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Regional high-speed rail services typology, demand and spatial implications

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REGIONAL HIGH-SPEED RAIL SERVICES TYPOLOGY, DEMAND AND SPATIAL IMPLICATIONS¹.

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Abstract

The paper focuses on the role of medium distance HSR services that exist in Spain. The paper uses data of the railway company on numbers of HSR passengers and census data on the municipalities of residence and of work of each inhabitant. The paper explores the relevance of HSR passengers compared to potential commuters. The purpose is to provide a first analysis of the regional implications of these peculiar HSR Spanish services, which has not yet been analysed. The paper explores two situations one related to several regional systems of cities and the other, also at a regional scale, but related specifically to those that at the same time are part of metropolitan urban regions.

First, the paper draws a typology of regional high-speed services in Europe, based on relevant factors which are interesting to analyse its usefulness and implications for the system of cities. Specifically it looks at mid-run services in Great Britain, France and Spain.

Second, the paper analyses passenger data in Spain to acknowledge how links between these cities are being developed through HSR and census data for those people that live in one HSR city and work in another HSR city linked by regional HSR services. The comparison seeks to find out if regional HSR services are useful for the potential commuters between HSR cities.

The paper debates the role of the HSR in regional systems of cities and the increasing importance of this infrastructure.

1. INTRODUCTION.

High-Speed Rail (HSR) was originally thought to compete with inter-metropolitan air transport, setting an optimal distance range between 400 and 700 km. France was the first European country to undertake a HSR network, being Spain the second one, following French parameters. However, because of different reasons pointed out in the paper, some HSR operations in shorter distances begun to take place on the Spanish network. This was a novelty in HSR operations at that moment, stepping into a new phase of this transport mode.

The paper has the aim of analysing the implantation process of HSR services, focusing on those running in mid-short distances and their demand of passengers, which could be called regional HSR, serving to connect cities not so far away than initially thought of.

First, the paper sets the general context of these services in Spain, France and the United Kingdom (Section 2) focusing on the Spanish case which is profusely analysed further on. This allows setting a basic typology of regional HSR services.

¹ Authors would like to thank the "Dirección General de Servicios de Cercanías y Media Distancia" of Renfe for facilitating the passenger data on the AVANT and AVE-LANZADERA High Speed Rail services used in this paper.

Section 3 covers all Spanish Regional HSR network, studying its characteristics and the spatial interactions derived from it. Factors analysed are HSR configuration for each regional service in operation, their respective demand and their relation to potential commuting.

The passenger data comes directly from the railway operator which allows making some calculations and comparing each situation for each regional HSR service. Sub-sections develop the results from a regional point of view, trying to evaluate different levels of use and spatial implications on the territory.

Section 4 deepens on the metropolitan process facilitated by HSR between distant cities. Reduction of travel times allows establishing frequent relations at longer distances. This section highlights the regional HSR role in these relations evaluating its use and potential in comparison with road transport and coach services. The paper finalizes pointing out conclusions in section 5.

2. REGIONAL HIGH-SPEED RAIL SERVICES IN EUROPE: Spain, France and United Kingdom.

Shortly after the introduction of HSR in Spain in 1992 it appeared an unexpected demand for intermediate distance travel. HSR services between Madrid-Seville (650 km) that stopped in the cities of Ciudad Real and Puertollano, around 200 km from Madrid, experienced a substantial travel demand between these two cities and Madrid. This meant that an important number of seats in these HSR services were not available to travel between Seville and Madrid.

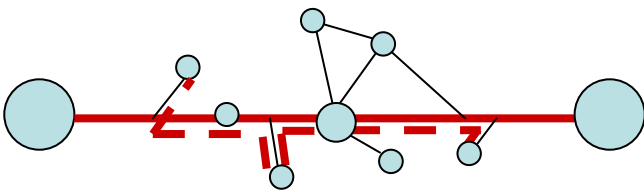
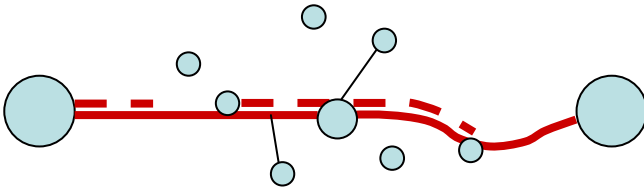
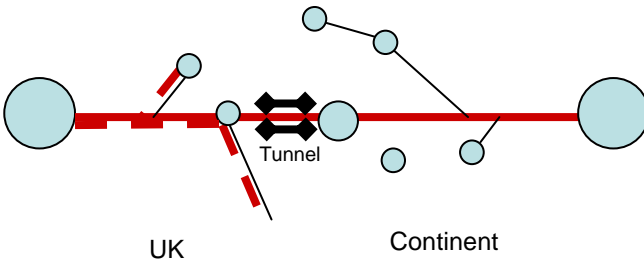



This unexpected demand for intermediate distance (200 km) HSR travel urged the railway company RENFE to create a new type of HSR regional service (called AVANT and AVE-LANZADERA) in what has been named a substitution strategy (Ureña, et al., 2009).

In France, regional high-speed services operate partly along the HSR network and partly along the traditional network (Table 1), in a process that has been termed 'irrigation' and 'regionalisation' (Menerault, 1998), thereby creating a genuinely regional network. In Spain, inter-network incompatibility between traditional rail and HSR one (different gauge) produces a greater need for HSR lines to deviate from the shortest routes so as to serve some regional cities, a process which we term 'selective deviation'. Furthermore, the low quality and diversity of traditional regional rail services has increased the demand for medium-distance travel, which has in turn encouraged the Spanish national railway company (Renfe) to create medium-distance HSR services at slightly lower speeds, always using the HSR network (Tables 1 and 3). These developments have created an indirect increase in long-distance passenger capacity, a process which we term 'substitution' (Table 1).

In the United Kingdom HSR is still in its infancy, only with one real new HSR infrastructure between London and the Continent across the channel tunnel. The appearance of this new HSR infrastructure and its compatibility (same gauge) with traditional rail, together with important commuting congestion both on motorways and traditional rail between the London extended region or metropolis and the London centre, opened up the opportunity to generate new HSR metropolitan-suburban services. The services have been called Domestic High-Speed and connect the central London station with the south east partially along the HSR line and partially along the traditional ones (see Table 1).

The number of services in each relation is also different in the three countries. In Spain and France it is similar, between 5 and 12 per day and sense, a number comparable to regional frequencies, while the number in UK is much more numerous, between 30 and 80 per day and sense, a number similar to suburban traditional rail frequencies around metropolitan areas.

Table 1. Main characteristics of HSR infrastructures and services in France, Spain and the UK.

