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"High-Speed Rail: Lessons for Policy Makers from Experiences Abroad"

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Abstract

In April 2009 the US government unveiled its blueprint for a national network of high-speed passenger rail (HSR) lines aimed at reducing traffic congestion, cutting national dependence on foreign oil and improving rural and urban environments. In implementing such a program, it is essential to identify the factors that might influence decision making and the eventual success of the HSR project, as well as foreseeing the obstacles that will have to be overcome. In this article we review, summarize and analyze the most important HSR projects carried out to date around the globe, namely those of Japan, France, Germany, Spain, and Italy. We focus our attention on the main issues involved in the undertaking of HSR projects: their impact on mobility, the environment, the economy and on urban centers. By so doing, we identify lessons for policy makers and managers working on the implementation of HSR projects.

JEL classification: L91; L92; R41; R42 ; R48
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1. Introduction

The first Chinese high-speed railway (HSR) connection was inaugurated in 2008 between Beijing and Tianjin. This was followed on 26 December 2009 when a high-speed line in the Wuhan-Guangzhou corridor came into service.[1] Today, the 664-mile distance between these two cities can be covered in little more than three hours on the non-stop, high-speed train (HST) services. Trains travel at an average speed of 217 miles per hour (mph), with a maximum of 244 mph on some stretches, a speed that is considerably higher than those averaged by HSTs in other countries, including Japan, France, Germany, Italy and Spain. Thanks to this new rail link, the two large metropolitan areas of Wuhan (9 million people) and Guangzhou (12.5 million people in 2005) have seen rail travel time cut from ten to three hours, placing the airlines servicing this route, particularly China Southern Airlines, under great competitive pressure. According to forecasts issued by the Chinese Ministry of Railways, by 2012 work will have been completed on 42 HST links covering close to 8,100 miles,[2] making it the most extensive HSR network in the entire world.

While the most populated country in the world speeds up work on its HSR network, in the United States, on 17 February 2009, President Obama signed the American Recovery and Reinvestment Act, which included funds ($US 8 billion and $US 1 billion yearly during at least five years) for the Federal Railroad Administration (FRA) to be devoted to intercity and high-speed rail projects. Two months later, on April 16, 2009, the President unveiled his administration's blueprint for a national network of high-speed passenger rail lines. The purpose of this plan, as stated by President Obama, is to reduce traffic congestion, cut dependence on foreign oil and foster urban and rural livable communities.[3] Indeed, the existing infrastructure is deemed to be insufficient to handle the nation's future passenger and freight mobility demands (FRA, 2009).

Official reports contemplate ten high-speed rail corridors, ranging between 100 and 600 miles in length, as potential recipients (see **Figure 1**),[4] although the FRA has received demands from 40 States totaling more than $US 100 billion. Two types of project are

[1] High-speed rail is typically used to mean railways capable of speeds close to or above 190 miles per hour on purpose-built track (de Rus and Nash, 2007).
[2] *People's Daily*, online English edition, December 26, 2009. *People's Daily* is the press organ of the Central Committee of the Communist Party of China (CCP).
[3] See Official report DOT 51-09 on Thursday 16 April, 2009 at the Federal Railroad Administration website www.fra.dot.com
[4] The length of these corridors is justified by the potential competitiveness and comparative advantage of HST versus other transportation modes.

included: one devoted to building world-class HST corridors as in Europe, and another aimed at making conventional services faster. Consequently, different investment strategies are envisaged: the promotion of new express services (on dedicated track operating at speeds over 150 mph), the development of emerging and regional services (operating at up to 150 mph on shared and dedicated track), and the upgrading of reliability and service on conventional rail services (operating at speeds up to 90 mph).

Figure 1. US designated High Speed Rail network.

Source: US Federal Railroad Administration (FRA).

The debate regarding the costs and benefits of building a high-speed rail system in the US is a long-running affair. Levinson et al. (1997), examining the full costs of an HSR system projected for a corridor connecting Los Angeles and San Francisco, concluded that it would be more costly than expanding the existing air service and marginally more expensive than auto travel. The infrastructure costs alone were estimated at more than $9.5 billion in 1994 US dollars (Leavitt et al., 1994), which is more than $22.5 million per mile. More recent evaluations suggest that total HST costs could reach $37 billion (assuming no overrun on any cost items), i.e., about $50 million per mile (O'Toole, 2008). The most recent estimates, conducted in December 2009 by the California High-Speed Rail Authority (CHSRA, 2009) as part of its Business Plan for the California HST (San Francisco-Anaheim system), put the costs at $US 42.6 billion, an increase of 7.2% in real $US on CHSRA's 2008 estimate. Given these figures it is doubtful that without a considerable subsidy a high-speed rail link could be constructed in California, much less a profitable one. Similar conclusions can be drawn when evaluating the Florida HST proposal, which would cost about $US 25 million per mile to serve four million travelers per year (FRA, 2005).

Previous research has provided interesting and useful lessons from worldwide experiences on policies such as congestion charging (see Albalate and Bel, 2009). In this work we review, summarize, and analyze the results of studies that have examined the five most prominent cases of HSR implementation: Japan, France, Germany, Spain, and Italy. All these countries have built relatively extensive HST networks to reduce rail travel time between their main cities. By identifying and examining the factors leading to different outcomes in these countries, this article offers valuable lessons learned from the building and operation of HST networks for policy makers, planners, and transportation managers in the United States.

This article is organized into four sections beyond this introduction. Next, we briefly discuss the most relevant issues involved in the building and operating of high-speed rail systems. Then, armed with the guidelines extracted from this discussion, we proceed to review the aforementioned international experiences, which is the core of this paper. We are then able to discuss useful lessons for American policymakers and planners. Finally, some concluding remarks are recorded.

