m	16h 32m	17h 49m
	HSLABO E5	18h 30m	20h 59m	21h 38m	22h 11m	01h 20m	03h 19m	08h 04m	08h 31m	09h 50m	11h 49m	12h 21m	13h 03m	13h 56m	15h 13m	16h 04m	16h 47m	18h 04m
	Cities Population	3,972	0,865	0,491	0,242	0,193	0,683	0,627	0,316	2,721	0,854	0,299	0,851	0,305	0,673	1,568	8,551	0,668
	Daily long Distance Passengers (dir LA-B)	2488	542	307	151	121	427	392	197	1942	608	240	597	319	1408	1304	965	Σ=11978
	Demanda Media previsible por tren	124 / 124	27 / 151	15 / 166	8 / 174	6 / 180	21 / 201	20 / 221	10 / 231	50 (97-47) / 281	30 / 311	10 / 321	30 / 351	16 / 367	46 (70-24) / 413	24 (65-41) / 437	84 (113-29) / 521	
	Composición propuesta	(4C)	(5C + 1M) – – –			(5C + 1M)	(5C+2M) – – –		(5C+2M)	(5C+2M+1S)	(5C+2M+2S) – –	(5C+2M+2S)	(5C+2M+3S) – –	(5C+2M+3S)	(5C+2M+4S)	(5C+2M+4S)	(5C+2M+6S)	C= Coche Cama
	Plazas ofertadas	128 / 128	176, 24 / 200	200	200	200	192, 48 / 240	240	240	192, 96 / 288	192, 144 / 336	336	192, 192 / 384	384	192, 246 / 438	438	192, 342 / 534	M= Coche Mixto; S= Coche Sentado
	Longitud (m) / Masa (t) cargado	108 / 219	134 / 254 – – –			134 / 254	174 / 286 – – –		174 / 286	186 / 305	200 / 324 – –	200 / 324	214 / 343 – –	214 / 343	226 / 362 – –	226 / 362	240 / 400	(incl 2 Tr+ 1/2 Rest) (mC+nM+pS)

BOSTON LOS ANGELES HIGH -SPEED TRAINS ("HSBOLA") TIME TABLE

Time Zones: Eastern Time (-1) · Central Time (-2) · Pacific Time · Δ=-3

Travel Times: 1 12" · 0 38" · 0 46" · 1 12" · 0 48" · 0 40" · 0 30" · 0 54" · 1 17" · 1 15" · 2 50" · 1 59" · 2 06" · 1 32" · 0 34" · 2 29" · Σ=19h 42"

Stop Times: 5" · 5" · 5" · 5" · 2" · 5" · 2" · 5" · 5" · 5" · 6" · 5" · 2" · 2" · 5" · Σ=1h 04"

	CITIES / HS TRAINS	BOSTON (MA)	NEW YORK (NY)	PHILADELPHIA (PA)	WASHINGTON DC	PITTSBURGH (PA)	COLUMBUS (OH)	CINCINNATI (OH)	INDIANAPOLIS (IN)	CHICAGO/GARY (IN)	SAINT LOUIS (MO)	KANSAS CITY (KS-MO)	DENVER (CO)	SALT LAKE CITY (UT)	RENO (NV)	SACRAMENTO (CA)	SAN FRANCISCO (CA)	LOS ANGELES (CA)
Morning Block	HSBOLA M1	06h 00m	07h 12m	07h 55m	08h 46m	10h 03m	10h 56m	11h 38m	11h 13m	12h 09m	13h 31m	13h 51m	16h 46m	17h 51m	29h 02m	21h 36m	22h 12m	00h 46m
	HSBOLA M2	06h 15m	07h 27m	08h 10m	09h 01m	10h 18m	11h 11m	11h 53m	11h 28m	12h 24m	13h 46m	14h 06m	17h 01m	18h 06m	20h 17m	21h 51m	22h 27m	01h 01m
	HSBOLA M3	06h 30m	07h 42m	08h 25m	09h 16m	10h 33m	11h 26m	12h 08m	12h 43m	12h 39m	14h 01m	14h 21m	17h 16m	18h 21m	20h 32m	22h 06m	22h 42m	01h 16m
	HSBOLA M4	06h 45m	07h 57m	08h 40m	09h 31m	10h 48m	11h 41m	12h 23m	12h 58m	12h 54m	14h 16m	14h 36m	17h 31m	18h 36m	20h 47m	22h 21m	22h 57m	01h 31m
	HSBOLA M5	07h 00m	08h 12m	08h 55m	09h 46m	11h 03m	11h 56m	12h 38m	13h 13m	13h 09m	14h 31m	14h 51m	17h 46m	18h 51m	21h 02m	22h 36m	23h 12m	01h 46m
Noon Block	HSBOLA N1	14h 30m	15h 42m	16h 25m	17h 16m	18h 33m	19h 26m	20h 08m	19h 43m	20h 39m	22h 01m	22h 21m	01h 16m	02h 21m	04h 32m	06h 06m	06h 42m	09h 16m
	HSBOLA N2	14h 45m	15h 57m	16h 40m	17h 31m	18h 48m	19h 41m	20h 23m	19h 58m	20h 54m	22h 16m	22h 36m	01h 31m	02h 36m	04h 47m	06h 21m	06h 57m	09h 31m
	HSBOLA N3	15h 00m	16h 12m	16h 55m	17h 46m	19h 03m	19h 56m	20h 38m	20h 13m	21h 09m	22h 31m	22h 51m	01h 46m	02h 51m	05h 02m	06h 36m	07h 12m	09h 46m
	HSBOLA N4	15h 15m	16h 27m	17h 10m	18h 01m	19h 18m	20h 11m	20h 53m	20h 28m	21h 24m	22h 46m	23h 06m	02h 01m	03h 06m	05h 17m	06h 51m	07h 27m	10h 01m
	HSBOLA N5	15h 30m	16h 42m	17h 25m	18h 16m	19h 33m	20h 26m	21h 08m	20h 43m	21h 39m	23h 01m	23h 21m	02h 16m	03h 21m	05h 32m	07h 06m	07h 42m	10h 16m
Afternoon Block	HSBOLA A1	15h 45m	16h 57m	17h 40m	18h 31m	19h 48m	20h 41m	21h 23m	20h 58m	21h 54m	23h 16m	23h 36m	02h 31m	03h 36m	05h 47m	07h 21m	07h 57m	10h 31m
	HSBOLA A2	16h 00m	17h 12m	17h 55m	18h 46m	20h 03m	20h 56m	21h 38m	21h 13m	22h 09m	23h 31m	23h 51m	02h 46m	03h 51m	06h 02m	07h 36m	08h 12m	10h 46m
	HSBOLA A3	16h 15m	17h 27m	18h 10m	19h 01m	20h 18m	21h 11m	21h 53m	21h 28m	22h 24m	23h 46m	00h 06m	03h 01m	04h 06m	06h 17m	07h 51m	08h 27m	11h 01m
	HSBOLA A4	16h 30m	17h 42m	18h 25m	19h 16m	20h 33m	21h 26m	22h 08m	21h 43m	22h 39m	00h 01m	00h 21m	03h 16m	04h 21m	06h 32m	08h 06m	08h 42m	11h 16m
	HSBOLA A5	16h 45m	17h 57m	18h 40m	19h 31m	20h 48m	21h 41m	22h 23m	21h 58m	22h 54m	00h 16m	00h 36m	03h 31m	04h 36m	06h 47m	08h 21m	08h 57m	11h 31m
Evening Block	HSBOLA E1	17h 00m	18h 12m	18h 55m	19h 46m	21h 05m	21h 56m	22h 38m	22h 13m	23h 09m	00h 31m	00h 51m	03h 46m	04h 51m	07h 02m	08h 36m	09h 12m	11h 46m
	HSBOLA E2	17h 15m	18h 27m	19h 10m	20h 01m	21h 18m	22h 11m	22h 53m	22h 28m	23h 24m	00h 46m	01h 06m	04h 01m	05h 06m	07h 17m	08h 51m	09h 27m	12h 01m
	HSBOLA E3	17h 30m	18h 42m	19h 25m	20h 16m	21h 33m	22h 26m	23h 08m	22h 43m	23h 39m	01h 01m	01h 21m	04h 16m	05h 21m	07h 32m	09h 06m	09h 42m	12h 16m
	HSBOLA E4	17h 45m	18h 57m	19h 40m	20h 31m	21h 48m	22h 41m	23h 23m	22h 58m	23h 54m	01h 16m	01h 36m	04h 31m	05h 36m	07h 47m	09h 21m	09h 57m	12h 31m
	HSBOLA E5	18h 00m	19h 12m	19h 55m	20h 46m	22h 03m	22h 56m	23h 38m	23h 13m	00h 09m	01h 31m	01h 51m	04h 46m	05h 51m	08h 02m	09h 36m	10h 12m	12h 46m
	Cities Population (2015 Census Mhab)	0,668	8,551	1,568	0,673	0,305	0,851	0,299	0,854	2,721	0,316	0,627	0,683	0,193	0,242	0,491	0,865	3,972
	Daily long Distance Passengers (dir LA-B)	689(215+474)	2753(740+2013)	588(163+425)	252(70+182)	279(93+186)	633(214+419)	222(74+148)	635(215+420)	1103(-1784+2884)	773	816	823	345	385	46	132	Σ=10474
	Demanda Media previsible por tren	35 / 35	138 / 173	30 / 203	13 / 216	14 / 230	32 / 262	11 / 273	32 / 305	55 / (144+89)360	39 / 399	40 / 439	41 / 480	17 / 497	19 / 516	2 / 518	7 / 525	
	Composición propuesta	(1M)	(5C + 1M)	(5C+2M)	(5C+2M)	(5C +2M+1S)	(5C+2M+1S)	(5C+2M+2S)	(4C+2M+2S)	(5C+2M+3S)	(5C+2M+4S)	(5C+2M+5S)	(5C+2M+5S)	(5C+2M+6S)	(5C+2M+6S)	(5C+2M+6S)	(5C+2M+6S)	
	Plazas ofertadas	16 / 24 / 40	176 / 24 / 200	192 / 48 / 240		192 / 96 / 288		192 / 150 / 342		192 / 198 / 390	192 / 246 / 438	192 / 300 / 492		192 / 348 / 540			192 / 348 / 540	
	Longitud (m) / Masa (t) cargado	68 / 168	148 / 268	160 / 284	160 / 284	186 / 305	186 / 305	200 / 324	200 / 324	214 / 343	226 / 362	240 / 400	240 / 400	240 / 400	240 / 400	240 / 400	240 / 400	

C= Coche Cama
M= Coche Mixto
S= Coche Sentado
(incl 2 Tr+ 1/2 Rest
(mC+nM+pS)

	LOS ANGELES (CA)	SAN FRANCISCO (CA)	SACRAMENTO (CA)	RENO (NV)	SALT LAKE CITY (UT)	DENVER (CO)	KANSAS CITY (KS/MO)	SAINT LOUIS (MO)	CHICAGO/GARY (IN)	CINCINNATI/ HAMILTON (OH)	COLUMBUS (OH)	PITTSBURGH (PA)	WASHINGTON /Dulles Int'l Airport (VA)	PHILADELPHIA (PA)	NEW YORK/JFK Int'l Airport (NY)	BOSTON/Suffolk (MA)
LOS ANGELES (CA)		598 113 2 h 42 m	765 1 stop 145 3 h 21 m	927 2 stop 175 3 h 58 m	1607 3 stop 304 6 h 11 m	2267 4 stop 428 8 h 11 m	3163 5 stop 598 11 h 10 m	3578 6 stop 676 12 h 32 m	3998 8 stop 755 13 h 55 m	4448 10 stop 840 15 h 13 m	4619 11 stop 873 15 h 48 m	4872 12 stop 925 16 h 33 m	5198 13 stop 982 17 h 39 m	5449 14 stop 1030 18 h 24 m	5631 15 stop 1064 18 h 58 m	5979 17 stop 1130 20 h 14 m
SAN FRANCISCO (CA)	598 113 2 h 42 m		167 32 0 h 36 m	329 1 stop 62 1 h 13 m	1009 2 stop 191 3 h 26 m	1669 3 stop 315 5 h 26 m	2565 4 stop 485 8 h 25 m	2980 5 stop 563 9 h 47 m	3400 7 stop 643 11 h 13 m	3850 9 stop 728 12 h 31 m	4021 10 stop 760 13 h 4 m	4274 11 stop 808 13 h 50 m	4600 12 stop 889 14 h 57 m	4851 13 stop 917 15 h 42 m	5033 14 stop 951 16 h 16 m	5381 16 stop 1017 17 h 32 m
SACRAMENTO (CA)	765 1 stop 145 3 h 21 m	167 32 0 h 36 m		162 31 0 h 34 m	842 1 stop 159 2 h 47 m	1502 2 stop 284 4 h 47 m	2398 3 stop 453 7 h 46 m	2813 4 stop 532 9 h 8 m	3233 6 stop 611 10 h 34 m	3683 8 stop 696 11 h 52 m	3854 9 stop 728 12 h 25 m	4107 10 stop 776 13 h 11 m	4433 11 stop 838 14 h 18 m	4684 12 stop 885 15 h 3 m	4866 13 stop 920 16 h 32 m	5214 15 stop 985 16 h 53 m
RENO (NV)	927 2 stop 175 3 h 58 m	329 1 stop 62 1 h 13 m	162 31 0 h 34 m		680 110 2 h 10 m	1340 1 stop 253 4 h 10 m	2236 2 stop 423 7 h 9 m	2651 3 stop 501 8 h 3 m	3071 5 stop 580 9 h 57 m	3521 7 stop 665 11 h 15 m	3692 8 stop 698 11 h 48 m	3945 9 stop 746 12 h 34 m	4271 10 stop 827 13 h 41 m	4522 11 stop 855 14 h 26 m	4704 12 stop 889 14 h 54 m	5052 14 stop 955 16 h 10 m
SALT LAKE CITY (UT)	1607 3 stop 304 6 h 11 m	1009 2 stop 191 3 h 26 m	842 1 stop 159 2 h 47 m	680 110 2 h 10 m		660 125 1 h 52 m	1556 1 stop 294 4 h 56 m	1971 2 stop 373 5 h 50 m	2391 4 stop 452 7 h 44 m	2841 6 stop 537 9 h 2 m	3012 7 stop 569 9 h 35 m	3265 8 stop 617 10 h 21 m	3591 9 stop 679 11 h 28 m	3842 10 stop 726 12 h 13 m	4024 11 stop 761 12 h 47 m	4372 13 stop 828 14 h 3 m
DENVER (CO)	2267 4 stop 428 8 h 15 m	1669 3 stop 315 5 h 26 m	1502 2 stop 284 4 h 47 m	1340 1 stop 253 4 h 10 m	660 125 1 h 57 m		896 169 2 h 56 m	1311 1 stop 248 3 h 50 m	1731 3 stop 327 5 h 40 m	2181 5 stop 412 6 h 58 m	2352 6 stop 445 7 h 31 m	2605 7 stop 492 8 h 17 m	2931 8 stop 554 9 h 4 m	3182 9 stop 601 10 h 9 m	3364 10 stop 636 10 h 44 m	3712 12 stop 702 12 h 0 m
KANSAS CITY (KS/MO)	3163 5 stop 598 11 h 10 m	2565 4 stop 485 8 h 25 m	2398 3 stop 453 7 h 46 m	2236 2 stop 423 7 h 9 m	1556 1 stop 294 4 h 54 m	896 169 2 h 56 m		415 78 1 h 19 m	835 2 stop 158 2 h 45 m	1285 4 stop 243 4 h 8 m	1456 5 stop 275 4 h 36 m	1709 6 stop 323 5 h 22 m	2035 7 stop 385 6 h 29 m	2286 8 stop 432 7 h 14 m	2468 9 stop 466 7 h 48 m	2816 11 stop 532 9 h 4 m
SAINT LOUIS (MO)	3578 6 stop 676 12 h 32 m	2980 5 stop 563 9 h 47 m	2813 4 stop 532 9 h 8 m	2651 3 stop 501 8 h 3 m	1971 2 stop 373 5 h 50 m	1311 1 stop 248 3 h 50 m	415 78 1 h 19 m		420 1 stop 79 1 h 23 m	870 3 stop 164 2 h 41 m	1041 4 stop 197 3 h 14 m	1294 5 stop 245 4 h 0 m	1620 6 stop 308 5 h 20 m	1871 7 stop 354 5 h 52 m	2053 8 stop 388 6 h 26 m	2401 10 stop 454 7 h 42 m
CHICAGO/GARY (IN)	3998 8 stop 755 13 h 55 m	3400 7 stop 643 11 h 13 m	3233 6 stop 611 10 h 34 m	3071 5 stop 580 9 h 57 m	2391 4 stop 452 7 h 44 m	1731 3 stop 327 5 h 40 m	835 2 stop 158 2 h 45 m	420 1 stop 79 1 h 23 m		450 1 stop 85 1 h 18 m	621 2 stop 117 1 h 51 m	874 3 stop 165 2 h 37 m	1200 4 stop 227 3 h 44 m	1451 5 stop 274 4 h 29 m	1633 6 stop 309 5 h 3 m	1981 8 stop 374 6 h 19 m
CINCINNATI/ HAMILTON (OH)	4448 10 stop 840 15 h 13 m	3850 9 stop 728 12 h 31 m	3683 8 stop 696 11 h 52 m	3521 7 stop 665 11 h 15 m	2841 6 stop 537 9 h 2 m	2181 5 stop 412 6 h 58 m	1285 4 stop 243 4 h 8 m	870 3 stop 164 2 h 41 m	450 1 stop 85 1 h 18 m		171 32 0 h 33 m	424 1 stop 80 1 h 19 m	750 2 stop 142 2 h 26 m	1001 3 stop 189 3 h 11 m	1183 4 stop 224 3 h 45 m	1531 6 stop 289 5 h 1 m
COLUMBUS (OH)	4619 11 stop 873 15 h 46 m	4021 10 stop 760 13 h 4 m	3854 9 stop 728 12 h 25 m	3692 8 stop 698 11 h 48 m	3012 7 stop 569 9 h 35 m	2352 6 stop 445 7 h 31 m	1456 5 stop 275 4 h 36 m	1041 4 stop 197 3 h 14 m	621 2 stop 117 1 h 51 m	171 32 0 h 33 m		253 48 0 h 46 m	579 1 stop 109 1 h 54 m	830 2 stop 157 2 h 39 m	1012 3 stop 191 3 h 14 m	1360 5 stop 257 4 h 30 m
PITTSBURGH (PA)	4872 12 stop 925 16 h 33 m	4274 11 stop 808 13 h 59 m	4107 10 stop 776 13 h 11 m	3945 9 stop 746 12 h 34 m	3265 8 stop 617 10 h 21 m	2605 7 stop 492 8 h 17 m	1709 6 stop 323 5 h 22 m	1294 5 stop 245 4 h 0 m	874 3 stop 165 2 h 37 m	424 1 stop 80 1 h 19 m	253 48 0 h 46 m		326 62 1 h 7 m	577 1 stop 109 1 h 52 m	759 2 stop 143 2 h 28 m	1107 4 stop 209 3 h 40 m
WASHINGTON (Dulles Int'l Airport) (VA)	5198 13 stop 982 17 h 39 m	4600 12 stop 869 14 h 57 m	4433 11 stop 838 14 h 18 m	4271 10 stop 827 13 h 41 m	3591 9 stop 679 11 h 28 m	2931 8 stop 554 9 h 24 m	2035 7 stop 385 6 h 29 m	1620 6 stop 308 5 h 1 m	1200 4 stop 227 3 h 44 m	750 2 stop 142 2 h 26 m	579 1 stop 109 1 h 54 m	371 70 1 h 18 m		251 47 0 h 45 m	433 1 stop 82 1 h 18 m	781 3 stop 148 2 h 34 m
PHILADELPHIA (PA)	5449 14 stop 1030 18 h 24 m	4851 13 stop 917 15 h 42 m	4684 12 stop 885 15 h 3 m	4522 11 stop 855 14 h 26 m	3842 10 stop 726 12 h 13 m	3182 9 stop 601 10 h 9 m	2286 8 stop 432 7 h 14 m	1871 7 stop 354 5 h 52 m	1451 5 stop 274 4 h 29 m	1001 3 stop 189 3 h 11 m	830 2 stop 157 2 h 39 m	577 1 stop 109 1 h 52 m	251 47 0 h 48 m		182 34 0 h 34 m	530 2 stop 100 1 h 50 m
NEW YORK/JFK Int'l Airport (NY)	5631 15 stop 1064 18 h 58 m	5033 14 stop 951 16 h 16 m	4866 13 stop 920 15 h 37 m	4704 12 stop 889 14 h 54 m	4024 11 stop 761 12 h 47 m	3364 10 stop 636 10 h 44 m	2468 9 stop 466 7 h 48 m	2053 8 stop 388 6 h 26 m	1633 6 stop 309 5 h 3 m	1183 4 stop 224 3 h 45 m	1012 3 stop 191 3 h 14 m	759 2 stop 143 2 h 28 m	433 1 stop 82 1 h 18 m	182 34 0 h 34 m		348 1 stop 66 1 h 16 m
BOSTON/Suffolk (MA)	5979 17 stop 1130 20 h 14 m	5381 16 stop 1017 17 h 32 m	5214 15 stop 985 16 h 53 m	5052 14 stop 955 16 h 10 m	4372 13 stop 828 14 h 3 m	3712 12 stop 702 12 h 0 m	2816 11 stop 532 9 h 4 m	2401 10 stop 454 7 h 42 m	1981 8 stop 374 6 h 19 m	1531 6 stop 289 5 h 1 m	1360 5 stop 257 4 h 30 m	1107 4 stop 209 3 h 40 m	781 3 stop 148 2 h 34 m	530 2 stop 100 1 h 50 m	348 1 stop 66 1 h 16 m	

LEYENDA SENTIDO 1 (Los Ángeles - Boston)

2267	Distancia en Km
4 stop	Número de paradas
428	Tarifa billete $
8 h 11 m	Tiempo en **horas y minutos**

LEYENDA SENTIDO 2 (Boston - Los Ángeles)

2267	Distancia en Km
4 stop	Número de paradas
428	Tarifa billete $
8 h 15 m	Tiempo en **horas y minutos**

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General and network aspects of HSR

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Low cost in high-speed train in France. Customer-king and the public service guillotine

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Abstract

Low cost air travel may be a longstanding and well-known phenomenon but up until now the same could not be said about rail travel, the topic of this article. This is changing, however, at least in France where low cost rail travel has started to spread in recent years. The present paper outlines different reasons why France's SNCF National Railways has embarked on a low cost trajectory over the past 15 years while discussing how this approach has affected work and employment at the company. The low cost paradigm has centred on a reduction in production costs, a restructuring of the commercial offer and a diminution in rail workers' social protections. The idea put forward here is that the SNCF's new commercial conditions hide a plan to undermine France's public service railway.

Keywords: Low cost, railways, railroads, High speed, SNCF, iDTGV ; OUIGO, Izis, yield management.

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1. Introduction

In the railway business line, if the opening of freight and passenger transport markets is the rule in the European Union, low cost in passenger transport remains, as of Fall 2017, a French specificity[1].

Strategies imagined from one country to another are very diverse. After very clear injunctions from the European Commission, SNCF has distinguished itself from other European countries by putting an emphasis on low cost, a degraded vision of fast-train travel, as it has developed from 1981 to 2003, for more than 20 years. As of today, low cost only operates LGV (fast trains), even though Izy (launched in 2016) announces changes in Bruxelles-Paris lines in parallel with the fast-train line.

Let us formulate an hypothesis: in rail transport as in air transport, employers' creativity in the commercial field results from the incapacity in which they find themselves to fight and ultimately defeat labor – meaning the workers – to adapt according to their will the production tools, in the composition of which the organization of labor is essential. In railways, work authorizes different types of deliveries (fast trains, express regional lines, Intercités). And because of those difficulties in convincing trade unions to accept the flexibility deemed necessary, which ultimately means renouncing some social achievements, the State-employer has used bypass strategies. Unable to transform as it wishes what exists, it modifies it sideways, disarming – more or less – resistance from hostile or skeptical forces.

iDTGV	
Launched	**Displayed objective**
2004 (disappearing in 2017)	Competing against air transport through prices
Commercial modalities	
Trips around Paris covering less than 300 km. Objective of an at least 80% occupancy rate. Traveler's welcome on platform.	
Technical modalities	
iDTGV trains attached at the back of an ordinary TGV (so one conductor and one slot for two trains)	

1 As we're writing these lines, LCR (Low Cost Rail), a freight society that also aims at transporting passengers, and apparently independant from existing operators, is launching its first convoys in Spain.
http://www.vialibreffe.com/noticias.asp?not=21630&cs=oper

<table>
<tr><th colspan="2">OUIGO</th></tr>
<tr><th>Launched</th><th>Displayed objective</th></tr>
<tr><td>2013</td><td>Competing against air transport through prices</td></tr>
<tr><th colspan="2">Commercial modalities</th></tr>
<tr><td colspan="2">Idem & important charges in case of booking cancellation (in order to avoid empty seats) one class only.

The same trip (but not necessarily the same timeslot) can cost from 10 to 85 euros. Target clientele: “entry range”, young, poor, and not in a hurry, or wishing, at fixed costs, to multiply trips. No first class. Phone contacts at prohibitive prices (20 euros, sometimes more than the ticket price), obstacles to reservation changes (4h before departure, minimum).

Alignement of OUIGO on Ryanair. « The corollary of simplification, slicing of the product, is the optionalization of all its secondary features (...). low cost is in fact the contrary of gratuity : everything has a price, and everything must be paid for » (Combe, 2011, p. 5). Added to a cabin luggage, billing of power outlet, on-board admission 30m before departure (controls on platform).</td></tr>
<tr><th colspan="2">Technical modalities</th></tr>
<tr><td colspan="2">a. constitution of filled trains over densification of occupancy on certain trains (bar disappears)[2]

b. In order to reduce tolls in some cities, trains leave and arrive in far away stations (Tourcoing, Marne-la-Vallée, Lyon-Saint-Exupéry, etc.), which means more time and another ticket. SNCF wishes for those trains to leave from Paris stations (in 2019).

Intensification of train utilization (sometimes 13h a day, compared to 6 or 7 for ordinary TGVs).</td></tr>
</table>

2 According to sources a OUIGO hosts 634 places against 545 in an ordinary TGV duplex, which means + 14 % or 1 268 sièges against 1 000 in an ordinary TGV (+ 26 %).

IZY	
Launched	**Displayed objective**
2016	Competing against main brand Thalys, created 20 years ago, buses and car-sharing.
Commercial modalities	
Compared to Thalys (launched 20 years ago), prices can be very low (for example 10e if traveling standing). The sale is reserved for French and Belgian historical operators. Loyalty programs (even Thalyscard) are not valid. Loss in case of cancellation. Only works off-peak (after 9am and after 8pm), two daily lines (three on Sundays). Significant elongation of travel times (Paris Bruxelles in 2 hours and 8 to 26 minutes, meaning 46 to 64 minutes more than in Thalys, which takes 1 hour 24 for Paris-Bruxelles). Transformation in a relative low standard travel. Auto-competing against Thalys, Izy showcases the beginning of International Railway low cost by implementing low cost in Belgium. Amongst reasons for which SNCF (which owns 60% of Thalys) and its Belgian homologue SNCB (which owns 40%) have chosen the low cost option over reducing prices would be marketing strategy. Thalys would not like to see its prestigious in business circles brand depreciated. Thalys sometimes are half empty, but administrators not really caring about environmental issues deem beneficial to make “less branded” trains function more.	
Technical modalities	
« Slow speed » by using on the French side of the trip ordinary rails in order to reduce tolls. Over densification of occupancy on certain trains (bar disappears). No Wifi (contrary to what exists on Thalys). « SNCF-mobilité », the main shareholder, would like to optimize the utilization of its TGVs (by renting two trains to Thalys, which are in fact destined to Izy).	

TGV POP	
Launched	**Displayed objective**
2016	Optimizing TGV occupancy
Commercial modalities	
Only using the train if the number of passengers registered (15 to 4 days before departure) is enough (from 25 to 50 depending on destinations) . Maximal flexibility (incertitude for clients until three days before departure).	

Eurostar Snap	
Launched	**Displayed objective**
2016	Idem for Eurostar
Commercial modalities	
Standard class exclusively. Reservations through Facebook only 7 days before departure, indicating whether morning or afternoon is preferred. The traveler receives confirmation and identification of the timeslot decided by Snap 48h before departure at the latest. Subject to availabilities of dates and trains. Return the same day sometimes is impossible.	

We could point out that the creation rhythm of those subsidiaries or new commercial modalities is increasing. Nine years separate OUIGO from iDTGV but IZY, TGVpop and « Eurostar Snap » have followed OUIGO in three years only, and those three last initiatives were born on the same year. We could also point out that over the years, commercial products are more and more "entry range".

Those formulas impose the dematerialization of sales (suppression of counters which implies that the client works, and spends time and money) and use yield management (price modulation combining the rate of reservation and the departure date, a logic that many of our European neighbors, even great rail nations such as Germany, Belgium or Switzerland, ignore). More and more often, the price of cancelled tickets is lost or a change of trains is subject to prohibitive prices. Optionalization (billing of any additional delivery, in Izy the second luggage can cost more than the ticket price) is now the rule. In some cases, train occupancy is over-dense (by suppression of bar wagon). Finally, in all the last formulas, the traveler is attracted by low fares but is not certain to be able to travel at this price, and if he still wishes to take the train, he might have to pay a very high price. According to Cyrine Gardes : "client is king, but you're not his queen".

2. The heart of resistance is attacked through its periphery

In 2004, with iDTGV, the introduction of low cost in SNCF materialized an important restructuration for public service on French railways, accompanied some years later by the apparition of long-distance bus travels. This important management decision was not a provisory measure, in order to straighten budgets, but a durable orientation which, along with the breakup of SNCF in 2 EPIC (in 1997) then 3 (in 2015), aimed at the bypassing of resistances coming from workers to adaptations deemed necessary by the opening of the market. And, as could be expected, sooner or later the experimentations of production re-organization would touch all activity, coming back to the parent company SNCF. In the same way that "helped jobs" have degraded the norm for ordinary jobs, the introduction of low cost has helped sooner or later to undermine public service and the working, living and job conditions of its personnel. The heart of resistance is attacked through its periphery.

Eurostar Snap	
Launched	**Displayed objective**
2016	Idem for Eurostar
Commercial modalities	
Standard class exclusively. Reservations through Facebook only 7 days before departure, indicating whether morning or afternoon is preferred. The traveler receives confirmation and identification of the timeslot decided by Snap 48h before departure at the latest. Subject to availabilities of dates and trains. Return the same day sometimes is impossible.	

We could point out that the creation rhythm of those subsidiaries or new commercial modalities is increasing. Nine years separate OUIGO from iDTGV but IZY, TGVpop and « Eurostar Snap » have followed OUIGO in three years only, and those three last initiatives were born on the same year. We could also point out that over the years, commercial products are more and more “entry range”.

Those formulas impose the dematerialization of sales (suppression of counters which implies that the client works, and spends time and money) and use yield management (price modulation combining the rate of reservation and the departure date, a logic that many of our European neighbors, even great rail nations such as Germany, Belgium or Switzerland, ignore). More and more often, the price of cancelled tickets is lost or a change of trains is subject to prohibitive prices. Optionalization (billing of any additional delivery, in Izy the second luggage can cost more than the ticket price) is now the rule. In some cases, train occupancy is over-dense (by suppression of bar wagon). Finally, in all the last formulas, the traveler is attracted by low fares but is not certain to be able to travel at this price, and if he still wishes to take the train, he might have to pay a very high price. According to Cyrine Gardes : “client is king, but you’re not his queen”.

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Both the redefinition of clientele segmentation comprised in those different low cost initiatives and the progressive but continuous reconfiguration of organization and labor rules must be seen as going hand in hand.

3.1 Bipolarisation of clientele

SNCF aims at keeping its offer of ordinary TGVs (that it would like to christen InOui), even if that implies, for the moment, proposing lower prices (like Prem's) or making billing modulation thinner.

For the most part (but not exclusively), those lines have a specific clientele, called "business" or "Pro". In a hurry, this clientele catches the fastest trains, and travels on rush hour. Pampered, it is demanding regarding service (high frequency) and flexibility (possibility to change a reservation at the last moment or – until very recently – after the departure of the train), service "on site", comfort (subdued light in order to work or relax). Rather indifferent to costs, as it is generally taken up by the businesses, this clientele is very "elastic" (cost is not its first problem). Convenience is also taken into account (being able to leave from city centers). If we look at the case of the Paris-Bordeaux line, the finalization of the TGV railway that was operational in July 2017 meant 70 minutes less of travel, for 10 euros more on the ticket price (due to the financing of the public-private partnership by Vinci). On this line, iDTGV has at the same time disappeared in the same way as in 2012, when the Paris Lyon and Paris Strasbourg lines, occupied mostly by managers, have ceased to offer this option.

On the other side, where it changes the most, starting in the middle of the 2000's, SNCF now targets a clientele that is deprived of monetary means and /or for which ticket price is the main criterion (students, young independents, members of the working class, etc.). A significant percentage of low cost travelers does not belong to any of those groups, but the target clientele are the 25 to 59 years-old that travel privately. On total, compared to a client traveling with ordinary TGV and at equal distance, speed and comfort, the price would be 30 to 50% less, and sometimes even a lot less if one books early. This clientele sometimes travels intensely. Oftentimes at ease with the numeric world, it has very few time constraints, and is very fast in identifying the best prices, and some can be very competitive, for example 10 to 15 euros for traveling 700 kilometers on OUIGO if one anticipates his journeys months before and sometimes accepts departing from far-away stations, which for many travelers implies an elongation of travel times. In the last low cost formulas, on the same destinations, the mandatory travel times are significantly longer than those of an ordinary TGV (for example Paris-Bordeaux with OUIGO if one accepts to go to Massy or Marne-la-Vallée, or Bruxelles-Paris on Izy).

Most of this clientele – that is becoming more and more numerous – is sensitive to price. According to OUIGO's CEO on the Paris-Rennes rail, 45% of the clientele (for the most part comprised of children), wouldn't without this offer have used the railway. This segmentation policy redefines the frontiers between social categories that have a comfortable buying power and working class categories. And, logically, low cost offers always suppose more work from the consumer (Dujarier 2008), construction of the consumer (Grandclément

2011), in both senses of the word construction, as “putting the client at work” and his “commercial education” (Tiffon 2013). It is again essentially those same working class populations that are subject to additional costs. This clientele segment is what’s more victim from monetary penalization if it changes its train schedules postpones or simply cancels its journey.

3.2 Making not solvent clientele accept a downgrading

The trend is, in both train categories, that the traveler pays his ticket a higher price as the day and hour of the departure approaches but in both segments, the yield management cannot be reduced to this simple rule (Finez & Perennes, 2015). Tickets can be sold again at lower fares than those that existed the day before. Some imagine that this deliberate opacity policy allows commercials to blur lines and disarm the homo oeconomicus that would be too virtuoso or would like to turn marketing algorithms to his advantage. In a deliberate way, everything is made in order to blur lines, like consumer associations have had the occasion to deplore. “Almost nobody pays his TGV ticket at full fare”, was happy to note “SNCF mobilités” CEO, G. Pepy. It is because the swamp of fares gives the illusion of low prices that blur lines and the perception of the consumer. Nobody could say anymore what the “normal price” of a train ticket would be on a given destination. This is why at the end of the 2000’s, a parliamentary report advised communication to the consumer buying a train ticket of what was its median selling price.

Blurring lines, but to what avail? Even in the limits presupposed by the low cost offer, the aim is to – what a paradox – sell at the highest possible price, even if that means reintroducing a form of 3rd class, a category suppressed in 1956 and surreptitiously reintroduced under the form of full trains that offer lesser facilities than the contemporary standard (Kestel and Larue, 2016). In managerial medias, the general director of Voyage SNCF explained thus her commercial strategy: “we prefer (…) putting a client that pays less in a seat that costs half as much than in a TGV. We do not oppose the two offers but are constructing a global offer with both, a low cost offer, that is an industrial model and a contract with a different and constrained traveler, and a more qualitative TGV offer, with very high travel frequencies.” We could not describe best the segmentation of clientele and the confinement of the poor (to make it easier) in poorer trains. But of course things are not said this way. One of the main difficulties in analyzing the public railway service resides in the “lack of coherence between words and things” (Quessette 2016, p. 21).

3.3 Drain all the clientele that can be drained

For SNCF and “SNCF Mobilité”, on the commercial side, this clientele segmentation fundamentally amounts to draining all the clientele that can be drained (even on the intermodal way by launching an interurban coach company, car-renting between individuals or a car-sharing company). It is probably the reason why all trains will not become low cost. There would exist, what’s more, some sort of ceiling to the extension of low cost, just like in air travel where it would represent, according to some, 50% of the market ; because of social status, comfort or convenience of correspondence, some parts of the clientele do not wish to use flights or train that are low cost. Coming out of the Board of directors’ meeting of January 2016, SNCF Mobilité’s direction envisioned that classic TGV would tomorrow be “a little smaller than today, and OUIGO bigger”. SNCF would try to have 25% of its trains becoming low cost in 2020 (five times more than today).

Inversely, some parts of the low cost clientele that are not deprived from economic capital estimate that one would have to be crazy to pay more than the minimum fare and they accept, for example for inhabitants of Ile-de-France, to depart from Marne-la-Vallée or Massy. Every little helps.

4. In the "side structure", work and employment degraded

Other than economic and management reasons that we have just discussed, what motivated the birth of the low cost in rail transport is of the same nature than in air transport ; bypass resistances. Those goals are divided in two dimensions: a) fight the routine and relative facilities offered by "path dependency" in the firm's management and the definition of its commercial strategy (North 190, Pierson 1994) and b) bypass the resistance of salaries that are turning against the weakening of their collective protections. If we should distinguish those two dimensions from an analytical point of view, the manager practical sense sees them both as intricate. We can consider by hypothesis that there is a functional relation between the productive act and the markets of both products and labor that, in a capitalist frame, makes them possible. This is what presumably meant a consultant, presented like one of the designers of the iDTGV model, when saying: "when we are trying to be innovative in a firm of this type (i.e. SNCF), we are blocked by the culture. The only way to act is to create a side structure" (told by Bouaziz 2012).

4.1 Making railway workers work differently

But the side structure isn't destined to remain lateral and soon irradiates the parent company. "Should we get more inspiration from OUIGO, that has reduced its cost by 40% compared to ordinary TGV organization by making the railway workers work differently ?" asks Le Figaro with a false ingenuity?[1] On the same plan, the breakup of SNCF in two, then three EPIC ("network", "mobilities" and "Head EPIC"), legacy from the railroad reform of July 2015, also obeys to the same logic, whatever be the circumstances that have favored its emergence.

Working in the railway low cost mainly supposes not to benefit from statutory protections of SNCF Railroad workers, except for train conductors, train controllers and maintenance in technical center, to the best of our knowledge. In this regard, firms or side low cost railway companies do not distinguish themselves from subcontractors (security, cleaning, welcome, etc.) whose primary vocation (but not exclusive) is to bypass the advantages often conquered by the workers of the main company, in this case the SNCF.

iDTGV is a great illustration of the weakening of closed labor markets (economists would say internal (Doeringer 1967; Doeringer & Piore 1971) of railroad workers by low cost initiatives. This entity functioned with very little directly employed personnel: 80 employees and 1200 providers (Bouaziz 2012). "The firm is using resources that are all located outside of its perimeter". Thus, exterior providers are operating its booking system and its customer service. It was the same for ticket control, which was done before the train departure by a provider society. In 1992, less than half of iDTGV's permanent employees came from SNCF (ibidem).