Cities	HSR strategy	Characteristic features	Diagrams
France	Irrigation and Regionalisation (TER-GV)	<ol style="list-style-type: none"> 1. Compatible rail networks: HSR & traditional rail 2. Regional HSR along HSR and traditional lines 3. Regional objectives in a compact structure 	
Spain	Selective deviation and Substitution (AVANT)	<ol style="list-style-type: none"> 1. Incompatible rail networks: HSR & traditional rail 2. Regional HSR only along HSR lines (with two exceptions) 3. Attract regional passengers away from long-distance HSR services 	
UK	Use of new infrastructure (Domestic High-Speed)	<ol style="list-style-type: none"> 1. Compatible rail networks: HSR & traditional rail 2. Regional HSR along HSR and traditional lines 3. Regional HSR (Domestic HSR) for metropolitan distances & roles 	
<p style="text-align: right;"><i>Source: Ureña, Mennerault and Garmendia, 2009. Extended for UK.</i></p> <p>  Traditional Railway Network  HSR Network  New regional HSR services </p>			

2.1. Birth, evolution and consolidation of Regional HSR in Spain.

This section is dedicated to a brief description of HSR regional services implementation process in Spain, which has evolved since 1992 in four different phases (Figure 1 and Table 2):

- First phase: 1992-2003 – Definition of a new type of HSR service

Regional HSR services existed only between Madrid-Ciudad Real-Puertollano, they were provided using only the new HSR infrastructure by the same trains and speeds as the long distance HSR services (travel time between Madrid and Ciudad Real was 49 minutes).

In this phase frequent traveller passes were for any number of trips during a given month, didn't required previous seat reservation and included free travel in suburban trains in central Madrid.

Table 2: Chronology of HSR lines and Regional HSR services (date of starting operations)

Year	HSR Lines (or stretches)	Regional HSR Services
1992	Madrid-Córdoba-Sevilla	Madrid, Ciudad Real, Puertollano
2003	Line Madrid-Zaragoza-Lérida	
2004		Sevilla, Córdoba
2005	Line Madrid-Toledo	Madrid, Toledo
2006	Line Córdoba-Antequera Line Lérida-Tarragona	
2007	Line Antequera-Málaga Line Madrid-Segovia-Valladolid	Madrid, Segovia
2008	Line Tarragona-Barcelona	Cordoba, PuenteGenil, Antequera, Málaga Calatayud, Zaragoza Huesca, Zaragoza Lerida, Tarragona, Barcelona
2009	By-Pass Madrid (Sevilla-Barcelona)	Segovia, Valladolid Jaén, Córdoba, Sevilla, Cádiz

Source: Own Elaboration.

- Second phase: 2004 – Service Consolidation

When the first part of the second HSR line, Madrid-Barcelona, started functioning (Madrid-Zaragoza), Renfe needed more long distance HSR trains, and thus removed those servicing regional HSR and substituted them by slightly slower and cheaper HSR trains (260 km/h as maximum speeds while previous ones had 300 km/h as their maximum speed).

The regional HSR services were also established between Córdoba and Seville.

At the same time, frequent traveller passes were changed into passes for a certain number of trips per month, they started to require previous seat reservation and free suburban travel in central Madrid was cancelled.

- Third phase: 2005-2009 – Territorial expansion phase

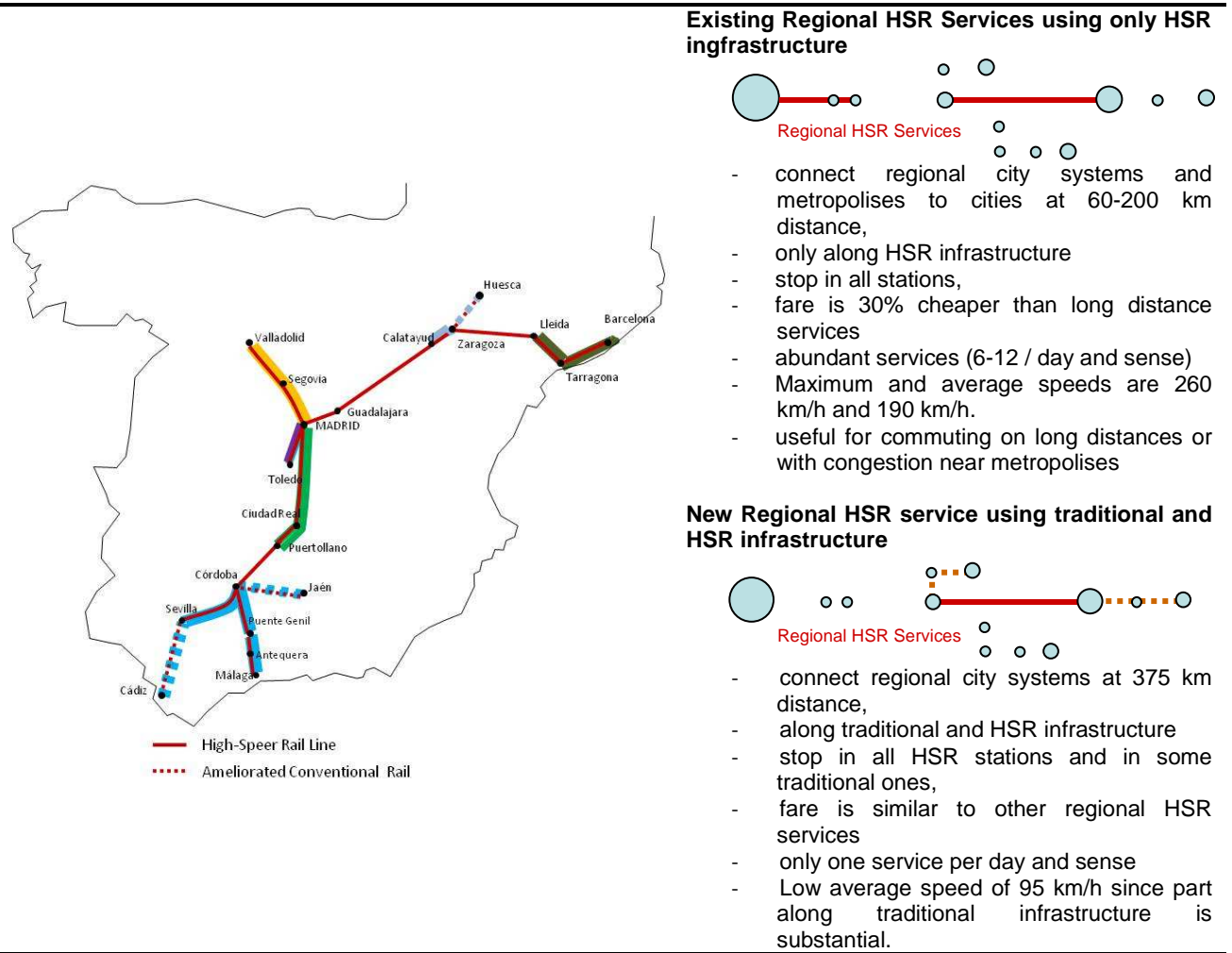
When the Madrid-Barcelona HSR line was completed, the initial part of the third Madrid-NortWest HSR line started operation (Madrid-Segovia-Valladolid) and when

the first Madrid-Cordoba-Seville HSR line was complemented with the Córdoba-Málaga stretch, every region started to demand new regional HSR services.