2. The case for the high-speed train: relevant issues

By reviewing the cases of European and Japanese HSR networks, we seek to extract lessons for the emerging American HSR plan. The structure of our analysis in each case will address: main motivation; network design and functions; economic costs; environmental costs; mobility impacts; and economic and regional effects.

Main motivation

The first issue we address are the reasons for the establishment of an HST network in each of the countries studied. Several reasons can motivate the construction or upgrading of rail networks to high-speed systems. Among others, congestion is the leading inefficiency factor that can justify capacity investments seeking travel time savings and boosting productivity. However, infrastructure networks become an essential source and means of economic and regional development and this feature may also affect public decisions on route location.

Structure: rails, functions and geography

Urban structure usually shapes HSR-network needs and their design, as do the functions they seek to fulfill, be they of an economic or political nature. In some instances countries have chosen to construct new HSR lines exclusively for passengers, while others have promoted a more efficient mobility of freight by upgrading existing infrastructure on a shared track for passengers and freight, albeit at lower speeds and by incurring higher costs. Politically centralized countries (such as France) have tended to design networks that link the capital to its peripheral centers. By contrast, decentralized countries (such as Germany) have tended to build more territorially balanced networks.[5]

A further decision regarding network design is the potential to use conventional lines to access city centers. By making this choice, construction costs can be reduced, although there is a parallel fall in commercial speeds.

Economic costs

HST services offer a punctual, comfortable and rapid mode of transport, and are highly competitive over medium distances (between 100 and 500 miles), since by connecting city downtowns they avoid the need to commute from the airport and the inconveniences of traffic congestion. This said, HST links involve huge investment costs, which will vary with network decisions and their functions. Because of these costs –which are designed to create a very high capacity service - high-speed rail generates more economic benefits as the volume of traffic increases (de Rus and Nash, 2007). Construction costs, together with the associated operating costs, condition the social suitability of undertaking HST projects;[6] thus, cost-benefit analyses are essential. In this review we pay special attention to the way in which network and design decisions affect investment, as well as the circumstances under which this huge fiscal effort is socially profitable. In short, we seek to determine what can be expected from each dollar spent on the project.

Mobility impacts

As an HST service enters a given corridor as a new or upgraded transport mode, its performance can attract new passengers, as well as those that had previously been using air, road or conventional rail services. Thus, upgrading rail transportation is expected to affect the

[5] A network map for each country studied here can be consulted in the appendix.
[6] Campos and de Rus (2009) present a detailed review of HST costs. While they do not consider costs related to mobility, economic effects and urban impacts, their survey does provide a very useful up date on cost considerations and data up to the mid-2000s.

airline industry and road usage over medium distances. The European Commission (1996) provides data on changes in modal shares following the introduction of HST on the Paris-Lyon (France) and Madrid-Seville (Spain) lines. In the first of these (Paris-Lyon), between 1981 and 1984, the modal share of air traffic fell from 31 to 7%, and that of car and bus traffic fell from 29 to 21%, whereas rail traffic rose from 40 to 72%. In the case of the Madrid-Seville line, between 1991 and 1994 the modal share of air traffic fell from 40 to 13%, and that of car and bus from 44 to 36%, while train increased from 16 to 51%. Hence, as modal shares are subject to dramatic changes, this review highlights the ways in which the introduction of an HST line can alter the modal split between two cities.

Environmental advantages

As HSR is more environmentally efficient than its natural competitor – the airline industry - making medium-distance transportation more environmental friendly is an obvious rationale for building HST networks. However, the building and operation of HSR systems are also responsible for environmental damage, in terms of land take, noise, visual disruption, air pollution and the increase in the global warming effect because of the high consumption of electric energy.

Economic and regional effects

Arguably the most interesting effects are the economic and regional impacts of HST networks. Does HSR generate new economic activities and promote job creation? Which sectors benefit most from HSR systems? Does HSR increase regional productivity and cohesion? Does HSR lead to activity dispersion across the territory? Does HSR affect firm location decisions? On these issues, Esteban Martín (1998) claims that cities served by HSTs benefit from improved accessibility, but at the same time there is a downgrading of conventional train services and air services on those lines where a HST alternative exists. HSTs do not appear to attract advanced services companies, which show no greater propensity to locate in areas neighboring HST railway stations. And while business tourism and conferences benefit from HST services, a reduction in the number of overnight stays cuts tourist expenditure and the consumption of hotel services. Interestingly, while a HST line improves accessibility between the cities connected by the service, it disarticulates the space between these cities - what has been referred to as the *tunnel effect* (Gutiérrez Puebla, 2005). Hence, HST lines do not seem to increase inter-territorial cohesion, but rather they promote territorial polarization.

3. International experiences

In this section we apply our simple implementation framework to five key cases of HSR-network development in the world: Japan, France, Germany, Spain, and Italy. Our inquiry is based on a review of the extant literature of these cases, as well as on our own research data. While there have been several studies on each of these cases individually, no study to date has combined analyses across a large number of cases. Unlike studies that examine only one case or, perhaps, compare two, our review allows us to draw general lessons for policy makers, planners and transportation managers in the US. We have selected these five cases because they are the most thoroughly documented experiences and there is sufficient information to record results and to draw conclusions.

3.1 Japan: '*Shinkansen*'

Japan was a pioneer in the building of high speed trains. The first link in its network, connecting Tokyo to Osaka, came into service in 1964.[7] The objective pursued by these early planners was to reduce the travel time between the two cities – standing almost 350 miles apart - to three hours. The main motivation underlying this policy was to promote mobility demand in this corridor due to the rapid economic growth experienced after World War II. Today, the Shinkansen network crosses Honshu Island – the nation's largest island - and serves more than 300 million passengers each year.

The regional structure of Japan, with large metropolitan centers located a few hundred miles apart with a high demand for travel, has favored HSR (Givoni, 2006).