On board of iDTGV, "supervisors" and "barristas" (responsible for food and beverages) were not iDTGV employees (in fact, railway food and beverages have been subcontracted

1 *http://premium.lefigaro.fr/societes/2016/01/22/20005-20160122ARTFIG00349-les-petits-prix-plombent-les-benefices-de-la-sncf.php*

for a very long time). Personnel characteristics are very telling. In iDTGV's headquarters, "beside direction functions, there is only one market cell that analyses live the prices of the competition (essentially air transport) so that the fares remain competitive".

In OUIGO branch, personnel are "SNCF agents that are sworn and certified by the Republic prosecutor to check for contraveners' identity." In order to save on workers' costs, workers affected to OUIGO come back home as often as possible, in order to spare the famous RHR (Rest out of Residence), also called "sleepovers", that make the employer give bonuses and pay for a collective house or a hotel room.

Controllers also have seen their mission evolve with rotations between long days on board and shorter ones, dedicated to "platform controls" of tickets before departure, and regular formations "integrated" to work planning, according to the Head of "SNCF Traveller"[2]. A controller in OUIGO explained that he was wearing the uniform of this branch and not the one of its original employer SNCF, but that accepting to work for OUIGO opened the perspective of an accelerated career. "In principle, becoming controller on TGV is only possible after some experience as a controller on most classic lines (TER, Intercités). But by applying on OUIGO, we can become ASCT (Agents of commercial train service) (which means controller) on fast train lines without waiting for the end of our careers. And honestly, working on Transilien wasn't my thing. Working on OUIGO gives me more responsibility and more bonuses" (interview, May 15th 2017). One couldn't say better that the aim is to jostle traditional promotion rules based on experience, even though they remain – whether we like it or not – the most objective criterion for personnel evaluation. On the controller's side, they have seen additional tasks added, like "taking the train to cleaning" when their ordinary TGV colleagues have "jockeys" taking care of this function according to the CFDT general secretary for conductors (FGAAC CFDT). For the time, the most significant seems to be that low cost has effects on workers, technical centers, those that the client never sees. "Maintenance of OUIGO trains is faster, is only done by night and is centralized on the Gerland (Lyon) technical center and its 400 railroad workers" (some parts of the maintenance is also done in Tourcoing (Kestel and Larue 2016). The acceleration of train cleaning tends to multiply by two their monthly exploitation, from 40-45 kilometers by month to 80. Besides recruiting non-statutory personnel, employed by other firms than SNCF, one of the most salient questions is relative to the extension of night work on technical centers (but night bonuses make it less unacceptable). Tomorrow, night work could extend to workers in charge of maintenance of ordinary TGV. A management teacher speaks of the managerial logic that ends up in "proposing worse working conditions to their employees" even though they "work longer" (Zilberberg, sd).

"Once those new practices, notably for equipment maintenance, have been implemented, I don't see why the direction would not try to enlarge them" declared a leader of the Unsa union to Les Echos. And the financial press indicates "with its low cost offer, SNCF aims at taking back some market sections to the road. But it also surely tries to use those changes to jostle its labor organization."[3]"All the TGVs will not turn into OUIGOs", declared the Head of "SNCF travelers", who nonetheless confessed that SNCF wished to "take into account some good ideas developed by OUIGO in order to generalize them on TGVs":

(http://www.lavoixdunord.fr/economie/tgv-ouigo-une-organisation-du-travail-aux-couts-resserres-ia0b0n3284093). All is said.

2 *http://lexpansion.lexpress.fr/actualites/1/actualites/tgv-ouigo-une-organisation- du- travail-aux- couts-resserres_1755834.html*

3 *https://www.lesechos.fr/05/06/2012/lesechos.fr/0202097879442_avec-son-tgv-low-cost--la-sncf-veut-aussi-tester-de-nouvelles-pistes-de-productivite.htm#Dud72A011Yq1cWyX.99*

5. Conclusion

Commercial strategies of SNCF Mobilités and the answers brought back from the clientele, forced (or not) to escape from high prices if it wishes to travel, have amounted to those incontestable truths: a) little by little, low cost according to SNCF is getting more and more degraded. In its "Eurostar Snap" or "TGV pop" versions, the business model (according to marketers) rests on the idea that the train will only leave if enough people on the internet have declared themselves interested. Could we imagine less consideration for the clientele called "entry level"? b) The implementation of low cost is an experimentation field for some dispositions that are then extended to all transport products, whether they be rail or road, by the great public railway firm, something that Kestel and Larue (2016) show very well by studying OUIBUS in parallel with OUIGO.

The multimodal policy of SNCF aims at instilling the idea that competition is the source of price reduction in transports, when public investment and most notably a taking up of the debt by public authority would be a surer and preferable alternative in order to lessen the price of the kilometer traveled in train. According to a transport lawyer: "generalization of low cost translates and shows the emergence of a precarious lifestyle, and an existence that is subdued to the laws of marketing. The buying power gained by this service does not put the client-user at the heart of the public service, because of buying without power" (Quessette 2016, p. 23). And finally it is the idea of public service "à la française" (Brouté, 2016) itself that is mined by those commercial initiatives.

In a press conference, the President of SNCF gave his conception of the client. "I am sure that low cost will be a great success in railways." "Our clients don't care at all in what kind of transport they travel: they want price, price, price, simplicity and that it be fluid. After that, it's better if it's ecological. So we will never have air transport."[4]17 This evokes the simplistic vision that engineer Taylor had of worker Schmidt as only moved by money, indifferent to the organization of work, its working collectives and hierarchical situation. His only identity was the will to bring back, at whatever cost, more dollars home.

If the deregulation of commercial offer is not appealing for public service, we now have enough hindsight to see that it is not a good thing for railway workers. This offer wouldn't have been possible without a weakening of union resistances and inversely the emergence of low cost, which as we have shown induces always more degraded performances, is an accelerator of this trend. Working conditions in the low cost are a model for the parent company. By paraphrasing M. Carolan (2015), we could say that on the social level, the cost of low cost is indeed very high!

We thus have sketched an outline that would have to be continued: under a commercial offer that seems at first sight to be inexpensive, is hidden a sound attack on the idea of equality supposed by French public service. Until the end of the 1960s, it relied – at least on traveler transportation – on the principle of fare equalization and the "obligation to transport". Or, as explained by Quessette, "now it is the client that has to oblige SNCF in order to travel, and not the contrary." For the lawyer specialized in transport, this bifurcation was made in 1971, when a decree allowed SNCF autonomy in management. From then on, the idea of "public service" had strongly lost its hold.

As for the client, the logic of immediate advantage in which low cost confines him isn't without any risks: "public service liberates when low cost oppresses. Low cost symbolizes the fall of society and an important part of its population into precariousness." (Quessette 2016, p. 25)

4 *https://investir.lesechos.fr/actions/actualites/france-la-sncf-anticipera-l-ouverture-a-la-concurrence-1561444.php#pTtOIyhabfSIwA3q.99*

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General and network aspects of HSR

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Evolution of the role of the Consultant Engineer in High-speed Railway Projects along the last 25 years, in Spain

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Abstract

Over the last 25 years, the design of High-speed Lines in Spain has undergone an important evolution, which has been enhanced by the multitude of High-speed kilometers that have been built throughout the National territory, and by the multitude of problems and constraints, of very different nature, which have been identified as challenges and have resolved in a favorable way. IDOM having participate in 2,300 kilometers around the world as a specialized firm in the design and supervision of works for construction of High-speed lines, has lived first hand this evolution, contributing through its different projects and studies, to the development of the current Spanish High-speed model. In addition, it has subsequently been able to export the Spanish model, as a more appropriate solution, to other European Union countries, such as Poland and Sweden. Throughout this presentation, a brief review of the variation of design over the last 25 years will be made, quoting different projects that were engineering milestones, such as: the Basic Design and Works Supervision of the stretch Lalín - Santiago with 47 km in length; as well as the Detail Design and Works Supervision of the sub-section of Alcántara-Garrovillas Reservoir, which includes the Almonte viaduct, with a 384 m central arch, which is the world's longest span for a High-speed arch bridge. On the other hand, a short review will be done later on the major international projects of great relevance, which have currently been or will be designed, having the Spanish High-speed model as one of its main reference bases. The main objective of this presentation is to show the particular vision of the Consultant Engineer on the historical evolution experienced by the Spanish High-speed rail network, and to highlight the great strengths presented by the Spanish concept of design.

Keywords: Civil engineering evolution, Spanish High-speed rail, railway challenges

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1. Introduction

Over the last 25 years there has been an important evolution of the role developed by the engineering consulting firms that has been determined by the evolution of the administration, its regulatory framework and the increase of the quality requirements demanded in the development of High-speed Infrastructures.

Regarding to the evolution experienced by the engineering consultant, it is important to highlight the improvement of the production processes within the engineering field that have been strongly influenced by the appearance of the computation technology, by the appearance of protocols and methodologies related to the quality assurance and, with the improvements of the national regulatory framework as well as the modernization of the public administration. The role of the engineering consultant has evolved from an engineering based on the design of the product under a pattern of technical excellence towards a more global approach, of analysis of the complete life cycle of the infrastructure, taking into account from the design stage the phases of operation, maintenance and the phases of renewal of the infrastructure once it has reached the end of its life cycle.

In addition, the influence of the concern about the environmental sustainability has become very important, consolidating the procedure that guarantees the correct evaluation and mitigation of the affections that the works of High-speed are able to generate on the environment in which they are constructed.

Throughout this article, a historical summary of the kilometers of High-speed built throughout the national territory is going to be made, highlighting some projects that were a technological challenge. In parallel, it will be described the main evolutionary phases of the design process from the introduction of hardware as a tool to support design, to the development of BIM models. In addition, the main strengths of the Spanish High-speed model and its influence will be highlighted so that this model has been exported to other countries where relevant Highspeed projects are being developed today.

2. State of the art

2.1 Spanish High-speed network

The first High-speed line appears in Spain in 1992 to connect Madrid and Sevilla. This line was designed with ballasted track for a maximum speed of 300 km/h and also allowed the connection between Ciudad Real and Madrid, as shown by Gutierrez Puebla (2004). This line generated a significant increase in the mobility between the cities of Madrid and Ciudad Real, which come from 310,161 travelers in 1990 to 740,972 in 2000, having reduced travel time from 160 minutes to 50, as describes Ureña et al. (2005).

The Spanish High-speed model has been designed for the most part for a design speed of 350 km/h, however, currently the operating speed is limited to 300 km/h by the signaling system implemented. The network now has a total length of 2,938 km of High-speed lines built, and has a length of 904 km of tracks under construction and a length of 1,061 km of tracks in the planning or design phase, according to UIC (2017).

2.2 Technological evolution

During the construction of these 2,938 km, Spain experienced a great technological revolution regarding the design works for the High-speed network. Burdea Grigore and Coiffet (1994) showed the main advantages of the application of design software for the development of the project drawings, setting the bases of what was the computer graphic design. During this period, which began in the late 1980's, a complete migration from the traditional design model to virtual systems of representation was performed, increasing precision and efficiency in the project development.

Then, Anumba and Evbuomwan (1997) showed the beginnings of the development of collaborative models of work in the field of construction, with Internet as the main source of communication. In this way, work models and new management systems, as described by Boddy and Macbeth (2000), began to be implemented during this stage, in which it was not necessary for all the technical team of specialists to be in the same location. In the second place, these new collaborative models changed the communication channels that existed with the client, in this case the administration, turned it into an agent that could influence and verify the development of the different stages of the project being an active part in every moment during the design phase.

This stage will continue to evolve up to the present day, with the implementation of the latest collaborative work systems that in turn include a complete integration of design information into a virtual model, better known as BIM, acronyms of Building Information Modeling. Suermann (2009) shows the main advantages of the implementation of BIM in construction, highlighting the impact it will have on the projects that will be developed in the future. Subsequently, authors such as Chen and Luo (2014) or Matthews et al. (2015) show the advantages of applying these working procedures as tools for quality management. Finally, Cao et al. (2017) shows the implementation of these systems in China and the main influence they have got on the construction sector.

2.3 Design evolution

However, during this evolution period, not only the technical tools and work processes have been modified, but also the design concept itself has been modified to adapt to the modern quality standards that have the safety and the sustainability as two of its fundamental pillars.

The new approach to take into account the complete life cycle has been analyzed in detail by authors such as Hokstad et al. (1998) or Zoeteman and Esveld (1999). In addition, the administration has also been modernized following the appearance of the European Standard EN-50126, with its respective transpositions to the Spanish legislation through regulation 402/2013 and its amendment with Implementing Regulation (EU) 2015/1136, in order to ensure that a risk analysis based on the methodology included in the RAMS analysis is taken into account in the development of the projects, with the aim of guaranteeing lines with high levels of reliability, availability, maintainability and safety. This new design philosophy seeks to avoid the traditional model in which the most important was the correct definition of the product, to enter into a more global approach in which the complete life cycle of the infrastructure is analyzed.

Regarding the analysis of infrastructure sustainability, García Álvarez (2007) showed how some of the main High-speed lines in Spain generates a CO2 emission per traveler much smaller than the other modes of transport, including conventional rail, in the realization of those same journeys. In fact, he sets an example for the Madrid - Barcelona line with a CO2 emission per traveler which is a 20% of the CO2 emission that would be generated if the journey was made by plane. With this aim, a lot of innovative studies were carried out by developing new methodologies and models for energy footprint estimation, like the research provided by Chester et al. (2010).

3. Experimental analysis

3.1 Historical growth of the network

As shown below, Figure 1 describes the evolution of the Spanish High-speed network including the latest projects that are currently under construction, but are estimated to be completed before 2022, according to UIC (2017).

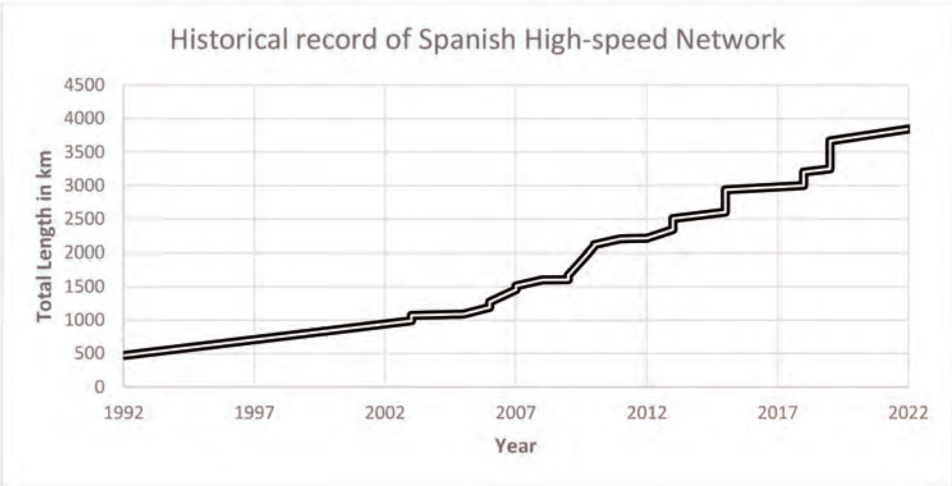

Figure 1. Total length of the Spanish High-speed network

As can be seen, the evolution of the Spanish High-speed rail network has experienced an linear growth since 2002, with an estimated growth between 2012 and 2022 of 1636 km, compared to the 1735 km already built between 2002 and 2012 and the 471 km built before 2002. This growth has been due to Europe's efforts to invest in the railways as a priority means to increase the connectivity of member states, especially the most peripheral, as is the case in Spain.

This strong investment derived from the political and social effort has progressed hand-inhand with the strong evolution experienced by the construction companies and especially by the consulting firms of design, which have improved the development and quality of its products to be able to face the technological challenge of developing the Spanish High-speed network, as shown above in the previous section.

3.2 Technological challenges of the Spanish engineering consultant

Some of these technological challenges have been due to the abrupt relief that exists throughout the Spanish geography and which, has forced, among other aspects, the construction of embankments with a height of more than 10 m. As shown by Melys (2006), this fact has generated that the solution of rail superstructure used in the network is that of ballasted track, since the slab track requires post-constructive settlements, that in countries like Japan or Germany, are limited around 30 mm, which forces, according to Esveld (2001), generally, to the construction of embankments that do not exceed 10 m in height. For this reason, the use of the slab track has been reduced only to specific cases, such as tunnels with a length of more than 1500 m, since their implantation in other sections would require a significant reduction of the height of the longitudinal profile of the infrastructure, generating a significant increase in the length of tunnels to be built throughout the High-speed network, with its consequent cost increase.

This hard relief has turned Spanish consultants into great specialists in the design of singular structures of great technical difficulty due to the number and length of tunnels and viaducts that have been necessary to be able to overcome the multitude of geographical features that exist in the environment of the Spanish High-speed network.

A clear example of this fact would be the project of the line Madrid - Galicia in its section between Lalín and Santiago. This project consisted of the development of 47 km of High-speed line for a design speed of 350 km/h, including the design of 15 viaducts and 18 tunnels, with an accumulative length of 9.74 km and 13.25 km respectively, representing a 49 % of the total length. Among the viaducts, it is worth to highlight the Viaduct over the Saramo River with 1,484 m in length and the Viaduct of O Eixo with 1,224 m in length, as shown in Figure 2.

Figure 2. O Eixo Viaduct in the High-speed line Madrid – Galicia

This technical excellence has been reflected later in other projects with unique structures such as the one developed in the High-speed line between Madrid, Extremadura and the Portuguese border, in the section between Alcántara and Garrovillas, where it was developed the design project of the Viaduct of Almonte to cross over the river Almonte in the vicinity of the Alcántara nature reserve. Figure 3 shows this viaduct, which constituted a world record of bridge arch typology, with a total length of 996 m, with the central arch having a span of 384 m.

Figure 3. Almonte Viaduct in the High-speed line Madrid – Extremadura – Portuguese Border.

(photo property of UTE AVE Alcántara-Garrovillas)

The stresses experienced by a High-speed bridge are much greater than those of a bridge of any other type due to the greater dynamic effects, the horizontal braking efforts, the effects of fatigue, etc.; On the other hand, there are strict additional functional considerations regarding deflections and accelerations, maximum length of expansion joints limited by technological reasons, etc. These considerations were included in the complete structural analysis of the viaduct, taking into account the viability of the construction, the integration in the reservoir environment, the correct structural response to the effects generated by the wind and, in conclusion, all the needed considerations to create a structurally efficient solution with simple and economical maintenance.

Regarding to signaling, it is necessary to emphasize that at present, in the Spanish railway network there are more than 1,800 kilometers that have installed the ERTMS system, of which almost 1,000 correspond with ERTMS level 2, which presents Spain as the country with greater implementation of this system, mainly associated with High-speed lines.

One of the main objectives of setting up a common European signaling system was to ensure technical interoperability and it is precisely this point which, with a great effort on the part of the suppliers and Adif, has been developed and validated in the Spanish High-speed network, guaranteeing high levels of punctuality and reliability, in all lines.

In order to guarantee interoperability not only with level 1 but also with level 2 of ERTMS, Spanish engineers are working, jointly, to achieve a correct communication between RBCs (Radio Block Center), which until now has been a great difficulty to achieve that interoperability in certain lines. Indeed, it is a proven fact, such as the work carried out in the Lleida-Barcelona section.

Also, the Albacete-Alicante High-speed line with 165 km long double track, operates exclusively with the last generation of ERTMS level 2 for the different types of trains operating in this line, also highlighting that it was possible to be implemented and put into service within a period of only 18 months.

3.3 Export of Spanish High-speed Model

In parallel to the achievement of these engineering milestones, there has been an export process in which Consulting companies have made important developments abroad thanks to this deep experience reached in the country of origin. These achievements include the example of the High-speed line Madrid - Lisbon, in which the Portuguese Administration planned an operation with mixed traffic, joining the High-speed traffic with the freight traffic.

This condition had a great importance during the design phase, having to develop a track with radii of curvature longer than 9000 m, or in other words, radii of curvature greater than those generally used in the Spanish lines of High-speed, with the aim of limiting the maximum cant to maintain the values of insufficiency and excess of generated cant, thus guaranteeing the possible coexistence between both traffics. In the phase of optimization of the alternatives of alignment, the most powerful tools that existed at the moment were used, such as Quantum software, which used genetic algorithms to obtain the three most favorable design alternatives for study in the preliminary design phase, along with the Environmental Impact Assessment.

On the other hand, it is also necessary to emphasize the design work provided for the development of the Polish High-speed network, in which more than 450 km of High-speed line were developed to connect the cities of Warsaw, Lodz, Poznan and Wroclaw, with a maximum design speed of 360 km/h. With respect to this project, it is important to highlight the work of revising the Spanish design standards to adapt them to the maximum speed of 360 km/h, taking into account the important design constraints derived from the low temperatures in Poland. These constraints forced to modify the existing solutions previously applied in Spain and to review, among other aspects, the design of the track bed layers, analyzing that the maximum stresses for each element were below the allowable limits and provided the necessary frost protection.

Currently, the Spanish engineering consultancy is also involved in the development of the first High-speed line in Sweden, in the East Link project, called Ostlanken in Swedish. This line has been designed to achieve operating speeds up to 320 km/h.

In addition, it should be noted that the Ostlanken project is being fully developed by implementing the BIM level 2 methodology in collaboration with Swedish designers, achieving a high degree of integration of all the technical specialties that are participating in the development of the project.

Within this international export of the Spanish Consultancy in the field of civil engineering, it is also worth mentioning the strong Spanish presence in the design of the Haramain High-speed Line in Saudi Arabia, the design of HS2 in the UK and participation in the High-speed line of California, in the United States. In this last project, the design of multicontinuous viaducts has been chosen, taking advantage of the best features of using the hyperstatic continuous viaducts, traditionally used in Spanish High-speed lines, which include the execution of a fixed point in one of the stirrups to avoid that there were important longitudinal stresses in the piles, what allows them to be slender, and secondly, also allows the reduction of the deck thickness.

On the other hand, multicontinuous viaducts avoid the main disadvantages associated with the design of long continuous viaducts, such as the need to execute expansion joints that present great movements and that constitute weak points of the line that demand a continuous and meticulous maintenance.

4. Conclusions

Throughout this article it has been developed a historical description of the main advances that the Consultancy has experienced in the field of civil engineering, during the last 25 years, since the implementation of the High-speed line between Madrid and Seville, going from the implementation of computer science to the introduction of modern working models such as the BIM methodology or the implementation of advanced calculation tools, such as those that incorporate the use of genetic algorithms to find the best solutions for the rail alignment.

These advances have been motivated by the important constraints existing in the Spanish territory, which have forced the consultant to achieve high levels of technical excellence, positioning Spanish engineering as a leader in the field of High-speed lines design, in the international scene.

This position has been evident with the development of international projects of great relevance that have been described throughout the previous points, highlighting in each of them the main improvements or advances provided by Spanish engineering.

Finally, the important work carried out in Spain regarding to the signaling systems has been mentioned, thus concluding the description of the main strengths that has been consolidated by Spanish engineering during the process of continuous evolution experienced in the last 25 years.

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Customer personalisation and service efficiency: the pillars of the new Renfe business policy

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Abstract

Financially-wise, high-speed transportation has been currently consolidated as the most profitable of all the services which integrate the railway sector at a global level, specially in Spain where this type of service is experiencing relevant growth in accordance with the infrastructure investments that have taken place in the last decade. Back in 2011, Renfe's high-speed commercial services (flagship company of the Spanish railway sector) transported little over twenty million passengers; nowadays -barely seven years later- that number surpasses the thirty-five million mark.

In order to consolidate our actual position in the passenger transport market and as regards the imminent liberalization of this sector at an European level, Renfe has decided to direct its different commercial strategies to its clients and their necessities, making the passengers the focus of its business vision and the essential reference framework for all the activity areas of the company, developing its trade policy from a service segmentation strategy towards the customization and using new technologies and the profound knowledge of the client CRM provides as tools.

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The deregulation of the railway industry on a continental scale, the regionalisation processes at a national level affecting the competitive framework and services funding, and the opening of the international passenger transport are some of the main challenges that the railway companies are set to face in the upcoming future.

In the context of a very near scenario of strong competition, added to the existing intermodal competition, Renfe has understood it should strengthen its market position and align its structure and strategy to such a complex future scenario, where it will have to abandon its position as the sole player in the passenger rail transport business and compete with other future operators.

In order to consolidate its current position in the passenger transport industry, Renfe, among many other measures, has decided to implement strategies focused towards the customers and their needs, placing the customer at the heart of the business vision and seeking the more and more necessary “Customer personalisation”, and as the essential reference framework in every business area of the company. Thus, for example, Renfe has strongly encouraged innovation and interaction with customers, leveraging all the potential offered by new technologies at the service of business and smart CRM management, improving the communication in different channels, such as the website, messaging, email or mobile phones for the purpose of creating a permanent real-time relationship with the customer. Always connected.

Beginning with simplifying the barriers in the purchase process to the extent possible, making the process to get a train ticket easier and more convenient and aiming towards a zero use of paper.

With the aforesaid objective of putting the customer at the heart of the business and placing Renfe at the forefront of progress in order to compete in a deregulated market, the company developed an ambitious Business Plan with the purpose of fostering high-speed rail versus air transport and consolidating its overriding position upon the arrival of future competitors for domestic traffic in mainland Spain, as other bigger, more profitable and more efficient European groups.

Before launching this Business Plan, a large study had of course been carried out in order to identify which were our weaknesses and which commercial aspects of our services and products could be improved.

The study found out that:

- AVE offered high prices and rather inflexible fares. Customer perception.
- The occupation level was not enough, it was low, subject to seasonal fluctuations, and there was a low investment optimization.
- Little attraction of new clients, especially among the youngest population.
- Medium- and long term impact of collaborative commerce on transport.
- Based on this analysis, we fixed the following objectives:
- Establishing more affordable rates for everyone; prices for all segments of society.
- Increasing the occupation level of the trains.
- Modernising and adapting the supply to demand.
- Attracting more passengers and boosting a great loyalty programme.
- Becoming more efficient in customer management.
- Creating a portfolio with services complementary to railway (cars, hotels, etc.)
- Creating a great intermodality model with other forms of transports with AVE as the central axis.

Thus, with these findings in mind, from the 8th of February 2013, Renfe started to implement a new strategy based on actions aimed at increasing the flexibility of the offer by introducing a dynamic price system, so that the nature of the ticket price would become mobile. This, by the way, was a widespread form of work in other modes, but it had never been implemented in Spanish railway.

The most relevant measures regarding prices adopted at that time were:

⁂ AVE	General Rate	-11%
⁂ AVE/LD	Return Ticket	-20%
⁂ AVE	AVE Pass	-35%
⁂ AVE/LD	Promo Rate	up to -70%
⁂ AVE/LD	Youth Card	-30%
⁂ AVE/LD	More frequency and new routes	

And from the date of implementation of this new business policy including, as it can be seen, great discounts on the most common rates, the railway use started to increase. This increase led rail transport to outperform air transport in 2014 for the first time ever, becoming, according to INE (Spanish National Institute of Statistics), Spaniards favourite means of transport and reaching 50,000 more passengers than airplane for trips within Spain.

Beyond this, today, 4 years after the beginning of this groundbreaking business policy, Renfe can boast it has attracted 9 million new customers, which means a 40% boost in the number of passengers and a 10% occupation increase.

A significant detail is the fact that the occupation increases achieved over these years have taken place in every AVE corridor. This means that the beneficial effects of this new business policy have reached all the lines and not only the most used ones (such as Madrid - Barcelona or Madrid - Seville), as it might have been expected.

These excellent results have taken Renfe to deepen into this line of work and extend and expand this business strategy, delving deeper into the customer loyalty concept too.

Major business milestones:

- 1993.- Quality commitments with the Customer
- 1994.- Punctuality commitment: “5 minutes late”
- 1999.- Outsourcing to the private sector of a 50% of train maintenance
- 2005.- Complete independence of Railway Infrastructure Administration (“Adif”)
- 2006.- Prices with less and less intervention

- 2007.- Prices discriminated by product
- 2007.- Web and Star rates introduction
- 2008.- New Rate Policy
- 2010.- “Revenue Management” Dynamic Rates
- 2012/3.-New Business Policy
- 2014.- New Company “Renfe Viajeros, S.A.” *The company’s corporate purpose is the provision of traveller transport services by train, both national and internationally, the mediation in the provision of any tourist service, the organisation, offer and/or selling of combined journeys or tourist products, as well as the provision of other services or complementary activities linked to train transport.*

Within the framework of the new Renfe business strategy complying with the planned targets, an innovative Marketing Plan was launched following steps:

- Segmentation and characterisation of the CRM market
- Product portfolio review and new commercial offer design
- Promotion of value-added products (Train +)
- Access to new sales and marketing channels
- Designing and developing a new commercial communication line
- Introducing connectivity on board and a new entertainment platform
- New customer policy for Renfe Empresas (1,500 associated companies)

All these actions had an essential objective for the company: increasing the number of loyal customers. All of this aiming at having not only more committed passengers, but also more satisfied travellers.

Thus, after a boost of 45% in the number of passengers in just 3 years thanks to the low-price policy and more services, the company took up a new challenge: getting to know better the customer to keep growing and be profitable. To this effect, Renfe relaunched its loyalty programme, opening it to all distances (commuter rail and medium distance) and introducing a series of further benefits for train users in order to avoid customer churn in favour of other modes.

Boosted in June 2015 with the launch of +Renfe, the loyalty programme has grown almost 78% from that moment up to the current 1.2 million members, generating customer knowledge, which helps to understand consumer habits and preferences.

The +Renfe programme seeks to obtain more customer knowledge, revert the benefit of the programme in the very business model, create induced demand through point exchange, reduce customer churn and create a new Relational Model with the customer.

Renfe has understood that getting to know the customers is essential in order to understand their consumer habits and preferences. The goal being pursued is adapting the company service to the customer demands, having a more personal relationship with the customer and launching segmented and exclusive offers in order to make them travel more repeatedly.

Renfe has also renewed its website (www.renfe.com) in recent years as part of its strategy to boost online ticket sale. At present (July 2017), online sales meant 46.14% of the total sales, that is to say, only through the internet channel, Renfe has sold 14,026,881 tickets between January and July.

In recent years, the tickets purchased through www.renfe.com have risen from 26,040 in 2000, when the channel was implemented, to almost 54 millions at year-end 2016, with a 47.40% share.

Renfe website, one of the most visited in the transport industry, reached more than 136 million visits in 2016; 56% of them came from mobile devices. In order to make online browsing easier, more user-friendly and accessible, Renfe is constantly upgrading its website.

Renfe has also developed a new portal (www.renfeviajes.com), which offers a number of products related to travel. Besides checking train schedules or buying tickets, the website allows purchasing other products linked to the trip, as hotels, rental cars, theme park tickets or a complete holiday package. All of this at a guaranteed minimum price and with every guarantee offered by Renfe and its partners in this project. This online channel is available on the usual Renfe web address, www.renfe.com, or on the portal www.renfeviajes.com.

To launch this website, Renfe has relied on leading companies of the industry, which sell their products through the brand www.renfeviajes.com. The three companies working with Renfe on this project are: Orizonia, the first issuing travel group focused on holiday products; Muchoviaje, a company marketing hotel services around the world which leads online sales in the leisure sector; and AutoEurope, vehicle rental consolidator. The incorporation of the travel portal into the company website is a part of Renfe's strategy to promote online sales.

At the same time, Renfe has also fostered in recent years a series of commercial measures aimed at making sales easier in through all channels: reducing to 0% the processing fee for the online ticket purchase, enabling auto-checking machines for ticket sales in most stations and expanding the sale period to 120 days. The minimum time required for online ticket purchase has also been reduced up to 15 minutes before the time scheduled for the train departure.

Beyond this and as a part of this commitment with our clients, last November Renfe introduced its WiFi platform PlayRenfe, unique in the world, in AVE trains.

PlayRenfe is more than a simple WiFi signal distribution service. It responds to the digital transformation and innovation strategy that Renfe is offering the customers of its AVE services. This platform is a new WiFi connectivity window, which also includes exclusive contents for every type of traveller and new services.

The actual project has a remarkable technical complexity and sets a new milestone in the history of high speed in Spain, becoming a reference in the railway industry worldwide, as it pioneers both connectivity during the trip and a content and service platform including live TV broadcast, something unique in the world.

PlayRenfe includes, on the one hand, the supply, installation and maintenance of an comprehensive WiFi system on board the whole AVE train fleet; and on the other hand, the deployment of a network to cover over 1,600 km of high-speed tracks, including 75 tunnels and 540 LTE coverage locations on a combined and specific 800 and 1800 MHz network, combined with a satellite solution.

The aim of the new PlayRenfe service window is to offer added value to the on-board WiFi connection, long demanded by passengers, with a full offering of contents included by Telefonica: latest film releases, TV shows, music, books and it even includes the possibility, for the first time ever, to stream live contents while travelling at 300km per hour. It is a customised on-demand service designed for every type of customer (family, leisure, business, etc.).

Renfe also features access to all its digital services, such as checking schedules and tickets, Renfe Viajes (the new range of tourist services linked to railway), the loyalty programme +Renfe or useful information on any aspect of the trip. Renfe offers this platform as well as a new Marketplace for the relationship with its customers.

The +Renfe programme customers and those who wish to join it free of charge, as well as those who travel First Class, will have direct free access to the connection and the contents. By doing so, Renfe aims at the creation of a new traveller relationship model, with priority given to those subscribed to its loyalty programme.

But it does not end here. Our engagement with customer satisfaction goes even further. For this reason, Renfe introduced some months ago a new after-sales commitment for the clients of its commercial services (AVE, Alvia, Euromed, etc.) simplifying the reference times for its punctuality commitments and adding new bonus options in the event of a delay. Thus, in addition to the usual cash refund of the amount of the relevant ticket, Renfe introduced the option of receiving such relevant amount plus a further 20% as a discount on the purchase of the next ticket, or its accumulation with an extra 30% for the customers subscribed to +Renfe loyalty programme opting for the refund in Renfe points (redeemable for tickets or other tourist services from the partners engaged in the programme).

The new Renfe after-sales commitment relating to its commercial sales expanded the voluntary punctuality commitment to any circumstances that might delay a train arrival, including also those circumstances due to force majeure (adverse weather, fire, service disruption by a court, government or police order, limitations stated by the railway infrastructure manager, etc.).

Thanks to this measure, Renfe expects to keep a leading position regarding the level of commitment towards its clients and improve one of the most advanced after-sales models among European transport companies.

Spain wants to travel by train

Between May 2016 and April 2017, 11 Renfe lines reached an all-time high in terms of travellers. The lines are those connecting Madrid with Barcelona, Asturias, Valencia, Cádiz, Málaga, Alicante, Pamplona, León and Cantabria, and the lines Barcelona-Valencia and Barcelona-Zaragoza.

All these lines reached historic levels until the end of April, positioning railway as the most used collective transport in Spain, well over airplane and bus for the routes around mainland Spain, where all three modes can compete.

Furthermore, Renfe reaches a high for its AVE and Long Distance trains during July and August, when 5.8 million travellers used the company, AVE and Long Distance commercial services. This data means an all-time high representing the biggest passenger volume of the company for the two months of highest demand in summer, as this result shows a 2.1% improvement, 122,000 more travellers, compared to the same period in 2016.

While high-speed commercial services (AVE, Alvia...) were chosen by more than 3.5 million travellers (+2.3%, 77,000 more travellers than in 2016), Long Distance services were the choice of 2.3 million clients (+2.1%, 47,000 more travellers).

These data are complemented with public service trains, Medium Distance and Commuter, used by more than 64.5 million travellers during July and August, a 3.2% increase compared to 2016. This means that, altogether, the trains operated by Renfe have served 70.4 million travellers.

Conclusion and next steps

In financial terms, high speed is the most profitable current railway service. Furthermore, Spain is experiencing a significant growth in line with the great infrastructure investments carried out over the last decade. Thus, high speed commercial services meant little more than 20 million travellers in 2011; today, this service involves more than 35 million travellers. And as AVE network is further completed, we are confident that railway will continue to attract many more users, thereby increasing its profitability.

In order to adapt to the open and deregulated future scenario, one of the pillars of the business policy is the evolution from a service segmentation strategy towards personalisation, using new technologies and CRM customer knowledge as tools to achieve it.

The next steps must be targeted to constantly improve customer information regarding both the service and the commercial offering. New technologies allow real-time connection, which will enable the company to develop a personal relationship with every customer to continuously adapt the offer to his/her needs.

This effort will be soon translated into a space we call “Dedicated Customer Portal”, which will be introduced before the end of the year. At the moment, almost 50% of the company sales are made through the online channel. With the Dedicated Portal, we seek to strengthen this channel through process customisation and simplification.

There is also a project to implement ChatBots to improve communication procedures with the client.

In conclusion, deregulation forces us to be more flexible. To know what our customers need at any time and offer efficient real-time solutions responding to this requirement. Today, Renfe is taking firm steps to improve its relationship with travellers. New technologies must help us delve into it in order to achieve an even more satisfying and complete relationship, making train the preferred transport mode for all citizen groups, both national and foreign, for their travels around mainland Spain network.

This effort is not and will not only be addressed to current users of train services; we also seek to maintain a direct relationship with any potential customer of other modes whom we can offer the possibility of accessing a service like ours, in which we believe he/she can be interested. There are now many potential customers who, for whatever reasons, are not interested in railway. We want to know what we have to do to change their minds. And we will strive for it.

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Atlas-rail: geo-referenced database on high-speed

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Abstract

The whole Atlas-Rail project has a very strong visual impact. On a methodological level, this feature can be noted, through the codification of available rail data in spreadsheet tables and after processing them for graphic outputs. Furthermore, it can be depicted in different format general information of the railway and technical characteristics of the rolling stock.

Keywords: Database, GIS, georeferencing, cartography, high-speed rail.

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1. Introduction

Atlas-Rail project is made up of a geographic database composed of information related to lines, sections and railway stations, of both European and Spanish high-speed railway services. All this information has positioning values, in other words, they are geographically located in the space.

Profits and appliances of Atlas-Rail project are multiple. The first one has mainly a visual component, and it refers to present geographic database elements in satellite platforms, for example Google Earth.

The variety of data depends on their accessibility and if they can be compared with the same data of other spatial units or not.

In particular, it has been possible to obtain and depict technical information related to track geometry and lines, sections and high-speed rail stations data, taking into account that this information can be updated according to the activities or actions undertaken.

Cartography is another appliance to be highlighted. If the variety of data increases, the possibilities to present information in a map also increase. For instance, it can be elaborated cartography both topological and choropleth map type, in different formats (raster and vector) and in different geographical base map (physical and political units).

To complement this, Atlas-Rail project can be considered a very interesting tool as a basis for future research in the area of high-speed railways.

2. Atlas-rail project elements

Atlas-Rail Project has two different types of elements, depending on the nature of the content offered. On the one hand, there are the database components. On the other hand, the elements which make up the GIS or Geographic Information System.

2.1 Database components

Regarding database components, there are line-type elements and point-type elements, but both of them are including inside feature-type or vector-type elements.

In the first case, it refers mostly to high-speed railway lines or, falling this, sections which have a certain length that, due to their technical characteristics, are capable of hosting high-speed traffic. Furthermore, it refers to sections that differ from adjacent lines in, at least, one of its characteristics.

As to point-type elements, they are identified with stations that currently offer high-speed railway services or cities that will be part of the high-speed network in the future because there is a high-speed line under construction near or across it.

In the case of lines or sections, each reference point has two coordinate values X and Y. It would be useful to have a Z value too, but if it is not possible, the height above ground level value is taken.

