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

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In April 2009, the U.S. 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 project, it is essential to identify the factors that might influence decision making and the eventual success of the HSR project, as well as to foresee the obstacles that must be overcome. The authors review, summarize, and analyze the most important HSR projects carried out to date around the globe, focusing on the main concerns of HSR projects: their impact on mobility, the environment, the economy, and urban centers. The authors identify lessons for policy makers and managers who are implementing HSR projects.

The first Chinese high-speed railway (HSR) connection was inaugurated in 2008 between Beijing and Tianjin. This was followed by a high-speed line in the Wuhan–Guangzhou corridor, which came into service on December 26, 2009.¹ Today, the 664-mile distance between the latter two cities can be covered in a little more than three hours on the nonstop, high-speed train (HST). 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 10 hours to 3 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 world.

While the most populated country in the world speeds up work on its HSR network, in the United States on February 17, 2009, President Barack Obama

signed the American Recovery and Reinvestment Act, which included funds (\$8 billion and \$1 billion yearly for at least five years) for the Federal Railroad Administration to devote 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 10 high-speed rail corridors in the United States, ranging between 100 miles and 600 miles in length, as potential recipients (see figure 1),⁴ although the Federal Railroad Administration has received demands from 40 states totaling more than \$100 billion. Worldwide, two types of projects are included in the high-speed rail effort: one devoted to building world-class HST corridors, as in Europe, and another aimed at making conventional rail services faster. Consequently, different investment strategies are envisaged: the promotion of new express services (on dedicated track operating at speeds of more than 150 mph), the development of emerging and regional services (operating at speeds of up to 150 mph on shared and dedicated track), and the upgrading of reliability and service on conventional rail services (operating at speeds of up to 90 mph).

The United States Conference of Mayors recently issued a study on the prospects for the development of HSR in the United States (USCM 2010). That study, sponsored by the multinational company Siemens (one of Siemens's business lines is selling rolling material and information technologies for high-speed rail), analyzes the economic impact of HSR in the four routes where HSR development is expected to begin, with trains running at speeds of about 220 mph. Table 1 displays some of the data provided in this study. Estimated demands indicate



Source: U.S. Federal Railroad Administration.

Figure 1 U.S. Designated High-Speed Rail Network

Table 1 Expected Demand for First Four U.S. High-Speed Rail Routes

| Route | Maximum Speed | Miles | Millions of Passengers (one-way trips) | Year Forecast |
|---------------------------|---------------|-------|--|---------------|
| San Francisco–Los Angeles | 220 mph | 500 | 7.2 | 2035 |
| Chicago–St. Louis | 220 mph | 297 | 2.1 | 2035 |
| Orlando–Tampa | 186 mph | 85 | 1.6 | 2035 |
| Albany–New York City | 220 mph | 142 | 2.3 | 2035 |

Source: Authors’ calculations based on United States Conference of Mayors (2010).

that the HSR in California is the only site likely to obtain volumes of demand close to those on the most successful routes elsewhere, such as the Paris–Lyon route, which served 25 million passengers in 2008. This is still far, though, from the Tokyo–Osaka line, which is the most successful corridor in the world with 130 million passengers.

The debate regarding the costs and benefits of building a high-speed rail system in the United States is a long-running affair. Levinson et al. (1997) examines the full costs of an HSR system projected for a corridor connecting Los Angeles and San Francisco and concludes 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 (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 over-run on any cost items), or about \$50 million per mile (O’Toole 2008). The most recent estimates, conducted in December 2011 by the California High-Speed Rail Authority (CHSRA 2011) as part of its 2012 business plan for the California HST (Phase 1), put the costs between 2010 \$65.4 billion (lowest cost feasible options) and \$74.5 billion (highest cost feasible options). 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

\$25 million per mile to serve 4 million travelers per year (FRA 2005).

Previous research has provided interesting and useful lessons from worldwide experiences on policies such as congestion charging (see Albalade 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 of 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. 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 article. We then discuss useful lessons for American policy makers and planners. Finally, some concluding remarks are recorded.

The Case for High-Speed Trains: 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 the main motivation, network design and functions, economic costs, environmental costs, mobility impacts, and economic and regional effects.

Main Motivation

First, we address the reasons for the establishment of an HST network in each of the countries studied. Several concerns may motivate the construction or upgrade of rail networks to high-speed systems. Among other reasons, congestion is the leading inefficiency factor that can justify capacity investments to seek travel time

savings and to boost 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 design, as do the functions that they seek to fulfill, whether they be economic or political in nature. In some instances, countries have chosen to construct new HSR lines exclusively for passengers, while others have promoted more efficient freight mobility by upgrading existing infrastructure on a shared track for passengers and freight, albeit at lower speeds and 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.