The network was given a new, purpose built infrastructure – with a different track gauge - and specific vehicles designed to offer commercial speeds of 130 mph, with a current top speed of 188 mph.[8] Although the service was designed to serve both freight and passengers, the huge passenger demand and maintenance needs – carried out mainly at night – favored a passenger orientation. In addition, its separation from the conventional rail service allowed HSTs to avoid problems derived from these conventional services and its ageing infrastructure.

[7] Although the High Speed Train was eventually proposed in 1957 and inaugurated in 1964 to coincide with the Olympic Games, construction work actually began in 1940 but was halted by WWII (Taniguchi, 1992).
[8] A new dedicated line was required as the conventional railway network ran on a narrow gauge that could not support HSTs (Givoni, 2006; p.595).

Table 1. Shinkansen construction costs.

Line	Year	Total Cost (nominal $US billion)	Miles	Cost per mile (nominal $US million)
Tokaido	1964	0.92	347	2.6
Sanyo	1975	2.95	389	7.6
Tohoku	1985	11.02	335	32.9
Joetsu	1985	6.69	209	32.0

Source: Authors' own adapted from Taniguchi (1992).

Construction costs for the 347 miles between Tokyo and Osaka rose to $0.92 billion in 1964, while the Sanyo (389 miles), Tohoku (335 miles) and Joetsu (209 miles) lines were considerably more expensive (**Table 1**). According to Taniguchi (1992), the cost share attributable to infrastructure (cuttings, banks, viaducts, bridges, tunnels) on the Sanyo line (58%) was the highest. Land price, the second most important share, represented a quarter of total costs. Tunnels and bridges built along the route meant costs were high. In fact, 30% of Japanese lines run through tunnels (Okada, 1994). Furthermore, building links into city centers added both to the complexity of the operations and to overall costs.

Demand forecasts proved to be underestimated. While the number of passengers-km (million) was 11,000 in 1965, in just ten years it had risen to 35,000. Time savings are estimated at 400 million hours per annum. Population growth offers interesting results. Cities with HST railway stations achieved average rates of 1.6%, while those by passed by the service only increased at a 1% rate (Hirota, 1985). It was found that HST stations resulted in marginal population impacts, and that these were more marked in cities with an information exchange industry, access to higher education and expressway access (Nakamura and Ueda, 1989). Employment growth in retail, industrial, construction and wholesaling was 16-34% higher in cities with a HST station (Hirota, 1985) and land value increased by 67%.

However, Sasaki, Ohashi and Ando (1997) found that HSR lines did not necessarily contribute to long-term regional dispersion. Furthermore, the studies indicate that although growth parallels the high-speed train route, most of the route was selected on the basis of expected growth independent of the HST (Haynes, 1997). Nonetheless, expectations regarding the economic gains of HSR led to political pressure and demands for HST stations, a fact that affected the economic viability of the system through debt increases and annual losses (Imashiro, 1997). In fact, debt surpassed $US 200 billion by 1987 leading to a financial crisis ending with the privatization of the railway (O'Toole, 2008).

Studies of the economic impact of HSR show that services was the most favored economic sector in Japan. Service industries became highly concentrated in the cities of Tokyo and Osaka, resulting in the centralization of this sector in the country's major nodes. Indicative of this trend is the fall in employment in Nagayo, a city located between Osaka and Tokyo, following the inauguration of the HST line. According to Plaud (1977), this fall was estimated at around 30% from 1955 to 1970. For the same period, the increase in employment in Osaka, Kyoto and Kobe was 35%. Tourism also showed significant growth – rising from 15 to 25% between 1964 and 1975. In the case of the retail industry, Tokyo would appear to be the dominant force following the opening of the HST service.

Similarly, since intra-organizational journeys have become easier, business travel has increased, albeit with a reduction in the number of business overnight stays in hotels in Tokyo and Osaka. Indeed, the reduction in travel time is the main impact of the Shinkansen (Daluwatte and Ando, 1995), and its mean delay time of just two minutes provides extremely high standards of reliability.

3.2 France: '*Train à Grande Vitesse*' (TGV)

The level of congestion on the rail link joining Paris and Lyon – the gateway to south-east France - led to the introduction of an HSR service in France with the building of a new, separate network. The line was named "Paris Sud-Est" and was constructed between 1975 and 1983. The total number of rail passengers increased following its inauguration, rising from 12.5 million in 1980 to 22.9 million in 1992 – 18.9 million of whom were TGV passengers according to Vickerman (1997). The subsequent expansion of the HST network was carried out chiefly to serve corridors with sufficient traffic, connecting cities of significant size. The policy was to invest only in socially profitable lines.

In fact, the French TGV was developed under a state-directed policy that insisted on cost containment and commercial viability (Dunn and Perl, 1994). It was the government's centralized and hierarchical decision-making structure that led the French National Railways (SNCF) to focus on commercial goals. In fact, the development of the HST in France has always given priority to economic objectives so as to prove that public enterprise can make money from operating the system. Unlike other projects with these objectives, state officials did not permit any public debate on how to distribute the HSR network and were immune to any social and regional pressures.

Its success led to the promotion of an investment plan that provided the funds to construct connections from Paris to Le Mans (1989), Tours (1990) and Calais (1993). The Rhone-Alpes

(1994) and the Mediterranée (2001) were the next corridors to be served. Today, France's HST network comprises 962 miles of line. Traffic demands, time savings and construction costs were all considered in the French project. Indeed, France decided only to create a new, separate network along congested links, and to use conventional services along less crowded connections and for accessing big cities when construction and expropriation costs were likely to be exorbitant. As a result, and in contrast to Japan, France has a mixed HST infrastructure system. In fact, the current share of specific HST lines over total network is just 37%, serving more than 100 million travelers. However, even with this system, commercial speeds fluctuate between 150 and 200 mph, but are lower on the conventional network (130 mph). All in all, HST has meant an 80% increase in speed on average.

