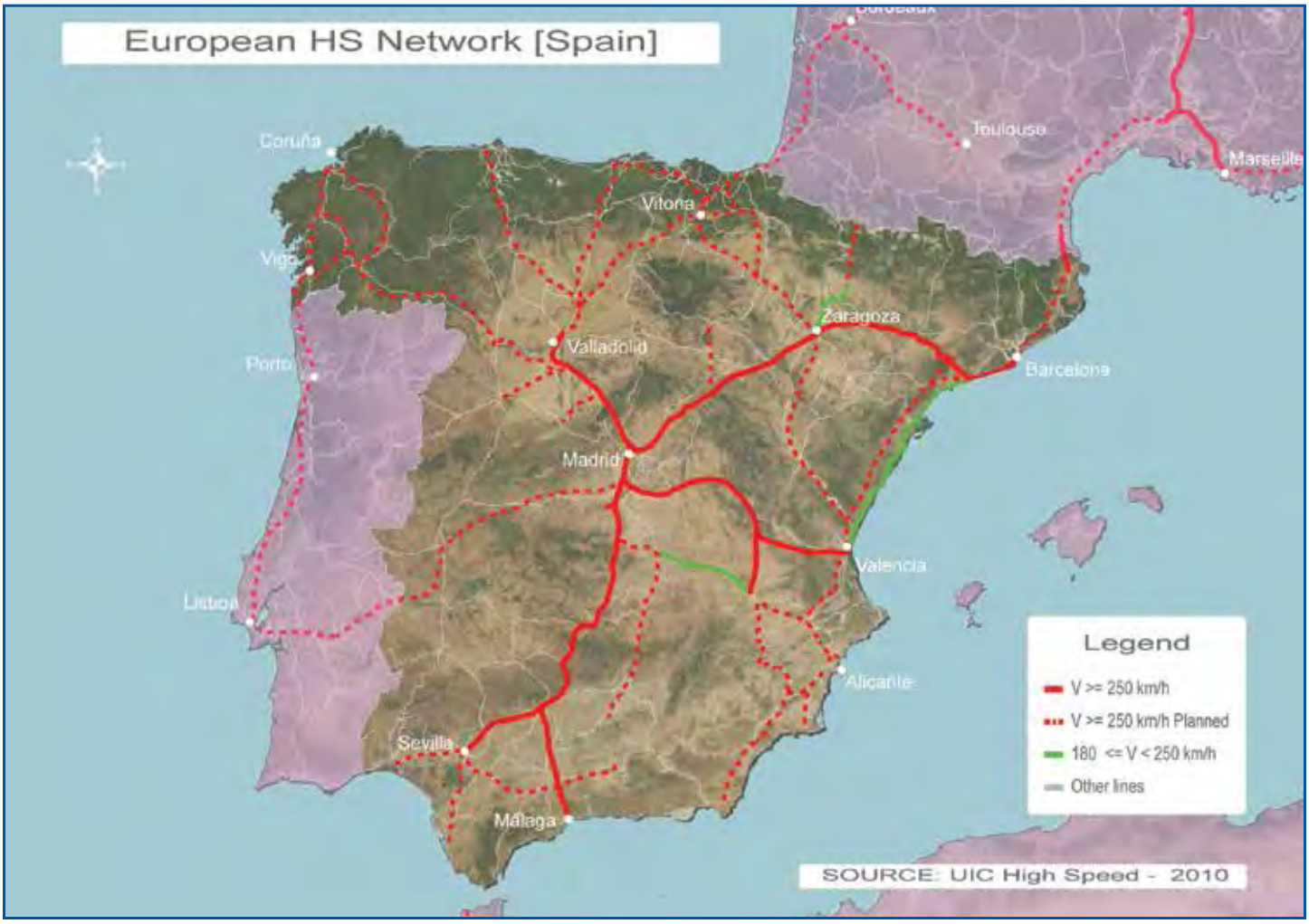
International System Summary: **SPAIN**

HighSpeedRail
TEXASHSR.ORG



UIC Map of the Spain's High-Speed Rail Lines

Spain is located in Southwestern Europe on the Iberian peninsula and is bordered by France to the north and Portugal to the west. About three-quarters of the physical size of Texas, Spain's population ranks 27th in the world with 47 million people—almost twice the current population of Texas. Seventy-seven percent of the Spanish people live in areas designated as urban. Madrid, the country's capital, is the largest city with 5.7 million people, followed by Barcelona with 5.0 million people. The GDP of $1.4 trillion ranks as the 14th largest economy, and the GDP per capita of $30,600 per year ranks 43rd. Spain maintains a robust high-speed rail network, currently comprising of over 2,000 km (1,275 miles) with an additional 1,770 km (1,100 miles) under construction. Furthermore, Spain has plans for future development of 1,700 km (1,050 miles) of high-speed rail lines, although the recent financial crisis may delay or put some of that development in doubt. The map above displays the existing and planned high speed lines in Spain, according to the International Union of Railways (UIC).

SYSTEM DESCRIPTION AND HISTORY

The first Spanish high-speed line opened in 1992 between Madrid and Seville, stretching from the center of the country to the southern end of the Iberian peninsula. Several sources speculate that the motivation to implement high-speed rail between Madrid and Seville, instead of between Madrid and Barcelona, could have been political in nature. Nevertheless, Seville hosted the Universal Exposition in April 1992, with the high-speed line opening during the event. The Administrador de Infraestructuras Ferroviarias or Administrator of Railway