The reference points whose X, Y and Z coordinates refer to high-speed railway sections are located on the track axis. In particular, in the case of being a single track, it is placed among both lanes. If it is a double-track, the reference point will be marked among both tracks. If the value exceeds the double-track or junctions, high-speed lines are digitized according to highspeed rails traffic system. Every reference points are geo-referenced.

The lengthwise separation between two consecutive reference points depends on the scale values used. A larger scale is recommended to digitize sections with small-radius curves, in order to improve the accuracy about the real track. As a general idea, interval between consecutive points from 50 to 200 meters will be considered.

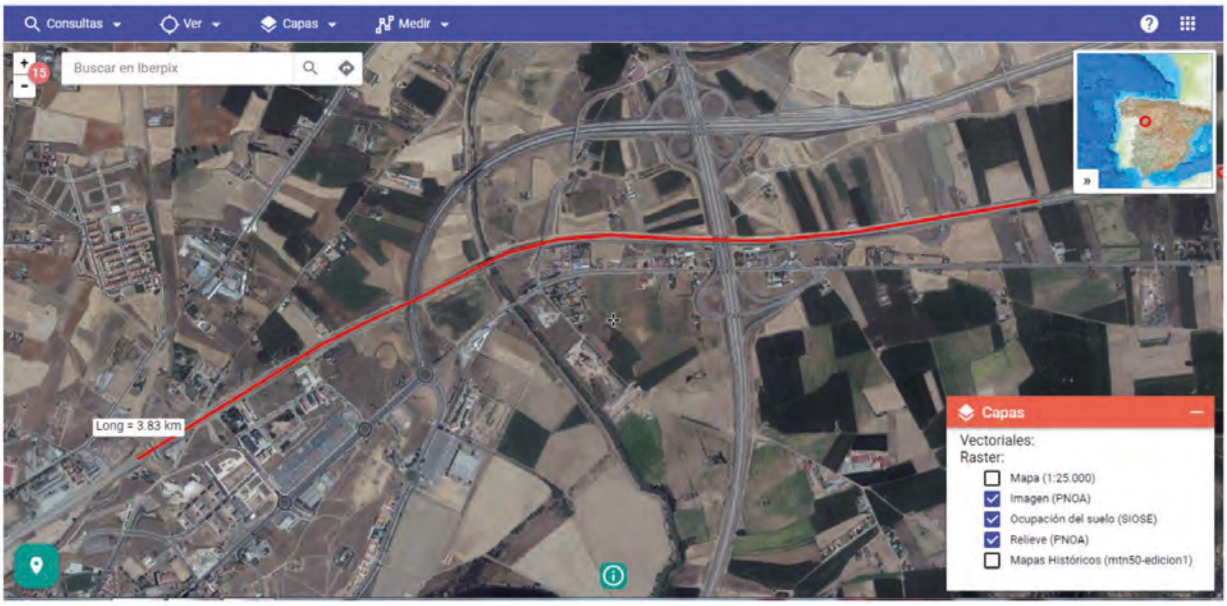
Sections are line segments of variable length with homogeneous technical and service characteristics, and they can have intermediate nodes. Both lines/sections in service and under construction are included in Atlas-Rail project.

The characteristics of the sections are called attributes, and they are shown in tables or databases through fields (columns). Each field has a number of specific characteristics, relating to accepted data format, interval of values, limited digits or text characters, and so on.

Each line or section is identified with a single code. This code must have unless one digit and it can be used to join or relate several tables or databases. This issue will be explained in detail in the following section.

In the case of nodes, the station reference point is always fixed with X, Y and Z coordinate values, and it is placed in the location of the passengers building. If no passengers building is found, reference point must be fixed close to the high-speed station.

Figure 1: Example of high-speed line scanning. Olmedo-Zamora HSR (Spain)



Source: Independently produced. Satellite image provided by IBERPIX (http://www.ign.es/iberpix2/visor/)

2.2 GIS components

GIS can be defined as software with specific capabilities, which are summarized in the following functions:

In first place, the functions for inputting data. These are the procedures that allow the conversion of geographic information from analogical (the traditional format in Geography, especially paper maps) to digital format. This conversion has to keep the baseline features of the spatial data through data entry procedures (digitizing or similars).

These functions also have to consider procedures to remove mistakes and bugs in the information to be included in the GIS. Previously, information has to be compiled and prepared, in order to be edited and converted into digital format.

In second place, functions for graphic and cartographic output of information. In particular, it refers to the activities that show the user the own data included in GIS database, and the results of the analytical operations performed on them. These functions make it possible to obtain maps, graphics, tables and other sort of results in different mediums: paper, digital images, data files, and so on.

In third place, spatial information management functions. Data required are selected from database, and these functions facilitate to reorganize all information and integrate it into the database in several different ways. GIS softwares are able to launch searches by spatial or geographic criterias. For instance: Which lines are in construction in this year? What countries have in a given year with unless one high-speed line? What are the stations through which the “x” line runs?

In fourth place, there are analytical functions. They make easier the processing of the data included in the GIS, so that it is possible to hold more information and to improve knowledges with respect to initial situation. In addition, these functions make GIS a simulator of territorial reality. This way, it is possible to build “cartographic models” and to solve a large number of issues in the spatial scope of application. In this case, regional planners and the rest of agents involved can observe which could be the result of a specific action in the territory and it can influence in the decision making process.

2.2.1 Obtaining the geographic data

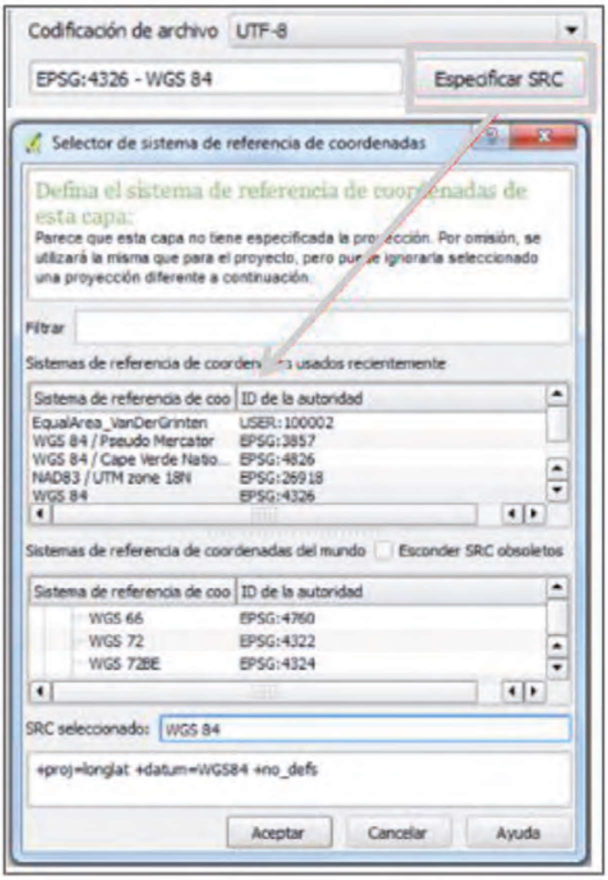
Digital information can be collected through data layers (vector and raster). Raster files represent the territory in the form of pixels or cells, which can have a very varied resolution. Depending on this number of cells, quality and level of detail of the display also varies. An example of a raster layer is a satellite image.

On the other hand, vector files represent the territory through three spatial element types: points, lines and polygons. For instance, a road layer. In this second case, there are different procedures to gather information: observation of reality, indirect sources (analogue maps, which can be digitized and converted into digital format) and geo-referenced vector layers. In particular for Atlas-Rail project, this would mean railway line layers, train station layers, tunnels, and so on.

Georeferencing is the procedure by which the location of a spatial object in a given coordinate system and datum is defined. In order to standardise information, the ETRS89 (European Terrestrial Reference System 1989) is taken as the official reference system, replacing the ED50 (European Datum 1950).

The coordinate system used to develop Atlas-Rail project is the WGS (World Geodetic System), specifically WGS84. This is also suitable for systems that do not use gravity to locate the position, such as GPS (Global Positioning System).

Figure 2. Coordinate System selection in QGIS



Source: Independently produced

Therefore, both the railroad tracks of the Atlas-Rail Project and the high-speed stations will be referenced in these systems.

2.2.2 GIS geo-referenced layers

In Atlas-Rail project, information is organized in two layers (lines/sections and stations), independent of each other. This implies that a train station can act as a start or end of a highspeed line and start of another or be placed in a intermediate position within a line. Thus, to change a section or line, it is necessary, at least, one change in the value of one of the attributes of the line layer.

Regarding attributes, different fields have been included in line layer: an unique identification code, name of the line or section, state of implementation (in operation or under construction), year of opening, the country it belongs to, distance in kilometres and maximum speed.

For the latter attribute, kilometres per hour are used as a unit. Reference is made to the maximum commercial speed at which the fastest train traveling on that line or section can travel.

According to data available or accessible, more attributes can be added to the table, for example: gauge, electrification system, signalling, traffic type (passengers or mixed), maximum gradient…

Stations layer consists of an unique identification code, name and the country they belong to.

To process the geographic information, it has been used software ArcGis (10.3 version) and QuantumGIS (2.12. version). These Geographic Information Systems include spatial analysis tools, advanced processing of data and they allow performing complex digital mapping.

3. Methodology

The methodological process consists of several phases. The first step is to get information on the current situation of high-speed railway lines and sections worldwide. These data have been obtained through the “High-speed Lines in the World. Statistical Yearbook”, published annually by the International Union of Railways (UIC). It is an “open access” report in MS Excel format that can be downloaded from its website www.uic.org.

This Excel database has been modified and edited so that it can be compatible with a Geographic Information System (GIS).

Afterwards, a geo-referenced database is established in a GIS, defining the same projection and coordinate system for all the information layers to be added so that they can be overlapped, edited and compared.

Once the layer is established, it is necessary to start the digitization of the high-speed lines in service and, as much as possible, under construction, with the support of satellite image display platforms (Google Satellite or comparables), trying to draw as closely as possible the railway lines. This platform operates as just another layer, and can be downloaded in the GIS itself. This layer will be the unique raster layer in the project.

Likewise, the location of the high-speed stations is referred by point layers, taking as reference the passenger building or, failing this, a nearby building, as mentioned above.

To complement the geographic information, other layers considered of interest are aggregated. For instance: administrative boundaries, country poligons, large bodies of water, and so on.

The result will be the creation of .shp type files, in vector format, that makes it possible to be exported to other types of format and to other softwares.

Once the digitization is carried out the next step is the aggregation of data to these geometries to enrich the geographic database and facilitate its subsequent cartography treatment. This aggregation can be done through contributions from the UIC Statistical Yearbook and/or other sources. This information can refer to multiple fields: state of implementation, total railway length, maximum speed, among others.

This data will be the attributes of lines/sections and train station layers. On the figures below we can see the structure of the tables.

Figure 3. High-speed lines/sections attribute table

	Name	VEL_MAX	YEAR	DISTANCIA	ESTADO	ID
3	Madrid-Sevilla	270	1992	471	IN OPERATION	1
2	La Sagra-Toledo	250	2005	21	IN OPERATION	2
10	Madrid-Valencia / Albacete	300	2010	432	IN OPERATION	3
4	Córdoba-Antequera	300	2006	100	IN OPERATION	4
14	Antequera-Málaga	300	2007	55	IN OPERATION	5
13	Albacete-Alicante	300	2013	239	IN OPERATION	6
5	Lleida-Camp de Tarragona	300	2006	82	IN OPERATION	7
7	Figueres-French Border	300	2010	20	IN OPERATION	8
16	Barcelona-Figueres	300	2013	132	IN OPERATION	9
12	Madrid-Lleida	300	2003	519	IN OPERATION	10
1	Bypass Madrid	200	2009	5	IN OPERATION	11
8	Zaragoza-Huesca	200	2003	79	IN OPERATION	12
15	Valladolid-León	200	2015	163	IN OPERATION	13
11	Madrid-Segovia-Valladolid	300	2007	184	IN OPERATION	14
0	Ourense-Santiago	250	2011	88	IN OPERATION	15
9	Olmedo-Zamora	200	2015	99	IN OPERATION	16
6	Camp de Tarragona-Barcelona	300	2008	88	IN OPERATION	17
17	Santiago-Vigo	250	2015	94	IN OPERATION	18
18	Santiago-A Coruña	200	2011	60	IN OPERATION	19
19	Utrera-Jerez	200	2015	72	IN OPERATION	20

Source: Independently produced

Figure 4. Stations with high-speed services attribute table

	Name	ID	COUNTRY
26	Graz	1	AUSTRIA
27	Klagenfurt	2	AUSTRIA
28	Sankt-Pölten	3	AUSTRIA
29	Vienna	4	AUSTRIA
30	Antwerp	5	BELGIUM
31	Bruxelles	6	BELGIUM
32	Leuven	7	BELGIUM
33	Liège	8	BELGIUM
70	Aix-en-Provence	9	FRANCE
71	Angoulême	10	FRANCE
72	Arrás	11	FRANCE
73	Avignon	12	FRANCE
74	Belfort-Montbéliard	13	FRANCE
75	Besançon	14	FRANCE
76	Bordeaux	15	FRANCE
77	Calais	16	FRANCE
78	Champagne-Ard...	17	FRANCE
79	Dijon	19	FRANCE
80	Est	20	FRANCE
81	Gare de Lyon	21	FRANCE
82	Haute-Picardie	22	FRANCE
83	Hendaye	23	FRANCE
84	Le Creusot	24	FRANCE
85	Le Mans	25	FRANCE

Source: Independently produced

Once these steps are completed, a variety of outcomes is obtained, although it would be more accurate to call them “products”, which will be explained in the following chapter.

4. Outcomes

4.1 Presentation of the product in google earth

The first result obtained from these processes has already been mentioned: the creation of a geo-referenced database, which serves as a starting point for later products.

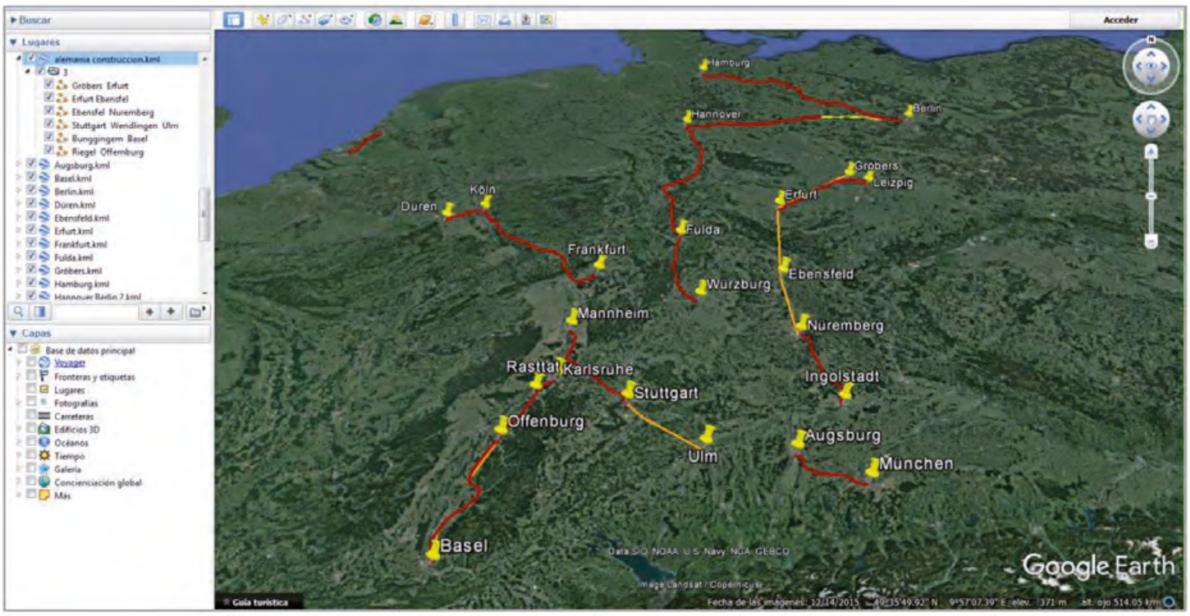
A first product developed has been the transposition of the geo-referenced database with lines and stations layers to the Google Earth platform. In other words, it means viewing the geometry of high-speed lines and their stations via satellite. So far, it has been made for European countries. In the future, it is expected that Atlas-Rail project will be implemented in countries of other continents that already have high-speed rail services.

For this, it has been necessary to transform the geospatial data, i. e. files with extension .shp created in the GIS to files type .kml (Keyhole Markup Language). In this way the identification and displaying of high-speed lines, sections, stations, connections between lines and neighbouring countries networks are possible using this online platform.

In Google Earth, users can customize the appearance of the railway lines giving different symbology depending on whether it is a line under construction or in operation, considering colour and thickness. It is also allowed editing the stations layer format, through the icon change.

Likewise, the platform enables users to select the items to display on the left side of the main screen and to obtain additional information by double-clicking in the corresponding geospatial element, either line/section or station. In the first case, clicking a high-speed line displays a table structure that looks like a GIS attribute table, offering the user the available data of that object. It is the same with stations layer.

Figure 5. Display of some high-speed lines and stations in Google Earth



Source: Own elaboration from the data provided by the Statistical Yearbook, UIC Passenger Department (2017)

In addition, it not only displays information relating to the object but also automatically approaches it until it is viewed perfectly framed on the screen on its full extent.

4.2 Atlas of high-speed rail in Spain

The second product to be highlighted is the elaboration and publication of the Atlas of Highspeed Rail in Spain, coinciding with the commemoration of the 25th anniversary of the commissioning of the Madrid-Seville high-speed line.

Atlas-Rail database and the International Ralways Union's (UIC) Statistical Yearbook have been used as well as for the rest of the products.

The Atlas of High-speed Rail in Spain is a collection of detailed maps showing the past and present development of the Spanish high-speed rail network, along with other elements of the railway system, represented in the form of graphs, tables and photographs. The purpose is to supply the user an overview of high-speed in Spain through a detailed analysis of its components.

Map 1. Spanish High-speed rail network (2017)

Source: Atlas of High-speed Rail in Spain, Spanish Railways Foundation (2017)

In particular, a two-fold objective is sought. On the one hand, show the evolution of highspeed in Spain since its inauguration and its current situation. On the other hand, assess the work carried out by the Spanish Railways Foundation through the analysis and compilation of statistical and geo-referenced information of the country's rail network.

Information is provided at different spatial and time scales. In fact, a first part with data referring to the situation of high-speed worldwide is included, comparing the key data of each rail network.

Furthermore, the Atlas contains thematic maps with the characteristics of the Spanish highspeed network: types of lines, infrastructures as well as the most valuable tunnels and viaducts.

It also includes relevant information regarding traffic density by type of service and the demand for transport, as well as, the main high-speed routes, and data related to distances and travel times between different links, the characteristics of the lines (orography of the terrain, rail facilities, profiles…)

Finally, a more technical chapter is devoted to the rolling stock that has operated in the past and which currently is used in the Spanish high-speed network.

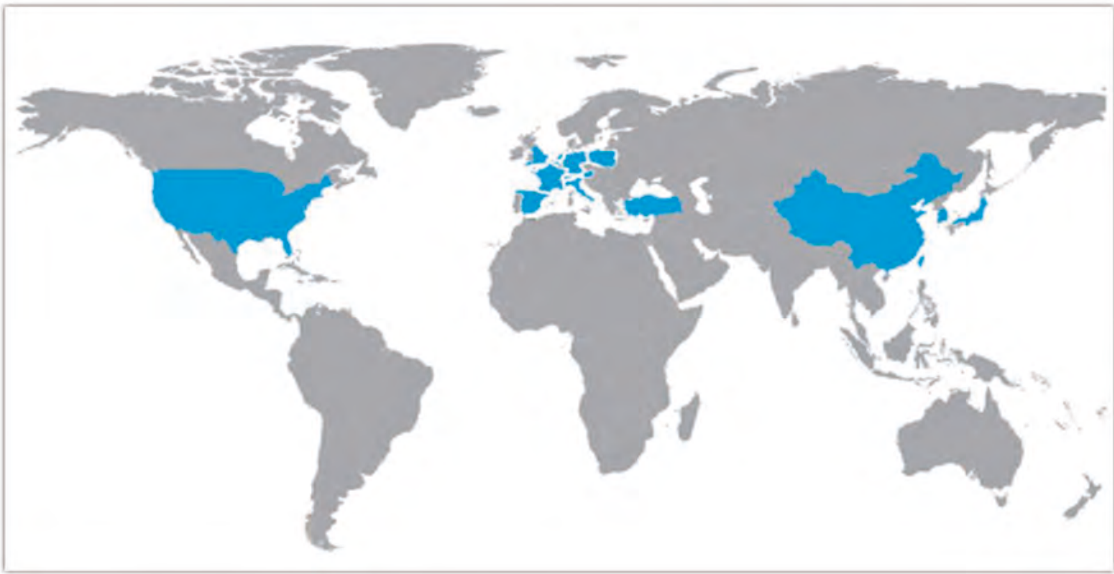
The Atlas has been published in Spanish language and has just been produced an English edition. In the Internet, the Spanish version can be downloaded by clicking on the following link: http://www.ave-altavelocidad.es/atlas.asp

A cartographic example of the aforementioned Atlas is shown in the next figure, and represents the high-speed rail tracks in Spain in 2017.

4.3 Cartographic models

Up to know, the third product has been the creation of customized cartography. The latter has already been applied partly to the second product exposed, offering a schematic representation of each of the proposed topics.

Map 2. Countries with high-speed railway services in the world (2017)



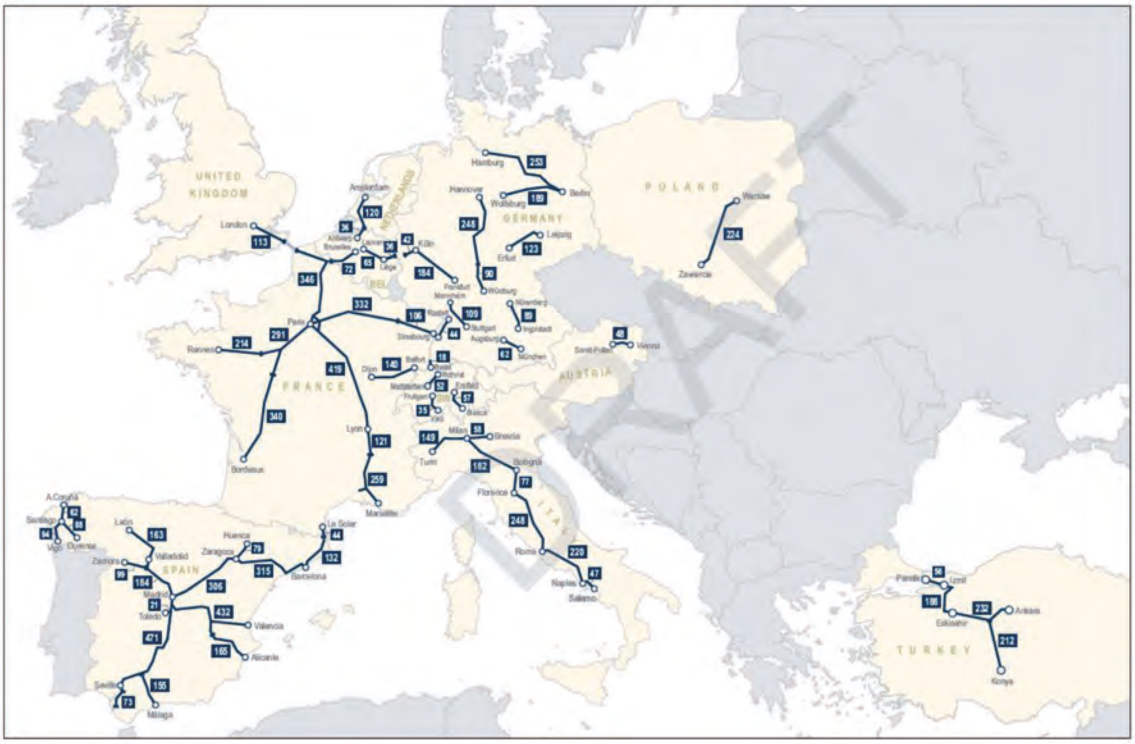
Source: Own elaboration from the data provided by the Statistical Yearbook, UIC (2017)

Atlas-Rail database, UIC Statistical Yearbook and the data that companies, operators or agencies wish to provide enable a very wide range of map contents as well as other supporting elements to illustrate the geographical reality of high-speed networks in the world, continents or even on a smaller scale.

All this depending on the data availability and the required level of detail to be depicted in the document.

The following are some examples of this cartographic tipology. They are shown from small to large scale.

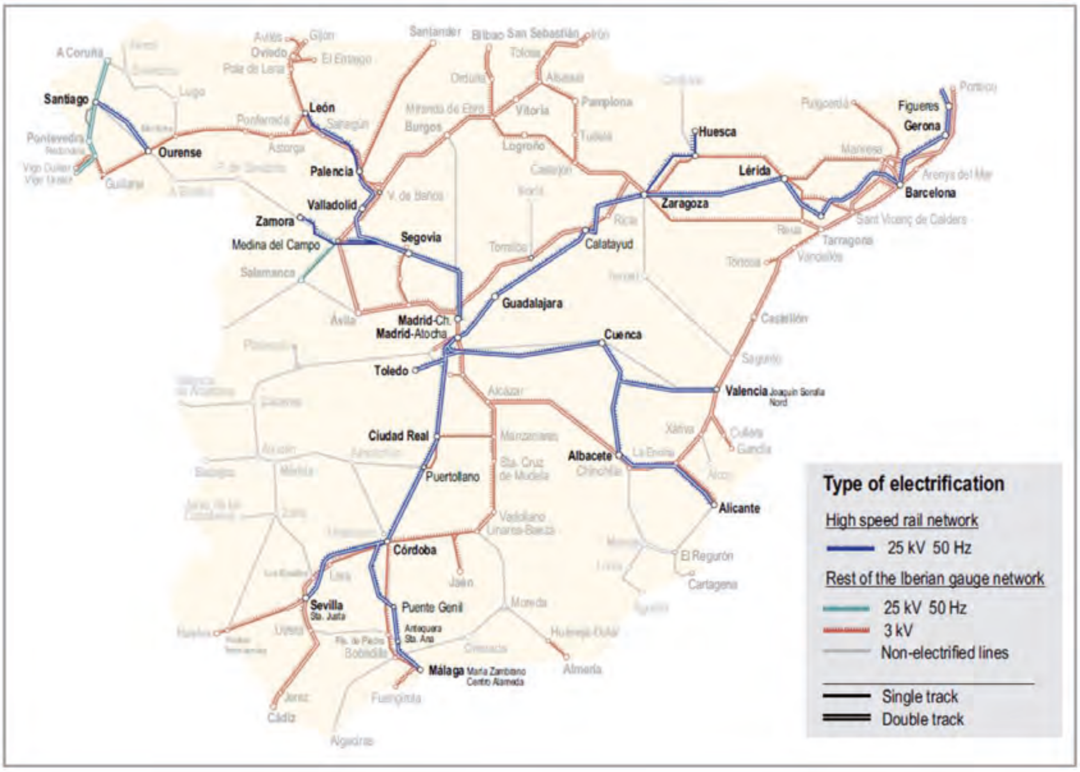
Map 3. Distances in kilometres of the European high-speed rail lines (2017)



Source: Own elaboration from the data provided by the Statistical Yearbook, UIC Passenger Department (2017)

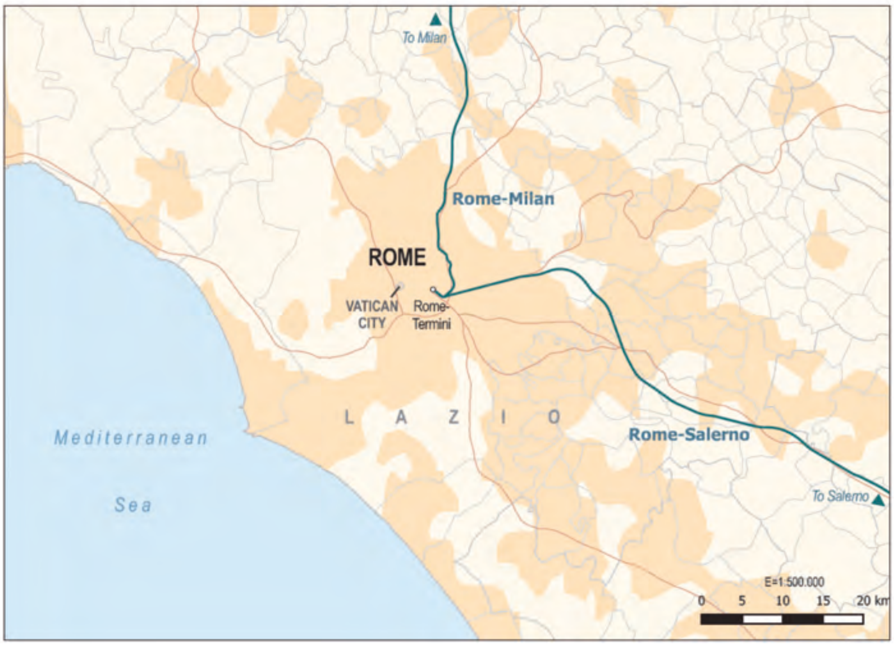
Note: Countries with at least one high-speed line are highlighted in another colour compared to those with no line

Map 4. Tipology of electrification in the Spanish railway network (2017)



Source: Own elaboration from the data provided by Atlas-Rail database and the Statistical Yearbook, UIC Passenger Department (2017)

Map 5. High-speed railway lines in the Lazio Region (Italy) (2017)



Source: Independently produced

5. Conclusions

Atlas-Rail Project consists in a database composed of geo-referenced information relating to high-speed rail.

It includes data at different scales and years, allowing comparative and evolutionary analysis between regions, countries, continents and for varied attributes.

With the support of other tools (data sources, specific software), this database makes it possible carrying out research activities of a wide variety in the railway field. As a result of this, it is the display of lines and railway stations on the Google Earth platform, the publication of an Atlas on the 25th Anniversary of Spanish high-speed, or the customized cartography production.

In short, Atlas-Rail aims to be a tool that supports the dissemination of research at rail level and also becomes a support tool that promotes the right decision-making to maintain or improve as far as possible the different rail networks.

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  http://www.sncf.com/
- DB (Deutsche Bahn):

  https://www.bahn.com/en/view/index.shtml

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High Speed Rail in Spain - a statement from a foreign expert

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Abstract

In Spain all high speed trains run over tracks in a special built high speed network. No disturbing influences have to be taken into account for daily operation process. This is a great advantage. Spain shares this advantage with the high speed rail networks in Japan, Taiwan and

China. Running trains on parallel train paths and at least from case to case in 3 minutes headway to each other is a basic condition to reach a high use to capacity. But Spain is running trains with different speeds on its high speed lines. Another condition for a high cost-benefitratio is a strict regular service with at least one service per hour. RENFE however is running the AVE trains in a rather irregular timetable. Some examples will be presented to demonstrate this fact.

The author gives some comparisons of travel times in Spain, Japan and China. The routing data of the AVE line Madrid - Sevilla is compared with those of the Shinkansen Shin Osaka - Hakata.

Based on this comparison the author proposes an upgrading of the AVE-Line Madrid - Sevilla for 300 km/h. A strict regular service for all AVE lines can be developed on the basis of a new travel time Madrid - Sevilla with 118 min together with a 142 min nonstop travel time Barcelona - Madrid. The cost-benefit analysis shows several results, above all nearly 100% more train kilometres as well as saving of running days from EMU's and track change constructions. These results could considerably improve the cost-benefit ratio of the AVE traffic.

Keywords: cost-benefit-ratio, use to capacity, regular service, comparison of travel times

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1. Introduction

High speed rail is a complex and expensive system. A continuos feedback between designing and constructing the new line as well as with the basic structure of future operation is urgently necessary to dimension the infrastructure in the right manner. Further a strict regular service is necessary to offer the passengers a timetable which can be easily remembered. A strict regular service is also an urgent condition to optimize the use of the EMU's. All these criteria have a great influence for the cost-benefit ratio of the high speed traffic.

In May 2013 the EU-commission wrote to the Spanish government to take care of the costbenefit ratio of the AVE traffic. In the same year the German newspaper "Die Welt" published a contribution "Spanien steckt Milliarden in unnütze Züge"[1]. The railway magazine "Eisenbahn Revue International" published a contribution "Schlecht ausgelastetes AVE-Netz in Spanien" in the issue from December 2013 [2]. The author uses all these information as an opportunity to scrutinize the present AVE traffic. He makes proposals to improve the present cost-benefit ratio of the AVE traffic. For this the author bases his research upon the present European Rail Timetable, summer 2017 edition, and on several publications about High speed rail in Spain.

2. Comparison of High-speed Rail systems

A comparison of High-speed rail systems can be made by using different criteria. A main criterion is the different way of operating high speed lines. For this we can distinguish between two different methods. The first method is marked by the fact that high speed trains run over exclusively dedicated high speed lines. No disturbing influences from outside must be taken into consideration for daily operation process. This advantage is mainly justified by the different gauges of the high speed network and the classic network in several countries. This is the case in Japan, Taiwan and in Spain. China is building a huge network only for high speed rail. Furthermore operation process on this separated network faces no disturbing influence from outside. Therefore from an operating view all these countries are comparable.

The second method of operating high speed trains is marked by the fact that high speed trains also run over classic lines in sections. This especially the case in France, where high speed trains use the classic lines when approaching or leaving the city centre stations of big cities. Germany faces the great disadvantage that high speed trains can only use isolated high speed lines with no high speed connection to each other. So both countries face the disadvantage of a mixture from high speed trains and classic trains in sections of the classic network for daily operation process.

3. Experimental analysis

3.1 High use to capacity

From an economic point of view a high use to capacity should be aimed at. This goal can be reached if the high speed trains run with the same speed on parallel train paths to each other given headway of at least 3 minutes in sections. But this is not the case in Spain. Spain is the only country in the world which carries out an operation with different speed on high speed lines. This criterion must be analysed intensely.

3.2 An example of the AVE traffic taken from the European Rail Timetable, valid from July 2017

Figure 1 shows an extract of the train diagram for the direction Madrid - Málaga. This figure shows impressively the problem of scheduling train paths with different speeds. AVE train 2152 running with a speed of 300 km/h is being delayed by 11 minutes to the in front running Alta train 9330, which runs only with a maximum speed of 200 km/h. This unsatisfactory timetable situation exists since December 2011. Absolute parallel train paths have a positive influence on the use to capacity and they are also a condition for an easier daily operation process. This unsatisfactory situation for the train diagram also applies for the mixture of AVE train paths (300 km/h) and Alvia train paths (250 km/h) respective Avant train paths (V_{max}=270 Km/h)

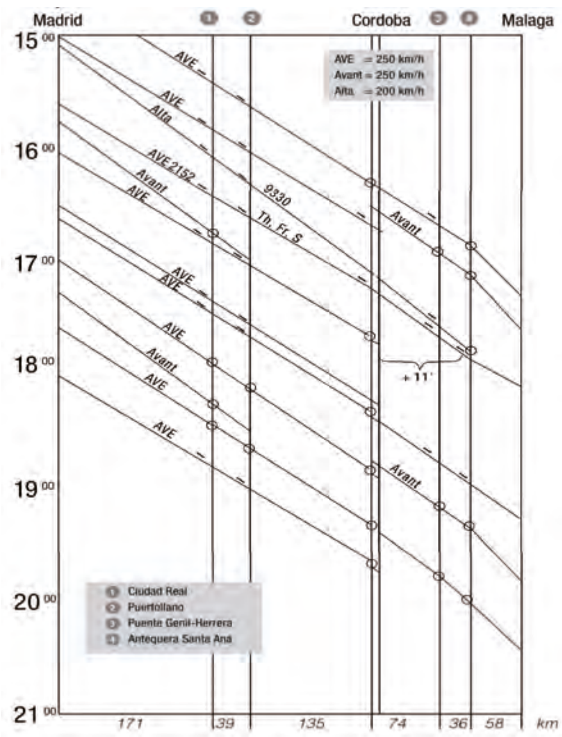


Figure 1. Extract from present train diagram Madrid - Málaga

A relative new unsatisfactory timetable situation exists since December 2016 on the Madrid - Sevilla AVE line. Since this date a nonstop AVE 2360 Madrid (16.00) - Sevilla (18.55) is affected by a 5 minutes delay approaching Sevilla. The in front running IC train 2364 Fr runs only 200 km/h.

3.3 Different travel times Madrid - Málaga

Although only 13 or less trains run daily Madrid - Málaga (Sunday to Wednesday = 12, Thursday and Friday = 13, Saturday = 10) nearly every AVE-train has a different travel time: 2082 + 2102 = 140 min; 2182 + 2212 = 143 min; 2152 = 151 min, 2162 = 152 min, 2112 = 162 min, 2143 = 163 min, 2072 = 165 min, 2092 = 167 min, 2192 = 168 min, 2172 = 170 min, 2122 + 2202 = 185 min). Such a divergence of travel times between two towns nowhere else can be found in a country with high speed traffic.

3.4 Scheduling the length of intermediate stops

Looking at the AVE Madrid - Barcelona timetable it can be noticed that an AVE-train with 4 intermediate stops needs a total travel time of 3h 10 min whereas a nonstop AVE train needs only 2 h 30 min. So the average length of an intermediate stop is about 10 min. This finding also applies for the stop in Córdoba although the AVE trains in this section at present only run with a maximum speed of 250 km/h.

This time should now be compared with a similar regulation in China. The Chinese Code for Design of High-sped railway formulates in chapter 4.2.3: *"Generally, the additional time for start of trains shall not be longer than 2,5 min, and that for stop of trains shall not be longer than 1,5 min."*[3]. With a length of 1 min for the stop we can calculate the whole amount of the stop to 5 min; with a length of stop with 2 min to 6 min. This is also the case in Japan. These amounts lie clearly below the amount of 10 min.

Travelling between Barcelona and Zaragoza Delicitas for the first time on Tuesday 03-10-2017 with train AVE 3122, the author could watch that the train was running relative slowly through the track leading from the main track to the platform track in the two stations Lleida and Zaragoza. Regarding this observation it should be possible that in total 24 min for the three intermediate stops at Zaragoza, Lleida and Camp de Tarragona should be enough. Concerning this assumption please have a look at the train diagram study at the end of the final paper at page 36.

Furthermore it is known that RENFE is proud of being absolutely punctual with the AVE traffic. From a certain amount of delay RENFE reimburses the costs for the tickets to their passengers. But it seems that this goal is achieved with a disproportionate prolongation of the stopping time in stations and in the running time. RENFE should give up this goal and take all effort to provide the highest possible commercial speed for a maximum of passengers. This goal always must have the highest priority in high speed rail traffic.