These services were expanded around Madrid and established for regional purposes in Andalucía (Sevilla, Córdoba, Puente Genil, Antequera and Malaga), Cataluña (Lérida, Tarragona and Barcelona) and Aragón (Calatayud, Zaragoza and Huesca, Zaragoza) (See Figure 2 and Table 1).

During this third phase some of the advantages for non frequent travellers of the HSR regional services were reduced by suppressing the points given to travellers holding HSR fidelity cards, which were equivalent to 10% of each ticket price, and some facilities in trains (i.e. the cafeteria) were cancelled.

Figure 1.- New Regional HSR service using traditional and HSR infrastructure



Source: Ureña & Coronado (2009), modified.

- Forth phase 2009-2010 – Irrigation

All the third phase regional HSR services take place along the new HSR infrastructure.

During this phase a new type of regional HSR service is established for the first time in Spain, similar to French ones. A service provided by HSR rolling material using the traditional rail infrastructure and the new HSR one. This is established in two regions, Andalucía, in which there are only 3 (Córdoba, Málaga and Seville) out of 8 provincial capitals connected to the new HSR infrastructure, and Aragón, in which only one of the

3 provincial capitals is served by the new HSR infrastructure (in reality this service is established in 2008, during the third phase).

The service is established between Jaen-Córdoba-Sevilla-Cádiz using the traditional rail infrastructure between Jaén and Córdoba and stopping in several places, the new HSR infrastructure between Córdoba and Sevilla with no intermediate stop, and the traditional rail one between Sevilla and Cádiz also with several stops. This new service connects the Andalucía region northeast-southwest. The other service is established between Huesca and Zaragoza (with an intermediate stop), along the traditional railway line on which a third rail was established so as to allow trains of Spanish and European gauges. Nevertheless, these two new regional HSR services attract very few passengers (see table 4), have only a slightly higher speed while proceeding along the traditional tracks and thus cannot be considered to change the basic characteristics of the overall regional HSR services.

During this forth phase another advantage for non frequent travellers was cancelled by diminishing from 20% to 10% the day return ticket price reductions.

3. PASSENGERS AND TERRITORIAL IMPLICATIONS IN SPAIN.

In this section the paper focuses on the implications of regional HSR services in Spain. Data collected includes passenger numbers given by the operator (RENFE, which currently is the only rail operator in Spanish network). We have also included information about inter-municipal labour markets and compared them with HSR relations in order to argue about the role that these regional HSR services could have in commuting.

Regional HSR services are called AVANT and AVE-LANZADERA and Figure 3 shows those services available in 2010. AVANT and AVE-LANZADERA trains usually run over HSR infrastructure and they are laid out and arranged with different parameters. These services have cut at least in half previous public transport (bus and traditional rail) travel times between a few cities.

This means that nowadays there are public transport services between any two major regional cities and towns in every region, that take about one minute per km; these services take less time, about 40 seconds per km, if they are direct services along motorways or good traditional rail lines, or more time, about 80 seconds per km, if they have intermediate stops, are undertaken along two lane roads or average traditional rail lines and/or are subject to congestion.

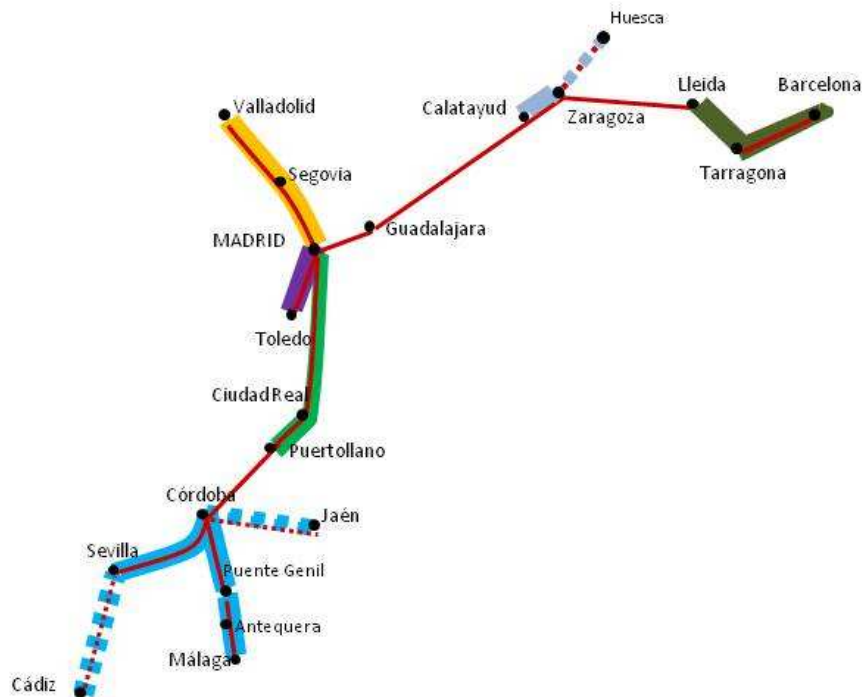
But this also means that between a few major regional cities there is a much faster new type of public transport (AVANT and AVE-LANZADERA) that only takes about 25 second per km. A much more polarized means of public transport that only connects a few cities (between 2 and 5 in a few regions or extended metropolitan areas), that generally has fewer services than buses (in the order of half to one third) and that are not able in any case to deviate and/or undertake occasional intermediate stops (as frequently busses do by having several stops near the initial origin and final destination).

This means in synthesis a very efficient and polarized means of transport, very fast but only between very few places, and very inflexible, few services and no intermediate stops.

Table 4 contains both passenger and commuter data for the Regional HSR connections. Commuter figures come from 2001 National Census (INE) while passenger data has been provided by RENFE and cover from January till October 2009. With basic calculations we have homogenized to a whole year in order to make better calculations later on. Rows marked in grey mean that those data is referred from June 2009 (the starting date of operations for these connections).

Table 3: Regional HSR services (AVANT)

Regional Scope	Regional HSR Routes	Frequency (both directions)
Centre (Madrid connections)	Madrid, Ciudad Real, Puertollano	24
	Madrid, Toledo	21
	Madrid, Segovia	5
	Madrid, Segovia, Valladolid	9
South (Andalucía)	Sevilla, Cordoba, Puente Genil, Antequera, Málaga	12 (Inc. 2 mixed services)
	Sevilla, Córdoba	17 (Including 2 mixed services)
	Jaén, <i>others</i> , Córdoba, Sevilla, <i>others</i> , Cádiz	2 (Mixed service)
North-East	Zaragoza, Calatayud	6
	Aragón Zaragoza, <i>another</i> , Huesca	6
	Cataluña Lerida, Tarragona, Barcelona	12



Source: RENFE. Own Elaboration.

Information in the table has been separated by blocks. First block includes relations in pairs for which data is developed later on, followed by two blocks showing population at 2009 for both cities and distance between them by road and HSR in kilometres. Last three blocks contain specific data:

- Potential Commuters: number of people in the 2001 Census that lived in one of the HSR cities and worked in the other, set out in both directions separately and together, and a calculation for potential commuting trips according to this figure. Calculation of equivalent trips has been made by multiplying total figures by 2 (return trips) and by 200 (average labour days in a regular year). Result tries to show the potential of this connection, assessing what the market would be for regional HSR.
- Regional HSR passengers: contains passenger data in terms described above. This data is more developed specifically in the following sub-sections.
- Ratios: in order to obtain criteria about regional HSR implications we have done three ratios that compare the relation between passengers and potential commuters, another focussing how HSR services are covering the functional links between cities by comparing passengers and potential equivalent trips and a distance ratio which compares road and HSR geographic distances.