Infrastructures (Adif) published several narratives on Spanish high-speed network development and adds that the existing conventional rail line between Madrid and Seville was a single-track line with capacity issues traveling through difficult terrain. Any upgrade to the existing rail infrastructure would have been costly; therefore, the decision was made to implement the new high-speed infrastructure in this corridor. Adif notes that the success of the first French high-speed line was an influence. The high-speed rail service on the corridor reduced travel time from over 7 hours using conventional rail service to less than 3 hours when initially instituted. Journey time is now further reduced to 2 hours 20 minutes, according to Adif.

Since the opening of the first line, Spain has rapidly expanded their high-speed service network. The Ministry of Public Works Strategic Infrastructure and Transport Plan 2005-2020 (PEIT) calls for all the provincial capitals to be connected with Madrid via high-speed rail. Madrid is located in the center of the country, while much of the other population centers are located along the coast. Therefore, Spain has developed a radial HSR system connecting through Madrid. The comprehensive high-speed rail network plan in the PEIT would connect 90 percent of the Spanish population with high-speed train service if fully implemented.

The table to the right provides the UIC documented high-speed rail segments in Spain, including those segments under construction and those in the planning stage. They report that in 2010 Spain had 2,056 km (1,278 miles) of operating high-speed rail segments and an additional 1,767 km (1,098 miles) under construction. There are currently 28 high-speed train stations; of which 17 are newly built and 11 are adapted for the high-speed services.