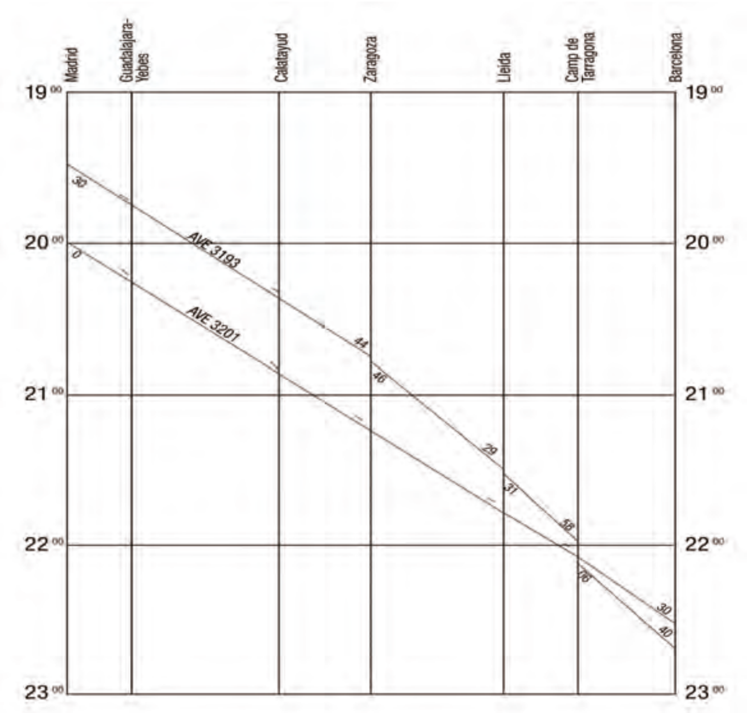


Figure 2. Extract from present train diagram Madrid - Barcelona

Figure 2, taken from the current timetable Madrid - Barcelona, proves this finding impressively. In the end AVE train 3193 needs additional 40 minutes for only 3 additional stops, including a surely unproductive waiting time in the intermediate station Camp de Tarragona. The insufficient infrastructure in this station doesn't allow a quick overtaking.

3.5 Comment on the present AVE timetable

With the present more or less irregular timetable including such different travel times between two cities as demonstrated for the Madrid - Málaga direction RENFE never will be able to receive sufficient revenues from the AVE traffic, which are necessary to justify the huge investment costs for this traffic.

3.6 Comparison of travel times

It is necessary to compare the fastest AVE travel times between Madrid and Barcelona respective Sevilla with those of some other countries that carry out high speed rail. For this step it is important that the distances of the connections are nearly the same as Madrid - Barcelona and Madrid - Sevilla.

3.6.1 Direction Madrid - Barcelona

The comparison shows the data for a nonstop train in this connection. All data are taken from the timetable effective from July 2017.

Table 1. Travel time comparison of two railway connections in Spain and China

Connection	Country	distance (km)	train number	running speed (km/h)	travel time (min)
Madrid P.d.A. - Barcelona	Spain	621	several	300	150
Guangzhou South - Changsha South	China	618	G 66	300	137

The figures in the last column require an explanation. RENFE puts too much recovery time into the running time in order to be punctual. A Swiss countryman, who travelled with a nonstop AVE Barcelona - Madrid, once told the author that he had watched an earlier arrival of almost 8 minutes at Madrid P.d.A. This observation proves that the present nonstop travel time Barcelona - Madrid contains too much recovery time.

For this detail a comparison with daily operation process on the Tokaido Shinkansen Tokyo - Osaka in Japan is useful. In the Annual Report 2016 JR Central informs about the daily operating performance: number of services per day: 358, average delay time pro train: 0,2 minutes [4]. And opposite to RENFE JR Central reaches this goal without any prolongation of running time and lengths of stop in stations. And on top of it from the fastest train category, the Nozomi train, 4 trains per hour and direction run during day time and 6 trains per hour and direction run during normal peak time. And all these Nozomi trains have to take into account 2 or even 3 overtakings of slower trains on their running between Tokyo and Shin Osaka.

3.6.2 Direction Madrid - Sevilla

The comparison of the travel times is shown in the table below. The data for Spain and China are taken from a timetable, effective from July 2017, those from Japan effective from March 2017.

Table 2. Travel time comparison of three railway connections in Spain, China and Japan

Connection	Country	distance (km)	number of trains	inter-mediate stop(s)	running speed (km/h)	travel time (min)	commercial speed (km/h)
Madrid - Sevilla	Spain	472	7	1	250 - 270	150	188,8
Zhengzhou East-Wuhan	China	472	2 6	1 2	300 300	112 119	252,8 238,0
Kokura Shin Kobe	Japan	465	2 29	2 3	300 300	113 119	246,9 234,4

The figures in this table raise the question if the Madrid - Sevilla AVE-line couldn't be upgraded to a speed of 300 km/h, because the line is designed for an operating speed of 300 km/h.

3.7 Upgrading the AVE line Madrid - Sevilla to a speed of 300 km/h

The profile of the speed of the line proves that it is mainly designed for a speed of 300 km/h [5]. When high speed rail started to become an important topic on the agenda of several countries in the last century no experiences existed between constructing and operating a high speed line. When a new line is built daily operation has to deal with the design criteria. Under this finding several countries now try to gain the highest speed from the infrastructure. In this way a comparison between the routing data of the Sanyo-Shinkansen line Shin Osaka - Hakata in West Japan and the AVE line Madrid - Sevilla in Spain could be very informative for Spain.

Table 3. This comparison is carried out in table 3.

Route	Country	minimum radius (m)	maximum gradient (‰)	tunnel cross section (m^2)	distance between tracks (m)	vehicle width (m)	distance between passing trains (m)	passing speed between trains (km/h)
Madrid -Sevilla	Spain	4000	12,5	75	4,30	2,96	1,34	500
Madrid -Sevilla in a section south of Puertollano	Spain	3250	12,5	75	4,30	2,96 (Talgo 350)	1,34	430
Shin Osaka - Hakata	Japan	4000 3500 = excep-tion	15,0	63,4	4,30	3,38 (N 700)	0,92	600

Comparison of routing data between Madrid - Sevilla in Spain and Shin Osaka - Hakata in Japan.

The routing data for the Sanyo Shinkansen are taken from source [6]. The minimum radius and the distance between tracks are the same in Japan and Spain, in all other criteria the routing data of the Madrid - Sevilla line are more convenient for a higher speed than those of Shin Osaka - Hakata line. But the trains between Kokura and Shin Kobe on the Sanyo-Shinkansen run with a speed of 300 km/h, as shown in table 2. This fact raises the question how a travel time Madrid - Sevilla would look like based upon a running speed of 300 km/h. For this step at first the travel time prolongation in the section south of Puertollano has to be calculated, where the minimum radius falls below an amount of 4000 m. This calculation is carried out in

Table 4. Calculation of travel time prolongation Puertollano - Sevilla

radius (m)	running speed (km/h)	length of the section (km)	travel time (min)	travel time prolongation (min)
4000	300	72	14,4	
3200	270	72	16,0	1,6
2300	270	28	6,2	
2300	215	28	7,8	1,6

The technical data were taken from source [7].

A new travel time Madrid - Sevilla with one intermediate stop at Córdoba can be calculated as follows :

Basic travel time: 112 min analogous to Zhengzhou East - Wuhan in China. This amount takes into account a 2 min stop at one intermediate station,

Travel time prolongation: 3,2 min

reserve: 2,8 min

total = 118 min.

A new travel time Madrid - Sevilla based upon a running speed of 300 km/h can be calculated to an amount of 118 min. This means a travel time reduce of 32 min (= -21,3%) compared to 150 min at present.

Additional remark: on his return trip from Ciudad Real on Saturday 07-10-2017 the author took train AVE 3993+3943. In the section before Madrid the author could watch that in a car of this train for a very short moment an amount of 298 km/h was shown.

3.8 Some basic statements for optimizing the AVE traffic

Some basic statements for the AVE traffic must be presented before an improvement for the AVE traffic shall be developed.

1. Compared with other countries (Japan, China) we must always bear in mind that very few trains will run over the tracks of the AVE lines,
2. these very few trains must run with the same speed over the tracks of the high speed line,

3. it is necessary to adjust the technical standards of all AVE lines to each other,
4. it is in the same manner urgent necessary, to adjust also the standards of the use of the EMU's to each other. Only one EMU type should be used on the AVE lines. The optimization proposal will be based on these statements.

3.9 Elimination of Alta, Alvia and Avant trains from AVE lines operated with a speed of 300 km/h

Because these trains run only 200/250 or 270 km/h train paths of these trains come into conflict with AVE train paths scheduled with a speed of 300 km/h. This topic now must be scrutinized.

Alta trains

The speed difference is too high. An Alta train does never delay an AVE train as figure 1 proves. The present Alta trains Madrid - Algericas must be replaced by AVE trains in the section Madrid - Antequera Santa Ana and by MD-trains in the section Antequera Santa Ana - Algericas. Passengers bound for Algaricas (= always the minority in the AVE trains) have to change trains in Antequera Santa Ana.

Alvia trains

This topic can be scrutinized by three train diagram studies. The first example refers to the AVE line Madrid - Barcelona. It is shown in figure 3.

Figure 3. Train diagram study for AVE line Madrid - Zaragoza - Barcelona

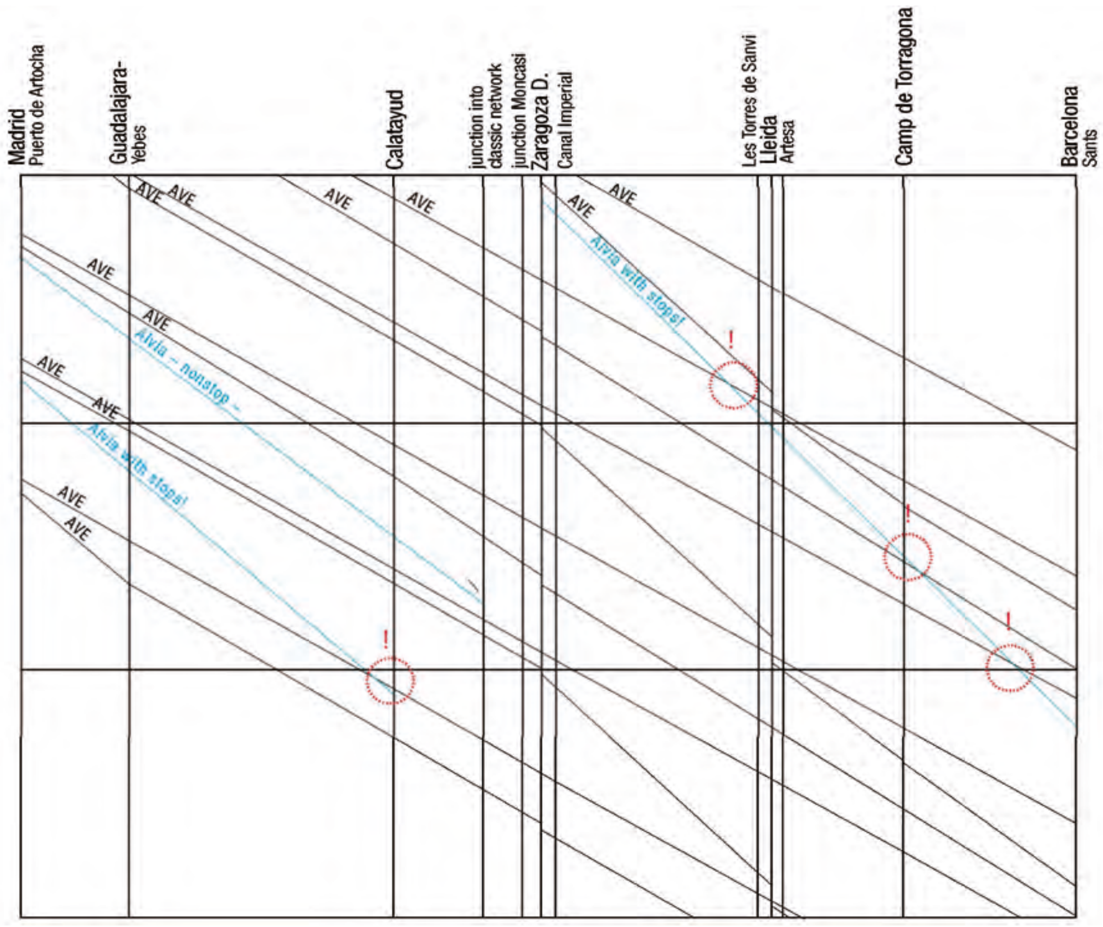


Figure 3 proves that an Alvia train West Spain - Barcelona, which also calls at Lleida and Camp de Tarragona, would be intersected by 3 AVE trains in the section Zaragoza - Barcelona .Such an Alvia train should be cancelled in the section Zaragoza - Barcelona. When such a train terminates in Zaragoza measures must be taken to improve the interchange modes in Zaragoza. For this refer to topic 3.10.3. Keeping up a through service Barcelona - West Spain would require an EMU, which is capable of running 300 km/h between Barcelona and Zaragoza on European track gauge (1435 mm) and than running on the Iberian gauge (1668 mm) beyond Zaragoza. This seems not to be an economic solution for RENFE, because this train must run additional to the proposed regular service and only very few special EMU's would be required for this through service.

The situation in the section Madrid - Zaragoza is a little bit less complicated. Given the possibility of departing three trains in a headway of 3 minutes to each other every hour only one train path with the fixed departure at minute /.20 o'clock would remain for an Alvia nonstop service Madrid - Pamplona. If the existing signalling system only allows a headway of 5 minutes, as by the present timetable may be assumed, no Alvia train path without any intersection can be scheduled. A target for the train diagram between Madrid and Barcelona is presented on page 36.

Figure 4. Train diagram study for AVE line Madrid - Sevilla

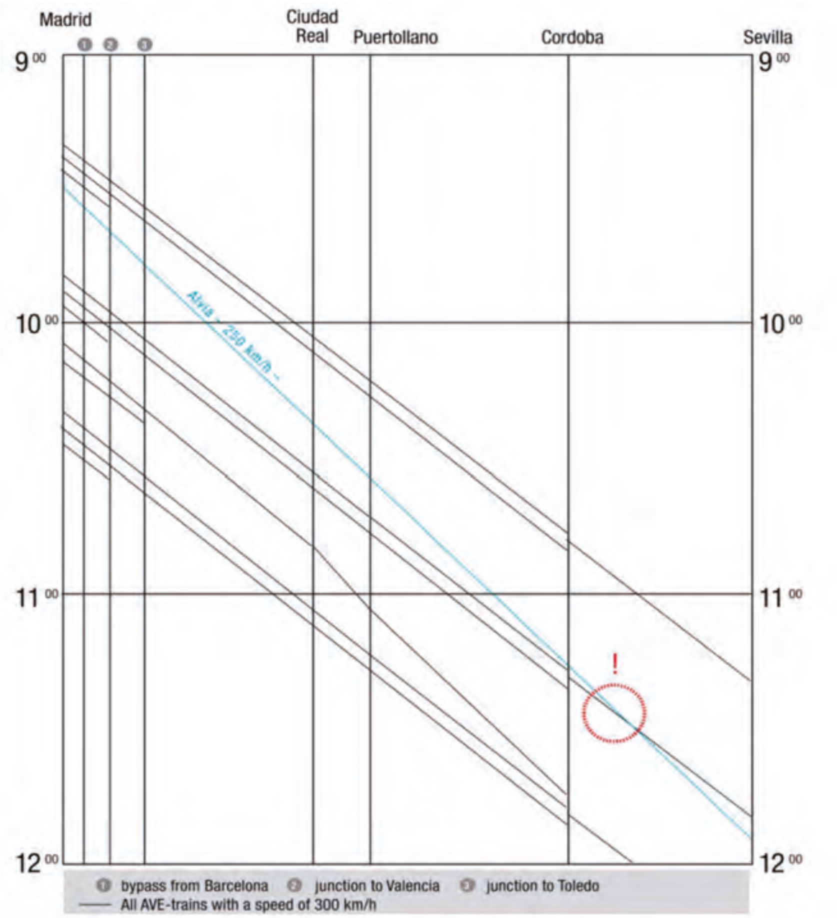
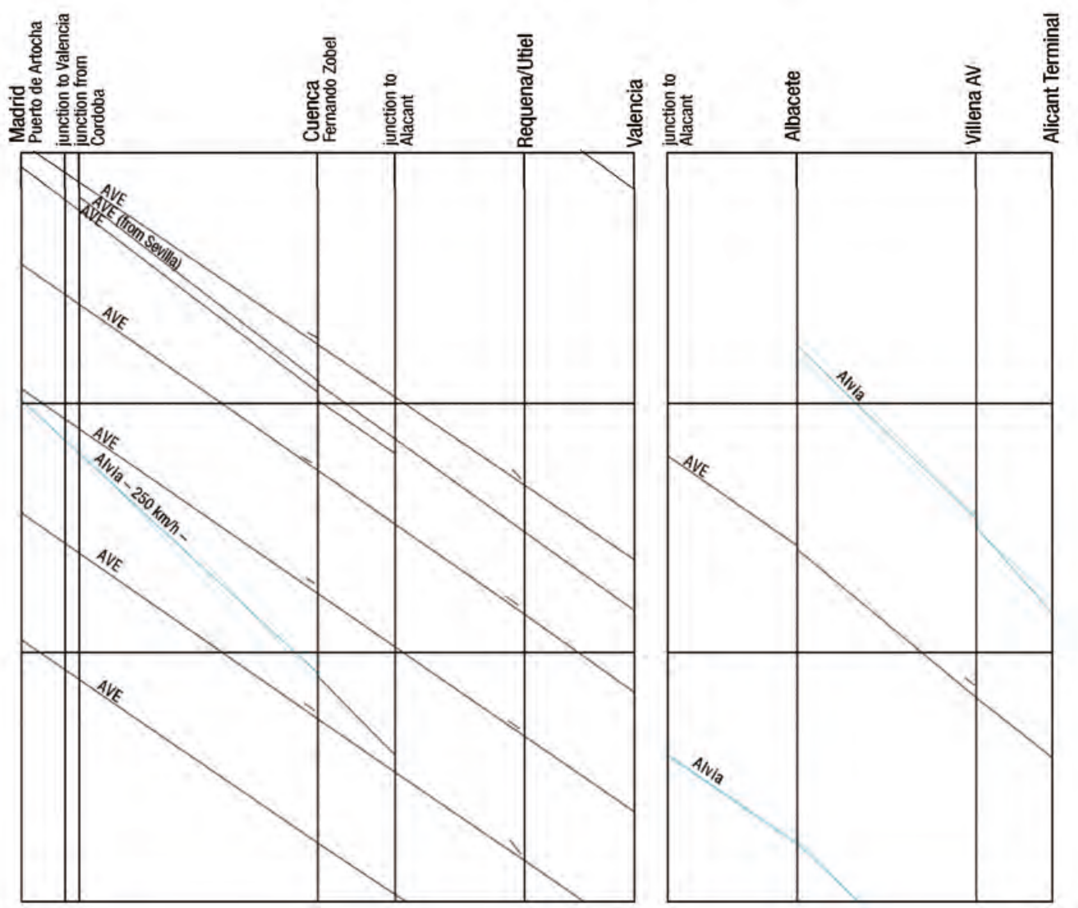


Figure 4 demonstrates the same problem for the Madrid - Sevilla route. A nonstop Alvia train path Madrid - Sevilla can't be scheduled without any intersection by an AVE train path, if the latter run in a 30 min space to each other. So an economic solution can only be that passengers from Madrid bound for Cadiz or Huelva use the AVE train until Sevilla and there change trains for their final destination, if possible at the same platform (see topic 3.10.3)

Figure 5 explains the situation for the Madrid - Valencia resp Alacant AVE line. If a nonstop travel time of 101 min is utilized for a nonstop travel time Madrid - Valencia an Alvia train path Madrid - Alacant may be scheduled exactly between two nonstop train paths Madrid - Valencia running in a space of 30 min to each other, if the Alvia train leaves the main AVE line at the junction splitting off to Alacant. But when the author travelled on 2016-04-21 with AVE train 5141 from Valencia (14.10) to Madrid (15.45) the travel time amounted to only 95 min. The train was absolute punctually. The presented train diagram situation may therefore be checked by RENFE again, if the in figure 5 described situation works, given a nonstop travel time Madrid - Valencia of 95 min.

Figure 5. Train diagram study for AVE line Madrid - Valencia resp. Alacant



Avant trains

The idea of running Avant trains (classes 104 and 114) with a maximum speed of only 250 km/h on AVE-Lines with a speed of 300 km/h, because there is surplus capacity (via libre special issue *"25 years of Spanish high speed rail"*, page 58) is a **wrong** conclusion. As already mentioned on page 2 it must always be a goal to run trains on parallel train paths in order to reach a high use to capacity. The demand for absolute parallel train paths refers also to the daily operations control. It is much easier to carry out operations control with trains running the same speed rather than with different speeds. Therefore it shall be checked, if the present Avant services Puertollano - Madrid, Toledo - Madrid and Sevilla - Málaga can be integrated in an economic manner in the rolling stock roster for the 300 km/h fast EMU's. For this see topics 3.10.4 and 3.10.5.

3.10 Developing of a regular service concept for the AVE traffic in Spain

A strict regular service concept shall be developed for the AVE traffic. The backbone for this concept shall be a half-hourly concept of express AVE-trains between Barcelona and Sevilla only calling at Madrid P.d.A. and Córdoba on their running. The nonstop travel time Barcelona - Madrid P.d.A. can be assumed to an amount of 142 min. This amount is in line with the data in table 1. The timetables for a strict regular service presented in the following statement are developed in a continous feedback with the available number of EMU's capable of running 300 km/h.

3.10.11 Sevilla/Málaga/Granada - Madrid - Barcelona - Figueres Vilafant

Table 5. Hourly AVE-Concept Málaga/Granada/Sevilla - Madrid - Barcelona - Figueres-Vilafant first hour

Hourly AVE-train concept direction south - north ***first*** hour

train number	5071	2171	AVE	3061	3253		AVE	2171	5073	AVE	3161	3255		3981		AVE
Malaga dep.							**06.29**									**06.59**
Granada arr.							07.19									07.49
Granada dep.							**07.41**									**08.11**
Malaga arr.							08.31									09.01
Malaga dep.		**06.08**		**06.16**						**06.42**						
Granada dep.			**06.02**								**06.36**					
Antequ.S.A. arr.		06.29	06.33	06.37						07.03	07.07					
Antequ.S.A. ep.		06.30	06.34	06.38						07.04	07.08					
Puento G.-H. arr.		06.42	↓	↓						↓	↓					
Puente G.-H. dep.			↓	↓				06.54		↓	↓					
Sevilla arr.			**07.29**							07.59						
Sevilla dep.					**06.41**							**07.11**		**07.14**		
Cordoba arr.				07.09	07.12			07.15			07.39	07.42		07.45		
Cordoba dep.				**07.11**	**07.14**			**07.17**			**07.41**	**07.44**		**07.47**		
Puertollano dep.				↓	↓			07.56			↓	↓		08.26		
Ciudad R. dep.				↓	↓			08.10			↓	↓		08.40		
Cuenca F. dep														09.56		
Valencia arr														**10.50**		
Valencia dep.	**06.52**						AVE		**07.22**					every	AVE	
Cuenca F. dep.							8091							two	8093	
Toledo dep.							**08.18**							hours	**08.48**	
Madrid P.d. At arr.	**08.33**			**08.36**	**08.39**		**08.47**	**08.54**	**09.03**		**09.06**	**09.09**			**09.17**	
train number					↓	3061			↓			↓	3161		↓	
Madrid P.d.At.dep.	**08.39**				**08.44**	**08.47**	**08.57**	**09.03**	**09.09**			**09.14**	**09.17**		**09.27**	
Guadj. Yebes dep.	rever-				↓	↓	rever-	rever-	rever-			↓	↓		rever-	
Calatayud dep.	sal to				↓	↓	sal to	sal to	sal to			↓	10.13		sal to	
Zaragossa D. arr.	Toledo				↓	**09.59**	Valen-	Alacant	Toledo			↓	10.34		Valen-	
Zaragossa D. dep.					↓	**10.01**	cia					↓	**10.36**		cia	
Lleida dep.					↓	10.47						↓	↓			
Camp de Tarr. dep.					↓	11.13						↓	↓			
Barcelona S. arr.					**11.06**	11.46						**11.36**	**12.00**			
Barcelona S. dep.												11.38				
Girona dep.												12.18				
Figueres V. arr.												12.33				

Important remarks: A.) The exact new travel times Sevilla - Madrid and Madrid - Barcelona for trains with intermediate stops must be calculated from RENFE analogous to the new non-stop travel times. B.)The travel time Granada - Antequera Santa Ana for an AVE-train is calculated as follows: 621 km: 142 min = 123 km: x x = 142 x 123: 621 = 28,1 rounded up = 31 min.

Table 6. Hourly AVE-Concept Figueres-Vilafant - Barcelona - Madrid - Sevilla/ Granada/Málaga first hour

Hourly AVE-train concept direction north - south ***first*** hour

train number	3254			3062	3256		3270					3162	3258				
Figueres V. dep.							**Mo -**						06.27				
Girona dep.							**Th**						06.42				
Barcelona S. arr.													07.22				
Barcelona S. dep.	**06.24**			**06.14**	**06.54**		**07.00**					**07.06**	**07.24**				
Camp de Tarr. dep	↓			06.47	↓		↓					↓	↓				
Lleida dep.	↓	rever-	rever-	07.13	↓		↓			rever-	rever-	↓	↓				rever-
Zaragossa D. arr.	↓	sal	sal	07.59	↓		↓			sal	sal	08.30	↓				sal
Zaragossa D. dep.	↓	from	from	08.01	↓		↓			from	from	08.31	↓				from
Calatayud dep.	↓	Alacant	Valen-	↓	↓		↓			Toledo	Valen-	↓	↓				Toledo
Guadj. Yebes dep.	↓		cia		↓		↓				cia	↓	↓				
Madrid P.d.At.arr.	**08.46**	**08.57**	**09.03**	**09.13**	**09.16**		**09.22**			**09.17**	**09.33**	**09.43**	**09.46**				**09.47**
train number		2176	8292			3062	AVE	AVE	2176	5012	8294			3162	AVE	AVE	5014
Madrid P.d.At dep.	**08.51**	**09.06**	**09.09**		**09.21**	**09.24**				**09.27**	**09.39**		**09.51**	**09.54**			**09.57**
Toledo arr.			**09.38**								**10.08**						
Cuenca F. dep																	
Valencia arr..										**11.08**							**11.38**
Valencia dep.																	
Cuenca F. dep.																	
Ciudad Real dep.	↓	09.50			↓	↓							↓	↓			
Puertollano dep..	↓	10.04			↓	↓							↓	↓			
Cordoba arr.	10.16	10.43			10.46	10.49							11.16	11.19			
Cordoba dep.	**10.18**	10.45			**10.48**	**10.51**							**11.18**	**11.21**			
Sevilla arr.	**10.49**				**11.19**								**11.49**				
Sevilla dep..								**10.31**							**11.01**		
Puento G.-H. arr.		11.06				↓		↓						↓	↓		
Puente G.-H. dep.						↓		↓	11.18					↓	↓		
Antequ.S.A. arr.						11.22		11.26	11.30					11.52	11.56		
Antequ.S.A. dep..						11.23		11.27	11.31					11.53	11.57		
Granada arr..								**11.58**						**12.24**			
Malaga arr..						**11.44**			**11.52**						**12.18**		
Malaga dep.							**11.59**									**12.29**	
Granada arr.							12.49									13.19	
Granada dep.							**13.11**									**13.41**	
Malaga arr.							14.01									14.31	

All trains assumed with a running speed of 300 km/h !

Some explanation must be given to tables 5 and 6.

The whole regular service system is fixed on the exact meeting of a train Madrid - Barcelona containing the service pattern of train 3061 with a train Barcelona - Madrid containing the service pattern of train 3062, exactly every hour at minute.59/.01 o'clock, at Zaragoza. By this optimal conditions for connecting services are given in Zaragoza (see page 36 for this purpose!) A nearly half hourly connection with the capital Madrid is also given for the Andalusian cities Málaga and Granada. Both cities have one hourly direct service (Málaga departure at minute /.16 o'clock; Granada departure at minute /.36 o'clock) and one hourly connecting service with the train bound for Sevilla (Málaga departure at minute /.42 o'clock, Granada departure at minute /.02 o'clock). This train shall provide a connecting service within a time space of 5 minutes at the same platform at Antequera Santa Ana (see also topic 3.10.3)

The smaller intermediate stations Puenta Genil Herera, Puertollano and Ciudad Real shall be served hourly by a special service Málaga - Madrid, train 2173 and in reverse direction train 2176. We can assume that the capacity of these trains is primarily used for passengers bound for these stations or for passengers, who want to get in these trains from these stations. The train, departing Madrid every hour at minute /.17 o'clock towards Barcelona, shall provide alternately a stop every two hours at Calatayud or Guadalajara-Yebes

Table 7. Hourly AVE-Concept Málaga/Granada/Sevilla - Madrid - Barcelona - Figueres-Vilafant second hour

Hourly AVE-train concept direction south – north ***second*** hour

train number	5075	AVE	2173	AVE	2073	2085		AVE	2173	5077	AVE	2063	2087	
Malaga dep.		**07.29**						**07.59**						
Granada arr.		08.19						08.49						
Granada dep.		**08.41**						**09.11**						
Malaga arr.		09.31						10.01						
Malaga dep.			**07.08**		**07.16**						**07.42**			
Granada dep.				**07.02**								**07.36**		
Antequ.S.A. arr.			07.29	07.33	07.37						08.03	08.07		
Antequ.S.A. ep..			07.30	07.34	07.38						08.04	08.08		
Puento G.-H. arr.			07.42	↓	↓						↓	↓		
Puente G.-H. dep.				↓	↓				07.54		↓	↓		
Sevilla arr.				**08.29**							**08.59**			
Sevilla dep.						**07.41**							**08.11**	
Cordoba arr.					08.09	08.12			08.15			08.39	08.42	
Cordoba dep.					**08.11**	**08.14**			**08.17**			**08.40**	**08.43**	
Puertollano dep.					↓	↓			08.56			↓	↓	
Ciudad R. dep.					↓	↓			09.10			↓	↓	
Cuenca F. dep														
Valencia arr														
Alicant dep.														
Valencia dep.	**07.52**						AVE			**08.22**				AVE
Cuenca F. dep.							8095							8097
Toledo dep.							**09.18**							**09.48**
Madrid P.d. At arr.	**09.33**				**09.36**	**09.39**	**09.47**		**09.54**	**10.03**		**10.06**	**10.09**	**10.17**
train number					↓	↓						↓	↓	
Madrid P.d.At.dep.	**09.39**				**09.44**	**09.47**	**09.57**		**10.00**	**10.09**		**10.14**	**10.17**	**10.27**
Guadj. Yebes dep.	rever-				↓	↓	rever-		rever-	rever-		↓	10.39	rever-
Calatayud dep.	sal to				↓	↓	sal to		sal to	sal to		↓	↓	sal to
Zaragossa D. arr.	Toledo				↓	**10.59**	Valen-		Alacant	Toledo		↓	**11.34**	Valen-
Zaragossa D. dep.					↓	**11.01**	cia					↓	**11.36**	cia
Lleida dep.					↓	11.47						↓	↓	
Camp de Tarr. dep.					↓	12.17						↓	↓	
Barcelona S. arr.					**12.06**	12.45						**12.36**	**13.00**	
Barcelona S. dep.												12.38		
Girona dep.												13.18		
Figueres V. arr.												13.33		

All trains assumed with a running speed of 300 km/h !

In every second hour a modified turning shall be carried out in Madrid P.d.A. Train 2073 from Málaga turns into the nonstop service towards Barcelona (09.36/.44 o'clock) thus providing a fast service Málaga - Barcelona. Train 2085 from Sevilla turns into the stopping service towards Barcelona. By this a direct service from Sevilla towards Zaragoza, Lleida and Camp de Tarragona ca be provided (see also topic 3.10.3). Half hour later the same modification applies for the trains 2063 and 2087.

Table 8. Hourly AVE-Concept Figueres-Vilafant - Barcelona - Madrid - Sevilla/ Granada/Málaga second hour

Hourly AVE-train concept direction North - south ***second*** hour

train number			2072	2084						3272	2062	2086			
Figueres V. dep.										from		07.27			
Girona dep.										Hu-		07.42			
Barcelona S. arr.										esca		08.22			
Barcelona S. dep.			**07.15**	**07.54**							**08.00**	**08.24**			
Camp de Tarr. dep			07.43	↓							↓	↓			
Lleida dep.	rever-	rever-	08.13	↓					rever-		↓	↓			
Zaragossa D. arr.	sal	sal	**08.59**	↓				rever-	sal		**09.24**	↓			rever-
Zaragossa D. dep.	from	from	**09.01**	↓				sal	from	**09.23**	**09.26**	↓			sal
Calatayud dep.	Mala-	Valen-	↓	↓				from	Valen-	↓	09.47	↓			from
Guadj. Yebes dep.	ga	cia	↓	↓				Toledo	cia	10.15	↓	↓			Toledo
Madrid P.d.At.arr.	**09.54**	**10.03**	**10.13**	**10.16**				**10.17**	**10.33**	**10.40**	**10.43**	**10.46**			**10.47**
train number	2170	8296			AVE	2170	AVE	5070	8298				AVE	AVE	
Madrid P.d.At dep.	**10.06**	**10.09**	**10.21**	**10.24**				**10.27**	**10.39**		**10.51**	**10.54**			**10.57**
Toledo arr.		**10.38**							**11.08**						
Cuenca F. dep								↓							↓
Valencia arr..								**12.08**							**12.38**
Valencia dep.															
Cuenca F. dep.															
Ciudad Real dep.	10.50		↓	↓							↓	↓			
Puertollano dep.	11.04		↓	↓							↓	↓			
Cordoba arr.	11.43		11.46	11.49							12.16	12.19			
Cordoba dep.	**11.45**		**11.48**	**11.51**							**12.18**	**12.21**			
Sevilla arr.			**12.19**								**12.49**				
Sevilla dep..					**11.31**								**12.01**		
Puento G.-H. arr.	12.06			↓	↓							↓	↓		
Puente G.-H. dep.				↓	↓	12.18						↓	↓		
Antequ.S.A. arr.				12.22	12.26	12.30						12.52	12.56		
Antequ.S.A. dep..				12.23	12.27	12.31						12.53	12.57		
Granada arr.,					**12.44**							**13.24**			
Malaga arr..				**12.44**		**12.52**							**13.18**		
Malaga dep.							**12.59**							**13.29**	
Granada arr.							13.49							14.19	
Granada dep.							**14.11**							**14.41**	
Malaga arr.							15.01							15.31	

All trains assumed with a running speed of 300 km/h

Table 8 shows the modifications of turnings in Madrid P.d.A in the reverse direction.

For reversal times less than 10 minutes it is assumed that a new train driver takes over the departing train. This procedure applies only for the reversals in Madrid P.d.A. with one exception in Málaga (minute .01/.08).

The timetable proposal is based upon three minutes headway also between Madrid and Barcelona. If the present installed signalling system doesn't allow this timetable, than the following modifications must be carried out: The reversals of the express trains Sevilla - Barcelona in Madrid must be shortened from 5 to 4 minutes and the following train departs a minute later. For example train 3252 at minute 08.39/.43 at Madrid and train 3061 at minutes 08.36/.48 at Madrid. The whole timetable in the section Madrid - Barcelona must be adapted according to this modification. It must be mentioned that a reversai of 4 min, where a new train driver takes over the departing train, is carried out every hour in Frankfurt(Main)-Flughafen.

At last the author wants to point out that according to the practice in China the stopping time for a stop at an intermediate station should be reduced to 6 - 7 minutes. Than a train with 3 intermediate stops leaves Madrid 5 minutes later than the express train and arrives Barcelona 5 minutes before the next express train arrives at Barcelona. This scheduling would provide an amount of 20 minutes for the three intermediate stops at Zaragoza, Lleida and Camp de Tarragona. In this the stops at Zaragoza und Lleida can be scheduled with an amount of 7 minutes due to a short longer distance of running compared with the nonstop train on the main line.

3.10.12 Toledo - Madrid - Valencia

Table 9. Hourly AVE-Concept Toledo - Madrid - Valencia

train number				AVE	AVE		AVE	AVE	AVE	AVE	AVE	AVE	AVE	AVE
Toledo dep.					06.18		18.18	18.48	19.18	19.48	20.18	21.18	22.18	23.18
Madrid Puerta de Atocha arr.					06.47		18.47	19.17	19.47	20.17	20.47	21.47	22.47	23.47
Madrid Purta.de Atocha dep..				06.27	06.57		18.57	19.27	19.57	20.36	20.57	21.57		
Cuenca Fernando Zobel arr.		every		↓	↓	every	↓	↓	↓	to	↓	↓		
Cuenca Fernando Zobel dep..		30		↓	↓	30	↓	↓	↓	Cor-	↓	↓		
Valencia Joaquin Sorolla arr.		mi-		08.08	08.38	mi-	20.38	21.08	21.38	doba	22.38	23.38		
train number		nutes	4.)			nutes				4.)				
Valencia Joaquin Sorolla dep.		until	from	06.22	06.52	until	20.52		21.52					
Cuenca Fernando Zobel arr.			Cor-	↓	↓		↓		↓					
Cuenca Fernando Zobel dep..			doba	↓	↓		↓		↓					
Madrid Puerta de Atocha arr.			07.24	08.03	08.33		22.33		23.33					
Madrid Puerta de Atocha dep.	05.39		07.39	08.09	08.39		22.39							
Toledo arr.	06.08		08.08	08.38	09.08		23.08							

Remarks: 1.) The station Requena/Utiel should be cancelled due to a too low passenger demand
2.) Cuenca Fernando Zobel - Madrid P.d.A. will be served hourly by the trains from Alacant towards Madrid P.d.A.
3.) Cuenca Fernando Zobel - Valencia will be served every two hours by the Sevilla - Valencia trains
4.) Train also calls at Villanueva de CLP

Because all present Avant services shall be integrated in the service of the 300 km/h fast EMU's the idea was created, to combine the Valencia - Madrid service with the Madrid - Toledo service. With a speed of 300 km/h in the 50 km long section Madrid - overtaking station La Sagra a travel time Madrid - Toledo of 29 min can be calculated. For the section Madrid - Valencia a travel time of 101 min is fixed according to the present timetable.