Table 4. Regional HSR services and passengers, potential commuters and ratios in Spain.

Relations	Population (2009)		Distance (Km.)		Distance (Min.)			Potential Commuters (2001)				Regional HSR passengers (2009)		Ratios		
	First city	Second city	HSR	Road	HSR	Road	Road -HSR	Total	First direction	Return direction	Equivalent trips	(Jan-Oct 2009)	Homogeneized to whole year	Year Passengers / P. Commuters	Year Passengers / Equivalent trips	Road/ Rail
Madrid-Toledo	3.255.944	82.291	75	81	30	59	29	2.182	1.190	992	872.800	1.337.672	1.605.206	736	1,84	1,08
Madrid-Segovia	3.255.944	56.660	68	92	30	69	39	1.443	1.260	183	577.200	487.303	584.764	405	1,01	1,35
Valladolid-Segovia	317.864	56.660	111	110	39	170	131	233	166	67	93.200	24.488	29.386	126	0,32	0,99
Madrid-Ciudad Real	3.255.944	74.014	170	201	62	137	75	948	261	687	379.200	766.036	919.243	970	2,42	1,18
Madrid-Puertollano	3.255.944	51.842	209	248	73	185	112	629	104	525	251.600	286.502	343.802	546,6	1,37	1,19
Ciudad Real-Puertollano	74.014	51.842	39	40	17	30	13	917	422	495	366.800	201.753	242.104	264,0	0,66	1,03
Madrid-Zaragoza	3.255.944	674.317	306	318	258	291	33	1.576	226	1.350	630.400	ND	ND	----	----	---
Madrid-Calatayud	3.255.944	21.933	221	233	88	207	119	ND	ND	ND	ND	ND	ND	----	----	---
Zaragoza-Calatayud	674.317	21.933	85	92	30	125	95	324	0	324	129.600	36.632	43.958	136	0,34	1,08
Zaragoza-Huesca	674.317	52.059	75	75	44	57	13	1.441	849	592	576.400	16.372	19.646	11	0,03	1,00
Barcelona-Tarragona	1.621.537	140.323	100	99	36	133	97	1.130	339	791	452.000	69.593	83.512	74	0,18	0,99
Barcelona-Lérida	1.621.537	135.919	178	178	70	169	99	767	153	614	306.800	320.660	384.792	502	1,25	1,00
Tarragona-Lérida	140.323	135.919	78	104	31	141	110	121	45	76	48.400	25.430	30.516	252	0,63	1,33
Córdoba-Jaen	328.428	116.557	106	116	98	155	57	222	115	107	88.800	1.439	3.741	17	0,04	1,09
Córdoba-Sevilla	328.428	703.206	125	142	45	162	117	1.104	716	388	441.600	529.877	635.852	576	1,44	1,14
Córdoba-Puente Genil	328.428	30.033	61	70	22	58	36	185	100	85	74.000	4.016	4.819	26	0,07	1,14
Córdoba-Antequera	328.428	45.168	96	115	36	145	109	37	25	12	14.800	3.084	3.701	100	0,25	1,20
Córdoba-Málaga	328.428	568.305	154	169	54	175	121	475	391	84	190.000	88.842	106.610	224	0,56	1,10
Córdoba-Cádiz	328.428	126.766	277	263	155	171	16	66	44	22	26.400	1.684	4.378	66	0,17	0,95
Sevilla-Málaga	703.206	568.305	279	203	115	150	35	664	370	294	265.600	192.380	230.856	348	0,87	1,32
Sevilla-Antequera	703.206	45.168	128	160	86	174	88	538	512	26	215.200	8.023	9.628	18	0,04	1,25
Sevilla-Puente Genil	703.206	30.033	61	144	72	159	87	43	17	26	17.200	24.759	29.711	691	1,73	2,36
Sevilla-Cádiz	703.206	126.766	152	123	148	183	35	677	282	395	270.800	3.586	9.324	14	0,03	0,81
Málaga-Antequera	568.305	45.168	58	52	105	142	37	1.208	512	696	483.200	11.660	13.992	12	0,03	0,90
Málaga-Puente Genil	568.305	30.033	93	113	25	53	28	74	18	56	29.600	25.402	30.482	412	1,03	1,22
Málaga-Cádiz	568.305	126.766	338	253	38	148	110	143	73	70	57.200	ND	ND	----	----	----

Source: INE, Census 2001. RENFE. Own elaboration.

Passengers data since June 2009, date for first operations in these connections

ND No Data

In relation to potential commuters we take this variable as a way to compare how real demand on HSR could respond to this potential and functional demand, assuming that obviously not every commuter would choose HSR to satisfy its transport necessity and some non-commuters will use the regional HSR services. Therefore, ratio below 1 means that HSR is not taking a relevant role in potential trips between these two cities while the opposite means that HSR is having more demand than this potentially ever had by commuting.

Analysing the results four groups of city relations can be proposed based on their Passengers versus Potential Commuters ratio:

- Ratio above 500: relations where there are plenty more HSR passengers than those that would have been generated by each potential commuter (400). This means that demands in these connections are far from being based only on commuters. The best example is Madrid-Ciudad Real (970). This group contains big metropolis connections, including most of Madrid relations, Barcelona-Lerida and two Sevilla links (Cordoba and Puente Genil). Adding to this, passengers/potential trips are considerably above 1, which strengthens the idea that demand is above potential commuting.
- Ratio between 160 and 500: this ratio defines frequent relations but normally below 1 in ratio passengers-potential commuter trips (with exceptions of Madrid-Segovia and Malaga Puente Genil). The prototypical connection in this group is normally given by medium distance (125-175 km) and one big city involved, except Ciudad Real-Puertollano which is a very unusual connection (two small cities close to each other).
- Ratio between 90 and 160: these connections are significantly below their potential and demand is clearly below potential commuter trips. Most of them are relations over short distances, between small or intermediate cities with already good transport choices apart from HSR (usually motorway), which makes regional HSR services less competitive and less demanded than longer distance connections with bigger cities. Growth potential in these cases would eventually come by improving competitiveness of these services. Other interpretation could be the novelty of most of them. Looking at the first two groups and comparing with chronology in Table 1, older services get better ratios which could be interpreted as if time increases the demand (do not forget that most of these services are operating since late 2008 and mid 2009). Nevertheless, demand on Madrid-Toledo and Madrid-Ciudad Real-Puertollano was very high already in the first years of operation.
- Ratio below 90: these are very weak connections where demand is considerably below potential commuter trips. There are few connections, but some even below 20, which means very insignificant number of passengers in relation to those that would have been generated by each potential commuter (400). Besides the novelty for services, there are normally better means of transport to satisfy this potential demand than HSR, so these services seem not being able to attract passengers from other transport modes. Normally there are motorways (almost as fast for not so long distances) and traditional regional trains (cheaper) that make regional HSR useless in terms of commuting purposes.