An interesting policy implemented at the regional level involves the development and improvement of the regional rail services that serve the nodes with HST railway stations so that benefits can be spread more widely and overall accessibility be enhanced. This strategy has resulted in an even greater increase in HST network traffic than was predicted - in the cases of St. Etienne, Marseille and Annecy the traffic volume was twice that expected by 1984 (Vickerman, 1997). However, some stations have been located outside urban areas and lack an efficient multimodal supply and a dynamic economic area surrounding the station. The cities of Mâcon, Le Creusot, Montceau and Montchanin illustrate the failure of this strategy (Martí Hennenberg, 2000). In Montchanin the HST link has attracted just four firms, creating 150 new jobs.

The French TGV lines were financed primarily according to their profitability, with an expected 12% minimum financial and social rate of return. This has been surpassed on several lines (Vickerman, 1997). For instance, the Sud-Est link is estimated to have provided a 15% financial rate of return, but a 30% return in social terms. It had already been amortized by 1993, just 12 years after coming into service. However, the other lines have provided lower rates of return.

Table 2. TGV infrastructure costs

Line	Year beginning operation	Miles	Cost per Km US$ million (1euro = 1.5 US$)
Paris-Lyon	1981	264	7
TGV Méditerranée	2001	155	19

Note: Data on cost per mile is originally in Euro1981 for Paris-Lyon and Euro2001 for TGV Méditerranée
Source: Adapted from Campos and de Rus (2009).

The preference for connecting only crowded cities means that it is almost always necessary to link them with Paris to justify the investment. In fact, the first three lines to be built connected Paris with the four major provincial cities: Lyon, Marseille, Bordeaux and Lille. This accounts for the centrality of Paris in the network structure, which takes on the form of a star with the capital at its core.

Indeed, in line with Arduin (1991), the most important node is the one that benefits most from HST. The Paris-Rhône-Alps route illustrates this point, as flight and train journeys to Paris increased by 144%, while journeys in the inverse direction only experienced a 54% increase due to the HST connection. This means that round trips originating in Paris increased much less than round trips originating at the other end of the city-to-city connection. Although a compatible network allowed the HST network to be extended, the region surrounding Paris (Ille du France) has been the one to enjoy the largest increase in its HST supply mainly due to the spatial concentration of population.

In spite of these asymmetries, big cities such as Lyon and Lille have also experienced positive effects as a result of the HST in the form of an increase in economic cooperation and exchanges with Paris. In Lyon, for instance, HST has attracted a significant number of third sector firms – mainly regional offices from Paris – thereby helping to consolidate this sector and improve Lyon's image.

Finally, as in Japan, HSR has promoted the centralization of economic service activities in big nodes and favored intra-organizational business trips. Such trips originating in Paris are up 21%, while those with Paris as their destination are up 156% (Rodríguez, Novales, and Orro, 2005). By contrast, the impact on industrial activities has been largely irrelevant.

The impact of HSR on business location decisions within the service sector also seems negligible. Mannone (1995, 1997) designed a survey to analyze how the HST was viewed by firms established in Dijon, the capital of the French region of Bourgogne, between 1981 and 1994. One third declared that HST was a factor they considered in their decision, but only 4 firms from a total of 663 claimed it was a key determinant in their choice of location. Similar results were obtained in Valence and Avignon. Consequently, it is consistently found that the HSR has neither accelerated industrial concentration nor promoted administrative or economic decentralization from Paris (Martí Hennenberg, 2000).

The surveys conducted looking at business trips provide additional information on the number of overnight stays and the reason for the journey. Train passengers staying at least one night at their destination fell from 74 to 46% with the introduction of HST (1981-1985) and the main purposes were stated as being internal contacts and buying/selling services (Bonnafous, 1987).

3.3 Germany: "*Neubaustrecken*"

The German InterCity Express (ICE) arrived a decade after the French TGV (1991). There are several reasons for this delay. Besides the obvious problems of constructing an HSR system in the country's mountainous terrain, it proved considerably more complicated to obtain the necessary legal and political approval for building to start (Dunn and Perl, 1994). Moreover, the rationale underpinning the HST network was somewhat different in Germany. Given the west-east orientation of the rail network constructed before WWII and the current north-south patterns of industrial cooperation, Germany sought to reform the network so as to facilitate freight transportation from the northern ports to the southern industrial territories. For this reason, the first two *neubaustrecken* – new lines - were those linking Hannover and Würzburg and Mannheim and Stuttgart, respectively. The main goal was to solve congestion problems in certain corridors and to improve north-south freight traffic. Following the country's political reunification the need to connect east and west became an additional priority, which explains why the Hannover-Berlin and Nuremberg-Leipzig corridors were the next links to be constructed (Gutierrez Puebla, 2005).

Thus, there are considerable differences between the German strategy and the models adopted by Japan and France. Instead of building new exclusive high-speed lines, Germany chose to operate a system that would serve freight traffic too (Dunn and Perl, 1994). The result has been much higher upgrading costs and, arguably, operating costs but the industrial centers served have enjoyed greater benefits (Haynes, 1997). Therefore, in most instances Germany did not build a separate HST rail network, but rather upgraded existing lines. This means the network is shared by high-speed and more conventional passenger trains together with freight trains and the country has renounced higher commercial speeds (with a maximum of >150-160 miles/h). Nevertheless, the HST system still offers commercial speed gains of around 60%.

The German multi-purpose HSR system was conceived, therefore, to spread benefits rather than concentrating them. In fact, as Heinisch (1992) claims, the main consideration when designing the new lines was not faster passenger traffic, but rather the highly profitable overnight traffic between the North Sea ports and the industrial areas and consumer markets in Southern Germany. Goods transport was deemed more important, because it contributes considerably more to the turnover than is the case of passenger traffic. A further difference with the TGV in France is that the HSTs in Germany are heavier, wider and more expensive to run, but offer greater flexibility (Dunn and Perl, 1994).