But it should be checked, if this time could be to an amount of only 95 min. This travel time he author experienced on his travel on 2016-04-21 with train AVE 5141

3.10.13 Madrid - Alacant

Table 10. Hourly AVE-Concept Madrid - Alacant

									a.)			
train number	AVE	Alvia	AVE	3981	AVE	AVE	3983	AVE	Alvia	3985	AVE	AVE
Madrid Puerto de At. dep	06.00	07.00	08.00		09.03	10.00		11.03	12.00		13.03	14.00
Sevilla dep.				07.14			09.14			11.14		
Cuenca Fernando Zobel arr.	06.52	08.05	08.52	09.55	09.58	10.52	11.55	11.58	13.05	13.55	13.58	14.52
Cuenca Fernando Zobel dep..	06.53	08.06	08.53	09.56	09.59	10.53	11.56	11.59	13.06	13.56	13.59	14.53
Valencia Joaquin Sor. arr.				10.50			12.50			14.50		
Albacete arr.	07.28	08.45	09.28		10.34	11.28		12.34	13.45		14.34	15.28
Albacete dep.	07.29	08.46	09.29		10.35	11.29		12.35	13.46		14.35	15.29
Villena AV arr.	↓	09.28	↓		↓	12.03		↓	14.28		↓	16.03
Villena AV dep.	↓	09.29	↓		↓	12.04		↓	14.29		↓	16.04
Alacant Terminal arr.	08.19	09.51	10.25		11.25	12.25		13.25	14.51		15.25	16.25
	Mo-Fr						a.)					
train number	AVE	AVE	3980	AVE	AVE	3982	Alvia	AVE	3984	AVE	AVE	3986
Alacant Terminal dep.	05.35	06.30		07.35	08.35		09.09	10.35		11.35	12.35	
Villena AV arr.	05.56	06.51		07.56	↓		09.31	↓		11.56	↓	
Villena AV dep.	05.57	06.52		07.57	↓		09.32	↓		11.57	↓	
Albacete arr.	06.31	07.25		08.31	09.25		10.14	11.25		12.31	13.25	
Albacete dep.	06.32	07.26		08.32	09.26		10.15	11.26		12.32	13.26	
Valencia Joaquin Sor. dep.			07.10			09.10			11.10			13.10
Cuenca Fernando Zobel arr.	07.07	08.01	08.04	09.07	10.01	10.04	10.54	12.01	12.04	13.07	14.01	14.04
Cuenca Fernando Zobel dep..	07.08	08.02	08.05	09.08	10.02	10.05	10.55	12.02	12.05	13.08	14.02	14.05
Sevilla arr.			10.46			12.46			14.46			16.46
Madrid Puerta de At. arr.	08.00	08.57		10.00	10.57		12.00	12.57		14.00	14.57	

Remarks: a.) from/to Santander

					b.)							
train number	3987	AVE	AVE	3989	Alvia	AVE	3991	AVE	AVE	3993	AVE	AVE
Madrid Puerto de At dep		15.03	16.00		17.00	18.00		19.03	20.00		21.03	22.00
Sevilla dep.	13.14			15.14			17.14			19.14		
Cuenca Fernando Zobel arr.	15.55	15.58	16.52	17.55	18.05	18.52	19.55	19.58	20.52	21.55	21.58	22.52
Cuenca Fernando Zobel dep..	15.56	15.59	16.53	17.56	18.06	18.53	19.56	19.59	20.53	21.56	21.59	22.53
Valencia Joaquin Sor. arr.	16.50			18.50			20.50			22.50		
Albacete arr.		16.34	17.28		18.45	19.28		20.34	21.28		22.34	23.28
Albacete dep.		16.35	17.29		18.46	19.29		20.35	21.29		22.35	23.29
Villena AV arr.		↓	18.03		19.28	20.03		↓	22.03		23.08	↓
Villena AV dep.		↓	18.04		19.29	20.04		↓	22.04		23.09	↓
Alicant Terminal arr.		17.25	18.25		19.51	20.25		21.25	22.25		23.30	00.19
		b.)										c.)
train number	AVE	Alvia	3988	AVE	AVE	3990	AVE	AVE	3992	Alvia	AVE	AVE
Alicant Terminal dep.	13.41	14.09		15.35	16.35		17.35	18.35		19.09	20.41	21.35
Villena AV arr.	↓	14.31		15.56	↓		17.56	↓		19.31	↓	↓
Villena AV dep.	↓	14.32		15.57	↓		17.57	↓		19.32	↓	↓
Albacete arr.	14.31	15.14		16.31	17.25		18.31	19.25		20.14	21.25	↓
Albacete dep.	14.32	15.15		16.32	17.26		18.32	19.26		20.15	21.26	↓
Valencia Joaquin Sor. dep.			15.10			17.10			19.10			
Cuenca Fernando Zobel arr.	15.07	15.54	16.04	17.07	18.01	18.04	19.07	20.01	20.04	20.54	22.01	↓
Cuenca Fernando Zobel dep..	15.08	15.55	16.05	17.08	18.02	18.05	19.08	20.02	20.05	20.55	22.02	↓
Sevilla arr.			18.46			20.46			22.46			
Madrid Puerta de At. arr.	16.00	17.00		18.00	18.57		20.00	20.57		22.00	23.00	23.43

Remarks. b) from/to Gijón, c.) train runs Fr, Sa, S

This timetable is based upon the train diagram already presented in figure 5. At present there run two Alvia train pairs from Northwest-Spain to Alacant via the high speed line (Aivia 4072/4092 and 4143 respective Alvia 4110 and 4181/4381). If this through service shall remain in the future, these trains should run in that manner via the high speed line that they can replace one AVE running day.

Due to the running of Alvia trains with lower speed and due to the fact of changing trains every two hours in Cuenca Fernando Zobel coming from Sevilla towards Alacant the modifications for the hourly service shown in the timetable must be accepted.

3.10.14 Sevilla - Valencia

Table 11. Algeciras-Antequera Santa Ana Córdoba -Valencia - Barcelona

km		MD	MD	MD	MD	MD	MD	MD
0	dep, Algericas arr.	06.22	08.22	10.22	12.22	14.22	16.22	18.22
12	dep. San Roque-La Linea dep.	06.37	08.37	10.37	12.37	14.37	16.37	18.37
104	dep. Ronda dep.	08.00	10.00	12.00	14.00	16.00	18.00	20.00
176	dep. Bobadilla dep.	08.49	10.49	12.49	14.49	16.49	18.49	20.49
(185)	arr.. Ant equera Santa Ana dep.	08.59	10.59	12.59	14.59	16.59	18.59	20.59
	dep. Antequera Santa Ana arr.,	*09.08*	*11.08*	*13.08*	*15.08*	*17.08*	*19.08*	*21.08*
	arr. Madrid Puerto.de Atocha dep...	*11.06*	*13.06*	*15.06*	*17.06*	*19.06*	*21.06*	*23.06*

Present travel times of direct services Algericas - Madrid: Alta 9367 5 h 22 min, Alta 9331 5 h 32 min

train number	3979	3981	3983	3985	3987	3989	3991	3993
dep. Sevilla arr.		**07.14**	**09.14**	**11.14**	**13.14**	**15.14**	**17.14**	**19.14.**
arr. **Cordoba** dep.		07.45	09.45	11.45	13.45	15.45	17.45	19.45
der. **Cordoba** arr..	05.47	07.47	09.47	11.47	13.47	15.47	17.47	19.47
dep. Puertollano dep.	06.26	08.26	10.26	12.26	14.26	16.26	18.26	20.26
dep. Ciudad Real dep.	06.40	08.40	10.40	12.40	14.40	16.40	18.40	20.40
arr. Cuenca Fernando Zobel dep..	07.55	09.55	11.55	13.55	15.55	17.55	19.55	21.55
dep. Cuenca Fernando Zobel arr..	*08.06*	*09.59*	*11.59*	*13.59*	*15.59*	*18.06*	*19.59*	*21.59*
arr. Alacant dep..	*09.51*	*11.25*	*13.25*	*15.25*	*17.25*	*19.51*	*21.25*	*23.25*
dep. Cuenca Fernando Zobel arr...	07.56	09.56	11.56	13.56	15.56	17.56	19.56	21.56
arr. Valencia Joaqin Sorolla dep...	**08.50**	**10.50**	**12.50**	**14.50**	**16.50**	**18.50**	**20.50**	**22.50**
train number	*Em*	*Em*	*Em*	*Em*	*Em*	*Em*	*Em*	
dep. Valencia Joaqin Sorolla arr...	**08.58**	**10.58**	**12.58**	**14.58**	**16.58**	**18.58**	**20.58**	
dep. Castello de la Plana dep.	09.38	11.38	13.38	15.38	17.38	19.38	21.38	
dep. L'Aldea - Amposta dep.	10.23	12.23	14.23	16.23	18.23	20.23	22.23	
dep.. Tarragona dep.	11.09	13.09	15.09	17.09	19.09	21.09	23.09	
arr. Barcelona Sants dep.	**12.14**	**14.14**	**16.14**	**18.14**	**20.14**	**22.14**		

Overview about the regular connecting service Algericas - Antequera Santa Ana - Cordoba - Valencia - Barcelona

Table 11 shows in the upper part the situation for the travel time Algericas - Madrid. Although passengers from Algericas bound for Madrid have to change trains in Antequera Santa Ana the overall travel time Algericas - Madrid amounts to only 4 h 44 min, which is Ø 43 min shorter than the Ø travel time with trains Alta 9367 or Alta 9331. A same situation applies for the reverse direction.

In the part below the proposed AVE service in the direction Sevilla - Valencia is shown by the train numbers 3979 - 3993. This service doesn't run via the capital Madrid. Therefore there is no travel connection to be seen, in which many people want to travel. For this service is assumed that passengers in many possible railway connections can use this service, For example: the departure stations could lie in the area Cadiz - Sevilla, Algericas- Antequera Santa Ana, Málaga and Granada and the destinations could be Córdoba, Puertollano, Ciudad Real, Cuenca Fernando Zobel, Valencia, Castello de la Plana, L'Aldea-Amposta, Tarragona, Barcelona, Albacete and Alacant. The blue underlined times prove this concept exemplary. A passenger may in the morning travel from Ronda towards Castello de la Plana. At present he must start at07.53 o'clock and he arrives at Castello de la Plana at 16.30 o'clock. Given a regular service he could start at 08.00 o'clock and arrive at Castello de la Plana at 13.38 o'clock. This is a travel time reduce of 179 min or = - 34,6%. And this described travel possibility exists every two hours during the day from 08.00 o'clock until 16.00 o'clock.

3.10.15 Future possible train service concept in Andalusia

Table 12. Future possible train service concept in Andalusia

train	MD	MD	MD	MD	MD	MD	AVE	AVE		AVE	AVE	
Sevilla dep.	06.06	07.06	08.06	09.06	11.06	12.06	07.01			06.31		
Dos Hermanas d.)							b.)			b.)		
via	a.)	a.)	a.)	a.)	a.)	a.)	c.)			c.)		
Antequera S.A. arr.	07.45	08.45	09.45	10.45	12.45	13.45	07.56			07.26		
Madrid P.d. A. dep	*05,54*	*06.54*	*07.54*	*08.54*	*10.54*	*11.54*						
Antequera S.A. arr	*07.52*	*08.52*	*09.52*	*10.52*	*12.52*	*13.52*			**and**			**and**
Antequera S.A. dep.		09.01		11.01	13.01				**so**			**so**
Bobadilla		09.09		11.09	13.09				**on**			**on**
Ronda		10.00		12.00	14.00				**every**			**every**
San Roque-La Linea		11.23		13.23	15.23				**hour**			**hour**
Algericas		11.38		13.38	15.38							
Antequera S.A. dep	07.57		09.57			13.57	07.57				08.23	
via	a.)		a.)			a.)	c.)				c.)	
Malaga arr.	08.56		10.56			14.56	08.18				08.44	
Antequera S.A. dep								07.53		07.27		
via								c.)		c.)		
Granada arr.								08.24		07.58		

train	MD	MD	MD	MD	MD	MD	AVE	AVE	AVE	AVE	AVE
Sevilla dep.	13.06	15.06	17.06	18.06	19.06	21.06			22.01		22.31
Dos Hermanas d.)									b.)		b.)
via	a.)	a.)	a.)	a.)	a.)	a.)	→		c.)		c.)
Antequera S.A. arr.	14.45	16.45	18.45	19.45	20.45	22.45	**last**		22.56		23.26
Madrid P.d. A. dep	*12.54*	*14.54*	*16.54*	*17.54*	*18.54*	*20.54*	**ser-**				
Antequera S.A. arr	*14.52*	*16.52*	*18.52*	*19.52*	*20.52*	*22.52*	**vices**		-		-
Antequera S.A. dep.	15.01	17.01	19.01		21.01		→				
Bobadilla	15.09	17.09	19.09		21.09						
Ronda	16.00	18.00	20.00		22.00						
San Roque-La Linea	17.23	19.23	21.23		23.23						
Algericas	17.38	19.38	21.38		23.38						
Antequera S.A. dep				19.57		22.57			22.57	23.23	
via				a.)		a.)			c.)	c.)	
Malaga arr.				20.56		23.56			23.18	23.44	
Antequera S.A. dep								22.53			23.27
via								c.)			c.)
Granada arr.								23.24			23.58

Remarks: a.) via classic line, b.) via a new high speed connecting line in the area SW from Cordoba allowing a direct Sevilla - Antequera S.A. running of high speed trains, c.) via AVE-high speed line, d.) It is assumed that an upgrading of the classic line (passing loops!) may provide a travel time of 1 h 39 min between Sevilla and Antequera Santa Ana.

Antequera Santa Ana could become an interesting interchange station not only for the AVE services Málaga - Madrid and Granada - Madrid and the MD/AVE service Algericas - Madrid but also for MD/AVE services coming from Sevilla via the classic line towards Málaga and Granada. Passengers living in the area of the classic stations between Sevilla and Antequera Santa Ana and between Antequera Santa Ana and Málaga can gain the advantages of high speed rail in Andalusia. And once more the advice shall be made to construct a short high speed connecting line in the area southwest from Córdoba allowing a fast direct service between Sevilla and Antequera Santa Ana. For the latter a travel time of 55 min is calculated in this study.

3.10.16 Comparison of train kilometre expense

Table 13. Comparison of train kilometres expense

The proposal for a regular service contains more train kilometres than the present timetable the increase of the train kilometre expense must be estimated. This detail has an important effect on the cost-benefit-ratio. The change of train kilometre expense is shown in table 13.

Direction	train-kilometre 12/2016 per week	train-kilometre in the timetable study per week	percentage
Barcelona - Madrid	154 496	267 538	+73,1%
Madrid -Sevilla resp. Málaga	134 079	279 634	+108,5%
Madrid - Valencia	37 145	73 117	+ 96,8%
Madrid - Toledo	7 125	16 615	+133,2 %
Madrid - Alacant	29 160	54 432	+86,6 %
Sevilla - Valencia	8 120	43 238	+432,4 %
Total	370 125	734 574	+98,4 %

3.10.2 Connecting services in Sevilla and Zaragoza

A regular service must also take into account the connecting service in important interchange stations. A regular service must also be scheduled on connecting lines in order to pass on the travel time reduce from the 300 km/h fast EMU's into destinations of the classic network. This fact must be explained by the interchange station Sevilla, because MD trains on the classic routes towards Cadiz and Huelva shall replace present Alvia services in the last section towards Cadiz or Huelva.

3.10.2.1 Sevilla

Table 14. Proposal for regular service Sevilla - Cadiz

MD		MD	MD	MD	km		MD	MD	MD	MD		MD
05.19	and	19.19	20.19	21.19	0	dep, Cadiz arr.	07.38	08.38	09.38	10.38	and	23.38
05.30	so on	19.30	20.30	21.30	15	dep. San Fernando- Bahia Sur dep.	07.26	08.26	09.26	10.26	so on	23.26
05.45	every	19.45	20.45	21.45	34	dep.Puero de Santa Maria dep.	07.10	08.10	09.10	10.10	every	23.10
05.54	hour	19.54	20.54	21.54	49	dep. Jerez de la Frontera dep.	07.01	08.01	09.01	10.01	hour	23.01
06.02	until	20.02	21.02	22.02	61	dep. Aeroporto de Jerez dep.	06.54	07.54	08.54	09.54	until	22.54
06.40		20.40	21.40	22.40	123	dep. Utrera dep,	06.19	07.19	08.19	09.19		22.19
06.50		20.50	21.50	22.50	140	dep. Dos Hermanos dep.	06.08	07.08	08.08	09.08		22.08
07.05		21.05	22.05	23.05	156	arr. Sevilla dep.	05.55	06.55	07.55	08.55		21.55
07.11		*21.11*				dep. Sevilla arr.				*08.49*		*21.49*
09.09		*23.09*				arr. Madrid P.d.A. dep.				*06.51*		*19.51*

At present the shortest travel time Madrid - Cadiz with an Alvia through service amounts to 3 h 55 min (Alvia 2164). The average travel time for daily services Madrid - Cadiz amounts to 4 h 4 min. This amount lies 17 min above the travel time of 3 h 47 min, which can be provided in the regular service concept. In the reverse direction the shortest travel time Cadiz - Madrid amounts to 3 h 59 min (Alvia 2175). The average travel time for daily services Cadiz - Madrid amounts to 4 h 15 min. This amount lies 25 min above the travel time of 3 h 50 min, which can be provided in the regular service concept.

Table 15. Proposal for a service concept Sevilla - Huelva

km			MD	MD	MD	MD	MD	MD	MD	MD	MD	MD
0	Huelva	dep.	07.05	08.05	10.05	11.05	13.05	14.05	16.05	17.05	19.05	20.05
40	La Palma del Condado	dep.	07.45	08.45	10.45	11.45	13.45	14.45	16.45	17.45	19.45	20.45
115	Sevilla	arr.	08.35	09.35	11.35	12.35	14.35	15.35	17.35	18.35	20.35	21.35
	Sevilla	*dep.*	*08.41*	*09.41*	*11.41*	*12.41*	*14.41*	*15.41*	*17.41*	*18.41*	*20.41*	*21.41*
	Madrid P.d.A.	*arr.*	*10.39*	*11.39*	*13.39*	*14.39*	*16.39*	*17.39*	*19.39*	*20.39*	*22.39*	*23.39*

km			MD	MD	MD	MD	MD	MD	MD	MD	MD	MD
	Madrid P.d.A.	*dep.*	*06.21*	*07.21*	*09.21*	*10.21*	*12.21*	*13.21*	*15.21*	*16.21*	*18.21*	*19.21*
	Sevilla	*arr.*	*08.19*	*09.19*	*11.19*	*12.19*	*14.19*	*15.19*	*17.19*	*18.19*	*20.19*	*21.19*
0	Sevilla	dep.	08.25	09.25	11.25	12.25	14.25	15.25	17.25	18.25	20.25	21.25
75	La Palma del Condado	dep.	09.23	10.23	12.23	13.23	15.23	16.23	18.23	19.23	21.23	22.23
115	Huelva	arr.	09.53	10.53	12.53	13.53	15.53	16.53	18.53	19.53	21.53	22.53

In the service concept with changing trains in Sevilla a travel time Madrid- Huelva of 3 h 32 min can be reached. The two services, which run daily except Saturdays need 3 h 40 in (Alvia 2384) or even 4 h 7 min (IC 2494). A similar situation is given for the reverse direction.

3.10.2.2 Zaragoza

Table 16. Proposal for a regular service Pamplona - Zaragoza

train category	IC	Alvia	Alvia	IC	Alvia	IC		IC	IC	Alvia	IC	Alvia	IC	IC y.)
Logroño dep.			07.25											
San Seb./Don. dep				x06.24	07.12					S 13.54			Sa16.24	
Pamplona arr				x08.02	08.58					S 15.35			Sa18.02	
Pamplona dep.	06.04	06.30		08.04	09.00	10.04		12.04	14.04	15.37	16.04	17.24	18.04	y.) 20.04
Castejon arr.	06.57	07.19		08.57	↓	10.57		12.57	14.57		16.57		18.57	y.)20.57
de Ebro dep.	06.59	07.20		08.59	↓	10.59		12.59	14.59		16.59		18.59	y.) 20.59
Zaragoza arr.	07.53			09.53	10.53	11.53		13.53	15.53		17.53	19.23	19.53	y.) 21.53
Zaragoza dep.	*08.01*			*10.01*	*11.01*	*12.01*	*13.01*	*14.01*	*16.01*		*18.01*		*20.01*	*22.01*
Madrid arr.	*09.13*	09.40	10.40	*11.13*	*12.13*	*13.13*	*14.13*	*15.13*	*17.13*	18.40	*19.13*		*21.13*	*23.13*
Zaragoza dep.	*08.01*			*10.01*	*11.01*	*12.01*	*13.01*	*14.01*	*16.01*		*18.01*	*19.36*	*20.01*	*22.01*
Barcelona arr.	*09.44*			*11.44*	*12.44*	*13.44*	*14.44*	*15.44*	*17.44*		*19.44*	*21.00*	*21.44*	*23.44*

Remarks : x = only Fr and Mo y.) not on Thursdays. There runs train 16111 Vitoria - Zaragoza in this time

train category					Alvia				Alvia			Alvia	
Madrid dep	*06.47*	*08.47*		*10.47*	11.20	*12.47*	*14.47*	*16.47*	18.20	*18.17*	*18.47*	19.20	*20.47*
Zaragoza arr	*07.59*	*09.59*		*11.59*		*13.59*	*15.59*	*17.59*		*19.34*	*19.59*		*21.59*
Barcelona dep	*06.16*	*08.16*	*10.00*	*10.16*		*12.16*	*14.16*	*16.16*		*18.00*	*18.16*		*20.16*
Zaragoza .arr	*07.59*	*09.59*	*11.24*	*11.59*		*13.59*	*15.59*	*17.59*		*19.24*	*19.59*		*21.59*
	IC	IC	Alvia	IC		IC	IC	IC			IC		IC
Zaragoza dep.	08.07	10.07	11.37	12.07		14.07	16.07	18.07			20.07		22.07
Catejon . arr	09.01	11.01	12.31	13.01		15.01	17.01	19.01			21.01		23.01
de Ebro .. dep	09.03	11.03	12.33	13.03		15.03	17.03	19.03			21.03		23.03
Pamplona arr.	09.53	11.53		13.53	14.25	15.53	17.53	19.53			21.53	22.25	23.53
Pamplona dep				Sa 13.54				Th 19.54			S 21.54		
San Seb./Don. dep				Sa 15.11				Th 21.11			S 23.11		
Logroño arr.									21.35				

The Ø travel time Madrid - Pamplona of the 4 Alvia trains 601/605/613/801 amounts to 3 h 5,5 min. Alvia 609 needs 3 h 21 min
The Ø travel time Pamplona - Madrid of the 4 Alvia trains 802/602/606/610 amounts to 3 h 10 min
The Ø travel time Barcelona - Pamplona of the 4 Alvia-trains 534/622/654/530 amounts to 3 h 50 min; IC 562 needs 4 h 4 min
The Ø travel time Pamplona - Barcelona of the 4 Alvia-trains 533/661/621/537 amounts to 4 h 6 min; IC 635 needs 3 h 45 min

As already mentioned in chapter 3.10.11 Zaragoza shall become an important interchange station. This fact shall be explained by table 16. A regular connecting service with IC trains every two hours from Pamplona towards Zaragoza shall provide attractive connecting services towards Madrid as well as to Barcelona always with the same train. For this proposed service is assumed that it can be carried out with the equipment expenses currently used in the IC trains

635/10657/562/10560/10655.The connecting AVE train from Zaragoza to Madrid is always a nonstop train whereas the connecting AVE train from Zaragoza towards Barcelona is always a AVE-stopping train.

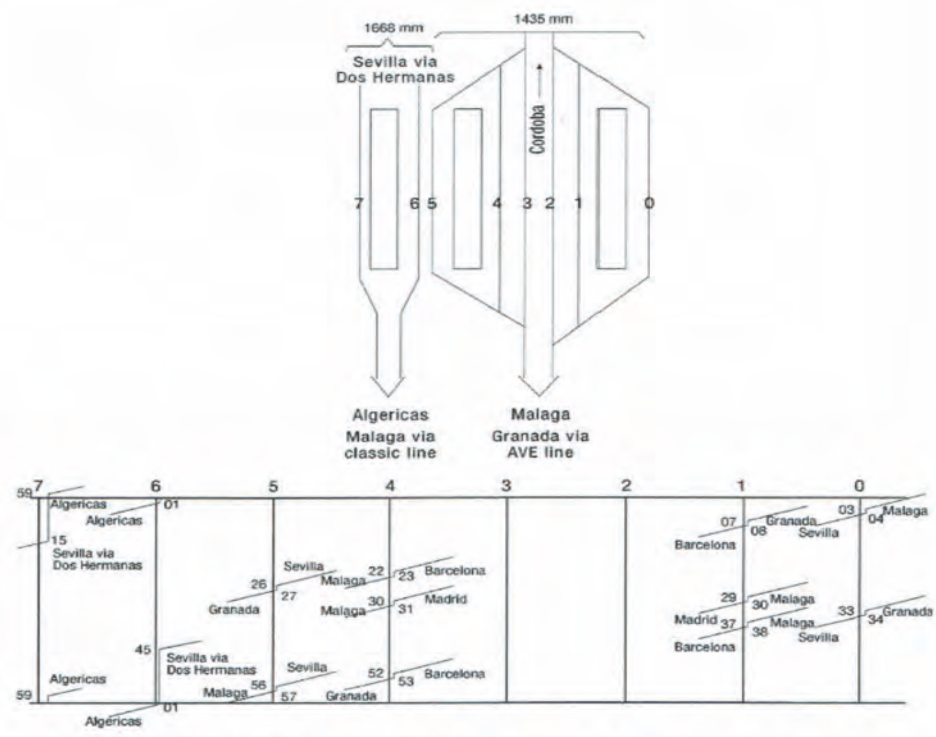
In the direction Pamplona - Madrid the travel time is the same as with a present Alvia service. In the direction Pamplona - Barcelona the average travel time of the 5 direct services with trains 635/533/661/621/537 amounts to exact 4 hours whereas the travel time Pamplona - Barcelona with changing trains at Zaragoza in the regular service would amount to only 3 h 40 min. For the role of Zaragoza Delicitas of being an important interchange station in the Spanish network see also page 36.

3.10.3 Discussing of the track diagram for several interchange stations

If a changing of trains is required for a service than all measures should be taken into account, to make the changing as convenient as possible for the passengers. This situation shall be briefly discussed by the regarding situation in the five stations Antequera Santa Ana, Sevilla, Córdoba, Zaragoza and Madrid P.d.A.

Antequera Santa Ana

Antequera Santa Ana could become an interchange station for several railway connections They are listed in table 17.



Track occupation diagram for Antequera Santa Ana station
Remark: It is assumed that platform track '0' may be reproduced

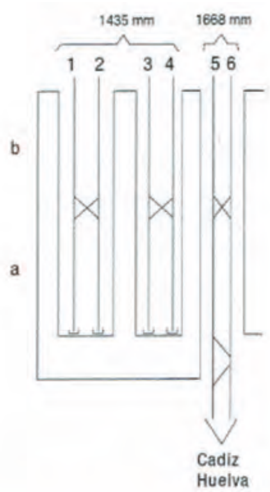
Figure 6

Table 17. Possibility of changing platform tracks in Antequera Santa Ana Interchange station

interchange connection	changing time in Antequera Santa Ana	platform tracks	remarks
Algericas - Madrid	minute 59 →08	7 →1	
Málaga - Madrid	minute 03 →08	0 →1	same platform
Málaga - Sevilla via classic line	minute 03 →15	0 →7	
Granada - Sevilla via classic line	minute 07 →15	1 →7	
Madrid - Granada	minute 22 →27	4 →5	same platform
Sevilla - Málaga	minute 26 →31	5 →4	same platform
Málaga - Sevilla	minute 29 →34	1 →0	same platform
Granada - Madrid	minute 33 →38	0 →1	same platform
Sevilla via classic line - Granada	minute 45 →53	6 →4	
Sevilla via classic line - Málaga	minute 45 →57	6 →5	
Madrid - Málaga	minute 52 →57	4 →5	same platform
Madrid - Algericas	minute 52 →01	4 →6	

The more the network grows the more the need grows to change trains at interchange stations. It is impossible to provide direct services in every connection. Concerning Antequera Santa Ana the consequence reads to take all measures to make convenient the interchange procedure for the passengers as far as possible.

Sevilla



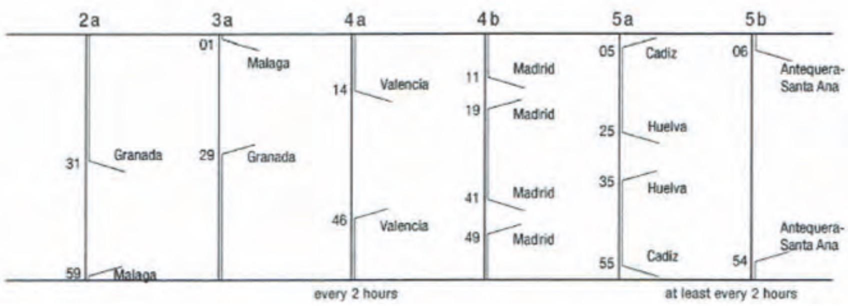


Figure 7. Track occupation diagram for Sevilla station

The interchange conditions for Sevilla could be optimized, if a platform with an European standard track at the one side (track 4) and a track with Iberian gauge at the other side (track 5) could be realized. This idea is shown in figure 7. This sketch was designed before seeing Sevilla station in practice. The platform between track 6 (1435 mm gauge) and track 7 (1668 mm gauge is the most important platform in Sevilla station.

Córdoba

The interchange situation in Córdoba is very convenient for passenger change. It is assumed that the third train can run in the track of the first train. A 4 minutes space between these two trains contains already 1 minute recovery time.

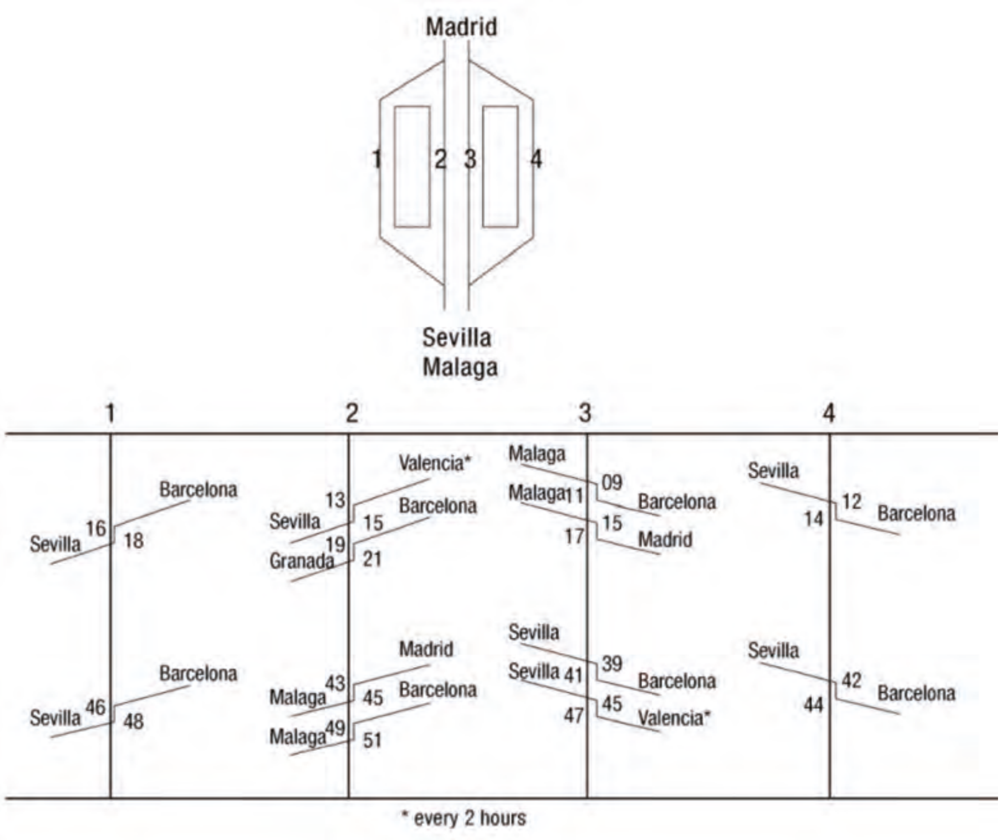


Figure 8. Track occupation diagram for Córdoba station

Zaragoza

In Zaragoza a connecting service from Pamplona with AVE trains bound for Madrid as well as bound for Barcelona shall be provided. This manoeuvre will never be possible, to carry out at the same platform. To make passenger change convenient it may be checked to build a passenger bridge between two neighbouring platform as it is shown in figure9.

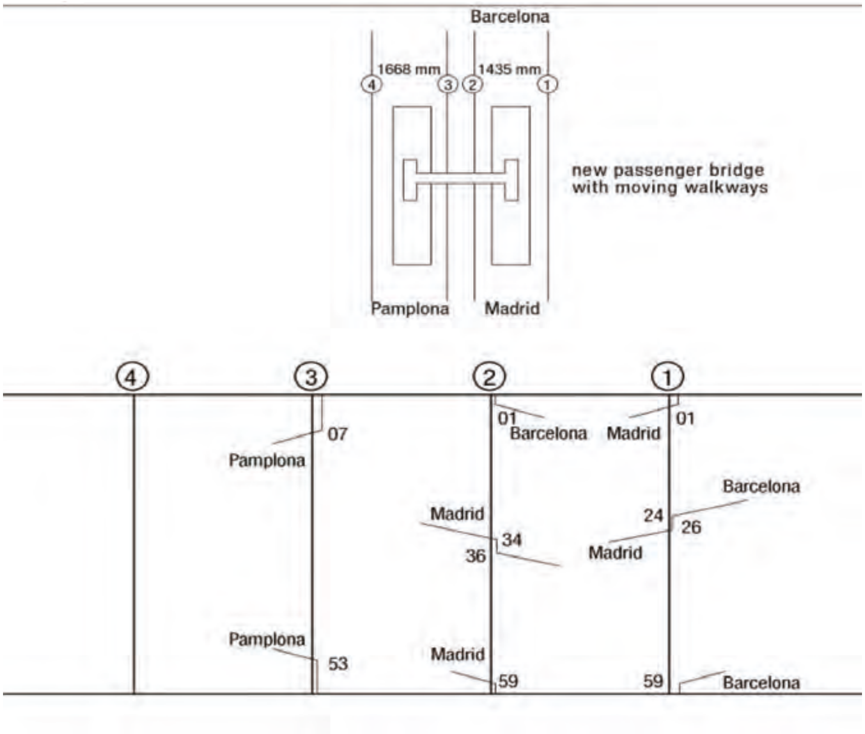


Figure 9. Track occupation diagram for Zaragoza station

Madrid Puerta de Atocha

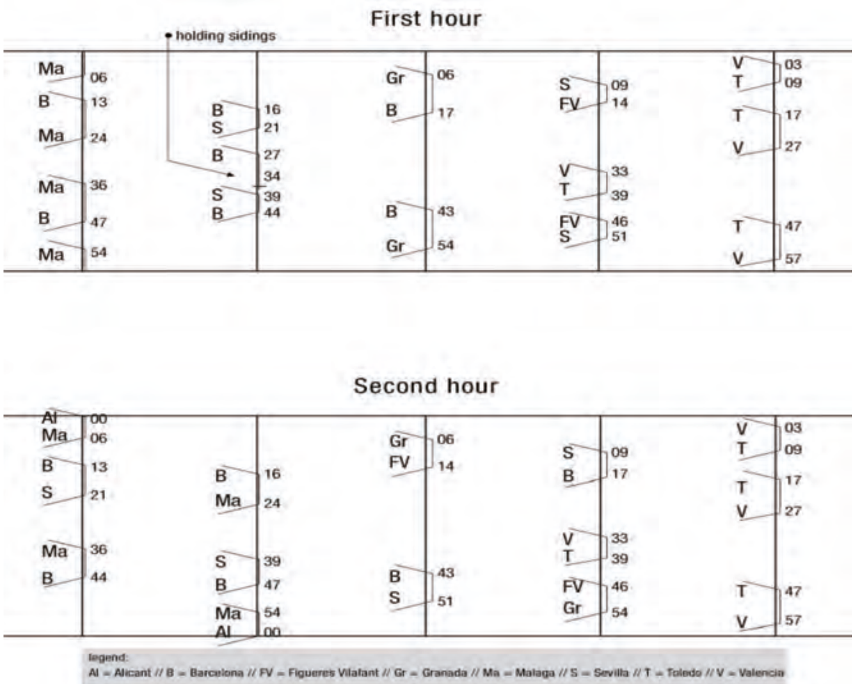


Figure 10. Track occupation diagram for Madrid Puerta de Atocha station

Madrid Puerta de Atocha The track occupation diagram for Madrid Puerta de Atocha proves that a combing of services, in which Puerta de Atocha will become an intermediate station, considerably reduces the need of platform tracks. And for this it must be mentioned that every platform track in Madrid Puerta de Atocha is 450 m long with a double crossover in the middle. So it should be possible to run four trains into two platform tracks in different sections. So in the end in total 4 trains could stand opposite to each other thus providing a changing of trains at the same platform in several directions.

It must be stressed that it is much more important to make possible the above designed track occupation diagram in Madrid P.d.A. rather than provide 15 platform tracks in this station.

3.10.4 Rolling stock roster study for regular service concept

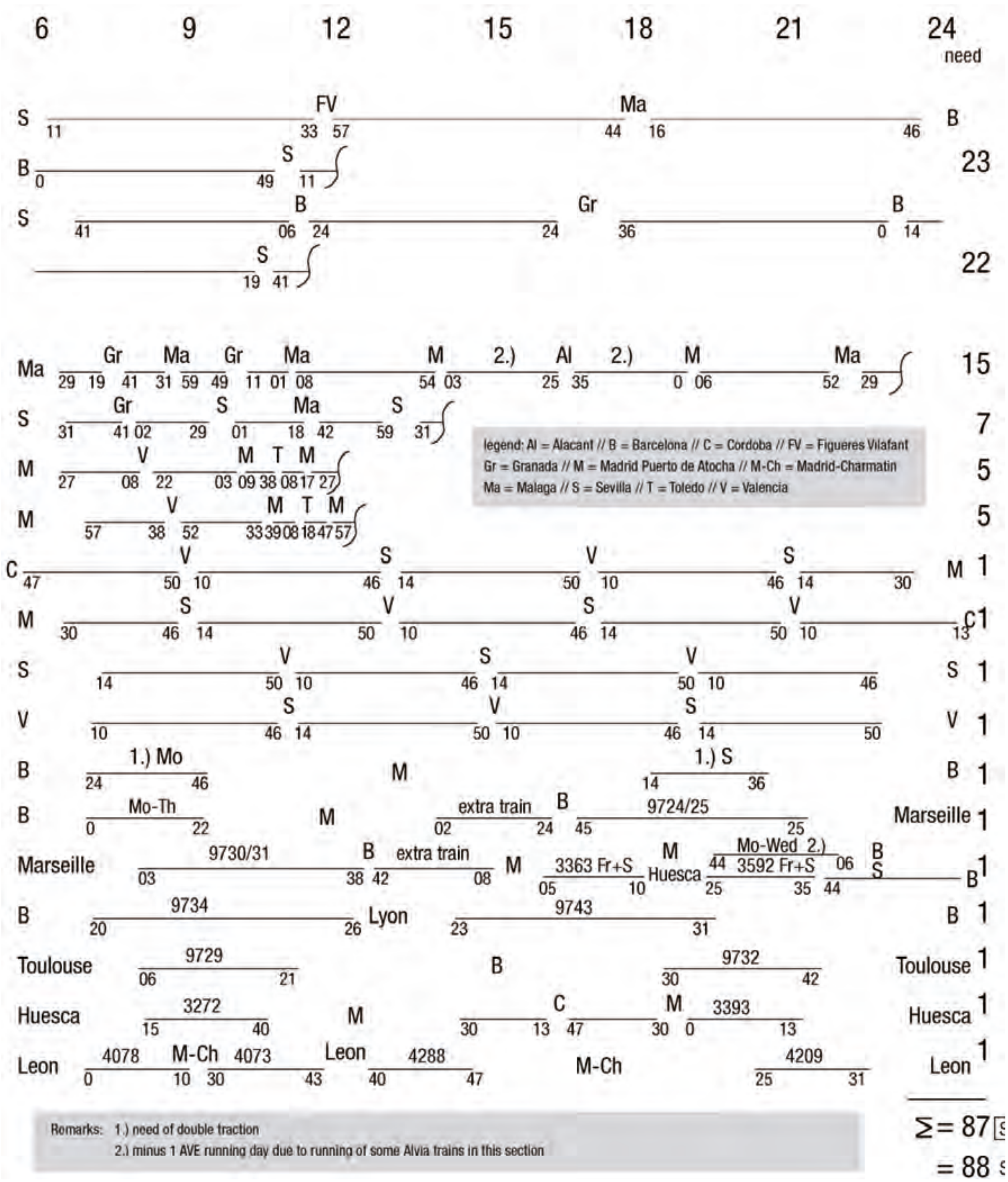


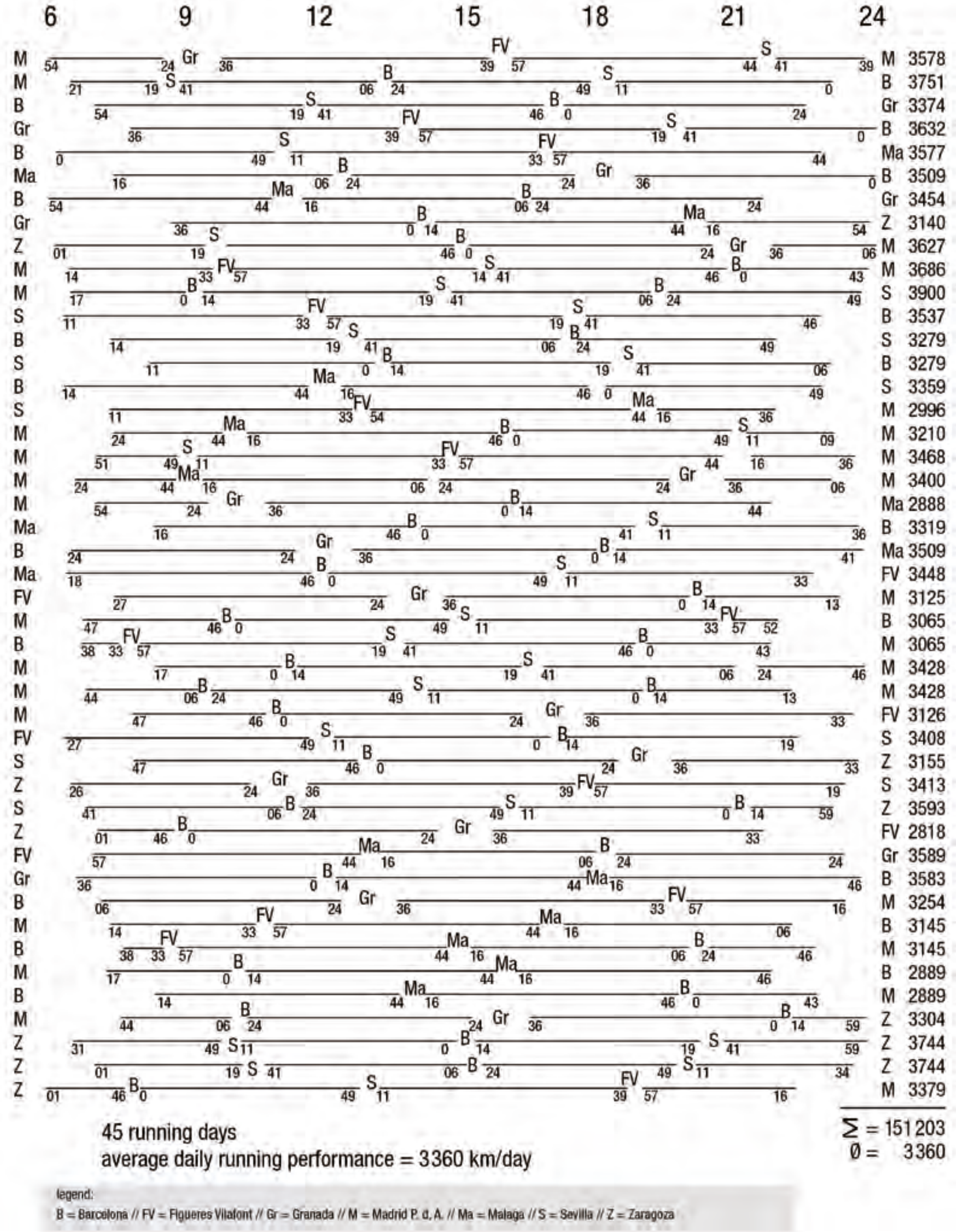
Figure 11. Principal overview about the rolling stock roster for the whole regular service concept

The change in rolling stock roster presents an important influence on the cost-benefit ratio. Therefore a rolling stock roster must be developed in order to assess the consequences. This step will be carried out in figure 11.