UIC Table of Spain's High-Speed Rail Lines

Stage	Speed		Year Opened	Length	
	km/h	mph		km	miles
In Operation:					
Madrid – Seville	270	170	1992	471	293
Madrid – Lleida	300	185	2003	519	322
Zaragoza – Huesca	200	125	2003	79	49
(Madrid -) La Sagra – Toledo	250	155	2005	21	13
Córdoba – Antequera	300	185	2006	100	62
Lleida – Camp de Tarragona	300	185	2006	82	51
Madrid – Segovia – Valladolid	300	185	2007	184	114
Antequera – Málaga	300	185	2007	55	34
Camp de Tarragona – Barcelona	300	185	2008	88	55
By pass Madrid	200	125	2009	5	3
Madrid-Valencia/Albacete	300	185	2010	432	268
Figueres – Frontera (-Perpignan)	300	185	2010	20	12
TOTAL				**2,056**	**1,278**
Under Construction:					
Barcelona – Figueres	300	185	2010-12	132	82
Ourense – Santiago	300	185	2011	88	55
(Madrid-) Alicante/ Murcia/Castellón	300	185	2012	470	292
Vitoria – Bilbao – San Sebastián	250	155	2012	175	109
Variante de Pajares	250	155	2012	50	31
Bobadilla – Granada	250	155	2012	109	68
La Coruña – Vigo	250	155	2012	158	98
Navalmoral – Cáceres – Badajoz – Fr. Port.	300	185	-	278	173
Sevilla – Cádiz	250	155	-	152	94
Hellín – Cieza (Variante de Camarillas)	250	155	-	27	17
Sevilla – Antequera	300	185	-	128	80
TOTAL				**1,767**	**1,098**
Planned:					
Valladolid – Burgos – Vitoria	300	185	-	211	131
Venta de Baños – León – Asturias	-	-	-	238	148
Madrid – Navalmoral de la Mata	300	185	-	191	119
Almería – Murcia	-	-	-	190	118
Valencia – Castellón	-	-	-	64	40
Olmedo – Zamora – Orense	300	185	2012	323	201
Palencia – Santander	300	185	-	201	125
Zaragoza – Castejón – Logroño	250	155	-	149	93
Castejón – Pamplona	300	185	-	75	47
Orense – Vigo (vía Cerdedo)	250	155	-	60	37
TOTAL				**1,702**	**1,058**
GRAND TOTAL				**5,525**	**3,433**

Talgo 350 Train. This series of trains are designed to reach a speed of 350 km/h (220 mph), although present lines and commercial services limit the speed at 330 km/h (205 mph).

The Madrid–Seville high-speed line segment was the first line in Spain to use the international gauge (UIC gauge) of 1,435 mm (56.5 inches), compared to the traditional Iberian gauge of 1,668 mm (65.7 inches) for most of the remainder of Spain's rail network. New dedicated high-speed line segments also use the international standard. Because of this difference in gauges, certain trains are required to accommodate both gauges. Adif indicates that gauge changers alter the train's wheel sets for operating on both standards. Therefore, some trains operate solely on the high-speed network, while others are equipped to alter their wheelset gauge to extend to additional markets beyond the high-speed lines, which spreads the benefit of higher speed operations to 50 additional cities.

An additional noteworthy aspect of the Spanish high-speed rail network and services is that three different rolling stock technologies are utilized: French Alstom TGV; Siemens Velaro ICE (Germany); and Bombardier (France) and CAF and Talgo (both from Spain). This "open architecture" of the Spanish HSR track and structures, allowing for the use of a variety of manufacturers' rolling stock, is quite different from the approaches in several countries where the infrastructure is designed to work with only one, specific type or manufacturer. Such flexibility provides potential for greater opportunities for connectivity with other HSR systems and for economic advantages from more open competition when new trainsets must be purchased in the future.

A final highlight of the Spanish high-speed services is the dedication to on-time performance. Several sources indicate near 99 percent punctuality—second only to the Japan Railways for on-time performance. Adif narratives indicate that beginning in September 1994 Alta Velocidad Espanola or Spanish high-speed (AVE), the name of the dedicated high-speed rail service, introduced a policy to provide full refunds to passengers if the train arrives more than 5 minutes behind schedule, unless the delay is not due to causes beyond the control of the railway.

Sources: Infrastructure and Stations – High Speed Lines; Network Statement Update 2012; High-Speed Rail: A Study of International Best Practices and Identification of Opportunities in the U.S.

The RENFE Class 130, a high speed dual gauge, dual voltage trainset consisting of eleven Talgo VII tilting coaches and two power cars.

ECONOMICS AND FINANCE

Red Nacional de los Ferrocarriles Espanoles (Renfe) was Spain's national railway company prior to European Union (EU) directives to separate rail infrastructure ownership and operations. That directive resulted in the creation of two government entities:

- Administrador de Infraestructuras Ferroviarias or Administrator of Railway Infrastructures (Adif) is in charge of infrastructure management and capacity allocation and
- Renfe-Operadora is the passenger and freight operator.