The average increase in the market share achieved by the introduction of the HST was 11%, while the average net revenue per train-mile of the ICE service was 1.7 times higher than the average for its other long distance services (Ellwanger and Wilckens, 1993). However, from the financial perspective, building delays and Germany's topography resulted in higher-than-expected construction cost overruns, as well as operating deficits and increasing debt burdens, which increased the financial pressures to reform the system. The source of some of these overruns was the need to satisfy the multiple, and at times conflicting, criteria of a wide range of policy participants (Dunn and Perl, 1994). As a consequence, the German lines have been much more expensive than the French lines, a situation that can be attributed to the more challenging nature of the terrain, its urban structure and various political and legal obstacles. Furthermore the network only serves around 67 million passengers a year. For this reason, the utility of continuing investment in HSR is being questioned, since it is seen as an expensive solution that might not provide the environmental gains that could be achieved with a more restrictive approach to road transport (Whitelegg, 1993; Vickerman, 1997).

Operational deficits are due in large part to the widespread nature of the German population and the small average size of German cities. The urban structure of Germany lacks France's monocentric focus and so for many years the country's intercity rail system had been based on a complex, interlinking network of services with interchanges that provided regular hourly or two-hourly connections between most major German towns and cities, and more frequent services on certain key lines (Vickerman 1997; p.28). This means there are few corridors providing sufficient demand. Compared to the 9 million annual passengers using the HST link between Koln and Frankfurt, the Paris-Lyon link can boast 20 million passengers and the Tokyo-Osaka link 130 million; i.e., more than 10 times the Koln-Frankfurt figure. Likewise, low population densities lead to higher accessibility needs, which usually result in high regional transportation costs and shorter distances between stations, which –in turn- negatively affect commercial speed.

In short, the dual function and compatibility of German HSR with conventional services, together with the country's mountainous terrain – freight traffic requires low gradients – have resulted in higher construction costs (Gutiérrez Puebla, 2005).

Table 3. Construction costs of the first HST lines in Germany (US$ Million)

Lines	Cost per mile (US$ million) 1 Euro = 1.5 $US
Hanover—Würzburg	37.2
Mannheim—Stuttgart	36.9

Source: Adapted from European Commission (1996)

3.4 Spain: '*Alta Velocidad Española*' (AVE)

The first Spanish HST link, the AVE, was inaugurated in 1992 between the capital Madrid and Seville on the eve of the Universal Expo'92 held in this southern Spanish city. The train covers the 320 miles between the cities in just 2 hours 15 minutes (direct service). By choosing Seville, Spain has been the only country not to start its HST in the most congested corridors of the country or to connect its most populated cities, although the conventional link south was arguably somewhat congested. A number of studies point to a political rationale, underlying a strategy aimed at promoting economic development in the country's poorer regions and at favoring cohesion. Thus, territorial equity was the main reason for the choice of this line, which represented a high social cost to the economic system (Sala-i-Martin, 1997).

Spain decided to construct a separate HST network, as had been done earlier in Japan and France, although in these two countries conventional railway lines are also compatible.[9] Moreover, Spain opted to buy in rail technology rather than developing its own (Vickerman, 1997), which is another distinguishing feature from the projects implemented in the other countries studied. [10]

In spite of good occupancy rates, infrastructure utilization of this line is under capacity given its length and relative isolation, but particularly because of the small population being served (Martí-Henneberg, 2000). The HST has had, however, a marked impact on mobility patterns. Before the introduction of the AVE in 1992, the combined number of rail and air passengers traveling between Madrid and Seville stood at around 800,000 each year. According to Menendez (1998), just three years later, in 1995, HST recorded 1.4 million passenger journeys, while the numbers of those flying fell to 300,000. No effects have been reported for the inter-urban bus service, which has continued to carry around 200,000 annual passengers in that period. However, the inauguration of the first AVE had a marked impact on conventional rail services, with the latter losing a large part of their traffic in the corridor. Yet, the absence of a

[9] Spain's conventional railway uses a wider gauge than that of the International Union of Railways, and that which is commonly employed across Europe.
[10] AVE vehicles were designed and constructed by the French company ALTSHOM.

complementary service for freight transport meant the conventional rail lines have remained operative (de Rus and Nash, 2007).

However, total traffic is still very small in comparison to the volumes carried on TGV, suggesting a particularly poor rate of return (Vickerman, 1997). The service's punctuality, speed and accessibility to city centers are its main attractions. And, indeed, commercial speed gains in Spain are over 100% with the AVE capable of a maximum speed of 217.5 mph.

In terms of its economic impact, Martí-Henneberg (2000) confirms that investment has not been guided by attempts to increase economic dynamism around AVE railway stations. Neither has it led to new firms establishing themselves within their vicinity. Yet, the image of cities with AVE stations has been enhanced and firms already established in these locations have benefited from this new transport infrastructure. It has also been argued that sizeable land value and population increases have resulted from AVE construction. However, Albalate and Bel (2008) report that Ciudad Real and Puertollano, two cities served since 1992 by AVE, did not experience higher rates of population growth than other cities in the region between 1991 and 2001. In fact, Puertollano is the only major city in the region to have lost population. Similar results can be drawn by considering the growth in housing.

Spain has made the HST network a priority in its transport policy. In fact, the Spanish government boasts that Spain will be the country with the largest network (around 1,400 miles) by 2010.[11] A third of all investment (amounting to 82.96 billion euros) in the country's strategic plan (PEIT) is to be devoted to HSR until 2020 (Bel, 2007), when 6,200 miles of the AVE network are expected to be in service. These plans are rooted in the desire to build a rapid connection between all the provincial capitals in the country and the political capital, Madrid, as formulated by former Prime Minister José María Aznar on 25 April 2000. Thus, the rationale for extending the network in Spain is to fulfill the political aim of centralizing rail connections.