Principal overview about the rolling stock roster for the whole regular service concept

The overall need is calculated to 87 running days with an exception of 88 units for the short time period Sunday evening to Monday morning.. On Monday morning the train from Barcelona arriving at Madrid P.d.A. at 08.46 o'clock needs double traction.

In the first 4 rows the need of running days for the direction Sevilla/Málaga/Granada - Madrid - Barcelona - Figueres Vilafant is shown. This relation presents the backbone of the whole service. The complete rolling stock roster of these 4 rows is shown in figure 12.



Overview about the rolling stock roster for EMU's running over the core section Córdoba - Barcelona

Figure 12 presents a very intensively used rolling stock roster with an average daily running performance of almost 3360 km per day. The high daily running performance may require a level one maintenance (bogie inspection) after every running day. It is assumed that equipment for this step is available at every station, where an EMU stands overnight.

Generally it is assumed that maintenance is exclusively carried out only during night. For this topic the author wants to point out to the new strategy of SNCF in this manner, which is explained up-to-date in source [8].

When the CEO of SNCF Voyages, Rachel Picard, points out that in future trains will be in service for 13 hours per day, it may be stated that the rolling stock roster presented in figure 12 is in line with this rule. RENFE isn't affected with the disadvantage of running AVE trains in section on classic lines like in France. And in Spain the EMU's don't have to take into account an overtaking of one in front running EMU in an intermediate station like in Japan and China. At least it must be mentioned that source [3] reads in topic 4.2.5 "The turn-back time of immediate turn-back multiple units should not be longer than 20 min" ([3] p.11)

The overall need of the rolling stock roster amounts to 87 running days. Only during Sunday evening to Monday morning 88 running days are needed. The real amount needed for the service must refer to the expense for maintenance. For this purpose a referring percentage must be calculated. This percentage refers to several criteria. If the percentage is assessed to 15 % than the overall need calculates to 87 x 1,15=100,05 respective 88 x 1,15 = 101,2 ≈101 EMU's. This means in practice 101-87=14 EMU's are available for daily maintenance and repair.

The present RENFE fleet of EMU's capable of running 300 km/h consists of 86 units (via libre "25 years of Spanish high speed rail", English version page 68, series 100R, 102, 112 and 103). Currently RENFE is buying an additionally part of 15 EMU's capable of running 300 km/h. In near future EMU fleet capable of running 300 km/h consist of 86 + 15 = 101 units.

3.10.5 Saving of rolling stock and gauge changing constructions.

As already mentioned the strict regular service concept is aimed to use only one EMU category on the 300 km/h fast Ave lines. The Avant, Alvia and Alta train sets, which can be saved, are listed in two figures.

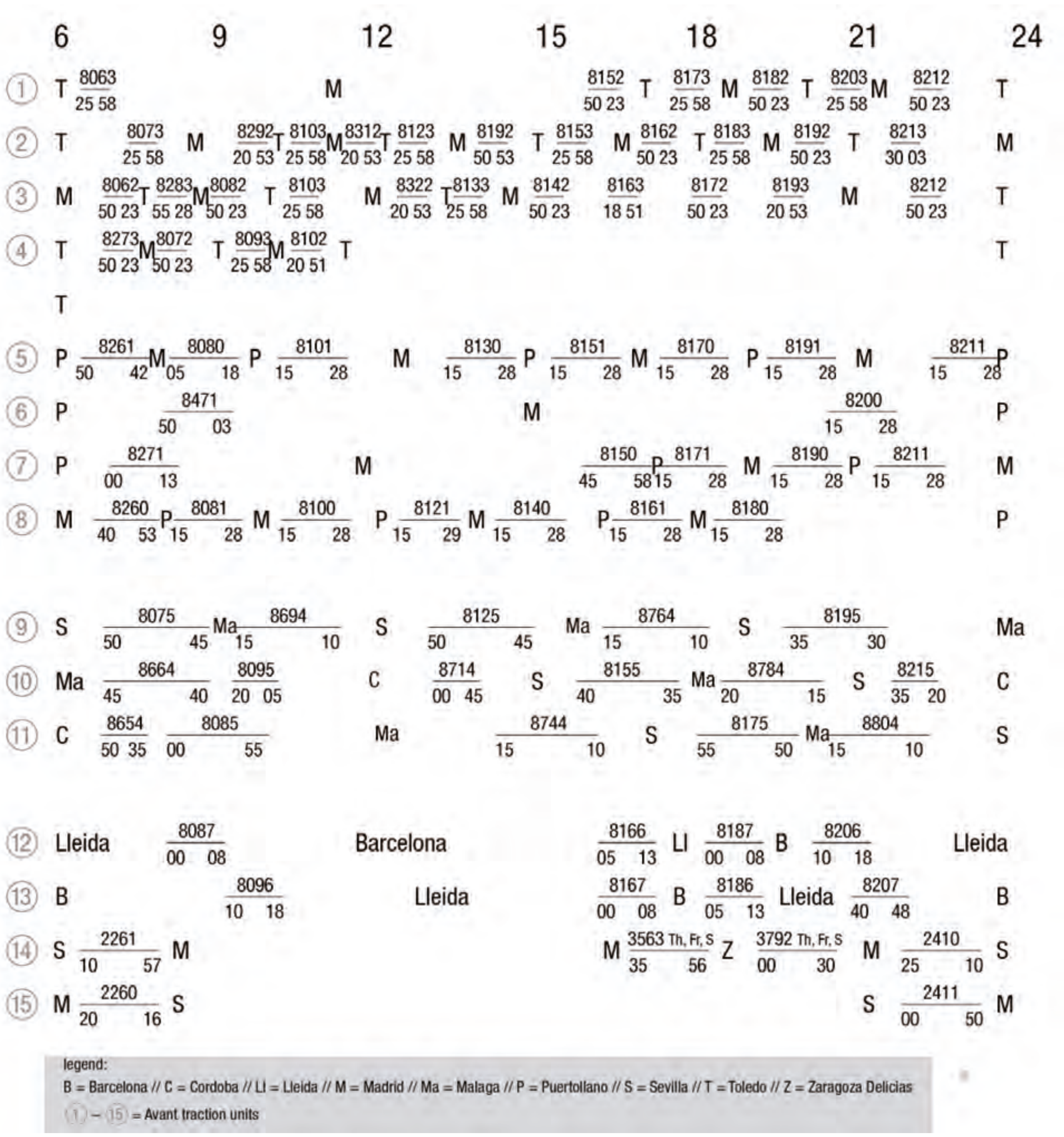


Figure 13. Overview about the Avant running days, which can be saved in a regular service concept

In figure 13 the number of Avant running days is shown, which shall be saved by an intensive use of the 300 km/h fast EMU's.

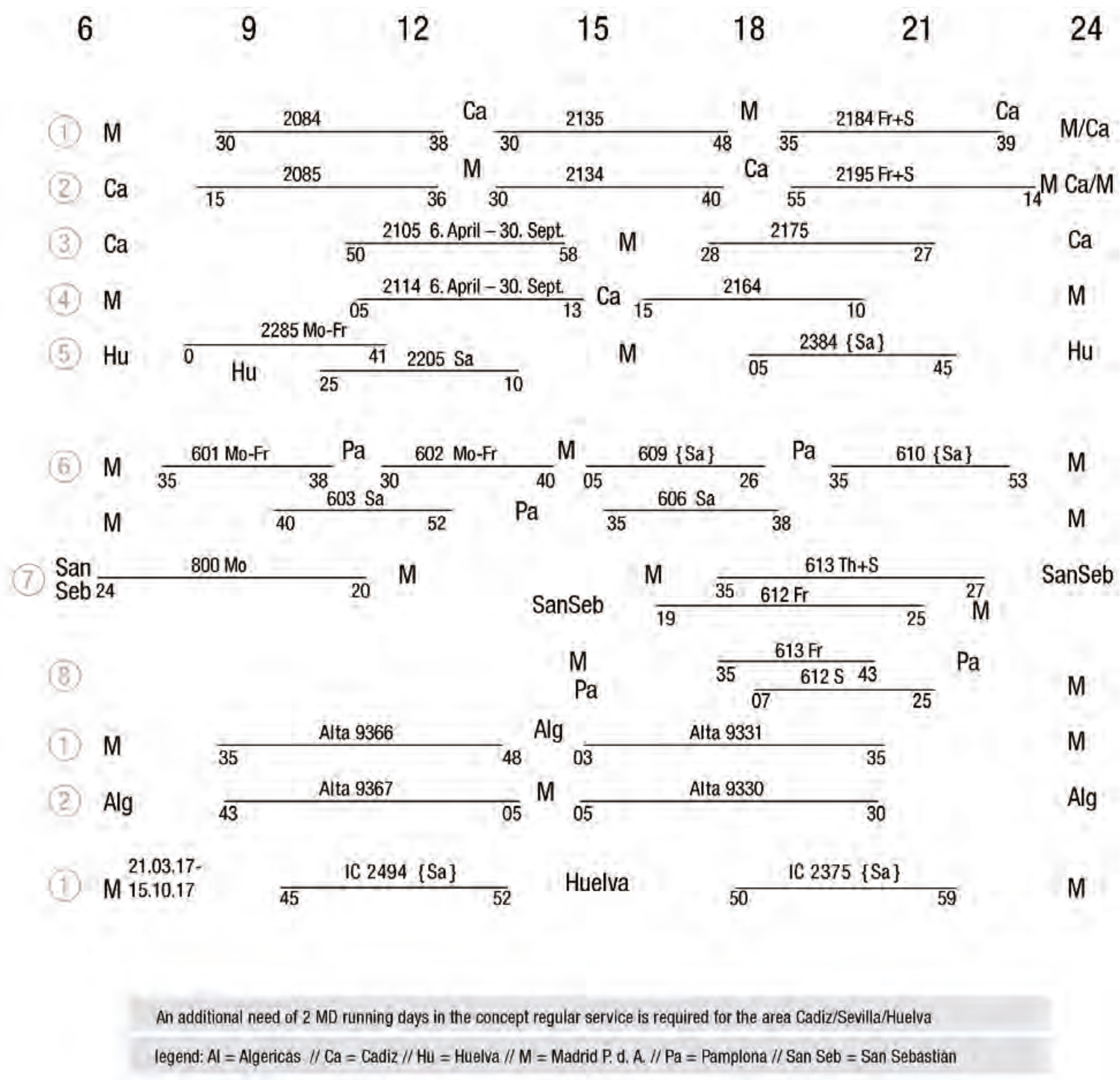


Figure 14. Overview about the Alvia- and Alta running days, which can be saved in a regular service concept

Figure 14 presents the number of Alvia and Alta train sets, which shall be saved by an intensive use of the 300 km/h fast EMU's. Because these EMU's run also beyond the 1435 mm AVE network the replacement of these EMU's must refer the new need of the MD running days in this area. Two additional MD running days are needed in the area Cadiz/Sevilla/Huelva.

3.10.6 Survey about all additional infrastructure facilities needed for a strict regular service

All measures, which are necessary to upgrade the infrastructure of the Madrid - Sevilla AVE line from 250 km/h to 300 km/h, come first. When the author returned on Saturday 07.10,2017 from Ciudad Real with train AVE 3993+3943 he could watch that the train for a very short time was running 298 km/h in the section between Ciudad Real and Madrid. Secondly the signalling system on the different AVE lines and the maintenance facilities must allow a rolling stock roster presented in figure 11. Thirdly the infrastructure approaching Madrid P.d.A, must allow a track occupation diagram presented in figure 10. Fourthly a short new high speed connecting line in the area SW of Córdoba is necessary, to allow a fast direct travel Sevilla - Antequera Santa. At least an upgrading of the infrastructure in some interchange stations is necessary, in order to make more convenient the changing procedure.

3.10.7 Overview about the main results with influence on cost-benefit ratio

A strict regular service with at least a service every hour allowing a high commercial speed for a maximum of passengers shall boost passenger demand. For this an increase of 98% for the train kilometres is designed. Although this goal is envisaged the alteration of the train sets needed for the proposed regular service reads as follows: an additional need of 15 running days capable of running 300 km/h and two MD running days is faced to a reduced demand of in total 15 Avant, 8 Alvia, 2 Alta and 1 IC train sets. Further the 3 gauge changing constructions facilities in Antequera Santa Ana, Sevilla-Majarabique and Zaragoza could be saved. All these criteria together could decisive improve the cost-benefit ratio of the AVE traffic.

4. Conclusion

The present AVE timetable contains too much recovery time in the running time of the AVE trains as well as in the stopping time at the stations. RENFE should give up the strategy to reimburse the passengers for the tickets if an AVE-train arrives with a certain delay at the final destination. RENFE should rather make all efforts to shorten the travel times. The top most goal of high speed rail is to provide the highest possible commercial speed for a maximum of passengers. This goal includes a strict regular service and leads to a lower load factor beyond peak times. For this RENFE should use the Market pricing strategy in order to raise demand in these times and maximize revenues [9]. By of all these criteria RENFE should be able to improve the cost-benefit ratio of the AVE traffic considerably.

5. Brief

Brief comment to the AVE network (important comment: this chapter is upgraded and completed **after** attending the high speed congress in Ciudad Real)

This brief addendum belongs to this research. In figure 15 the present AVE network development is shown. At present the extension of the AVE network gears to the Northwest region of Spain. But for this strategy we must state the following statements:

Madrid - junction Olmiedo will be the trunk section for all trains from NW Spain bound for the capital Madrid.

1. In the European Railway Timetable, valid from June 2017, in the three tables 679, 679a and 680 in total 39 trains per direction could be counted out departing on Friday from Madrid Charmartin to this junction. This number of 39 trains now must be distributed to

the different destinations Salamanca, Santiago de Compostela, Gijon, Santander, Bilbao and San Sebastian. The result reads 39:6 =7 trains per day and direction. Although a future higher traffic demand can be expected we can surely assume that during a 14 hour service not even every hour a high speed train will be running per hour and direction.

2. And from these 39 trains at present only two are high speed trains capable of running 300 km/hand more (AVE 4099 and 4209); all the other trains (Alvia, Avant and IC) are only running max 250 km/h or less (IC). But the high speed lines in Galicia are all designed for a speed of 350 km/h.

3. Due to this expected very low use to capacity the new AVE line Palencia to Léon it is built as a single track line in sections, The 162,7 long AVE line from Valladolid to Léon comprises 78,7 km of double track and two single track sections totalling 84 km[10]. The line is designed for a speed of 350 km/h. By these results and all other new AVE lines in Northwest Spain someone only can come to conclusion that these measures never will receive a positive costbenefit ratio for the AVE traffic.

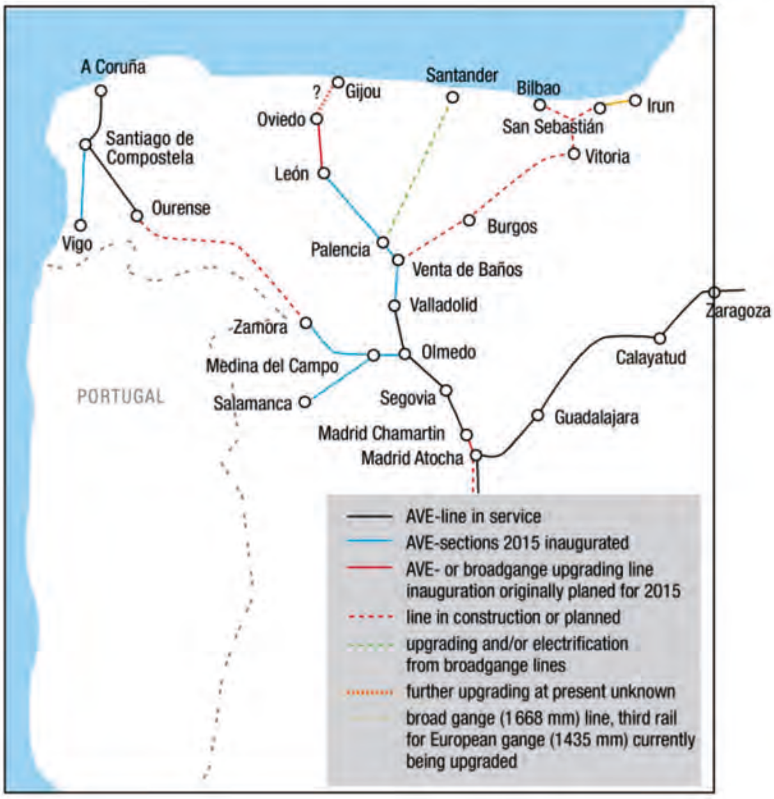


Figure 15

When a foreign expert looks at the Spanish high speed network he is wondering about the subject that no high speed line is planned between the second largest city in Spain, Barcelona, and the third largest city, Valencia. This becomes clear, when someone studies the information given on page 32 of the brochure "25 years of Spanish high speed rail" (in English) which was published from the *Spanish Railway Journal Vía Libre*. The criteria normally given for constructing a new high speed lines as improvement in quantity and quality for the passenger service by switching from the classic line to the new high speed line and making free capacity for the freight traffic on the classic line are obviously not given - at least in a necessary scope - on all high speed lines currently under construction in Spain. But these criteria would apply to a new high speed line between Barcelona and Valencia, exactly between Camp de Tarragona and Valencia. So a foreign expert can only agree with with Catalan and Valencian businessmen,

when they urge Spanish Government to build Mediterranean Railway Corridor. When a Spanish countryman argues: *"This situation occurs in a country with the second-longest High Speed network in the world, 80% of which is useless."* [11] so should every Spanish railway expert this statement making thinking even if he disagrees with this opinion.

In the author's opinion upgrading of Madrid - Sevilla high speed line to a speed of 300 km/h gains highest priority concerning the development of Spanish High Speed network. The introduction of a strict regular service belongs together with this step as described.

After this the introduction of a strict regular on all AVE lines gets highest priority. This important goal shall finally be demonstrated by the train diagram of the Madrid - Barcelona high speed line, see figure 16. Zaragoza Delicitas could become an important interchange station in the Spanish network, where train from direction and reverse direction meet each other every two hours at minute "0". Someone should imagine that also the trains in the classic network from Huesca and Logroño or even Teruel could arrive every two hours about minute /.50 o'clock and leave the station about minute /.10 o'clock. By such a timetable scheduling optimal connections in all possible directions in the interchange station Zaragoza Delicitas could be provided.

And last but not least the signalling system must provide 3 minutes headway. 3 minutes headway is an international standard for all highs peed lines in the world. A signalling system, which doesn't allow a departure of two trains in a 3 minute space, doesn't fulfil its purpose. And a departure of two trains in a 3 minutes space or arrival or the main terminus station is even urgent necessary as figure 16 proves.RENFE should make all effort to reach the timetable train diagram goal as demonstrated in figure 16.

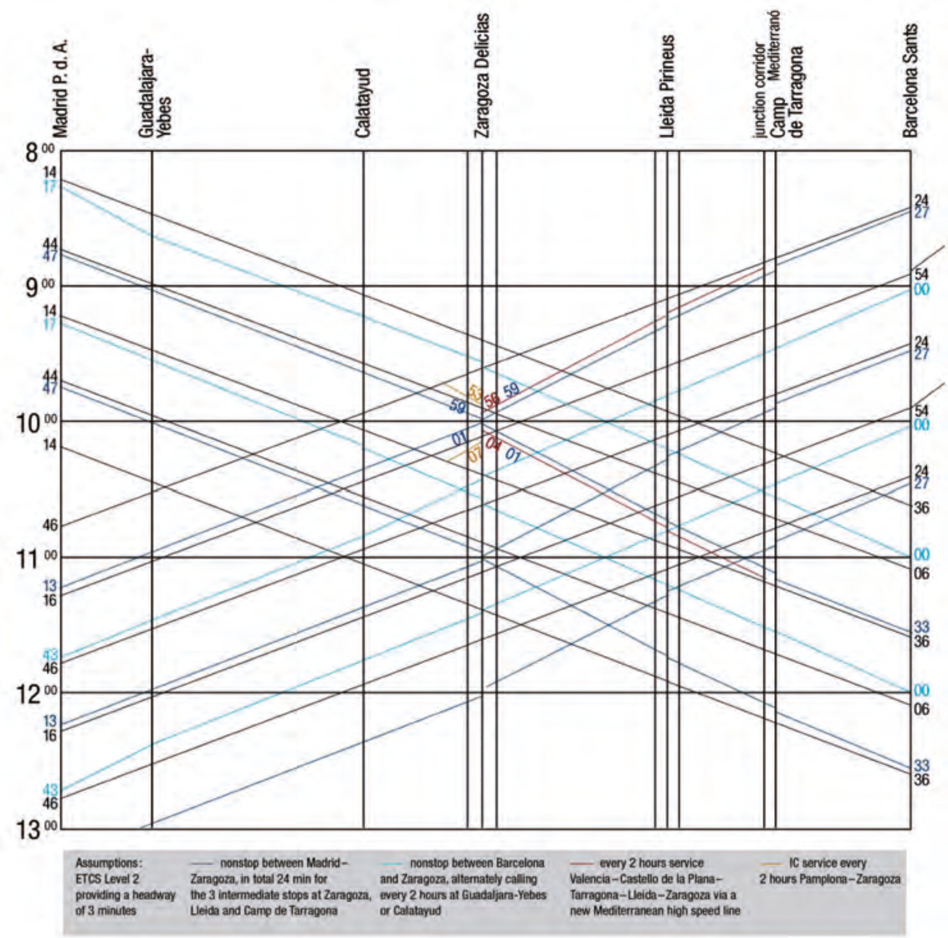


Figure 16. Train diagram goal for the Madrid - Barcelona AVE line

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General and network aspects of HSR

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High Speed Railway in Saudi Arabia: Lessons to be learnt from the Spanish experience

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Abstract

With 25 years of experience, Spain has the largest High Speed Railway (HSR) network in Europe. Taking advantage of this experience, a Spanish consortium was awarded a €6.7 billion contract to construct, operate and maintain the second phase of the Haramain HSR line in Saudi Arabia, as well as the supply of trains and their maintenance for a period of 12 years. For the transport and geographic characteristics of Saudi Arabia, the Spanish HSR is a good example to look at. A comparison of the main topics that can influence HSR development and demand is done including geography, economy, institutional and legal framework and transport characteristics. Even though this kind of comparison was difficult due to a different culture and the development of the country some lessons can be learned.

First, the know-how gained by construction firms and the infrastructure manager has helped drive down costs and is the key to overcoming the challenge of HSR under extreme climate circumstances.

Second, although HSR demand mostly relies on the evolution of national income and the transport system competing with train, Train Operating Companies have control over influencing variables (such as commercial speed, prices or frequencies) and therefore must have freedom to adapt their strategy to increase demand and revenues.

Third, there are difficulties to predict demand and although rapid traffic growth can be expected it seems doubtful the Haramain HSR line will reach 60 million users per annum in 12 years.

Finally, due to the high risks involved in the project a greater understanding by the parties of each other's' position is crucial to its success: Saudi Arabia will gain expertise in the development and operation of HSR and will be able to attract international funding in the future, whereas Spanish companies will benefit by improving their technology and the possibility of exporting its know-how to other countries.

Keywords: Country com-parison, high-speed rail, Spain, Saudi Arabia

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1. Introduction

High Speed Rail (HSR) was defined services as being provided on dedicated, new line with the infrastructure capable of operating speeds of 250 kilometres per hour and up to 350 kilometres per hour. Moreover, there are multiple objectives of HSR such as speed, capacity, reliability, prestige, economic development, etc. (Preston, 2014, 2017). On the first of October 1964, Japan started to operate the first HSR line in the world, the Tokaido Shinkansen from Tokyo to Osaka with a distance of 515 kilometres using a standard gauge (1,435 mm). This line was built to enhance capacity to the transport system, which was necessary for the Japanese economy as rail had become the main transport mode of passenger in Japan. Moreover, the Tokaido Shinkansen was designed to operate at a speed of 210 km/h using electric motor units powered at 25 kV ac. By 1977, Italy started the operation of the Direttiissima services in Europe, followed by France at a maximum speed of 260 km/h (TGV, 1981), Germany (ICE, 1988), TGV Atlantique (1989), Spain (AVE, 1992), Belgium (1997), United Kingdom (HS1, 2003), South Korea (KTX, 2004), Taiwan (2007), China (CRH, 2008), and Netherland and Turkey (2009). In 2007, the world highest speed record was achieved in France at 574.8 km/h, while the total HSR lines in the world extends over 37,964 kilometres by 2017, as there are about 14,973 km under construction. Many countries are nowadays developing HSR in the world. For example, China has implemented approximately 23,914 kilometres of new HSR lines, which is more than half of the total HSR lines in the world. Other countries are developing HSR lines: Morocco, Saudi Arabia and the USA (UIC, 2017) are the most remarkable examples. For the transport and geographic characteristics of Saudi Arabia, the Spanish HSR is a good example to look at. Apart from this brief introduction, this paper contains four further sections. The following section offers the evolution of the Spanish HSR. The background for the Saudi Arabia HSR is provided in section 3. Section 4 shows a comparison of the main topics that can influence HSR development and demand: geography, economy, and legal framework and transport characteristics. This is followed by the policy lessons raised from the research, which might be useful for regions attempting to develop HSR. Although the conclusions are based on the comparison done here, these lessons can be applied to any developing region with similar characteristics.

2. Background of the Spanish HSR

Nowadays, Spain has the largest HSR network in Europe accounting for 2,938 km in service in 2017 and expected to reach 4,903 km once the whole network is completed. It is the second largest in the world after China. On 21st of April 1992 the first HSR line, Madrid – Seville entered into service. The very first year of operation 1.3 million travellers used the new line. Thanks to the new lines that entered into service gradually mainly since 2008 and the new pricing scheme prompted by Renfe (State-owned Train Operating Company) in 2013, in 2016 there were almost 60% more passengers travelling on the entire network than in 2012. HSR average commercial speed is 222 km/h, 99% of HSR trains arrive on time. Before the development of the HSR, the commercial speed for the majority of the lines was around 90km/h, so thanks to HSR the commercial speed has been at least doubled on all the lines. In 2016 HSR was used by 35.2 million passengers which represents a rise of 5.3% with respect to 2015 and its occupancy rate was around 80%. HSR has helped to promote regional cohesion by providing higher accessibility improvements to the peripheral cities than to central cities (Monzon, Ortega and Lopez, 2013), to modernise railways in Spain, to foster economic development, and is an environmentally friendly transport mode. Spatial equity was one of the main reasons to promote HSR in Spain. However, HSR has also disadvantages such as the huge investment necessary to build the infrastructure, the high maintenance costs and the low demand in many corridors that makes difficult to justify some investments from a socioeconomic point of view (Betancor and Llobet, 2015; De Rus and Nombela, 2007), although support for investment in HSR cannot rely only on expectations of economic benefits (Givoni, 2006) and must be part of a broad transport planning. One of the differential characteristics of Spanish HSR is that the average cost per km is cheaper than in other European countries (SDG, 2004) ranking from the initial investment of €5.91 Million/km (1992 prices) of Madrid- Seville to the most expensive of €28.9 Million/km (2012 prices) in Galicia, in the stretch Ourense – Santiago where due to the uneven orography it was necessary to build 31 tunnels, 29.3 km underground, and 38 viaducts, to a total of 20.4 km. The Spanish infrastructure manager, Adif, has also reduced maintenance costs per year and km and efficiency gains are also achieved in the construction of new HSR (Fernandez and Vazquez, 2012). In fact, in the period 2009 – 2017 Adif report a 33% decrease in maintenance costs. Transition areas between bridges and embankments and short rigid structures were found to have the highest deterioration in the Madrid – Seville line (Lopez et al., 2007). Therefore, some changes in the design were required. The reduction of the maximum vertical force exerted by wheels on the track, the reduction of track's vertical stiffness and finally the increment of the minimum radius to 7,000m after the first HS line explain these costs reductions (Lopez and Robuste, 2003).There are therefore economies of experience and economies of scale once the network is being developed that help reduce costs. HSR has been the means of transportation where the Government of Spain has invested the most over the last 25 years with more than €51 Billion. Moreover, after joining the EU in 1986, Spain took advantage of European funds, with around 20% of the investment paid by these funds.

From a technical perspective, the Spanish HSR is broadly regarded as a success, since it helped to improve the service standards and the quality of infrastructure and rolling stock. To have an idea of the know-how and experience gained with the HSR; it is remarkable that in the last decade Spanish construction companies have exported projects for a value of around €10 Billion, including projects in USA, Norway and especially Saudi Arabia.

This first HSR line, Madrid – Seville, linked both cities in 2 hours and 55 minutes compared to the formerly 7 hours required. Seville is the country's fourth largest city and had been elected to host the 1992 Expo World's Fair and through this investment the economy of the south region was expected to be stimulated. The infrastructure also connected the intermediate cities of Ciudad Real, Puertollano and Cordoba. One year later the maximum commercial speed was increased up to 300km/h and the travel time was reduced to less than 2hours and 30 minutes. The effects on the transport system on that corridor were large: the share of the train rose from 14% to more than 43% mainly at the expense of the airplane and by capturing additional users as well.

In 2003, the stretch Madrid – Zaragoza in the line Madrid-Zaragoza - Barcelona was opened at a reduced speed of 200 km/h due to the lack of the European signalling system, known by its acronym ERTMS (European Railway Traffic Management System), and some geotechnical issues in the first years. In 2006 and thanks to the ERTMS, the commercial speed was increased to 250 km/h. Only one year later, in August 2007, there was a new increment to 300 km/h. By the end of that year, two new stretches entered into service: Madrid – Valladolid and the stretch Cordoba – Malaga in the Northwest and South corridor, respectively. The HSR to Barcelona, the second largest city in Spain, was inaugurated in February 2008. Again, the effect on the competition with the airlines was enormous. The HSR increased the market share of trains in that relationship from 12% to 47%, and reduced the share of the airlines to 53%. The year 2012 was the first in which HSR transported more users than air transportation (2.688 Million users vs. 2.573 Million users) on this corridor. This trend was consolidated in the period 2013 – 2016 with HSR market share around 60% and the remaining 40% for airplanes (62.4% of the corridor for the HSR in 2016). The new pricing scheme implemented by Renfe in 2013 helped this consolidation.

In December 2010, the connection between Madrid and the third most populous city in Spain, Valencia, entered into service, reducing the travel time by train from 7 hours to 1 hour and 35 minutes. In this origin-destination pair, the modal share of the train grew from 12% to 46%. The share of air and bus transportation went down from 17.4% and 9.2% to 2.6 and 3.1%

respectively. This HSR line also connected small cities such as Cuenca and Albacete to Madrid. In 2011, the speed for Madrid–Barcelona was increased to 310 km/h to become the fastest commercial speed in the network. The same year the stretch Orense – La Coruna in the line to the northwest was opened. In June 2013, the stretch Albacete–Alicante opened, with a length of 165 km. In September 2015 the stretch Valladolid – Leon of 166 km came into service. This stretch was designed to operate at a maximum speed of 350 km/h but the ERTMS system is still being installed and tested, so this branch has used ALFA signalling system in 2016 and its actual maximum speed is 200 km/h. Finally, in 2016 the stretch Olmedo (Valladolid) – Zamora (in the HSR to Galicia) was opened.

Due to the concerns about lack of demand and low occupancy rates, in February 2013, Renfe implemented a new pricing scheme which reduced ticket prices by at least 11%, and introduced flexibility in their purchase in order to boost the usage of HSR. This pricing scheme is similar to the Yield Management technique used in airplanes, which sets the price depending on the hour of the day, the category of the user (i.e. first class or tourist), the demand expected, and how far in advance the booking is made. The year after the introduction of the new pricing scheme, the revenue was increased by 6.7% and the average occupancy rate of HS trains rose from 66% to 74.3%, so it met the initial objective of boosting the demand and increasing travellers by train. The economic growth since 2013 and frozen prices by Renfe boosted this tendency, this occupancy rate has been hugely improved and is above 80% in 2016. Despite the small increase of 1% tickets price in 2017 according to Renfe demand is growing at 4.5% on average in the first half of 2017. The effect on corridors with high demand and competing with airplanes was more remarkable than on corridors with low demand (Ortega et al., 2016). Madrid – Barcelona and Madrid – Seville corridors have almost reached their capacity (i.e. occupancy rates above 90%) and more trains will be necessary in the upcoming years to cope with demand expectations. These new trains are supposed to enter into service by 2019.

The last milestone reached by the Spanish HSR was by late 2016 when Renfe officially awarded Talgo Company to modernize and extend its fleet. The main objective of the bid is to adapt Renfe to the upcoming liberalisation in 2020 and at the same time keep the reduction of prices aimed at gaining market share. The bid was composed of two parts, economic and technical, and four companies made their bids: Talgo and CAF from Spain, Siemens from Germany, and finally, Alstom from France. Talgo won the competition with 94.6 points (29.6 points in the technical and 65 in the economic) with the Avril train. The high capacity of the Avril (521 seats) implies at least a 30% increase in the offer of seats per train compared to the existing trains. The actual maximum capacity is 407 passengers and corresponds to the trains that entered into service in 2007, whereas the first HS trains from the nineties can carry up to 321. The composition of 5 seats per row in the tourist class is similar to the already existing composition in many airplanes and makes this increase possible. The greater capacity and lower cost and consumption will allow Renfe further reduce ticket price.

3. Background of Saudi Arabia HSR

The Haramain High Speed Rail (HHSR), also known as the Western Railway, is the Middle East's first HSR line linking two Muslim holy cities, Makkah and Madinah, in Saudi Arabia with a total distance of 453 km. The majority of this distance corresponds to the main link between cities, whilst there is a branch of just 3.75 km connecting to King Abdulaziz International Airport (KKIA) in Jeddah. The line will also pass through Jeddah and King Abdullah Economic City (KAEC) in Rabigh and connect with the national network in Jeddah. This HSR double track line will be electrified with a maximum operation speed of 300 km/h, and will reduce the journey time to 2 hours and 30 minutes (less than 30 minutes from Makkah to Jeddah, and about two hours from Jeddah to Madinah). The main motivation to develop HHSR line was to address the transportation needs of a growing number of seasonal pilgrims to Makkah, performers of Umrah and the people of the city. The estimated demand is quite high, with 60 million passengers per year (Arabnews, 2017). The city of Makkah attracts about 2.5 million pilgrims during period of Hajj every year as well as more than 2 million of Umrah performers during the month of Ramadan and seasonal holidays and a heavy passenger traffic during Fridays. Due to the safety and comfortable transport, the HHSR is seen by the Saudi Arabian government as the best option for the pilgrims, and it will help reduce traffic congestion and accidents on the roads linking Makkah and Madinah. The design and construction of this project will help it to withstand heavy traffic conditions and tough climate, while the track, rolling stock and stations will be designed to handle the temperature change up to 50°C. Due to this environmental conditions, slab track was chosen as the best option for this country, unlike Spain where due to the lower initial investment requirements, ballast track is largely installed (i.e. only in a few special sections such as tunnels or bridges slab track is installed). Partial operations on the HHSR line would begin in December 2017 whilst the service full opening will be in March 2018.

The Saudi Railway Organization (SRO) is responsible for the HHSR project with allocated a budget of over €12 billion of public investment in terms of its completion. The project of dunes, sands and strong winds involves in two phases, with Phase 1 that was awarded in 2009 and divided into two packages. The first package in phase 1 was awarded to Chinese-French consortium for €1.48[1] billion which includes the civil works of the track such as construction of viaducts, bridges, subways, tunnels, shafts, retaining walls, and embankments). The second package was awarded to Saudi Bin Laden and Saudi Oger, which consists the construction of the five stations- Jeddah central and KAIA in Jeddah (€631.8 million), Makkah central in Makkah (€692.5 million), King Abdullah Economic City in Rabigh (€381.2 million), and Knowledge Economic City in Madinah (€336.8 million). Moreover, the design contracts for the stations was awarded to the FosterHappold Joint Venture (FHJV) in 2009 for €30.9 million, which have adopted for designing a modularised approach with aesthetically iconic designs and taking into account Islamic architectural traditions. Moreover, all stations will have a separate distinctive design and same planning strategy as well as different arrival and departure zones will be provided, while the public areas of stations will be environmentally controlled along with the platforms to provide comfort. On the other hand, Phase 2 of the project has been awarded to the Spanish consortium "Al-shoula Group" in 2011 for €6.7 billion, which includes Adif, Copasa, Imathia, Consultrans, Ineco, Cobra, Indra, Dimetronic, Inabensa, OHL, Talgo, Renfe, and the Saudi companies Al-Shoula and Al-Rosan. It consists of the remaining infrastructure and related tasks that were not included in the first phase such as the study of the market, assembly and supply of railway track, and installations of electrification, communications, signalling, power, etc. It also includes the supply and maintenance of rolling stock, and the operation and maintenance of the line for a period of 12 years. Talgo will supply 35 trains with a capacity of 500 passengers for each train, while there is a possibility of requesting additional trains due to demand. Moreover, this phase 2 is divided to two parts; the first part involves the construction of the superstructure (i.e. track, catenary and signalling systems), the supply of rolling stock and the commissioning of the line which will take about 4 years and 3 months. The second part relates to the operation of the line and the maintenance of rolling stock for 12 years, while Renfe and Adif will operate the trains and manage the line.