3.1. Analysis of southern regional HSR services (Andalucía).

These services combine almost all possibilities in Spanish rail operations. The Cordoba-Sevilla HSR connection was available since 1992, although there was no regional HSR service until 2004, 12 years later than former regional HSR services Madrid-Ciudad Real-Puertollano.

Andalucía (Andalucía) is the largest Spanish autonomous region and the most populated one (8,3 mill. inhabitants) with a distributed urban network under the hierarchy of Seville which is the forth city of Spanish system below Madrid, Barcelona and Valencia. Table 3 showed the scheme for regional HSR services available in Andalucía, principally linking Seville, Cordoba and Malaga, with an extension towards Cadiz and Jaen but with lower frequencies and using partially traditional rail.

Table 5 shows calculations made for passengers in these lines, enlarging the figures shown in table 4. As it was set out, Jaen and Cadiz were linked recently (June 2009) and figures for them are referred to that date till the end of the year.

Table 5. Passengers in Regional HSR in Andalucía services. 2009.

Station Origin	Station Destination							Total
	Sevilla	Cordoba	Puente Genil	Antequera	Malaga	Cadiz	Jaen	
Sevilla		305.396	2.356	1.874	54.552	4.664	4.352	373.195
Cordoba	330.492		14.904	5.206	116.688	1.646	2.220	471.156
Puente Genil	2.464	14.807		430	15.143			32.843
Antequera	1.826	4.422	358		6.703			13.309
Malaga	52.058	114.168	15.340	7.289				188.855
Cadiz	4.659	2.733					1.115	8.507
Jaen	3.692	1.521				905		6.118
Total	395.192	443.047	32.957	14.798	193.086	7.215	7.688	1.093.983

Source: RENFE. Own calculations

Results show a preferential relation between Sevilla and Cordoba (630.000 passengers in both directions) which is a direct effect from the facts that Sevilla is the regional capital city with nearly 1 million inhabitants in its metropolitan area and this connection has no intermediate stops in 150 km distance and both stations are central. Therefore, the characteristics of this connection are optimal for full development of regional HSR services.

A smaller passenger demand can be found in Malaga relations with Cordoba and Sevilla, where there are two and three intermediate stops respectively despite all stations being central. Distance is also important; because the number of passengers in the Cordoba-Malaga relation (154 km) doubles that of the Seville-Malaga one (279 km), while in relation to the distance HSR is more useful for the latter. However, in this case, the distance by road in the relation Seville-Málaga is 76 km smaller than by HSR, thus passengers prefer to travel by road. On top between Seville and Málaga there are three intermediate stops, thus reducing its attractiveness for passengers.

There are quantitatively insignificant relations with smaller cities (Puente Genil and Antequera) because their distances to bigger cities are too small (70 and 115 km with Córdoba, respectively, and 113 and 52 km with Malaga) and stations are peripheral in

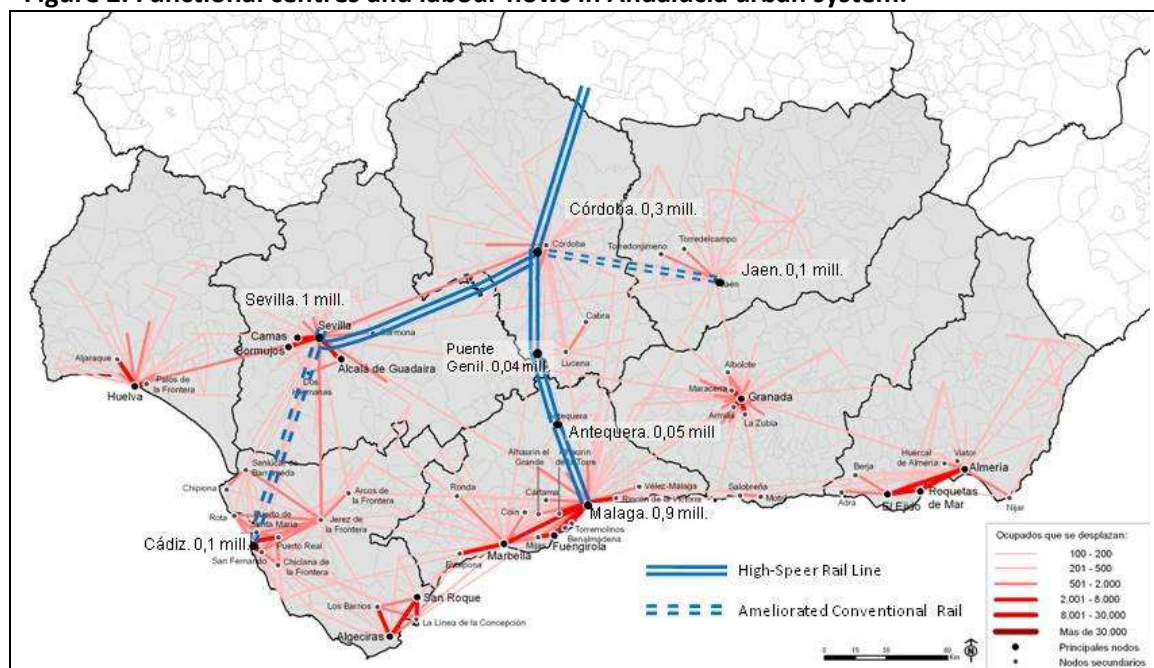
both cases. In this situation HSR is less competitive in comparison with road transport in terms of travel time and price.

Data for mixed traditional-HSR regional service between Jaen and Cadiz shows very few passengers, which could be interpreted because the novelty of the service and the small frequency (only two by day and sense) and speed while proceeding along the traditional rail infrastructure. This service is only significant in the Sevilla-Cadiz connection where distance is in a medium range.

A second argument is done by comparing this demand data with the labour market articulation. Inter-municipal labour market relations (commuting) are calculated following 2001 National Census which made an analysis for inter-municipal dependence of workers which could be regarded as obliged mobility. A map for this situation was draw by De Cos et al (2009) and is shown in Figure 2, where we have depicted the scheme of HSR network for a better understanding of rail operations and labour market interaction.

Obliged mobility in Andalucía can be characterized as well-balanced in general terms. Each provincial city keeps influence in their province territory. In a regional scope, mobility vectors preferably go to and from Sevilla which is perfectly understandable in terms of hierarchy. In this general trend, flows with Cadiz are stronger than those to Malaga and Granada in a second level and progressively fewer to the rest of the southern urban system in Spain.

Figure 2. Functional centres and labour flows in Andalucía urban system.



Source: De Cos et al (2009); modified.

Obviously there is only a weak relation between labour mobility structure and HSR network. First of all, we must highlight a date divergence because Census data is from 2001 and the whole regional HSR system described started to operate as a whole in mid 2009. By the 2001 Census no regional HSR service was available so we cannot evaluate the influence of these services in labour market configuration besides general conclusions extracted from deduction and field work carried out. Following those,

Sevilla-Cordoba relations have been strengthen integrating progressively Cordoba's labour market in the Sevilla market.