Adif receives track access payments from the train operators. The Spanish HSR system is characterized by Thompson and Tanaka (2011) as having similar complexity to the system in France, including "variable usage charges for different lines and by time of day along with capacity reservation charges that are meant to recover a significant portion of the financial cost of the high-speed line." The UIC *High Speed and the City* report also mentions in the case studies for Madrid and Barcelona high-speed rail stations that the high-speed train operator pays a toll of 0.83 Euro ($1.00) per traveler to the infrastructure manager for use of the station.

Renfe-Operadora offers several passenger rail options, including three services considered high-speed.

- AVE (Alta Velocidad Espanola, or "Spanish high-speed") – This is the dedicated high-speed long-distance service that operates on the UIC gauge high-speed network. It operates at speeds of up to 300 km/h (185 mph). Several sources indicate the AVE services do not receive government subsidies.
- Alvia – The other long-distance service operates on both the UIC gauge and Iberian gauge tracks. The services travel up to 250 km/h (155 mph) on high-speed lines and up to 220 km/h (135 mph) on conventional lines.
- Avant – This is a medium-distance service with high-speed trains specifically designed for short journeys. It travels up to 250 km/h (155 mph) with commercial speeds around 150 km/h (90 mph).

Financing and funding of the high-speed network development in Spain has largely been through government and European Union sources. A Ernst & Young (2009) report highlights the major European Union funding programs include funds from the Trans-European Transport Network (TEN-T) funds, Cohesion funds, and European Regional Development Funds (ERDF). Additional sources

highlight the acquisition of loans from the European Investment Bank (EIB). The purpose of much of the funding from European Union sources has been provided to allow Spain and other European countries that have benefitted from it to develop systems on par with the more advanced HSR systems in France and Germany prior to the formation of the EU.

Sources: High Speed Passenger Rail – Future Development Will Depend on Addressing Financial and Other Challenges and Establishing a Clear Federal Role; High Speed 2: International Case Studies on Delivery and Financing – A Report for HS2; High Speed Rail Passenger Services: World Experience and U.S. Application; High Speed and the City; Passengers – Timetables; High-Speed Rail: A Study of International Best Practices and Identification of Opportunities in the U.S.; "High-Speed Railways in Spain Example of Success?"

RIDERSHIP AND TRANSPORTATION SYSTEM IMPACTS

The following table provides high-speed ridership numbers according to two different sources, as reported by Thompson and Tanakan (2011). Between 1992 and 2003 the only high-speed line was the line between Madrid and Seville. This table shows steady growth during that time period for that segment. A major jump in ridership occurs between 2006 and 2008 as the different segments between Madrid and Barcelona were completed. For the most recent year total high-speed ridership was 28.75 million (2009), with the AVE service reporting 17 million passengers.

Many sources examine the modal comparison along the Madrid to Seville corridor after implementation of the high-speed train service. Gines De Rus et al. (2012) reports that prior to high-speed rail (1991) the mode split was 44 percent road, 16 percent rail, and 40 percent air. Ten years after high-speed rail implementation (2002) those splits had changed to 30 percent road, 1 percent conventional rail, 61 percent high-speed rail, and 8 percent air. Several documents point out and caution that the Madrid to Seville mode shift is partly due to the government-owned airline specifically not competing with the high-speed rail service. Airlines are now deregulated in Spain and air service will become potentially more competitive between major internal nodes. For the Madrid to Barcelona corridor, several sources indicate that total rail share compared to air shifted from 12 percent to 48 percent following full implementation of high-speed rail service in that corridor. Likewise, the Madrid to Valencia corridor saw the rail share increase from 40 percent to almost 75 percent, and the Madrid to Malaga corridor saw the rail share increase from 28 percent to 69 percent.