In fact, any discussions as to the social profitability of HST investments have been largely absent from the political debate because – besides the political rationale – the AVE is considered a symbol of modernity, and enjoys user support – perhaps because passengers pay low prices thanks to huge public subsidies (de Rus and Roman, 2006).[12] Cost-benefit analyses

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[11] See *El País* newspaper on 15/02/2007. "España tendrá en tres años la mayor red de AVE del mundo, según Zapatero". On-line consultation at www.elpais.com

[12] In the first year of operation (October 1992), price reductions of 30% on the Madrid-Seville route and 50% on the Madrid-Ciudad Real line were introduced to offset the effects of the closure of Expo'92. According to de Rus and Nash (2007), these low prices have led to high load factors for HSR, but the company is still a long way from breaking even, even when operational costs alone are taken into account.

carried out prior to its building showed that the Madrid-Seville link could not be justified economically on the grounds of negative net benefits, and its continuing poor performance is due to the low volume of traffic (de Rus and Inglada, 1997). More recent cost-benefit analyses (de Rus and Roman, 2006) of the profitability of the Madrid-Barcelona route – the two largest and more dynamic cities in Spain – still highlight that potential demand does not compensate for the high investment, while time savings are very low on an aggregate basis.

Table 4 shows the building costs for the most recently constructed AVE lines in Spain. Although the Madrid-Barcelona line has the lowest cost per mile, construction of the first stretch between Madrid and Lleida (270 miles), which started in 1996, was not completed until 2004 and the AVE did not reach Barcelona until February 2008. As no information is available for separate stretches on the Madrid-Barcelona line, we are only able to give total investment figures. Thus, the 12-year investment on the Madrid-Barcelona link ($US 10,600 million) is lower than that for the Córdoba-Málaga and Madrid-Valladolid projects, which were completed relatively quickly between 2004 and 2007.

Table 4. Construction costs of the most recently inaugurated Spanish AVE lines

Lines	Length (miles)	Construction costs (nominal terms) (Million $US 1 Euro = 1.5 $US)	Cost per Mile (Million $US/Miles)
Madrid-Valladolid	112	6,307	56
Córdoba-Málaga	96	3,808	40
Madrid-Barcelona	386	10,624	28

Source: Authors' own calculations based on information from the Spanish Ministry of Transportation.

As regards the environmental impact of the AVE, we are able to evaluate its CO_2 emissions with respect to those produced by conventional trains. Data presented by García Alvarez (2007) on distances, emissions and passenger capacity means we can compare CO_2 emissions per passenger-km on three Spanish HST lines and their corresponding conventional rail services. On two routes (Madrid-Seville and Madrid-Barcelona) there are no significant differences in CO_2 emissions per mile between the two services. However, CO_2 emissions per passenger-mile on the Madrid-Toledo link are almost 50% higher in the case of the AVE. While the first two routes can be considered medium-distance links (between 320 and 400 miles), the Madrid-Toledo connection is a short-distance, commuting link (50 miles), which would seem to affect its environmental performance.

3.5 Italy: 'Rete Alta Velocità/Alta Capacità (AV/AC)'

Work on Italy's HST network, the Rete Alta Velocità/Alta Capacità (AV/AC), began in 1991 with the founding of the TAV Company (Società TAV). The company was awarded a concession to build and operate the Milano-Napoli and Torino-Venezia lines. This concession was extended in 1992 to include the Milano-Genova line. Società TAV is of mixed public-private ownership, with 60% of the capital in private hands and the remaining 40% belonging to the State Railways - Ferrovie dello Stato (GFDS, 2007a). The main rationale behind the introduction of the HST in Italy was the extremely low share of rail traffic in Italian mobility statistics. Even in recent years, rail journeys account for just 5% of all passenger transit, while the trains are responsible for carrying just 12% of the nation's freight (GFDS, 2007b). Both figures are well below European averages. Moreover, air transport cannot guarantee the intermediate stop-over that is possible for land transport, because of the relatively short distances between the main cities in Italy (Catalani, 2006).

Interestingly, the initial plan envisaged the construction of a HSR network that would run independently of the conventional system, as had been the case in Japan, France, and Spain. However, by 1996 this had changed towards a more integrated conception of the network, and so the Alta Velocità plans were replaced with the AV/AC plans (GFDS, 2007a). The latter sought the integration of the new HST network with the conventional network, thus enhancing rail transportation capacity, expanding the effects of HSR, and avoiding the degradation of the conventional service in those areas between cities served by the new HSR. However, it soon became apparent that there was a marked lack of willingness on the part of private shareholders to provide the capital required, and so 60% of this private share was acquired by Ferrovie dello Stato in 1998.

Contrary to the HST strategy adopted in Japan, France and Spain, the Italian HST was conceived to provide a spread of benefits – linking up with the conventional lines - rather than concentrating them. However, this strategy caused an increase in projected costs. The decision to shift from the AV strategy to that of the AV/AC caused these projected costs to rise by about a third. HST costs have since grown unchecked: from 10.7 billion euros in 1992 (15.5 billion at 2006 prices) to 32.0 billion euros in 2006 (GFDS, 2007a). Thus, projected costs have more than doubled in constant terms.

The first lines to come into service were Roma-Napoli in 2005, and Torino-Novara and Modena-Lavino in 2006. Today, the Italian HST network covers 411 miles, with additional

HST services running between Torino-Milano-Bologna-Firenze,[13] and Rome-Napoli-Sorrento. Construction costs, provided by Ferrovie dello Stato in 2007 (GFDS, 2007a), are shown in Table 5:

Table 5. Construction costs of HST lines in Italy (US$ Million)

Main lines	HST Lines Miles	Connecting Lines (to conventional network) Miles	Construction costs (US million) 1 Euro = 1.5 $US	Cost per mile (US$ million) 1 Euro = 1.5 $US
Torino-Milano	78	12	11,682	130
Milano-Bologna	115	25	10,734	77
Bologna-Firenze	49	5	8,815	163
Roma-Napoli	129	16	8,476	58

Source: Authors' own computations based on information from Grupo Ferrovie dello Stato (GFDS, 2007a)

The cost per mile of HST lines in Italy is much higher than those reported in the other European countries reviewed above. On average, the cost per mile of the lines currently operating in Italy has been US$ 77 million. This marked price differential is attributable in the main to the characteristics of Italian territory: with its high population density, dense urbanization and urban structure, mountainous terrain, and high seismic risk. However, given the recent introduction of the service, no systematic information is yet available regarding any changes in modal shares. Having said this, the HST in Italy is clearly in competition with road transportation, since air routes between the Italian cities that have so far been linked up to the HST network are of limited importance because of the short distances involved.