Finally, some dynamic tests are being developed in a satisfactory way, in extreme environmental conditions, with very high temperatures close to 50°C and with the presence of desert sand, proving the good response of the trains in such conditions. The maximum speed of operation of 300 kilometres per hour was reached in July 2017. This test are being carried out in 370 kilometres of the line, 80% of the route.

1 *Convert rate used in the paper 1€=1.22$*

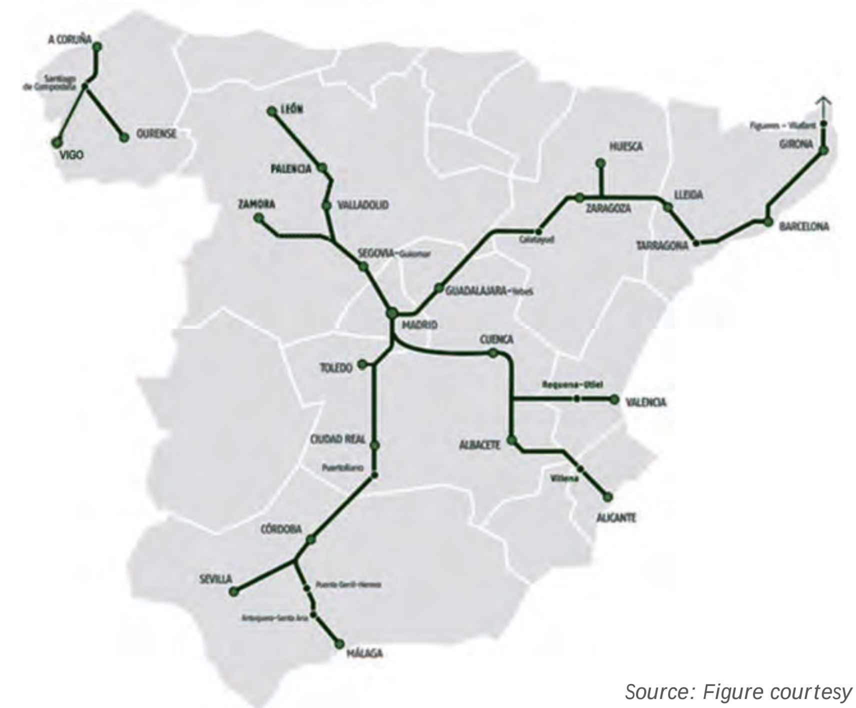
4. A comparison between countries: geography, economy, legal framework and transport

This section is split into four subsections. The first one offers a comparison between the two countries in terms of the geography and distances between main cities. The second one replicates the same comparison but for the economy of both countries. The third subsection explains the institutional, legal and procurement framework in Spain and Saudi Arabia. The last subsection shows the transport evolution of Spain since the HSR entered into operation and the interurban transport system in Saudi Arabia.

4.1 Geography

Spain is located in Southwestern Europe, has a population of roughly 47 million people, an increase from 39 million inhabitants in 1992. Despite this, the density is only 92 inhabitants per square km which is quite low compared to other European countries. The majority of the population is sparsely distributed except for two areas: Madrid located in the centre of Spain and along the coast. Moreover, Madrid is 700 metres above sea level, whilst the remaining major cities are at sea level. That makes the profile of the HSR lines more difficult than other European countries where there is no need to serve this natural level difference. Figure 1 provides the HSR network by the end of 2016. The distance between the most important metropolitan areas in Spain (Madrid, Barcelona, Valencia, Seville and Bilbao) is between 400 and 700km, which is believed to be a good distance for the development of HS. That is, lower distances do not justify HSR because of the completion with car, whereas larger distance are very difficult because of the competition with airplanes. Rothengatter (2011) noted that strong competition between air transport and HSR can occur on routes with distance up to 1,000 km, but this is most likely between 400 and 800 km. Therefore the main transport networks (highway and conventional rail networks) have a radial typology, with the centre on the country's capital, Madrid. The HSR network follows the same structure, linking Madrid with the most populated cities (Barcelona, Valencia and Seville).

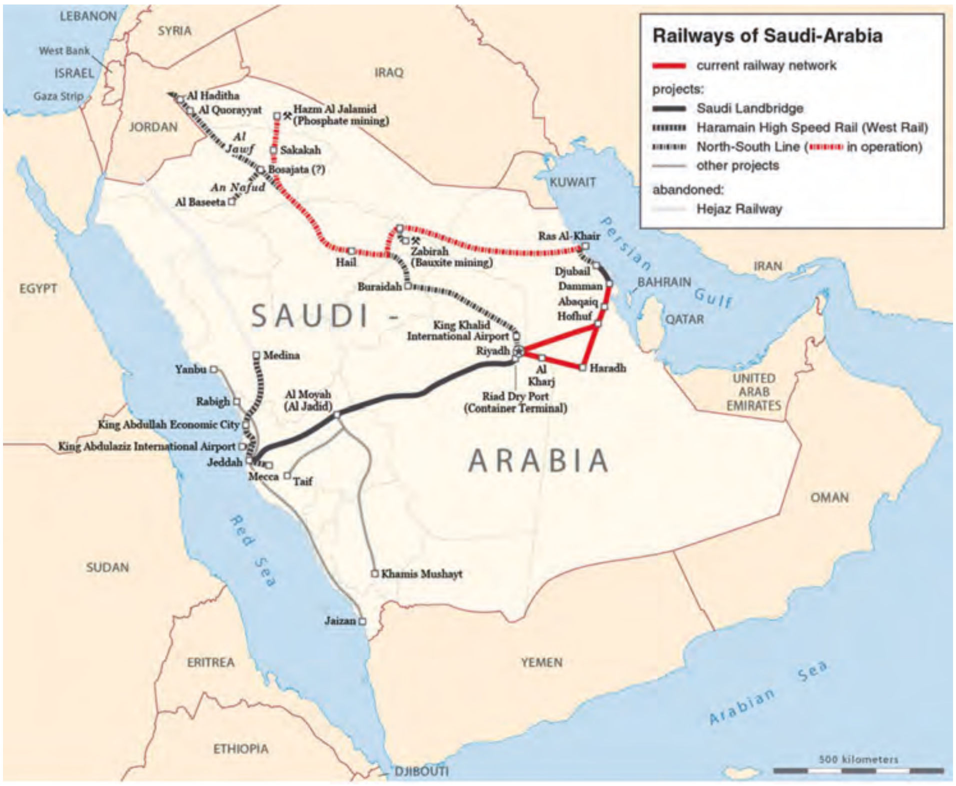
Figure 1. Spanish HSR network by 2016



Source: Figure courtesy of Adif, 2016.

Saudi Arabia is located at the furthermost part of south western Asia and has a diverse topography because of its large total land area of 2,143,865 km^2. It includes a coastal plain in the east which is 610 kilometres long and consists of large sand areas and Salinas. It also includes the Empty Quarter in the south-eastern part of the Kingdom having an estimated area of 640,000 square kilometres composed of sand hills and lava fields. Storms of sand are very frequent and this is one of the main challenges to develop HSR in the country. The population of Saudi Arabia is expected to reach 33 million people by 2017, from nearly 28 million in 2010, which is an average annual increase of 2.54%. The density is 16 inhabitants per square kilometre which is even lower than in Spain.

Figure 2. Plan and existing railways in Saudi Arabia



Source: Figure courtesy of Maximilian Dörrbecker, 2009.

Some important similarities arise from the comparison: both populations are sparsely distributed and concentrated in some cities, with overall low density but inter-urban distances good enough to be covered by HSR, and some topography features that make the development of HSR a challenge. There are also other differences that makes the development of HSR in Saudi Arabia a tough challenge, such as the even lower population density in Saudi Arabia than in Spain and storms of sand in some stretches of the future HSR.

4.2 Economy

When Spain joined the European Union, it lagged far behind the average of the European countries in terms of the most relevant macroeconomic indicators such as income per capita, public capital stock, inflation, interest rates, and unemployment rates. After joining the European Union the improvement of Spain's economy was remarkable. This effect was exceptionally good after Spain began using the single currency in 1999. The development of the HSR network contributed to the Spanish's boom of the economy. The Spanish GDP (Gross Domestic Product) per capita grew by 103% from 1992 to 2016 (€25,696 in 2016), which is an average annual growth above 3%. Income distribution across the population also improved, and the Gini index (i.e. degree of inequality in the distribution of family income in a country where higher values means higher inequalities) in 2015 was at 34.4. The economy relies heavily on the services sector which accounts for 75% of the GDP (this figure was 61% in 1992), whereas industry accounts for 17% of the GDP (down from 25%), constructions provides 5.5% (9% in 1992), and the remaining 2.5% of the GDP is based on agriculture and fishing activities (down from 5%). Tourism is crucial for the economy since it accounts for around 12% of the GDP. For instance, in 2016, more than 75 million people travelled to Spain, spending €77 Billion.

Due to the high prices of oil in recent years, the economy of Saudi Arabia has grown very strongly, while the rising oil prices and production has resulted in large external and fiscal surpluses. The Saudi Arabian GDP per capita was recorded at €17,481 in 2016. The Gini index was 45.9 in 2013, which was still below other developed countries (Trading Economics, 2016), but higher than in Spain. In 2016, the Saudi economy grew by 1.4% and the nominal GDP per capita at purchasing power parity was €41,227 whilst there is significant impact in reduction of oil prices. This figure was €27,176 in Spain, proving that prices are higher in Spain. Saudi Arabia was the second largest oil producer in 2015 with around 11% of global output and has the largest oil reserves in the world, within over 264 billion barrels. In fact, the importance of oil and mining decreased from 46.47% of the GDP in 2005 to 25.45% in 2015. In this case, the Saudi Arabia has responded to the oil prices crises by announcing its vision 2030 to reduce the dependency on oil and shift its focus on other sectors including education, tourism, transport, etc. Religious tourism is one of the main growth factors of the tourism industry in Saudi Arabia, as it has the two religious cities of Makkah and Madinah. However, the value of the tourism industry in 2015 was €17.42billion, with €4.64billion coming from the religious tourism sector and it is expected to contribute between 5.4% and 5.7% in 2025 of the total non-oil GDP of the country (Pinter, 2014).

As in the previous subsection there are some common points and some differences between both countries. Despite some economic turmoil in the period both countries have enjoyed buoyant growth and have redirected their economies to make them more services-oriented. The main differences arise in the GDP configuration and how income is distributed across population. Whereas Spain is a country with a developed economy, services-oriented economy and with an income distribution similar to other Mediterranean countries, that is not the case in Saudi Arabia. Apart from GDP growth, two topics could influence future HSR demand. Firstly, the economic structure of a region with regions where the economy is based on tertiary and administrative tasks with higher demand than industrial related economies (Garmendia, Ureña and Coronado, 2011). Secondly, the effect of tourism on HS demand. Tourism has helped boost HSR, particularly in cities with strong tourism activities (Campa, Lopez-Lambas and Guirao, 2016). However, the opposite is not necessarily always true as there are examples of both cases, where HSR stations helped attract more tourists and where HSR stations did not have any influence on visitors (Albalate, Campos and Jimenez, 2017).

4.3 Legal & institutional framework

4.3.1 Spain

Transport infrastructure in Spain is delivered through two approaches. The first one is the so called Contractual PPPs, where the best-known model is the concession model, which is characterized by the direct link between the private partner and the final user (Commission of the European Communities, 2004). In this approach the remuneration for the contractor will consist of charges levied to the users that may be supplemented by subsidies from the public authorities. Concessions have a long tradition in the Spanish legal framework, have been particularly used to construct highways, and have been characterized by the allocation of considerable risk —demand, acquisition of the right of way and financial risks— to the private sector in the contracts; but also by important guarantees by the government (Ortega, Baeza and Vassallo, 2015).

The second approach to deliver transport infrastructure is the Design-Bid-Build (DBB) or DesignAward-Build (DAB) where the public administration develops contract documents with an engineer consisting of a set of plans and a detailed specification. Based on these documents the contract is then awarded to the bidder with highest qualification. This is done largely on the basis of an "open procedure." Unlike other long-term infrastructure contracts in the world —i.e. Design-Build-Finance-Operate contracts in the UK, and most of the PPP contracts in Germany— (Tang, Shen, & Cheng, 2010), public works in Spain are hardly ever awarded by means of a negotiated procedure.

This open procedure means that any company that fulfils the minimum requirements set out by the government in the tender provisions is allowed to participate in the process. The government chooses the winner in terms of a set of criteria —both economic and technical— according to which the offers presented by different bidders are qualified. Contracts are not negotiated in this approach since the government submits standard contracts to the bidders along with the bidding terms. This was, for instance, the procurement process used in the new HSR trains awarded by Talgo.

Sanchez and Gago (2010) prove that the transaction costs of the open procedure, for both bidders and the government, are much lower than those of the negotiated procedure. These low transaction costs are likely the most important reason why the number of participants in the tendering processes in Spain is often quite large (Vassallo & Sánchez, 2007). However, most of the construction companies are well-known Spanish firms since the lack of publicity and transparency of the tendering and awarding processes in Spain creates strong barriers that prevent foreign companies to compete fairly. Despite this problem, the construction cost of HSR in Spain is cheaper than in other European countries, which could be explained by labour cost, the existence of less-populated areas outside the major urban centres and also by the construction procedures (Campos and De Rus, 2009). The long experience of Spanish companies in public works, which have enjoyed competitive advantages against their competitors, could also partially explain the technological and scientific innovations developed in Spain linked to the HSR market (Guirao, 2013).

4.3.2 Saudi Arabia

Saudi Arabia is one the fastest growing markets in the world and considered as the largest construction market in the Middle East. The value of projects that were announced by King Abdullah during the G20 summit on 14-15 of November 2008 in Washington was €333 billion to guarantee finance for development projects, including different sectors such as transport, utilities, infrastructure, healthcare, education, etc. (Alrashed *et al.*, 2008). However, the largest allocation for the 2015 budget was paid toward the transport and infrastructure sectors of €155.44 billion to complement the growth and development across Saudi Arabia. On the other hand, construction is the largest non-oil sector in Saudi Arabia and many mega projects are anticipated to be launched in the next year, including Haramain High Speed Rail, North-South Rail, Riyadh Metro, etc. In this case, Saudi Arabia has experienced problems that have caused delay in many projects. Alofi et al. (2016) mentioned that the procurement system is one of the major factors that affect the construction performance in Saudi Arabia. There are three different types of the Saudi Arabian procurement system, including public procurement competitions, and direct and specific purchases. The public procurement competitions have the majority of acquired purchases whilst projects under this category starts with the first phase of submitting the proposal that cannot be less than 35% below the project budget (market prices), including sending an announcement to all competitors regarding to the date of the pre-bid meeting, the location where the bids will be opened and the deadline of submitting bids. The selection phase will start directly after opening all the bids at appointed date and location, as the main factor of this phase is determining the winning contractor who has given the lowest price. The final phase is the proposals formulation and all the documents include in this phase, including contracts, project specifications, time of the tasks, drawing, and correspondence need to be in Arabic if possible, but another language such as English is accepted by the Ministry of Finance (Alofi et al., 2016). Alkharashi and Skitmore (2009) found out that construction project delay is considered to be one of the most serious issues in terms of follow on consequences in Saudi Arabia, which affects the direct costs of the project. In Mecca, 37% of construction projects were believed to be delayed by contractors whilst 84% of all projects that were under the supervision of the consultants had serious delays (Elawi et al., 2015). In fact, the Spanish companies wanted to extend the deadlines of the work due to the delays accumulated by the Sino-Saudi consortium in charge of phase one which included the construction of the platforms. In addition, they claimed for the Saudi Arabian Government to pay a series of extra costs for the unforeseen events that arose in the course of the work. Finally, the consortium believes the expected demand is overestimated by 30% and the loss could be up to €1 billion so it is an important risk for the companies. Initially, Saudi Arabia was reluctant to negotiate more funds because the original contract did not include the payment of extra costs, but neither the extra developments nor stations that have been finally constructed. Moreover, there are budget constraints due to the fall of the price of oil. Nonetheless, the Saudi Arabian Government finally seek a comprehensive solution to all project problems. So an agreement was reached to pay an extra cost of €150 million and to extend the work 14 months to finish the phase 2. The pact also acknowledges that delays in the work are attributable to the delay of phase one, which is in charge of the Sino-Saudi consortium. In this way, Spanish companies were exempted from the penalty for delay fixed by the contract. Although after the agreement the official date of completion of the works is set for the end of 2017, some stretches could be inaugurated sooner. The start-up of the corridor will be progressive, so that some stretches of service in the upcoming months.

In terms of the political, Saudi Arabia is divided into 13 administrative regions, with a Prince who performs the role of the governor (Chairman) and deputy governor (Vice-Chairman). Each province has its own council that gives advice to the governor regarding the needs of the province, as well as monitoring ongoing projects and considering future development plans.

In April 25, 2016, the Saudi Vision 2030 was announced by Crown Prince Mohammed bin Salman, which plans to reduce the dependency on oil in Saudi Arabia, diversify its economy, and develop service of other sectors such as infrastructure, transportation, health, recreation, education, and tourism. There are other specific goals besides increasing the share of non-oil from 16% to 50%, in terms of GDP, include the following objectives:

1. Increase the contribution of the private sectors from 40% to 65%, and raise the nonprofit sector’s contribution from less than 1% to 5%, in terms of GDP.
2. Improve the quality of Umrah services including visa application procedures, to make it possible for over 15 million Muslims per year to perform Umrah and satisfy with their pilgrimage experience by 2020, and 30 million by 2030, compared to 8 million in 2015.
3. Facilitate the listing of private and government owned companies, on the local stock market, including Aramco.
4. Increase the average life expectancy from 74 to 80 years.

The vision will speed-up the strategies of development and decision making, and enhance their performance through establishing the Council of Economic and Development Affairs, and the Council of Political and Security Affairs. However, making decisions will be based on detailed studies and benchmarks, and a complete analysis of programmes, related performance indicators and plans for each agency. As Saudi Arabia has had a special place in the heart of pilgrims, the number of Umrah performers entering the country from abroad has increased to reach eight million people in the last decade. In terms of serving visitors to the two holy cities, a third expansion of the two holy mosques has begun, as well as increasing the capacities of Saudi airports and finishing the railroad and train projects has been launched to complement this. In Saudi Arabia, building more museums, preparing new sites for tourist, historical and cultural venues, and improving the experience of pilgrimage.

By 2030, the Saudi Vision in terms of tourism, increasing the number of visitors from eight million to 30 million every year and register more than double the number of Saudi heritage sites with UNESCO. Jackson *et al.* (2010) identified that women in Saudi Arabia constitute 45% of the total population and 56.5% have completed university. In this case, the vision is planning to reduce the unemployment rate from 11.6% to 7% and increase the participation of Saudi's women from 22% to 30% in the workforce, through developing their talents, enabling them to the Saudi society and economy. There are some major factors that could act against women participate in Gulf Cooperation Council (GCC) countries. First, most women wish to care for and be with children and families, as it is a common factor in all societies. Second, many women live far away from major cities and would find it impossible to work. Third, transport to the workplace could be one of the factors. One of the main aims in the Vision 2030 of Saudi Arabia is emerging technologies from around the world and participating in large international companies to maximize its investment capabilities whilst this requires an open formation of a capital market and advanced financial to the world. In terms of the business environment in Saudi Arabia, the public-private partnership (PPP) will be pursued to improve the Saudi competitiveness and facilitate the movement of private investment, as well as increasing the reliability and quality of Saudi services through developing the necessary capabilities and creating an environment attractive to both foreign and local investors. As a result, Saudi Arabia is looking forward to increase the share of non-oil trades in non-oil GDP from 16% to 50% and from SAR163 billion to SAR1 trillion of non-oil government revenue.

According to Saudi Arabian law, women are not allowed to drive, and have to go with male relatives or paid services, to school, stores, airport, work, etc. In 2014, Uber operated in Riyadh, Dammam and Jeddah, and estimated that 70% to 90% of Saudi Uber users are women, as the women in Saudi arabia only make up 13% of the Saudi workforce, while there are 60% of university students that accounts for the high demand of daily commutes (Staff, 2015). However, Uber has made a difference in Saudi women's mobility whilst its next step is increasing availability with the cities and take people back and forth between Mecca and Jeddah during Ramadan (holy month). On the other hand, the project of Riyadh Metro planned to be completed by 2019, which will help in travelling cheaper and quicker, and give women greater movement around the city. As a result, it is interesting to see the role of the public transport system within Saudi Arabian develop, given on-going demographic and social changes, thus providing alternative solutions of mobility. This includes the Haramain HSR, the North-South rail, Landbridge Rail, etc. (Alatawi and Saleh, 2014).

Regarding the legal and institutional framework there are not many similarities and the main differences between these two countries are: the absolute monarchy in Saudi Arabia whereas in Spain, which is a constitutional monarchy, the Government can change after elections; the long experience of Spanish companies in public works; construction procedures; transaction costs higher in Saudi Arabia due to the use of a negotiation procedure and institutional framework; and finally, there are social factors that could pose downside risks for the future demand in Saudi Arabia (e.g. in Spain there are no restrictions for women to travel independently).

4.4 Transport

Domestic passenger transport in Spain is dominated by the road mode with almost 90% of the share. This high value is encouraged by the large highway network developed over the last two decades. With regard to the remaining transportation modes for domestic use, it is noteworthy that rail and air transportation have not been able to threaten the road dominance despite the fact that passenger rail's share has slightly increased from 5.2% in 2009 to 6.4% in 2015. Similarly to the French 'avion sur rails', the former goal of HSR investment in Spain was not to change Spanish transport modal share inside out, but rather to change modal share in specific point to point relationships. However, taking advantage of the connection between the main cities, the strategy soon changed to connect every provincial capital to the network and nowadays 67% of the population is linked by HSR. The approach used was a mixed model where some conventional trains, after being adapted to the European standard gauge, are able to circulate on HS lines. Back in 1942 Talgo developed the technology for the interoperability of international services with narrow and standard gauge. A similar system was used and improved to be able to change gauge at higher speed. The main benefit of this approach relies in the saving of rolling stock acquisition and maintenance costs on the one hand and the flexibility for providing 'intermediate high-speed services' on certain routes which are not fully HS on the other hand. However, the majority of the HS network is sanctioned at 300 km/h with a maximum design speed of 350km/h, making its construction more expensive than it could be at lower speed. For instance, an increase of the design speed from 250km/h to 350km/h could make the construction up to 50% more expensive (Gonzalez, 2015). For the sake of clarity, only the effect of HSR on the densest corridors is shown here. Below, Table 1 shows the main characteristics for the most important HS connections.

Table 1. Main routes in Spanish HS network

Origin	Population Metropolitan area in 2015	Destination	Population Metropolitan area in 2015	Distance (km)	Year service opened	Fastest Travel Time by HSR (min)	Million Passengers 2016
Madrid	6,513,075	Barcelona	4,892,634	621	2008	150	3.874
		Valencia	1,619,463	391	2010	102	2.336
		Seville	1,418,233	471	1992	140	2.545
		Malaga	853,516	513	2007	140	1.743
		Zaragoza	753,884	306	2003	75	1.373
		Alicante	459,387	493	2013	136	1.394

In order to have a better idea of traffic evolution in the aforementioned services, Table 2 provides traffic growth in the last decade. Several ideas arise from this table. First, when traffic growth is compared to the performance of the economy, when the economy is doing well, the travellers tend to be more prone to use the HSR. Two reasons could explain this trend. The first one is that the greater the income of families and companies, the higher will be their willingness to pay. The second reason is that the greater the total trips in the corridor, i.e., public and private transport that increases when the economy does well, the more congested will be other transport alternatives and therefore HSR can become a better option. Second, related to the first one, once the ramp up period is over and traffic is consolidated the Tran Operating Company (TOC) has certain degree of control over demand: commercial speed, frequencies and price prove it. However, *ceteris paribus* HSR demand seems to anticipate economic cycles. The increment in traffic in 2013 is explained by the yield management prices introduced by Renfe. Third, the ramp up period usually lasts the first two years once the infrastructure fully open. As we have already seen after that point two factors influence demand: GDP growth and TOC's policy. For instance, in the Madrid – Barcelona route the first year traffic growth was huge (255.78%), similar to the first year of Madrid to Seville (246.8%), whereas for other routes it was lower with Madrid to Malaga (139.5%) and Madrid to Valencia (149.1%) with similar traffic growths (Fernandez, 2012). These figures do not match figures in the table because the first year of full operation is not the calendar year (e.g. Madrid – Barcelona route was opened on 20th February 2008).

Table 2. Traffic growth in the last decade

YEAR	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GDP GROWTH	3.8%	1.1%	-3.6%	0%	-1%	-2.9%	-1.7%	1.4%	3.2%	3.2%
Madrid – Seville	-0.6%	0.7%	-5.8%	-7.4%	-3.4%	-7.6%	10.2%	6.8%	6.8%	2.6%
Madrid – Zaragoza	20.9%	33.7%	-20%	-7.7%	-6.6%	-7.5%	8.2%	8.6%	3.2%	4.2%
Madrid – Malaga		140.9%	2.6%	-4.4%	0.1%	-4%	11.5%	6.2%	4%	2.9%
Madrid – Barcelona		178%	26.6%	-2.7%	-2%	5.6%	14.1%	12.1%	8%	4.2%
Madrid – Valencia					161.2%	-6%	7.7%	5.5%	8.2%	10.1%
Madrid – Alicante							32.7%	25.8%	20.8%	4.3%

In the case of the route Madrid – Zaragoza, the growth in the first year of service (56%) was lower than these figures, but higher in the second (21.6%) and third (20.7%) year of operation. 2007 was the fourth year in operation and can be seen in Table 2. This lower demand is explained because in the first years of the service, trains were not operating at full capacity (its maximum commercial speed was 200 km/h, but it has been designed for speeds of 350), and there were not enough HS trains to cope with the demand. Once these improvements (higher speed and more frequencies with better trains) were introduced, the demand responded positively. In fact, after five years of operation, the accumulated growth (241%) was quite similar to those reported above. The same can be said with respect to the HSR line to Alicante. The full line entered into service on 17th June 2013, so the first year increment would feed through 2013 and 2014. Moreover, before that date intermediate HSR trains were on the route from Madrid-AlbaceteAlicante providing already time savings.

Finally, with respect to the induced demand triggered by HSR it ranks from the 9% induced demand on the Madrid – Barcelona route to the highest figure found on the Madrid – Seville route with 26% (PWC, 2010). Similar figures are found on the route Madrid – Malaga 11% (AEA, 2008) and Madrid – Valencia 14% (PWC, 2010). The remaining demand can be attributed to transport mode shift. There are also important differences between induced traffic expectations and reality that can be explained by higher prices and lower frequencies than forecasted as well as economic downturn (Fernandez, 2012). In fact, as Fernandez pointed out official forecasts were revised downwards before the new lines entered into service to take into account the new services and prices. So, forecasting HSR demand accurately is difficult (Guirao and Campa, 2014) and therefore there are usually implicit risks associated with demand. Moreover, official forecasts could also be deliberately biased upwards due to strategic misrepresentation from the Government (van Wee and Flyvbjerg, 2010); they can justify potential demand in the future to develop HSR.

By contrast, domestic transport in Saudi Arabia is composed of three main modes: road, air and marine. Despite the recent increase in air transport demand, road transport has the lion's share of the transport in Saudi Arabia by far, with more than 95% of the national passenger-km. This high percentage can be explained by the easy accessibility to private automobiles as well as low fuel prices, which have increased automobile traffic levels in recent years resulting in congestion problems. Below, Table 3 shows the main characteristics of the existing and planned Railway Network in Saudi Arabia.

Table 3. Main routes in Saudi Arabia Railway network

<table>
<tr><th>Origin</th><th>Population Metropolitan area in 2014</th><th>Destination</th><th>Population Metropolitan area in 2014</th><th>Distance (km)</th><th>Year service opened</th><th>Fastest Travel Time by HSR (min)</th><th>Passengers 2014</th><th>Passengers 2015</th></tr>
<tr><td rowspan="3">Riyadh</td><td rowspan="3">6,300,000</td><td>Dammam</td><td>2,275,000</td><td>449</td><td>1981</td><td>240</td><td>1,247,000</td><td>1,317,000</td></tr>
<tr><td>Al-Qassim</td><td>1,387,996</td><td>352</td><td>2017</td><td>105</td><td colspan="2">Two million annually (Projected)</td></tr>
<tr><td>Jeddah</td><td>4,025,000</td><td>950</td><td>Planned</td><td>360</td><td>--</td><td>--</td></tr>
<tr><td rowspan="2">Jeddah</td><td rowspan="2">4,025,000</td><td>Makkah</td><td>1,780,000</td><td>77</td><td>2018</td><td>30</td><td colspan="2" rowspan="2">60 million annually (Projected)</td></tr>
<tr><td>Madinah</td><td>1,270,000</td><td>373</td><td>2018</td><td>120</td></tr>
</table>

As there are about eight million pilgrims and Umrah performers who arrive to Saudi Arabia every year to visit the two holy cities of Makkah and Madinah in the west of Saudi Arabia and the solution chosen was building the Haramain High Speed Rail (450 km) to European HSR standards. However, there has been a steady decline in the number of pilgrims arriving to Saudi Arabia but the number of tourist has been increased, and this could influence future HSR demand. In terms of transport mode, 93.4% of the total domestic tourism trips were made by land based transport including car, rail, bus, etc., while the air transport captured 6.6%, as shown in Table 4.

Table 4. Transport mode for domestic tourism in Saudi Arabia in 2011

Mode of Transport	Total	Market Share (%)
Air	1,489,142	6.6
Private Car	18,325,857	81.5
Rented Car	363,546	1.6
Taxi	23,839	0.1
Bus	2,199,405	9.8
Rail	46,155	0.2

Source: Tourism Information and Research Centre, 2011.

Saudi Arabia wants to complete the national plan of constructing 9,900 km of railways by 2040, which also including the 2,750km North-South Railway from the north to Riyadh and the 950km Landbridge from Riyadh to Jeddah. The only HSR line will be the Medina – Mecca. The remaining links will have speeds from 180km/h to 220km/h and some of the stretches will be designed to accommodate freight transport as well, which could increase maintenance costs.

The two main similarities between both transports systems are the dominance of the road mode for domestic passengers and the design of HSR to serve initially only point to point connections between main cities, although it will be extended afterwards. There are, however, two main differences that make the comparison difficult: there is no actual train transportation from Medina to Mecca and difficulties associated to forecast induced demand will be even greater in Saudi Arabia due to the different context. The induced demand and ramp up period might see important demand increases, due to the great change that the new train services will deliver in the corridor. Traffic growth might be higher than traffic growth in Spain, not only because GDP growth is greater but because the proposed opening-up of the Saudi Arabian economy. However, looking at the broad figures from tables 1 and 2, it seems difficult to reach the expected demand of 60 million users annually even some years after it enters into service.

5. Conclusions

Japan was the first country to develop its own HSR network in 1964. Many countries have followed its example with Saudi Arabia about to join that group of countries. Taking advantage of 25 years' experience in HSR a Spanish consortium was awarded with €6.7 Billion to construct, operate and maintain the second phase of the Haramain HS line, as well as the supply of trains and their maintenance for a period of 12 years. Given the transport and geographic characteristics of Saudi Arabia, the Spanish HSR is a good example to look at. A comparison of the main topics that can influence HSR development and demand has been undertaken. That includes geography, economy, institutional & legal framework and transport characteristics. Derived from this comparison we can offer the following lessons:

The comparison was difficult due to a different culture and the different development of the countries. There are more data and statistics available in Spain than in Saudi Arabia, which makes the comparison even more complicated.

The know-how gained by construction firms, the infrastructure manager and TOCs in Spain has helped drive down costs not only in the construction costs but in the maintenance and operating costs and is key to overcoming the challenge of HSR under extreme climate circumstances. This experience is also useful to promote Spain's own national railway sector, helping in this way the economy afterwards. The case of the Spanish consortium constructing the Saudi Arabia HSR proves this fact.

Although HSR demand is extremely sensitive to the economic cycles and the transport system competing with train, TOCs have control over variables influencing it (commercial speed, prices or frequencies) and therefore must have freedom to adapt their strategy to increase demand and revenues. Table 2 suggests that when the GDP grows positively, demand for HSR services in Spain tends to grow even more positively. On the other hand, HSR traffic tends to decrease even more sharply than does the GDP, when GDP decreases in Spain. The sensitivity referred to previously becomes greater in the cases of seasonal destinations, such as Malaga and Valencia.

There are inherent difficulties to predict demand and although rapid traffic growths can be expected it seems difficult to reach 60 million users per annum for the Haramain HSR line in Saudi Arabia in 12 years. So, taking into account all the culture differences, classical transport models could not be valid to predict demand, and therefore they must be adapted to this particular corridor.

Finally, due to the high risks involved in the project, a greater understanding by the parties of each other's' position is crucial to its success: Saudi Arabia will gain expertise in the development and operation of HSR and will be able to attract international funding in the future, whereas Spanish companies will benefit by improving its technology and the possibility of exporting its know-how to other countries. Failure to do so would be bad for both parties, so they should be open to even further renegotiations or changes of the contract.

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General and network aspects of HSR

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Methodology to determine the optimal design speed in a High-Speed Line

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Abstract

Over the past 30 years, high-speed railway in Europe has experienced a great development due to, among other things, the reduction of travel times, the increase of frequency and the continuous improvement of service quality.

However, the construction of a new high-speed railway infrastructure requires an enormous mobilization of resources, has a long lifetime and the alternative uses of this huge investment are very few. Consequently, this kind of investment is always preceded by a rigorous analysis in order to ensure the best possible results.

In an analysis of these characteristics, there are different variables that have an influence on costs and benefits that a high-speed line could generate and, therefore, it can be asserted that there are certain parameters with direct impact on the profitability of a high-speed line; among them, maximum design speed of a high-speed line can be highlighted. If real experiences are analysed, real high-speed lines currently in service or under construction, maximum design speed is, essentially, the same all over the European high-speed networks (300km/h or 350km/h), a solid reason behind this pre-determined speed has not been found.

The design speed plays a crucial role in a framework in which the efficiency and the social benefit are essential. A higher design speed implies higher investment costs and, sometimes, implies slight increases in exploitation costs, but also brings journey time reductions and, consequently, an increase in the number of passengers that implies an increase in revenues and time savings.

At this point, this paper develops a methodology capable of obtaining the maximum design speed that allows obtaining the maximum revenues with the minimal cost, which implies achieving the maximum profitability of a high-speed railway line.

Keywords: design speed, financial profitability, socio-economic profitability, revenues and benefits.

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1. Introduction and methodology

1.1 Planning a high speed line

The construction of a new transport infrastructure, such as a railway high-speed line, requires an enormous mobilization of resources, has a long lifetime but the alternative uses of this investment are very few. Consequently, this kind of investment is always preceded by a rigorous analysis and occasionally also by a public debate in order to ensure the best possible results.

Normally, the final decision made about the construction of a railway infrastructure is based on a Cost Benefit Analysis (CBA) methodology, supported by different indicators (i.e. NPV, IRR…) which, depending on the value obtained, will support or reject the final decision of building the infrastructure.

The methodology (CBA) is based on intermediate results obtained from different models (exploitation cost models, revenue models…). These intermediate models also process different input parameters, which usually are: (i) characteristics of the infrastructure (maximum speed, slopes, etc.), (ii) socio-economic variables (such as population, GDP per capita…), (iii) train parameters (e.g. maximum speed, architecture…), (iv) service variables, as load factor, frequency, and (v) unit costs. Thereby, it can be said that the final decision made, in an indirect manner, is influenced by the value of a set of parameters (input parameters), and depending on the value they take will increase or decrease the profitability of the project.

Among the input variables capable of increasing or decreasing the profitability of a HS project, it can be stated that the maximum design speed of a railway line is of a major significance to the final output and to the socio-economic profitability, due to it has an influence on each and every of the parameter that feed a CBA (see Figure 1).

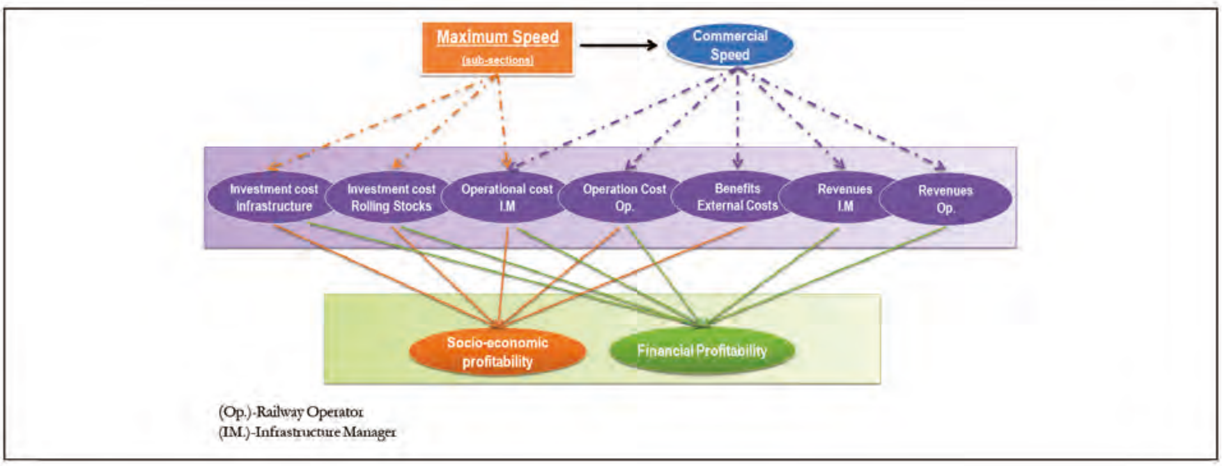


Figure 1. Effect of the speed on the economic and financial profitability.

As well as, many others manageable parameters are, occasionally, field of study within the CBA (i.e. fare, frequency…); maximum design speed usually is a pre-defined value and previously established to an economic appraisal. If real high-speed lines currently in service or under construction are studied, maximum design speed is practically the same (300km/h or 350 km/h) all over the European high-speed networks.

Maximum design speed plays a crucial role in a framework in which the efficiency and the social benefits are essential. A higher design speed implies higher investment costs and, sometimes, implies small increases in exploitation costs, but it also brings journey time reductions and, consequently, an increase in the number of passengers that implies an increase in revenues and time savings.

In addition, an increase of the commercial speed (journey time reduction) also brings new indirect effects on the demand. Traditionally, journey time reduction is accompanied by improvements in the services offered by the operator (frequency increases, trains with greater capacity…). These improvements imply greater number of passengers, either because of the operator reduces its costs (higher train capacity) and reflect these reductions in the ticket price or because passengers have greater “possibilities” for travelling (higher number of frequencies).