Year	Renfre (AVE only)			Renfre (All "High-Speed")		
	Passengers (thousands)	Pass-Km (millions)	Pass-miles (millions)	Passengers (thousands)	Pass-Km (millions)	Pass-miles (millions)
1992	–	–	0	1,314	400	249
1993	–	–	0	3,256	900	559
1994	–	–	0	3,554	900	559
1995	3,900	1,290	802	3,826	1,200	746
1996	–	–	0	3,415	1,100	684
1997	–	–	0	4,032	1,266	787
1998	–	–	0	6,946	1,516	942
1999	–	–	0	5,093	1,674	1,040
2000	5,600	1,940	1,205	6,425	2,210	1,373
2001	–	–	0	6,998	2,409	1,497
2002	6,300	2,180	1,355	7,208	2,506	1,557
2003	6,000	2,030	1,261	7,334	2,531	1,573
2004	6,200	2,090	1,299	7,560	2,747	1,707
2005	7,200	2,320	1,442	7,176	2,325	1,445
2006	8,700	2,700	1,678	6,519	2,601	1,616
2007	9,100	2,590	1,609	11,409	3,593	2,233
2008	16,300	5,480	3,405	22,955	10,490	6,518
2009	17,000	5,977	3,714	28,751	11,505	7,149
Stated sources: UIC, International Railway Statistics and AVE, Anuario Estadistica de Fomento						

Madrid and Barcelona High-Speed Rail Stations

The UIC report *High Speed and the City* documents how high-speed rail stations relate to urban planning and development through a series of case studies. The case studies for Spain's high-speed rail stations include both the Madrid and Barcelona stations.

Madrid, the country's capital, has a population of over 3.2 million people. The city and additional metropolitan population of 6.4 million people rank it as the third largest metropolitan area in Europe after London and Paris. Madrid's population is spread over an area of 5,364 square kilometers (13,983 square miles) placing it in the low population density range compared to most other UIC case study cities. Conversely, Barcelona is one of the most densely populated cities in Europe and only followed the density of Seoul, Korea, in the worldwide case studies. The dense population is largely the effect of the location between the mountains, coast, and two rivers. Barcelona's city population of 1.6 million comprises only 28 percent of the total metropolitan population of 5.8 million in the Barcelona region.

Madrid Stations

Madrid currently has two high-speed train stations: Atocha, located in the southern part of the city and Chamartin, located in the northern part of the city. The report highlights that during the case study investigation that both stations provided dead-end services but a new tunnel, in addition to the two existing tunnels, was under construction that would connect high-speed rail between the stations, allowing for a through-running scheme. The new operations will solve capacity problems facing the stations. Both stations provide connections with subway, other passenger rail, and bus transit services.

The Madrid Atocha station first opened in 1892, with modern additions to the station occurring in 1985 and 1992. It had 209 daily high-speed services (arrivals and departures) described in the case study that moved approximately 38,000 passengers per day. Current infrastructure projects at the station will double current high-speed train capacity.

High-speed service through the Chamartin station began in 2008 resulting in 35 daily high-speed rail services (arrivals and departures) and 3,200 passengers per day. A major aspect of current plans is a major urban development at the station named Operación Chamartín that includes not only both transportation infrastructure improvements and expansions but also new housing and green areas.

Barcelona Stations

The Barcelona metropolitan area has three high-speed train stations, two of which are located in Barcelona: Sants, located in the western part of the city; Sagrera, located in the eastern part of the city; and Prat, located in the western metropolitan area in the vicinity of the airport. The report indicates that the Sagrera and Prat stations were under construction at the time the UIC report was completed.

Arrival of the high-speed rail services in to the Sants station involved constructing dedicated lines because of the gauge differences between high-speed trains and other passenger trains served by the station. Additionally, there are currently two underground tunnels (one for high-speed trains) with a third tunnel for high-speed services under construction. The new tunnel will convert the current dead-end scheme to a through scheme. A significant aspect of the Sagrera station is the number of major infrastructure projects at the station and extensive urban renewal and redevelopment taking place around the station. Daily high-speed services in Barcelona include 76 services (arrivals and departures), which accommodate 7,224 daily passengers.