4. Lessons from worldwide experience

Based on the case studies reported above, we are now in a position to highlight a number of useful lessons for those planning the HSR project in the United States. This should ensure that it achieves its maximum potential and avoids the most frequent obstacles.

Motivation

HSR projects seem to make most sense when they seek to solve capacity restrictions, lightening congestion in certain corridors, and when facilitating industrial connections by enhancing accessibility for freight transportation. The linking up with other corridors to

[13] The Firenze-Roma line (150 miles) – known as the 'direttissima'- has been in service since 1978. Its technical characteristics, however, are not comparable to those of the AV/AC lines.

promote regional equity or to foster regional development only seems to result in the economic failure of the project.

Structure: design and functions

Perhaps the first major decision to be taken is whether to run a joint passenger/freight network. Some countries have chosen to build high-speed lines exclusively for passenger services; others have chosen to share the upgraded tracks with freight transport even though this means renouncing higher speeds and accepting higher costs so as to promote industrial connections. As few economic impacts are directly attributable to passenger HSR, it seems reasonable to allow freight transportation, especially in the US where a much higher share of freight is transported by rail than is the case in Europe and Japan.

Lower construction costs have been reported in those projects that have combined conventional rail with dedicated HST tracks to reflect the level of traffic in a corridor or in order to access downtown areas. The rationale underpinning this strategy is the avoidance of the high costs of land expropriation that make it particularly expensive to build a dedicated railway through a city. Using conventional railways for this purpose alleviates the cost burden considerably.

A third lesson to be learnt from network design concerns decisions regarding which routes to implement. Routes have to be established between the most highly populated centers so as to ensure satisfactory occupancy rates and to guarantee that the service can break even, particularly in light of high construction and operation costs. This is the case in France, where HST lines are centered on Paris to reflect the country's strong political, economic and demographic centralization. Given the decentralized regional structure of the United States, with its different mega-regions, a more decentralized network connecting these hubs would seem to make better sense.

A further point to bear in mind is the fact that European and Japanese downtown areas are denser than their American counterparts. In fact, few people live in America's downtown districts. For this reason, the American HSR project will not reap the benefits of one of the main comparative advantages of HSR, namely city center connection. Thanks to HSR links, commuting from airports can be avoided, as can road congestion at the entrance to big cities. In the American case, however, it is necessary to travel downtown from residential areas, which means there is a need for better local transportation connections or the provision of more park-and-ride services. Finally, it should be pointed out that HSR stations located outside the downtown district and without adequate multimodal connections are usually unsuccessful.

Economic Costs

The development of an HSR network entails huge construction and operation costs. The key decision at the outset, as discussed above, concerns the complementarity of carrying passengers and freight. Complementarity with freight transport increases costs, since the track gradients have to be more carefully controlled. However, making freight carriage compatible with that of passengers can boost industrial productivity and increase connectivity between industrial areas and airports, ports, and logistic areas.

Various costs need to be taken into account when considering the additional expenditure incurred from building HST lines. Land expropriation costs increase the initial investment substantially, and this is a key factor when HSR lines enter densely populated areas and downtown districts. For this reason, France chose to use conventional lines to access its major cities, given that construction and expropriation costs would have been exorbitant. Similarly, the provision of bridges and tunnels increases construction costs notably. Finally, cost overruns would seem to be high in almost all instances; administrations should be fully aware that eventual construction costs might far outstrip initial expectations.

One issue that certainly should not be ignored are the political pressures that are brought to bear and which can lead to incremental costs and decreasing benefits. These political pressures might emerge from the supply side, with governments placing greater emphasis on political interests than on satisfying transport needs when planning the HST network, as illustrated by the Spanish case. While from the demand side, local and regional governments might exert pressures for an HST railway station, even if this runs contrary to sound transportation rationale. All these factors can combine to raise construction costs and lower the average commercial speed.

According to estimates calculated by de Rus and Nombela (2007, p. 21), investment in HSR is difficult to justify when the expected first-year demand is below 8–10 million passengers for a line of 312.5 miles, a distance at which HSR's competitive advantage over road and air transport is clear.[14] The economic rationale for new HSR infrastructure depends heavily then on the expected volume of demand. Thus, building an HST line should only be considered in the case of links with high demand expectations for rail travel, i.e., routes connecting densely

[14] De Rus and Nombela's computations take into account actual construction, rolling stock, maintenance and operating costs of European HSR lines, average values of time, potential travel time savings, and a 5 per cent discount rate.

populated metropolitan areas, with severe problems of road congestion, and a deficient air connection.

This economic framework hinders the use of public-private partnerships (PPPs) in HSR projects. This is clearly illustrated by the Italian case where the HSR was originally conceived as a PPP but was later nationalized owing to a shortage of additional private investments. The difficulties encountered in recouping costs and the need for higher subsidies increase the government role in the enterprise and the risks involved for private investors.

Mobility impacts

HSR provides significant travel time savings when compared to conventional rail services, but similar door-to-door timings are reported for air transportation on routes of around 400 miles. However, HSR provides a highly reliable service with average delays of just two minutes and it can offer considerable advantages in terms of comfort, the fact that passengers can use their electronic devices while in transit and are subject to less rigorous security restrictions and controls. Its comparative advantage would seem to lie on routes that range from between 100 to 500 miles. Over shorter distances, HSR finds it difficult to compete with road transportation, while over longer distances air transportation takes the upper hand.