1.2 Design speed of a high-speed line

In view of the above, this paper develops a methodology capable of obtaining the combination of maximum design speeds for each sub-section and, consequently, commercial speed that allows obtaining the maximum incomes with the minimal cost, which implies obtaining the maximum profitability of a high-speed line (greater socio-economic NPV).

The methodology proposed in this paper carries out a financial and socio-economic assessment of a new high-speed infrastructure, which links Madrid, Cuenca and Valencia aiming to obtain the combination of the maximum design speed to which the infrastructure should be built. Therefore, all the different combination of the maximum design speed assigned to each sub-section defined are analysed in terms of social and financial profitability. The combination of maximum design speed and therefore the commercial speed, which obtains the maximum social profitability, will be the one selected.

In addition, the economic and financial analysis is also assessed for two different ticket prices, allowing not only to determine the commercial speed that obtains the maximum profitability of the line, but also allows knowing the effect of the ticket price paid by the travellers on the economic and financial profitability.

The methodology developed is defined in five more sections. Section 3 defines the study case and the initial hypothesis used. Section 4 will address the demand calculation and its relationship to the commercial speed and, consequently, the revenues and the benefit of the project. Section 5 will define and explain the cost models used both in the operational costs model and the investment cost model. Section 6 estimates the economic and financial profitability of the study case, taking into account the model defined in previous sections and, finally, section 7 establishes the conclusions of the work.

It is important to mention here that the models developed not only have one application or use (one high-speed line), as it is for this paper, but also allow its use in the different degrees of development of a railway network or corridor.

2. Definition of the study case and initial hypothesis used

2.1 Study case

The scenario chosen corresponds to the study of the financial and economic profitability of a generic high-speed layout. This layout would link the cities of Madrid, Cuenca and Valencia (see Figure 2) and would be composed of two sections and four sub-sections.

For each of the sub-section different types of terrain will be assigned (flat profile, slightly-rough profile, mountainous and very mountainous profile) and the percentage of type of terrain and, therefore, the length of each of the sub-section used in the analysis carried out is described in the following table (Table 1).

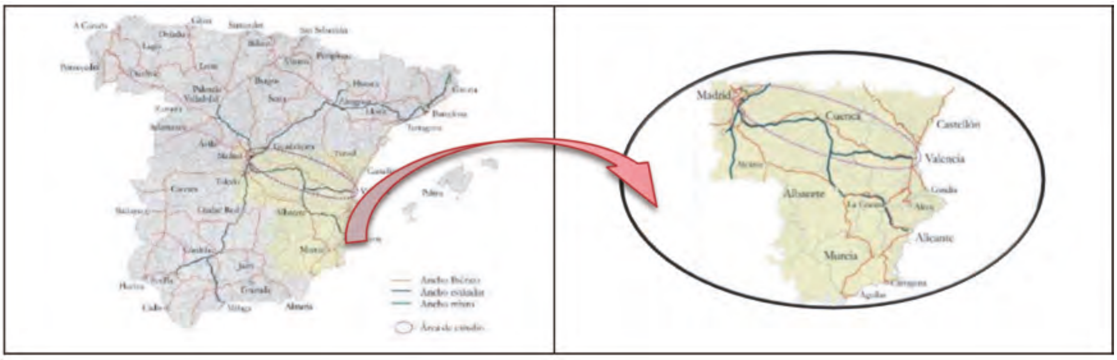
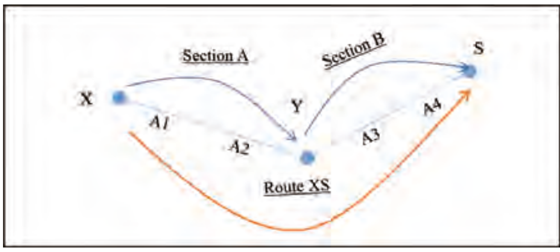


Figure 2. Study case analysed.

For each of the sub-section different types of terrain will be assigned (flat profile, slightly-rough profile, mountainous and very mountainous profile) and the percentage of type of terrain and, therefore, the length of each of the sub-section used in the analysis carried out is described in the following table (Table 1).

Table 1. Types of terrain of the study case.



Section	Oreography	% of kilometres	Length of straight line (km)	Length of the section for Smax 350km/h
A1	Very Montanous	9,6%	35	37,6
A2	Montanous	35,4%	132	138,4
A3	Slightly-rough	21,9%	83	85,6
A4	Flat	33,2%	125	129,7
			Total	**391**

The percentage of the type of terrain that the line would cross has been determined and predefined from average values of the Spanish high-speed lines. Furthermore, for each of the subsections a maximum design speed is assigned within a range between 200km/h and 500km/h with increments of 10km/h, which implies that it is necessary to solve 923,521 scenarios.

Table 1: Combination of the maximum design speed for each scenario proposed.

	Section A1 Very Montanous	Section A2 Montanous	Section A3 Slightly-rough	Section A4 Flat
	Max. Speed (km/h)	*Max. Speed (km/h)*	*Max. Speed (km/h)*	*Max. Speed (km/h)*
Case 1	200	200	200	200
Case 2	200	200	200	210
...	...	...	...	...
Case 923.521	500	500	500	500

$$V_{31}^{4} = 31^{4} = 923{,}521$$

2.2 Hypothesis of a CBA

The table below (Table 2) gathers the main hypothesis used in order to apply the CBA model.

Table 2. CBA input parameters.

Baseline year	2011 euro
Time Horizon	30 años
Financial Rate of Return (FRR)	5%
Economic Rate of Return (ERR)	5,5%

2.3 Rolling stock characteristics

Some of the characteristics of the rolling stock considered differ depending on the scenario analysed, since the train used in the model developed will be one or another depending on the maximum design speed considered. Essentially, the parameters which vary are the train maximum speed and, as a result, the power output.

The rest of the characteristics have been established and correspond to the train Velaro. Velaro is a family of high-speed EMU trains used in Germany, Belgium, the Netherlands, Spain, China, Russia and Turkey and are based on the ICE 3M/F high-speed trains manufactured by Siemens for Deutsche Bahn. The table included below (Table 3) show the main train parameters considered in the model.

Table 3: Main train characteristics.

Seats	404
Articulated Coach	Articulated_bogies
Traction	Distributed
Body width	Normal-Body (2,550mm-3,400mm)
Single or double-deck	Single-decker
Signalling System	ASFA+ETCS 1+ETCS 2
Seats density	Luxurious (3 classes and dining car)
Installed Power (kW)	3.074kW -27.900kW

3. Effect of the speed on revenues and benefits

Before explaining the existing relationship between commercial speed and revenues and benefit it is necessary to define the relationship between speed and passenger mobility (demand model). Essentially, because revenues and benefits are monetary compensations paid by passengers for the service rendered by the railway operator.

There is a clear link between transport mobility and commercial speed; the effect produced by the commercial speed in the market share (demand) lies in the influence that the commercial speed has in the travel time and in the travel cost (also called travel "resistance" or generalized cost). As the commercial speed increased, the travel time decreased and, therefore, the generalized cost that every passenger has to pay is also reduced. Provided that the rest of variables that affect to the generalized cost remain constant, if the generalized costs is reduced the "attractiveness" of the transport increases.

Based on the classical methodologies that allow determining the market share (i.e. Logit Model) it is possible to demonstrate how the railway market share will increase (if the generalized cost of the rest of transport modes remains constant) with a travel time reduction and, therefore, with a reduction of the generalized cost of the railway line.

$$P_i = \frac{exp(\beta \times C_{gi})}{\sum_{j=1}^{n} exp(\beta \times C_{gj})} \tag{1}$$

Where: P_i: Market share; Cgj: generalized cost; "i" railway transport mode; "j"; n: transport modes; β: model parameter

(González Franco, 2015b) has applied this empirical demand model in the HS Levante Corridor, obtaining that the demand elasticity for commercial speed (travelling time) varies with the journey time. This study obtained the following elasticities:

- Journey times shorter than 40 minutes obtain demand elasticities between -0.2 and -0.5 with an average value of -0.35.
- Journey times between 40 minutes and 80 minutes obtain demand elasticities between - 0.4 and -1.2 with an average value of -0.6.
- Finally, journey times between 80 minutes and 180 minutes obtain demand elasticities between -0.6 and -1.7 with an average value of -0.95.

It can be asserted that the demand elasticities determined in **(González Franco, 2015b)** are in line with other studies, as **(Yousefi Mojir, 2011)** or (**Cascetta & Coppola, 2011)** and they will be used in the study case analysed in this paper.

3.1 Effect of the speed on revenues

As it has been mentioned, revenues obtained in the transport sector are the monetary compensations by the service provided, that means, the revenues of a railway transport operator mainly come from the traffic and the price paid by the service. Therefore, when thinking about the revenues of a railway operator, two basic concepts are quickly related: (i) number of tickets sold and (ii) the price of them (ticket price).

If the analysis is focused on each of the two issues independently, without analysing the relationship that exist between them, it can be assumed that, the higher the number of passengers transported, the higher the number of tickets sold and, therefore, it is clear that the incomes of the operator will increase. In addition, it is understood that if the ticket price is increased, the price paid by the passenger is higher and, therefore, the operator will "earn" more by passenger.

This study will focus on the analysis considering that the price established by the operator remains fixed, without any interference of the speed on its establishment. The effect of the speed in the ticket price has been studied and analysed in detail by the author in **(González Franco, 2015b).**

In this case, to determine the revenues of the operator is relatively simple, basically, it is a matter of calculating of the number of passengers transported by the operator (based on the demand model) and multiply it by the revenue per traveller obtained by the operator.

3.2 Effect of the speed on social benefits

Therefore, it should not be forgotten that a socio-economic analysis is a counterfactual analysis, which means that in order to determine the benefits (savings on external costs) of a railway project, it is necessary to obtain the number of passengers transferred from each transport mode to high-speed train mode.

Therefore, the estimation of the benefits is based on the calculation of the difference between the passengers who use each mode before the construction of the new infrastructure (*"baseline scenario"*) and those who would use each mode after the construction (*"high-speed scenario"*). In addition, it is also necessary to know the induced demand due to the new service, the length of the line and the travel time of each mode. As it was mentioned before, a proper demand model is vital to estimate the benefits.

However, what are the benefits that a high-speed line may provide? according to the **(INFRAS/ IWW., 2004)**, the savings on external costs (social benefits) obtained from the construction of a new railway infrastructure may be sourced from: (i) net excess of new traveler consumer (induced traffic), (ii) net saving on travel time, (iii) net savings on operational costs, (iv) net savings on accidental costs and (v) net shavings on environmental costs.

Quantifying all these effects and integrate all of them in a complete economic analysis is a very complex task that it has been broadly studied the last years. As a relevant work can be cited **(INFRAS/IWW., 2004).** The methodology and monetary values provided in this study have been used in order to determine the benefits in the study case proposed for this paper.

3.2.1 Study case: Effect of the commercial speed on demand revenues and benefit

According to the demand, elasticities for journey time (commercial speed) determined in **(González Franco, 2015b)** and shown in chapter 3, the relationship between demand and commercial speed and, consequently, the relationship between revenues and benefits and commercial speed is estimated for the study case.

Figures below (Figure 3) show, for two different ticket prices (12c€/passenger-km and 20c€/passenger-km) the influence of the commercial speed on the demand, revenues and social benefit in the study case analysed (HS Madrid-Valencia).

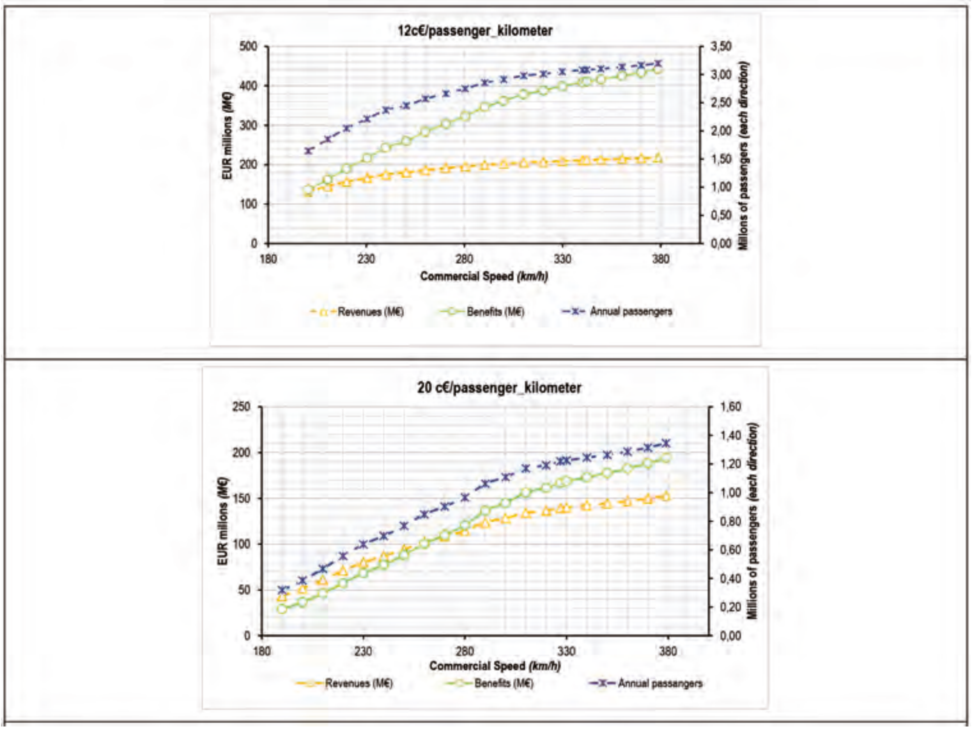


Figure 3. Relationship between demand, revenues and savings on external costs and commercial speed

According to the results obtained, the following can be highlighted:

- Whatever the ticket price is, the higher the commercial speed (or, in other words, reductions in the journey time), the greater the number of passengers transported, the revenues and the savings in the external costs (benefits).
- Finally, it is found that for low-ticket prices, whatever the commercial speed is, savings in external cost are higher than incomes. However, in case of high tariffs and low commercial speeds, revenues are lower than savings in external costs. The reason behind this statement is that the demand gained by the high-speed train, with reference to other transport modes, is not enough and lower than the revenues generated multiplying the number of passengers by the price paid by them.

4. Effect of the speed on costs

The final aim of this section is to establish the relationship between speed and the different costs and then apply it in the study case in order to analyse the results obtained.

This section will focus on: (i) operational and Exploitation costs, (ii) investments costs.

4.1 Operational and exploitation cost

Not necessarily, an increase on the speed (commercial or maximum speed) implies increases in operating costs. An increase in commercial speed implies a reduction in the journey time, which entails, a reduction in the usage time of the available resources (i.e. rolling stock), and therefore, it may cover a higher number of kilometres and increase its production (seats-kilometre).

This effect (an increase in the speed and a reduction in costs) is even bigger in the case of on board personnel. An increase in the commercial speed implies an increase in the kilometres covered during its service hours, thus the annual productivity of the staff increases and, therefore, the cost per kilometre assumed by the operator is reduced.

This can be asserted, although there are not many studies which relate both parameters. As a relevant analysis the one performed by **(Kottenhoff, 2003)** can be highlighted. In the Spanish case, others can be highlighted, on the one hand **(Minayo de la Cruz, F. & García Álvarez, 2009)** and on the other hand, the paper presented for the 7th High Speed Congress held in Beijing (García Álvarez, 2010).

Besides, the doctoral thesis written by **(García Álvarez, 2012)** may be underlined where a detailed analysis of the relationship between the exploitation costs and the speed of the trains is carried out. This study defines, quantifies and provides the methodological foundations for the calculation of the cost function and for the estimation of the influence of the speed in them; methodology used in **(Roanes-Lozano, González Franco, Hernando, García Álvarez, & Mesa, 2013)**, and also used by the author in this paper.

As a summary, the cost assumed by the transport operator can be divided into two different costs; exploitation cost and operational and, in turn, each of them can be also divided into different items, as follows:

- Regarding exploitation costs, costs produced by the movement of the trains, the following have been identified: (i) Costs related to train ownership; (ii) Cleaning and maintenance costs; (iii) Traction energy costs; (iv) Train operation personnel costs.
- The operational costs are those incurred by the movement of vehicles (exploitation cost) and by offering safe, fast and quality service. These costs include: (i) Passenger services; (ii) Distribution, sales and access control costs; and (iii) Overhead cost.

4.1.1 Study case: Effect of the commercial speed on exploitation costs

After using the methodology defined in **(García Álvarez, 2012)** for each of the costs assumed by the operator in the study case here analysed, the following results were obtained Figure 4.

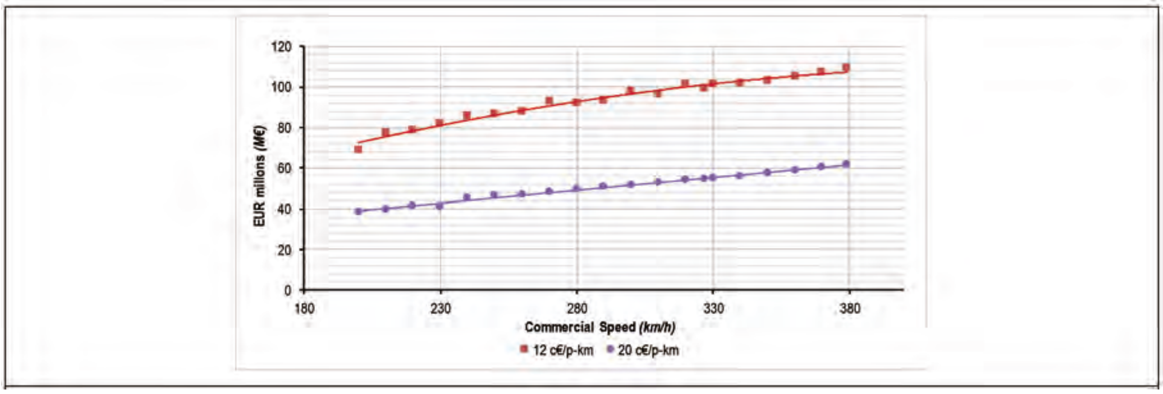


Figure 4. Total operational costs (M€) generated in the study case for two different ticket prices.
Note: the figure depicts the annual operational costs for the first year of service.

The results obtained can be summarized in:

- The lower the ticket price is, the higher the operational cost is. That is because the number of passengers increase and, therefore, the operator needs more trains or trains with higher capacity (higher acquisition cost) in order to provide the service required.
- Commercial speed influences the operational costs in two ways:
  - The higher de speed is, generally, the lower the number of trains needed to provide the service, since the operator can increase the use of the rolling stock.
  - In those scenarios, where the speed (journey time) does not reduce the number of trains required to provide the service, the operational costs can be slightly increased by an increase of the commercial speed, this can be because of, in some cases, an increase in the speed which can imply an increase in the energy consumed.

It is important to mention that the results here shown may suffer significant variations if it were considered a different train (different characteristics), with different capacity (seats). The operational costs it is clearly linked to the train seats and these are linked to the number of trains needed to provide the service required.

4.2 Effect of the maximum speed on investment costs

As the previous cost model, there are not many studies that could be used as a basis. However, it does not mean that there is not any relationship; it is clear that, the higher the maximum speed, the greater the line investment costs. For example, a greater maximum speed leads to wide curve radii and, therefore, it leads to straighter railway lines, which, in mountainous areas, results in a longer length of the line built under tunnel and/or length of bridges.

Before explaining the methodology used and the results obtained for the relationship between speed and investment cost, different studies in this field were analysed. It can be asserted that the existing literature is focused on two main fields:

Analysis of the cost structure of building a railway infrastructure designed to a certain maximum speed. Among the studies more relevant may be highlighted (**Campos, De Rus, & Barrón, 2009)** and the report **(Atkins, 2002)**.

Those studies focusing on solving particular problems, which limit the speed of the train, amongst them **(Subhash & Verma, 2007)** it is underlined.

There is also a large amount of studies linked to other disciplines aiming to determine the optimal layout taking into account the investment cost **(Lee & Cheng, 2001)** and other studies which take into account the optimization of the layout depending on the limitation of the railway system (radii of curve, grades…). Important studies in this field may be cited **(Malo Gaona, 1992)** or **(Linkerhägner, 1985)**.

Besides, there is relevant literature focusing on construction methods, definition of the different construction phases of a railway line and important analysis about the different costs generated in building a new railway high-speed line **(López Pita, 2008)**.

Regarding the relationship between speed and investment costs, the following studies may be highlighted **(Fröidh, 2012)** and **(Fröidh, 2014)**. In these papers a detailed costs analysis and indepth analysis of the influence of the maximum speed on investment costs is carried out. Another outstanding work is the study performed in **(Baumgartner. J.P, 2001)**. This study determines different infrastructure building costs for two different design speeds (100km/h and 300km/h) and provide a number of values for the different parts of the infrastructure.

As it was previously mentioned, the influence of the maximum design speed in parameters such as radii, slopes… is widely studied. However, the relationship with other parameters and elements of the infrastructure is not so obvious (percentage of tunnels, bridges…) and even less its relationship with the investment cost. These relationships have been duly quantified in **(González Franco, 2015a)**. A brief qualitative summary of the findings follows.

1. **Effect of the speed on the line length**. It can be said that, the higher the speed, the lesser winding layout the line will have and, therefore, there will be a shorter distance between origin and destination, this will affect the final cost of an infrastructure, since less line kilometres will be built.

2. **Effect of the speed on the type of construction and investment cost**. Maximum speed plays a very important role in the construction cost, mainly in very mountainous and mountainous areas. It also has a very important relationship with the quantity and length of the tunnels and bridges built; the lower the speed, the higher possibility of “escape” of those areas with orographic difficulties, since the line has smaller curve radii, that situation offers the possibility of building a more winding layout, which in most cases skirted round the hillsides.

3. **Effect of the speed on the maximum slope.** Greater upward slopes, allow a better adaptation of the layout of the line to the terrain (orography) and, therefore, shorter distances (kilometres) of tunnels and bridges are needed, which means a reduction in the investment costs. Besides, greater upward slopes imply trains with a higher power output; the higher the power output, the greater the capacity of the trains to climb upward slopes.

4. **Effect of the speed on the transversal section of a tunnel**. The greater the transversal sections of a tunnel, the lower the drag resistance of a train and, therefore, the lesser the pressure difference experienced by passengers. It is considered very important to increase the transversal section of a tunnel in order to increase the maximum speed that means an increase of the investment costs.

5. **Effect of the speed in the track width**. The greater the speed, the greater the distance between tracks, which increases the width of the track bed, therefore the cost grows.

6. **Effect of the speed on the track**. The greater the speed, the greater the thickness of the ballast layer underneath sleepers. The speed also affects the typology of the siding equipment; the higher the speed the greater the complexity of the technology used, therefore, the cost increases considerably.

7. **Effect of the speed on the electrification costs**. It can be highlighted that, the higher the speed, the greater the power output of trains and, therefore, the power of the substations must be greater (greater power of the traction transformer), and the electrical current through the cable, increases. If the electrical current increases, it is necessary to use cables with greater transversal section. Both effects (increase the power of substation and the greater section of cables) imply an increase in the investment costs.
8. **Effect of the speed on the signalling cost**. The influence of the speed lies, essentially, on the technology installed, both on-board and on ground. If the speed increases, the signalling systems must be more technologically advanced, since the safety requirements are increased, which means an increase in the investment costs.

Each and every effect of the speed on the different parameters or infrastructure elements have been quantified in the doctoral thesis **(González Franco, 2015b)** and in **(González Franco, 2015a)** The following graph shows a summary of the results obtained after the application of the different models developed.

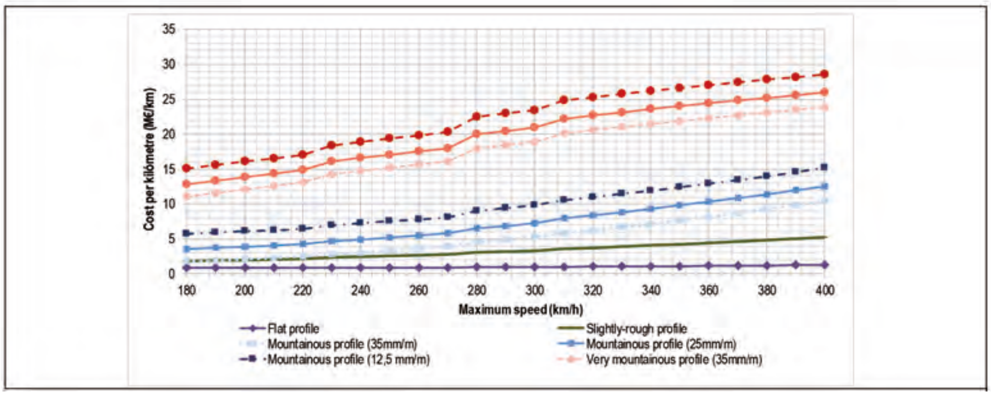


Figure 5. Investment cost per kilometre.

From the results obtained it can be highlighted that:

- The higher the maximum speed, the higher the investment cost, and that happens in all types of terrain. It can be said that, this growth is approximately linear in all analysed cases.
- Under equal conditions, the costs increase with orographic difficulties. The range of costs per kilometre, considering the same speed, is wide (i.e. for 300km/h the cost varies between 4 and 25M€/km).
- The largest increases in cost, due to the increase in the maximum speed are observed in slightly-rough profile and mountainous areas. In this type of terrain, an increase in the maximum speed entails a larger increase in the percentage of tunnel over the total length of the line.
- It is also remarkable that, the cost per kilometre of building a high-speed railway infrastructure in a mountainous area can be ten times higher than build the line in a flat profile. Even, it can be five times higher that build the line slightly-rough profile. Regarding the difference between the cost per kilometre of building a line in mountainous terrain or in a very mountainous terrain is approximately 2.5 time bigger.

In the following table (Table 4), the range of total investment cost obtained for each type of terrain considering different speed intervals is shown.

Table 4: Range of cost per kilometre depending on the type of terrain and maximum speed.

	Investment costs per kilometre *(M€/km)*		
	Smax<200km/h	200km/h<Smax<350km/h	Smax>350
Flat profile	4	4,2 - 5	5 - 6
Slightly-rough profile	5,3	5,3 - 8,5	8,5 -16
Mountainous profile	5,5 - 9,5	6 -17	12 - 42
Very mountainous profile	15,5 - 20,5	16 - 32	27- 60

4.2.1 Study case: Effect of the maximum speed on the investment cost

The idea of this section is to allocate, for each of the sub-sections defined in the scenario (chapter 2.1), a maximum design speed and estimate the investment cost of this sub-section according to the values obtained in Figure 5. The total investment cost of the line will be the sum of the investment cost for the four different sub-sections in which the line has been split.

For each combination of maximum design speed (one maximum design speed for each subsection) an investment cost is obtained, but also (knowing the length of each sub-sections) a commercial speed. Thus, it can be asserted that for each commercial speed there are different investment costs, since there are numerous combinations of maximum speed that obtain the same commercial speed.

Below it is included graphically (Figure 6) the relationship between commercial speed and investment cost (total cost and cost per kilometre) for the study case here analysed.

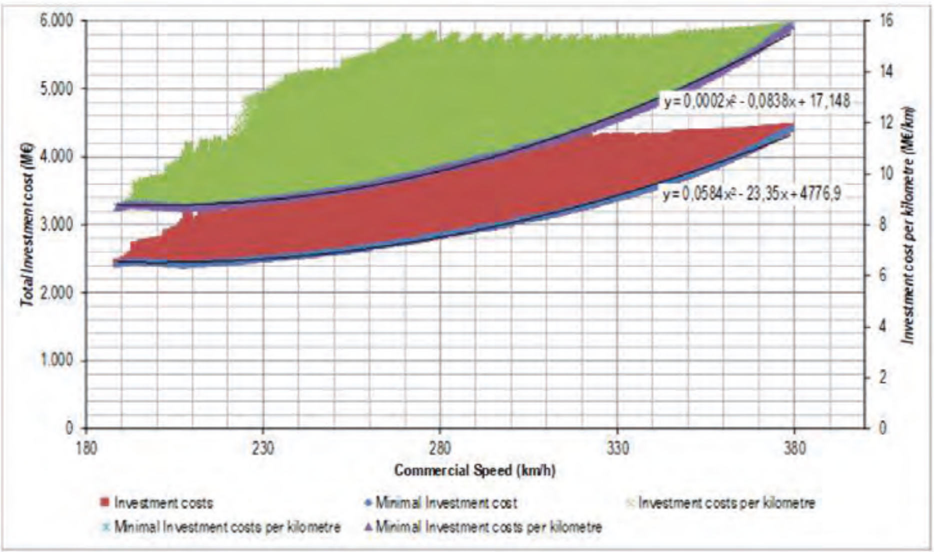


Figure 6. Study case: relationship between commercial speed and investment cost.

As it can be observed in Figure 6, cost per kilometre lies within a range between 8.6M€/km and 15.8M€/km, depending on the maximum speed considered. In view of the results, in can be asserted that the values obtained for the study case are in line with the real cost of the MadridValencia high-speed line.

If the influence of the speed in the investment costs is analysed, the results clearly show that the higher the speed the higher the costs. This make sense because, in order to increase the commercial speed, it is necessary to increase the maximum design speed of some or all of the sub-sections. As it was shown in the previous section, an increase in maximum speed, whatever the type of terrain is, implies an increase in the investment cost.

Other important issue to point out from the results is that each commercial speed has a minimal investment cost, which results from a certain combination of maximum design speed per subsection. If it is determined for each combination of maximum design speed the minimal investment cost, as it been performed in Figure 6, it is obtained the curve of minimal investment, which establish the boundary of the minimal investment.

5. Study case: Effect of the speed on the financial and socio-economic profitability

$$VAN_{f_{T0}} = -\left[I_{T0} \times (1+r)^{(T_0-T_{0+s})}\right]_{t=T_{0-s}} - \cdots - \left[(I_{T0}+CF)_{T_0} \times (1+r)^0\right]_{t=T_0} + \left[CF_{T_0+1} \times (1+r)^{-1}\right]_{t=T_{0+1}} + \cdots + \left[(CF+RV)_{T_{0+n}} \times (1+r)^{(T_0-T_{0-n})}\right]_{t=T_{0+n}} \quad (2)$$

The tools or parameters used that allows supporting the decision of tackling a project from costs and revenues previously studied are the “Financial value of infrastructure” and the “Economic value of infrastructure” calculated from a profitability indicator called Net Present Value (NPV).

The Net Present Value (financial and economic) allows calculating the flow of profit and cost from total life of an infrastructure, therefore it allows knowing the economic value of the infrastructure with the ability to update this value to the start-up period of infrastructure exploitation **(Jaro Arias, 2011)**. The equation used to calculate the NPV is:

where I_{To} is the initial investment *(€)*, *CF* estimates the cash flows *(€)*, *RV* is the residual value of the project *(€)*, *t* is period/year, *s* are the periods from the action starts to exploitation starts, *n* are the periods from the beginning of the exploitation to the end of the assessment, *r* is the economic or financial discount rate and $(1+r)^{(T_0-t)}$: is the discount factor for the value of r in the t period.

Knowing the relationship between speed and investment costs, revenues and social benefits and also knowing the relationship between exploitation and operational costs (see previous sections), the financial and economical profitability of all scenarios proposed (923,521) by means of NPV decision tool is determined.

Below the results obtained for the different scenarios and fares considered are shown graphically (Figure 7 and Figure 8).

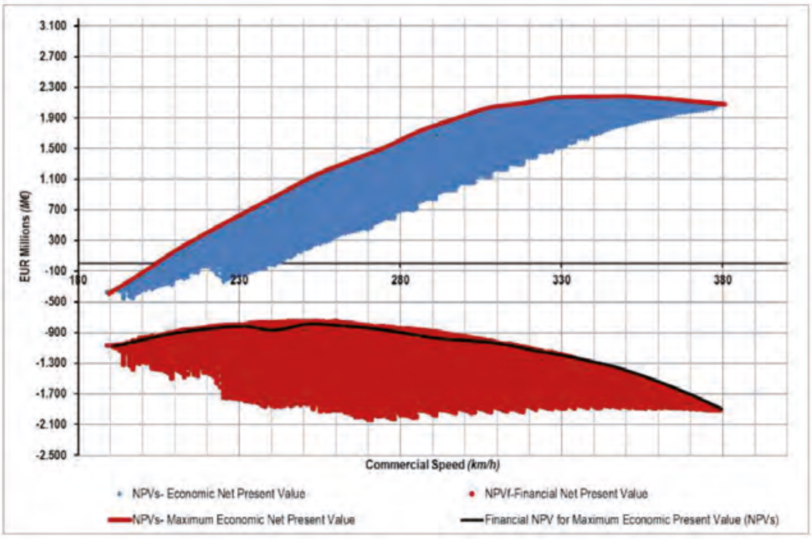


Figure 7. Financial and Economic NPV for 12c€/pkm.

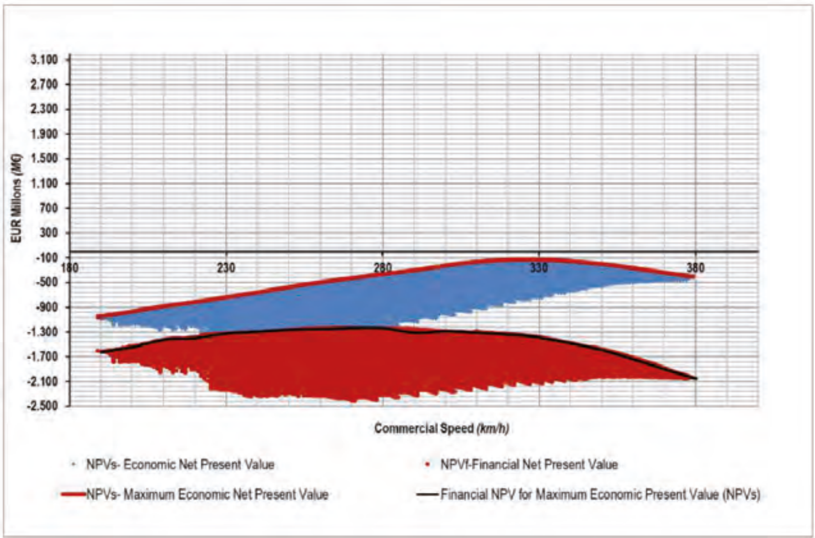


Figure 8. Financial and socio-economic NPV for 20c€/pkm.

If the decision-making criterion is to obtain maximum economic profitability (maximum Economic NPVs) without any additional restriction, as it is for this study case, it is necessary to analyse in which point (commercial speed) the economic NPVs reaches its maximum. The maximum economic NPVs corresponds to a certain commercial speed and to a certain combination of maximum design speed for each sub-section, therefore, this commercial speed will be the one that maximizes the profitability of the project. For the study case analysed in this paper the maximum economic profitability is reached at different speeds depending on the ticket price considered. Below (Table 5), the commercial speed and the combination of the maximum speed for each sub-section, which maximized the study case analysed, are shown.

Table 5: Commercial speed and combination of maximum design speed which maximize the Economic NPVs.

		12c€/p-km	20c€/p-km
Sub-section 1	*Very Mountanuos*	380	360
Sub-section 2	*Mountenous*	390	360
Sub-section 3	*slightly-rough*	410	360
Sub-section 4	*Flat*	500	500
Commercial speed	*(km/h)*	342	327
Journey Time	*(h)*	1,11	1,17
Anual passenger	Millons	3,08	1,219
Revenues	*(M€)*	212	139
Social Benefits	*(M€)*	410	167
Investment Cost	*(M€)*	3.593	3.364
Operatinal Costs Operator and IM*	*(M€)*	101,85	54,37
Socio-económic NPVs	***(M€)***	**2.172**	**-136**
Socio-económic IIR	*(%)*	12,1%	5,0%
Financial NPVf	*(M€)*	-1.322	-1.359
Financial IIRf	*(%)*	1,7%	1,1%

*IM - Infrastructure Manager

The following can be highlighted:

a. The higher the commercial speed, the higher the socio-economic profitability of the project. This increase is produced until certain commercial speed, above which the economic profitability starts to decrease.

   It can be said that, for each fare an optimal point in terms of economic profitability, which correspond to a certain commercial speed is obtained. The results obtained, show: for a tariff of 12c€/pkm the optimal (maximum economic profitability) is reached at 342km/h and for a tariff of 20c€/pkm the optimal is obtained at 327km/h.

b. The economic profitability is reduced with the increase of the ticket price; this argument is in line with **(García Álvarez, González Franco, & Rubio García, 2015)**. The higher the ticket price the lower the savings on external costs but the investment cost remains constant.

c. There are some differences between financial profitability and economic profitability. The higher the commercial speed, the higher the financial profitability of the project, in all cases analysed (tariffs). As in the economic profitability, this increase is produced until certain commercial speed, above which the financial profitability starts to decrease. It is seen that this "optimum financial" is reached at commercial speed lower than the commercial speeds that obtain the "optimum economic".

d. Furthermore, the results obtained also show the combination of maximum speed which should be built each sub-section. It can be observed, in order to obtain the optimal commercial speed, the maximum design speed is always assigned to the flat terrain and the minimal maximum design speed is allocated to the very mountainous terrain.

6. Conclusions

The conclusions of this study are grouped into three big sections:

6.1 Effect of the speed on revenues and benefits

a. **Effect of the speed on the demand:** As the commercial speed is increased, the travel time decreased and, therefore, the generalized cost that every passenger has to pay is reduced. Decreasing the generalized cost implies increases in the market share and therefore increases in the demand. An increase in the commercial speed (journey time reduction) can also bring more passengers. Traditionally, journey time reduction is accompanied by improvements in the services offered by the operator (frequency increases, trains with greater capacity…). These improvements imply a greater number of passengers.

b. **Effect of the speed on revenues:** Considering a fixed fare, the lower the travel time, due to an increase in the commercial speed, the higher the demand and, therefore, the higher the revenues obtained by the operator.

c. **Effect of the speed on external costs.** Speed is an important parameter in terms of savings in external costs, due to the high volume of passengers transferred from other transport modes to the high-speed trains and increases with it.

6.2 Effect of the speed on exploitation costs and investment costs

a. **Effect of the speed on exploitation costs.** After the analyses carried out, it can be said that (in the generic examples where the methodology was implemented) an increase in the commercial speed could imply a slightly increase in the exploitation costs.

b. **Effect of the speed on investment costs.** The higher the maximum speed, the higher the investment cost, and that happens in all types of terrain. It can be said that, this increase is approximately linear in all analysed cases. The largest increases in cost, due to the increase in the maximum speed are observed in slightly-rough and mountainous areas. In this type of terrain, an increase in the maximum speed entails a larger increase in the percentage of tunnel over the total length of the line.

It is also remarkable that, the cost per kilometre of building a high-speed railway infrastructure in a mountainous area can be ten times higher than building the line in a flat area. It can even be five times higher that building the line in slightly-rough profile. Regarding the difference between the cost per kilometre of building a line in mountainous terrain or in a very mountainous terrain is approximately 2.5 time bigger.

6.3 Effect of the speed on the economic and financial profitability

a. **Effect of the speed on the economic profitability** The higher the commercial speed, the higher the socio-economic profitability of the project. This increase is produced until certain commercial speed, above which the economic profitability starts to decrease.

b. **Effect of the speed on the financial profitability.** The higher the commercial speed, the higher the financial profitability of the project, in all cases analysed (fares). As in the economic profitability, this increase is produced until certain commercial speed, above which the financial profitability starts to decrease. The results obtained for the study case are: (i) for a tariff of 12c€/pkm the maximum profitability is reached at 342km/h and (ii) for a tariff of 20c€/pkm the maximum is obtained at 327km/h.

In addition, it is remarkable that the optimum financial profitability is reached at commercial speed lower than the commercial speeds that obtain the optimum economic profitability.

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