Modal Comparisons

Both of the case study sheets have Madrid to Barcelona modal comparisons of travel time and fares. The conventional rail service prior to high-speed rail took approximately 9 hours, but travel time has reduced to only 2 hours 40 minutes with the introduction of high-speed rail service. The approximately 621 km (368 mile) corridor is traveled by plane in only 1 hour 15 minutes, with extra time required for check in, boarding, and baggage collection. Air travel provides the lowest cost option according to the UIC study with a travel fare of 41 Euro ($53) compared to the travel fare for high-speed rail of 54 Euro ($70) . The following table provides the modal comparison for the Madrid to Barcelona corridor presented in the UIC report.

UIC Madrid Atocha Station to Barcelona Modal Comparison

Travel Mode	Travel Time	Travel Fares
High-Speed Train	2 hr 40 min	54 Euro ($70)
Conventional Train	9 hr (before HSR)	–
Car	6 hr 30 min	83 Euro ($107)
Plane	1 hr 15 min*	41 Euro ($53)
*only travel time		

AVEs in Seville's Santa Justa station

The Madrid Chamatrin station serves the 193 km (120 mile) high-speed route between Madrid and Valladolid. This short corridor only takes the high-speed rail service 1 hour at a travel fare of 20 Euro ($26) . The following table compares the high-speed service to conventional train and passenger car as no air service exists for this shorter corridor.

UIC Madrid Chamartin Station to Valladolid Modal Comparison

Travel Mode	Travel Time	Travel Fares
High-Speed Train	1 hr	20 Euro ($26)
Conventional Train	2 hr 40 min	16 Euro ($21)
Car	2 hr 15 min	29 Euro ($37)
Plane	N/A	N/A

Sources: High Speed Rail Passenger Services: World Experience and U.S. Application; Economic Analysis of High-Speed Rail in Europe; High Speed Rail and Sustainability; "When Trains go Faster than Planes: The Strategic Reaction of Airlines in Spain"; High Speed and the City

SUSTAINABILITY

Adif has developed an annual sustainability report which it has published since 2005. In the *2010 Sustainability Report*, Adif espouses its ultimate goal is to "develop an excellent rail system which will promote sustainable development and constitute a public and social service." The pillars of their strategy include:

- The integral safety of the rail system.
- Operational efficiency: quality, reliability, compliance with deadlines.
- Economic efficiency: financial stability, economic and social return.
- Innovation.
- Environmental protection.
- Professional development and pride of belonging to Adif.
- The contribution of value in local communities where we operate.
- Integrity in management.
- Transparency and dialogue with stakeholders.

Sources: 2010 Sustainability Report

BIBLIOGRAPHY

2010 Sustainability Report
Adif (Administrador de Infraestructuras Ferroviarias or Administrator of Railway Infrastructures)
URL: http://www.adif.es/en_US/conoceradif/informe_de_sostenibilidad.shtml
Date Accessed: November 1, 2012

Economic Analysis of High-Speed Rail in Europe
Prepared by Gines De Rus, et al. with BBVA Foundation, May 2009, revised July 2012.
URL: http://www.fbbva.es/TLFU/dat/High%20Speed%20Rail_2012_web.pdf
Date Accessed: October 8, 2012

High Speed and the City
Prepared for the International Union of Railways (UIC) by BB&J Consult, September 2010
URL: http://www.uic.org/IMG/pdf/20101117_highspeed_thecity_finalreport.pdf
Date Accessed: June 20, 2012

High-Speed Lines in the World
International Union of Railways (UIC), Updated November 1, 2011
URL: http://www.uic.org/IMG/pdf/20111101_a1_high_speed_lines_in_the_world.pdf
Date Accessed: May 30, 2012