Other significant relations are less important for different reasons. Cadiz has had and is still having an intense relation with Sevilla and recent mixed rail HSR regional services take a small share of their general flows. A different interpretation deserves Sevilla-Malaga connection which means the connection between the first and second cities in the system. In that case HSR network configuration clearly contributes to a lower efficiency of current regional HSR services in comparison with road connection: rail operations have to cover almost double distance than road. Potential of this connection along a more direct HSR infrastructure will be significantly better between these two metropolitan areas, of around 1 mill inhabitants each, as figures from other regional services will show.

3.2. Analysis of North-East regional HSR services.

These recent operations include two different sets of services in two regions (see table 3), one in Cataluña (Cataluña) and the other one in Aragon. Table 6 shows passenger data in a similar way we did in table 4 which are analyzed separately in this section for each service.

Table 6. Passengers in Regional HSR services in North-East Spanish network. 2009.

Station Origin	Station Destination						Total
	Barcelona	Tarragona	Lerida	Zaragoza	Calatayud	Huesca	
Barcelona		40.670	190.120				230.790
Tarragona	42.841		14.868				57.709
Lerida	194.672	15.648					210.320
Zaragoza					22.349	7.362	29.711
Calatayud				21.610			28.972
Huesca				9.010			9.010
Total	237.513	56.318	204.988	30.620	22.349	7.362	

Source: RENFE, own elaboration.

- Cataluña

First conclusion from Cataluña is how small are passenger figures, considering Barcelona's size and importance in a National scope, being the second city of the country. These services are operational since late 2008 and data available begin in January 2009, so a very short time of operations to consider they are already implanted and running at their full potential.

Nevertheless, relations show a stronger link for Barcelona-Lerida connection in comparison with Tarragona-Barcelona and, clearly, Tarragona-Lerida. The reason for that is probably a better optimal distance (170 Kms.) and central station at Lérida, while Tarragona has a peripheral station (10 Kms. from city centre) and distance to Barcelona is closer (90 Km), that means lower potential for HSR services advantage.

Second conclusion, the connection between Lerida and Tarragona has fewer passengers that could be explained by cities size (Lérida, 160.000 and Tarragona-Reus, 380.000), 100 Km distance, the peripheral position of Tarragona's station and a non-congested motorway that links both cities.

- Aragón

The two services Calatayud-Zaragoza and Huesca-Zaragoza mean a very small part of the network, linking two small regional cities with the big pole of Zaragoza (0,7 mill. inhabitants). Despite Zaragoza's hierarchy as the biggest regional city and being in the middle between Madrid and Barcelona, flows created in the Calatayud-Zaragoza and in the Huesca-Zaragoza regional HSR connection are not very significant. Several reasons can be argued, the small size of Calatayud (22.000 inhabitants), very good coach services in less than 100 Km distances, the very small frequency of these regional HSR services (3 in each direction), in general and particularly in comparison to bus services, and the lack of several stops at Zaragoza. On top, the number of passengers is comparatively smaller in the relation Huesca-Zaragoza than in the Calatayud-Zaragoza (see Table 6) due to smaller time savings, because in the first case the regional HSR service uses a traditional track.

So, the impact of HSR in this regional framework is very limited and its growth potential is still unclear.

3.3. Analysis of Madrid regional HSR services.

These operations are mainly regional HSR services between Madrid and two sets of small cities at 60 to 90 km from it, already integrated into metropolitan processes before the HSR, and at 150-200 km from it, non-integrated in metropolitan processes before the HSR. Though there are three exceptions: two connections not including Madrid (Segovia-Valladolid and Ciudad Real-Puertollano) and one medium size city (Valladolid, 450.00 inhabitants).

The common point they have is that Madrid is the reference city. As previously said, Madrid-Ciudad Real-Puertollano was the first Spanish (and European) experience (in 1992) in this kind of services we have called Regional HSR. Until 12 years later no other service of this kind was available in Spain.

Looking at data showed in Table 7 it can be seen that Madrid-Toledo is the most demanded regional HSR service with 1,5 mill. passengers in 2009, in nearly 70 Km distance and barely 3 years of operation. An explanation could be that traditional rail services were cancelled since HSR started to operate and that regional HSR towards Madrid is the only rail service. Madrid and Toledo are also connected by a motorway already congested due to 20-years of metropolitan expansion/urban sprawl effects from Madrid metropolitan area towards Toledo. Daily passengers Toledo-Madrid were already large before HSR and process here could be called better a substitution of transport modes rather than the implementation of new relations.

Cualitative analysis of this demand has also showed a share of 30% of tourists in these figures (Menendez and Rivas, 2009). Toledo is a historic city with a high quality city centre protected by UNESCO, National and Regional instruments. This tourism is being done mainly on a day return basis from Madrid. Subtracting this percentage of tourists, around 1 mill. passengers are remaining with other travel purposes, mainly working, business and educational.

Table 7. Passengers in Regional HSR services in Madrid connections. 2009.

Station Origin	Station Destination								Total
	Madrid	Ciudad Real	Puertollano	Madrid	Toledo	Madrid	Segovia	Valladolid	
Madrid		462.149	170.564						632.713
Ciudad Real	457.094		119.284						576.378
Puertollano	173.238	12.282							185.520
Madrid					761.297				761.297
Toledo				758.599					758.599
Madrid							289.878	173.028	462.906
Segovia						294.886		14.606	309.492
Valladolid						178.518	14.779		193.297
Total	630.332	474.431	289.848	473.404	304.657	187.634	304.657	187.634	

Source: RENFE. Own elaboration.

Demand for Madrid-Ciudad Real connection has no such influence of tourists, despite distance is nearly 170 km. Extending the analysis to Puertollano we find a strong demand among cities that are slightly above 50.000 inhabitants with a strong big city such as Madrid. This demand partially explains further development in this sort of operations and has also developed synergic projects in terms of transport and commuters.

Madrid-Segovia link is also important, almost 600.000 passengers last year. Explanation for that is quite similar that argued for Toledo. First, Segovia is also a World Heritage city close to Madrid (less than 100 km.) but several differences can be set out from Toledo case: Madrid-Segovia axis is not an industrial and business corridor and there is topographic barrier north Madrid that also separates the middle part of Iberian Peninsula, while motorway compared to HSR distance is 90 km compared to 60 km by HSR. Nevertheless, figures are important, even so if we take into account that Segovia station is peripheral (about 10 km. from city centre) and urban connections are still weak.