The modal distribution of traffic has been affected by the introduction of HSR in all the cases studied, having the greatest impact on the airline industry in France and Spain. As **Table 5** highlights, immediately following the inauguration of the HST service, the share held by air transport fell significantly in both countries. Similarly, road transportation has suffered from competition from HST, albeit to a lesser extent. Surprisingly, the impact on the modal shares of the Paris-Lyon and Madrid-Seville lines were very similar according to the European Commission (1996). Recent data on the traffic between Barcelona and Madrid, the main air corridor in the Spanish airline market (and indeed in the entire world market, with almost five million passengers per year in 2007), show that after a year of HST service a third of air traffic has switched to rail.

Table 5. Modal share change before and after the introduction of the first HST corridor.

Mode	Paris-Lyon (1981-1984) 264 miles	Madrid-Seville (1991-1994) 292 miles
Airports	-24	-27
Rail	+32	+35
Road	-8	-8
Total	37	35

Source: European Commission (1996)

Environmental advantages

There has yet to be a detailed, systematic evaluation of the impact of an expanding HST network on the reduction in CO_2 emissions at either an aggregate or country level. However, information is available on the environmental effects of HSTs, particularly as regards their energy consumption. According to estimates conducted by van Essen et al (2003), energy consumed per MJ/seat mile by air transport is 240% higher than that attributable to HSTs. However, the energy consumed by HSTs is 12.8% higher than a petrol-driven car when traveling on the motorway, 55.9% higher than a diesel-driven car on the motorway, and 140.9% higher than an intercity train. Other estimates (van Wee, van den Brink and Nijland, 2003) conclude that while energy use and emissions for HSTs are much higher than for conventional trains, they are relatively similar to those for cars and buses. In the most favorable analysis for HSTs –conducted by García Álvarez (2007) for Spain, HSTs and conventional trains were reported as producing similar emissions on two of the lines analyzed, while the conventional train was much more efficient on the remaining line.

Clearly, the overall impact of HSTs on energy consumption is heavily dependent on the source of its traffic - whether it is newly generated or attracted from previously existing modes (and, in the case of road transportation, on whether it replaces cars or buses). However, HSR is not a particularly useful tool for fighting CO_2 emissions, being less environmentally efficient than conventional modern trains. Further, building a new and separate HST line involves significant CO_2 emissions that environmental HST analyses do not take into account. [15]

Economic and regional impacts

It is consistently reported that HSR does not generate any new activities nor does it attract new firms and investment, but rather it helps to consolidate and promote on-going processes as well as to facilitate intra-organizational journeys for those firms and institutions for whom mobility is essential.

In fact, for regions and cities whose economic conditions compare unfavorably with those of their neighbors, a connection to the HST line may even result in economic activities being drained away and an overall negative impact (Givoni, 2006; Van den Berg and Pol 1998; Thompson 1995). Medium size cities may well be the ones to suffer most from the economic attraction of the more dynamic, bigger cities. Indeed, Haynes (1997) points out that growth is

[15] Together with the environmental impact caused by land take, noise, and visual disruption.

sometimes at the expense of other centers of concentration. Several reports describe the centralization of activities in big nodes, especially in the services sector.

It is perhaps worth pointing out that only those cities with a significant weight of services in their economic structure appear to benefit from HSTs. In other words agricultural and industrial activities are indifferent to HST stops. Evidence of this lack of economic impact is the little attention given to a HST railway stations by firms in their location decisions, even those of service companies.

Besides business journeys, tourism is the first sector to show an immediate effect following the inauguration of an HST line. Indeed, the number of tourists in cities linked to the network tends to increase thanks to this alternative mode of transport. However, the number of overnight stays falls due to easier same day travel, which also has a marked impact on business trips. Therefore, HSR impacts on the tourist industry by promoting the number of leisure travelers to connected cities but at the same time it reduces the number of nights spent in hotels.

Finally, the reports reviewed also show that HSTs had only marginal impacts on population and housing growth.

5. Conclusion

In this paper, we have highlighted the main questions that policy makers must consider when designing high speed rail networks to reduce traffic congestion, cut dependence on foreign oil and improve the environment. A number of obvious lessons can be drawn from the five cases we review here. First, the project design must take into consideration the specific characteristics of the urban patterns and economic structure of the country, including its traffic patterns, because of the overriding importance of a country's mobility characteristics. Second, cost considerations are of central relevance when making choices concerning HSR projects and their implementation. The fixed costs of HSR investment are huge, and cost overruns notoriously high. In addition, political factors (on the supply as well as on the demand side) can contribute to further increase costs. Therefore, the potential demand for HSR services must be particularly high in order to make investment in HSR socially profitable. This means its main targets must be those corridors linking densely populated metropolitan areas, suffering severe road congestion problems, and deficient air links. These constraints also hinder the use of PPPs and governments must be prepared to intervene in constructing their HSR networks.

While HSR is more environmentally efficient than air transportation and the use of the private car, it is responsible for more CO_2 emissions than conventional intercity trains. For this reason, HSR is not a very useful tool for fighting CO_2 emissions. Finally, the economic impacts of HSR are somewhat limited. The largest cities in the network might receive limited gains, but this is not the case for intermediate cities, which might see economic activities being drained away and suffer an overall negative impact.

The present paper was based on a review of the main HSR experiences around the world. Future research should seek to draw on recent developments in U.S. transportation planning, which provides an increasing number of project analyses, including those already underway in California and Florida. Additionally, new lessons should be learned by comparing the American HSR planning process and the context in which it is being undertaken (political system, mobility patterns, energy policy, fiscal constraints) with the experiences and contexts of other countries around the globe.

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