High Speed Passenger Rail – Future Development Will Depend on Addressing Financial and Other Challenges and Establishing a Clear Federal Role
United States Government Accountability Office (GAO), Report to Congressional Requesters, GAO-09-317, March 2009
URL: http://www.gao.gov/new.items/d09317.pdf
Date Accessed: May 29, 2012

High-Speed Rail: A Study of International Best Practices and Identification of Opportunities in the U.S.
Prepared for the Southwest Region University Center by the Center for Transportation Research at The University of Texas at Austin, August 2011
URL: http://swutc.tamu.edu/publications/technicalreports/476660-00071-1.pdf
Date Accessed: May 30, 2012

High-Speed Rail: Lessons for Policy Makers from Experiences Abroad
Prepared for the Research Institute of Applied Economics by Albalate and Bel at the University of Barcelona, 2010
URL: http://www.ub.edu/irea/working_papers/2010/201003.pdf
Date Accessed: October 25, 2012

High Speed Rail and Sustainability
Prepared for the International Union of Railways (UIC) by Jehanno, Palmer and James with Systra and TRL, November 2011
URL: http://uic.org/IMG/pdf/hsr_sustainability_main_study_final.pdf
Date Accessed: May 30, 2012

High Speed Rail (HSR) in the United States
Prepared for the Congressional Research Service by Peterman, Frittelli, and Mallet, December 8, 2009.
URL: http://www.fas.org/sgp/crs/misc/R40973.pdf
Date Accessed: August 8, 2012

High Speed Rail Passenger Services: World Experience and U.S. Applications
Prepared by Thompson and Tanaka with Thompson, Galenson and Associates (TGA), September 20, 2011
URL: http://www.tgaassoc.com/documents/final-version-hsr-corrected-9-20-11.pdf
Date Accessed: May 31, 2012

"High-Speed Railways in Spain Example of Success?"
Found in Transportation Research Record. No. 2261, pp.39-48, 2011, Prepared by Sanchez-Borras, Robuste, and Criado
URL: http://trb.metapress.com/content/1783390k673797lj/fulltext.pdf
Date Accessed: November 1, 2012

High Speed 2: International Case Studies on Delivery and Financing – A Report for HS2
Ernst & Young, December 2009
URL: http://www.chippingwarden.org/hs2documents/casestudies.pdf
Date Accessed: May 30, 2012

Infrastructure and Stations – High Speed Lines
Adif (Administrador de Infraestructuras Ferroviarias or Administrator of Railway Infrastructures)
URL: http://www.adif.es/en_US/infraestructuras/lineas_de_alta_velocidad/lineas_de_alta_velocidad.shtml
Date Accessed: November 1, 2012

Network Statement Update 2012
Adif (Administrador de Infraestructuras Ferroviarias or Administrator of Railway Infrastructures)
URL: http://www.adif.es/en_US/conoceradif/declaracion_de_la_red.shtml
Date Accessed: November 1, 2012

Passengers – Timetables
Renfe Operadora website
URL: http://www.renfe.com/EN/viajeros/horarios.html
Date Accessed: November 5, 2012

"Rail Infrastructure Charging Systems for High-Speed Lines in Europe"
Found in Transport Reviews: A Transnational Transdisciplinary Journal. Vol. 31, Issue 1, 2011, Prepared by Sanchez-Borras and Lopez-Pita
URL: http://www.tandfonline.com/doi/abs/10.1080/01441647.2010.489340
Date Accessed: November 1, 2012

"When Trains Go Faster Than Planes: The Strategic Reaction of Airlines in Spain"
Found in Transport Policy. Vol. 23, pp. 34-41, September 2012, Prepared by Jimenez and Betancor
URL: http://www.sciencedirect.com/science/article/pii/S0967070X1200087X
Date Accessed: November 1, 2012

The World Factbook
United States Central Intelligence Agency
URL: https://www.cia.gov/library/publications/the-world-factbook/
Date Accessed: May 31, 2012