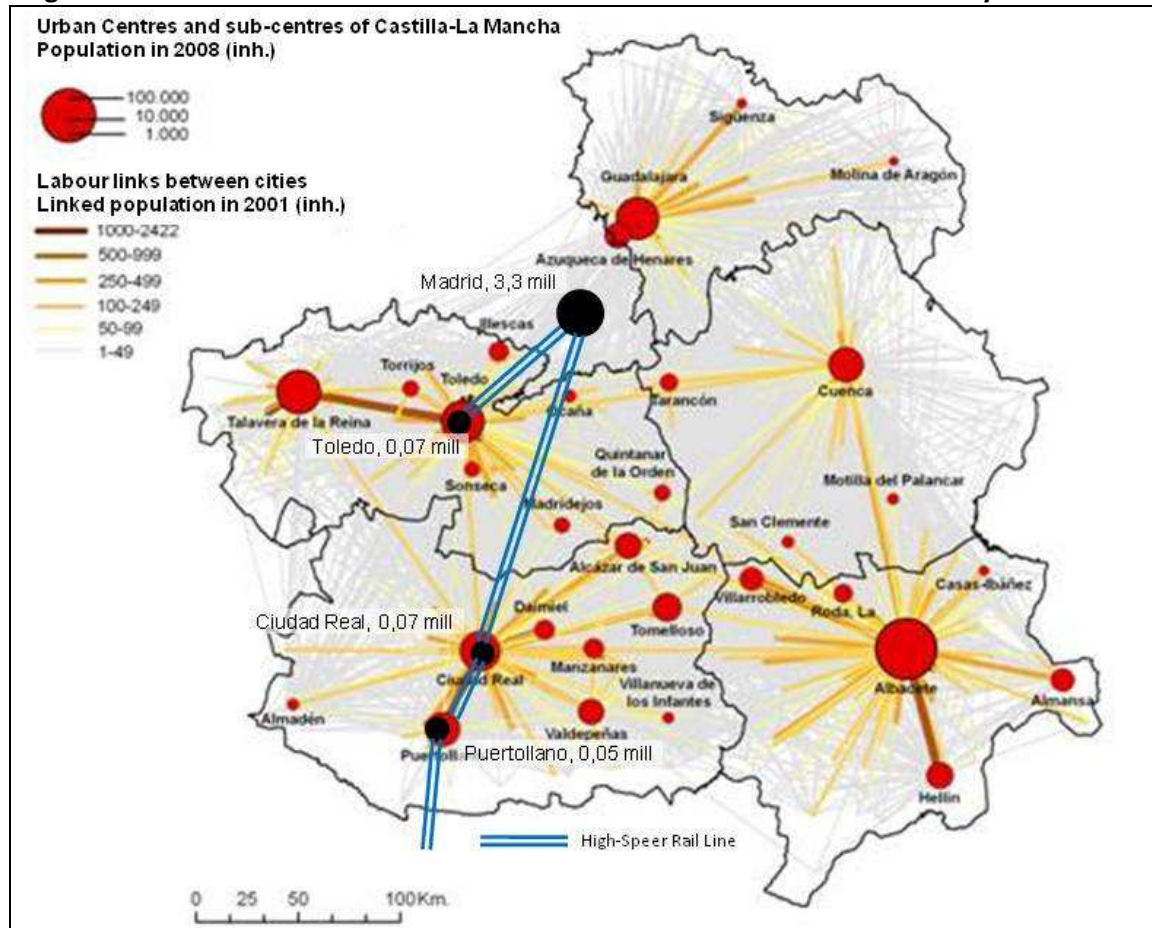
Similar smaller relations can be seen in Madrid-Puertollano and Madrid-Valladolid, around 350.000 passengers each. In both cases they are the second stop in their relation with Madrid (the first ones being Ciudad Real and Segovia respectively).

In a regional scope, not including Madrid, there is a difference between north and south links. There is an important relation Ciudad Real-Puertollano while Segovia-Valladolid is smaller, 240.000 passengers in the first case and only 30.000 in the second one. This is a curious case because Puertollano is just 40 Km distance from Ciudad Real and with a motorway since 2008, so demand should be preferably balanced with the road. In opposition, Segovia is 110 km. distance from Valladolid and also with a motorway since 2008. Potentially, the Segovia-Valladolid distance and no rail connections prior to HSR would supposedly show better factors to induce a relevant use of HSR, while Ciudad Real-Puertollano do not. But on the contrary, the use of HSR is greater in the Ciudad Real-Puertollano relation than in the Segovia-Valladolid one.

To deepen in this debate on regional HSR services and their role in terms of functionality we can count with a recent study that makes a specific analysis of labour flows in Castilla-La Mancha region in a very similar way as the study carried out by De Cos et al (2009) and used in Figure 2. Castilla-La Mancha region is south of the Madrid

region, placed between it and Andalucía and characterized for being mostly a rural region with just a few cities, small and medium size, weakly related among them but usually better connected with bigger cities outside the region, such as Madrid. Toledo, Ciudad Real and Puertollano are three of the six biggest cities in this region, being the first one the regional capital.

Figure 3. Functional centres and labour flows in the Castilla-La Mancha urban system.



Source: Pillet et al, 2010; modified.

In Figure 3 we present part of Pillet et al (2010) analysis for urban functional network polycentrism in this region, highly influenced by outer cities, principally Madrid. Over their cartography we have depicted the HSR cities and the configuration of the HSR network. HSR could be considered one of the most attractive forces that operate inter-regional integration of these cities in the Madrid metropolitan area, rather than promoting a better intra-regional integration (Martinez, 2010), and this idea is easily conveyed just by looking at the general HSR scheme (see Table 3 and Figure 3), where Toledo-Madrid is a completely separated infrastructure from the other southern HSR line which connects Madrid and Sevilla with three intermediate stops, two of them in Castilla-La Mancha (Ciudad Real and Puertollano). This is to say; that an important and expensive infrastructure like this one is not connecting regional cities (i.e. Toledo with Ciudad Real and Puertollano) while it is connecting them with other cities outside the region, Madrid (and also with Sevilla but not by regional HSR services). This clearly strengthens Madrid position in the regional urban network.

Analyzing the inter-municipal labour flows structure in the region we can also confirm this statement, proving how weak is the relation between HSR services and the configuration of labour inter-municipal market flows. As Pillet et al (2010) and Martinez (2010) stated, these flows are supported by local and regional transport links rather than by the HSR network which operates at a bigger national scale, connecting some cities with Madrid in a separately way.

4. METROPOLITAN INTEGRATION OF DISTANT CITIES BY HSR.

In previous section we have briefly commented several ideas about the role of regional HSR services in some regional areas in Spain. In this section the paper will try to deepen in the last idea given that HSR is contributing more to metropolitan attraction of distant cities than to regional integration. Taking into account HSR characteristics in terms of distance requirements, investment needed and operation costs among others, this statement is everything but a surprise. Nevertheless, HSR could be a powerful way to bring closer in terms of travel time, some cities that are far away in terms of geographical distance. The integration process of two very different cities (a big metropolitan area with a small city) caused by regional HSR can be analyzed in some cases. In the paper we will focus on Madrid and Barcelona.

In Spain, prior to HSR, work related commuting distances, only very occasionally, were bigger than 100 km, and they were much more frequent up to 60 km. HSR opened up commuting on 200 km distances (around one hour HSR travel time), see Ureña, et. al. (2005).

All HSR cities distant between 170 km and 200 km from one of the two biggest Spanish metropolitan areas have regional HSR services (AVANT) that connect them with lower fares than long distance HSR services, both for occasional travel (between half and 60%) (see Ureña, et. al., 2009a) and for frequent travellers (one third of the price, comparing day return long distance fare with frequent traveller pass of 40 trips a month).

The number of regional HSR passengers is not proportional to each city size and distance to the metropolis (see Table 1). The rationale has to be different; our hypothesis is that it might be more related to the local development and connectivity prior to the HSR and to a certain city size threshold so as to attract sufficient high level professionals.

This hypothesis is far from being objectively and thoroughly tested because there are not enough cases in Spain; there are only 4 cases, Ciudad Real, Lerida, Puertollano and Valladolid.

Nevertheless, the analysis of the above mentioned variables (see Tables 1 and 8) show that there are three types of relations between those four cities and the corresponding metropolitan areas:

- Small cities (between 50.000 and 100.000 inhabitants), previously to HSR not on major national road corridors and having HSR Regional services with no intermediate stops and up to one hour travel time to a metropolis show very strong relations with it (near 1 million AVANT HSR passengers). This may be so because prior to HSR they were quite isolated and did not develop a strong local economic base and the HSR opened up plenty job opportunities for local inhabitants in the metropolitan areas and opportunities to improve local high

level activities by commuting metropolitan professionals. In fact these cities prior to HSR had been characterized by out migration and HSR starts to make feasible for locals not to emigrate but to access a big labour market by commuting to the distant metropolis. This is the case of Ciudad Real.

- Intermediate size cities (between 100.000 and 500.000 inhabitants), previously to HSR located by major national road and rail corridors and having HSR Regional services with one intermediate stop and over one hour travel time to a metropolis show weak relations with it (around 350.000 AVANT passengers). This may be so because prior to HSR they were already well connected and developed a sound local economic base and offered abundant job opportunities to their inhabitants. The HSR, although strongly ameliorated the day return travel possibilities with the metropolis, it doesn't attract so many passengers because there are enough job opportunities locally and because there are enough high level professionals also locally. This is the case of Lerida and Valladolid.
- Even smaller cities (up to around 50.000 inhabitants), previously to HSR not on major national road corridors and having regional HSR services with one intermediate stop and over one hour travel time to a metropolis, show weak relations with it (around 350.000 passengers) although as big as other much bigger cities (3 to 6 times). This might be so because prior to HSR they were quite isolated and the HSR opened up job opportunities in the metropolitan areas, but the travel time above one hour and the intermediate HSR stop, make the metropolitan interaction much smaller and also the local opportunities for metropolitan high level professionals commuters are smaller. This is the case of Puertollano, which also has a strong labour dependence on the industrial petrol sector, and thus is potentially less inclined to take advantage of HSR, since HSR transports passengers but no industrial goods.

Table 8: HSR Cities between 170 and 270 km from a major metropolis

City Name & Population	Metropolis Name & Population	Avant pass. by year	Distances (km)			Services Travel time (minutes)			National corridor prior HSR 1st/2nd HSR stop
			Motor way	Min. by road	HSR	Buses	Avant/Total HSR	Trad. Rail	
Lérida 135.000	Barcelona 5,0 mill	384.792	173	173	170	16 130-180	6 / 22 70	10 75-224	Yes Second
Valladolid 318.000	Madrid 6,0 mill	468.396	212	190	150	28 120-210	4 / 18 70	10 160-200	Yes Second
Ciudad Real 74.000	Madrid 6,0 mill	919.243	245	183	170	6 150-210	12 / 26 53	1 161	No First
Puertollano 52.000	Madrid 6,0 mill	343.802	270	218	200	6 180-230	12 / 26 73	1 198	No Second

Source: RENFE; <http://www.alsa.es/portal/site/Alsa/>; <http://www.aisa-grupo.com/>. Own elaboration.

5. CONCLUSIONS.

The initial objective of HSR in Europe was to connect metropolitan areas at distances between 400 and 700 km (between two and three hours travel) and to reduce the dependency on air transport. The infrastructure compatibility in France, the need to improve regional rail services in Spain and the opportunity to increase the usefulness of a long distance infrastructure in UK lead to the introduction of regional HSR services.

This has meant the creation of a new type of HSR that may play relevant roles in not so long distances as initially thought.

In the case of Spain, regional HSR services serve very few cities (except a very recent service that uses also the traditional rail infrastructure and that has a very small number of passengers) and compete with motorway transport, rather than with air transport. This very polarized and fast regional transport services may facilitate intense contacts between a more limited and polarized system of cities, cities at greater distances than before.

The paper suggests that there are several types of HSR regional services:

- Some are intraregional while others are inter-regional. In the case of Cataluña or Andalucía, a medium size region in terms of surface and one of the largest regions respectively, the regional HSR services are intra-regional. In the case of Castilla-La Mancha, also one of the largest regions in terms of surface almost all the regional HSR services are only inter-regional.

- Some connect all the provincial capitals of the region, others connect only a few of them and other does not connect any of them. In the case of Cataluña the present regional HSR services connect 3 of the 4 capitals, but it is expected that when the HSR infrastructure is built until the forth one this will also be served by the regional HSR services. In the case of Andalucía the regional HSR services connect 6 out of the 8 provincial capitals, although two of them through a regional HSR service of rather lower speed because much of it is done along the traditional rail infrastructure. In the case of Castilla-La Mancha none of the provincial capitals are connected by the regional HSR services.

- Some attract a big number of passengers, others a limited number and others a very small number. In distances between 150 and 270 km with no intermediate stops the number of passengers is big, while less numerous if there are intermediate stops. In distances below 100 km passenger numbers are big only if one of the cities is a big metropolis, with two exceptions; first, the relations with metropolis when the HSR station in the city at less than 100 km is peripheral and second, the relations between two small cities with central stations. In the first case, the relation Tarragona-Barcelona, and in the second one, the relation Ciudad Real-Puertollano.

- Peripheral stations attract smaller number of passengers while central ones attract greater number. The cases of Puente Genil, Antequera or Tarragona with peripheral stations have few passengers, while the cases of Ciudad Real, Puertollano or Toledo with central stations have greater number of passengers. Nevertheless, there are some exceptions: Calatayud, with central station but very small size, Segovia, with a peripheral station but important relations with Madrid, and Valladolid with a central station but few passengers.

The paper suggests that regional HSR services in Spain have evolved from a sole regional HSR with similar service quality and speed than long distance HSR, to the existence of many more services with a lesser quality (lesser speed and in-train commodities) and lesser side advantages (free suburban travel and reductions for day return travel). A tendency that may be coherent with the more business related travel and higher prices of long distance HSR and the more work related travel (daily commuting) and much cheaper fares of the regional HSR.

The paper also shows that almost all the regional HSR services use exclusively the HSR infrastructure and stations, while the very recent last new regional HSR service has

started to use a combination of the HSR infrastructure and also the traditional rail infrastructure. This service while using the traditional infrastructure is much slower, has more stops, and attracts a very small number of passengers.

Finally, the paper suggests that regional HSR services may be crucial to extend metropolitan influence to a few cities up to 200 km from the metropolitan centre, by increasing the distances over which commuting is feasible.

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