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 they are highly competitive over medium distances (between 100 and 500 miles) because, by connecting city downtowns, they avoid the need to commute from the airport and the inconveniences of traffic congestion. That said, HST links involve huge investment costs, which 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;⁵ thus, cost–benefit analyses are essential. In this article, we pay special attention to the way in which network and design decisions affect investment, as well as the circumstances in 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 passengers who previously used air, road, or conventional rail services. Thus, upgrading rail transportation is expected to affect the 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 percent to 7 percent, and the share of car and bus traffic fell from 29 percent to 21 percent, whereas rail traffic rose from 40 percent to 72 percent. In the case of the Madrid–Seville line, between 1991 and 1994, the modal share of air traffic fell from 40 percent to 13 percent, and that of car and bus traffic from 44 percent to 36 percent, while train traffic increased from 16 percent to 51 percent. Hence, as modal shares are subject to dramatic changes, this article 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 an 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 an 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 interterritorial cohesion, but rather they promote territorial polarization.

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 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 United States. 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.

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 1964.⁶ The objective pursued by 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 because of 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.⁷ 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 aging infrastructure.

Construction costs for the 347 miles of track 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 (see table 2). According to Taniguchi (1992), the cost share attributable to infrastructure (cuttings, banks, viaducts, bridges, and tunnels) on the Sanyo line was the highest at 58 percent. Land price, the second most important share, represented a quarter of the total costs. Tunnels and bridges built along the route meant that costs were high. In fact, 30 percent of Japanese lines run through tunnels (Okada 1994). Furthermore, building links into city centers added to both the complexity of the operations and overall costs.

Demand forecasts proved to be underestimated. While the number of passengers per kilometer (millions) was 11,000 in 1965, in just 10 years, it had risen to 35,000. Time savings are estimated at 400 million hours per year. Population growth offers interesting results. Cities with HST railway stations achieved average rates of 1.6 percent, while those bypassed by the service only increased at a 1 percent rate (Hirota 1985). It was found that HST stations resulted in marginal population impacts, and 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 percent to 34 percent higher in cities with an HST station (Hirota 1985), and land value increased by 67 percent.

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 \$200 billion by 1987, leading to a financial crisis that ended 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 decline was estimated at around 30 percent from 1955 to 1970. For the same period, the increase in employment in Osaka, Kyoto, and Kobe was 35 percent. Tourism also showed significant growth, rising from 15 percent to 25 percent 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, because intraorganizational 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 has been 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.

France: Train à Grande Vitesse (TGV)

The level of congestion on the rail link joining Paris and Lyon—the gateway to southeastern France—led to the introduction of HSR service in France with the building of a new, separate network. The line, named “Paris Sud-Est,” 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 HST passengers, according to Vickerman (1997)—and to more than 25 million in 2008. 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—that is, lines generating a positive net social return on investment.⁸

In fact, the French HST 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 Rhône-Alps (1994) and the Méditerranée (2001) were the next corridors to be served (see table 3). Today, France's HST network comprises 1,178 miles of line. Traffic demands, time savings, and construction costs were all considered in the French project. Indeed, France decided only to create new, separate networks 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 HST lines over the total network is just 37 percent, serving more than 100 million travelers. However, even with this system, commercial

Table 2 Shinkansen Construction Costs

| Line | Began Operation | Miles | Total Cost (nominal \$US billion) | Cost per Mile (nominal \$US million) |
|---------|-----------------|-------|-----------------------------------|--------------------------------------|
| Tokaido | 1964 | 347 | 0.9 | 2.6 |
| Sanyo | 1975 | 389 | 2.95 | 7.6 |
| Tohoku | 1985 | 335 | 11.0 | 32.9 |
| Joetsu | 1985 | 209 | 6.7 | 32.0 |

Source: Adapted from Taniguchi (1992).

speeds fluctuate between 150 mph and 200 mph but are lower on the conventional network (130 mph). All in all, HST has meant an 80 percent increase in speeds 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-Henneberg 2000). In Montchanin, the HST link has attracted just four firms, creating 150 new jobs.

The French HST lines were financed primarily according to their profitability, with an expected 12 percent 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 percent financial rate of return but a 30 percent 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.

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 percent, while journeys in the inverse direction experienced only a 54 percent increase as a result of 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 (Île-de-France) has enjoyed the largest increase in its HST supply, mainly because of the spatial concentration of population.

In spite of these asymmetries, big cities such as Lille and Lyon have also experienced positive effects as a result of the HST in the

form of increased 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—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 intraorganizational business trips. Such trips originating in Paris are up 21 percent, while those with Paris as their destination are up 156 percent (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 that they considered in their decision, but only four firms out of a total of 663 claimed that it was a key determinant in their choice of location. Similar results were obtained in Valence and Avignon. Consequently, it has been consistently found that the HSR has neither accelerated industrial concentration nor promoted administrative or economic decentralization from Paris (Martí-Henneberg 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 percent to 46 percent with the introduction of HST (1981–85); the main purposes were stated as internal contacts and buying or selling services (Bonnafous 1987).

Germany: *Neubaustrecken*

The German InterCity Express arrived a decade after the French HST (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 World War II 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 to Würzburg and Mannheim to Stuttgart. 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 Wolfsburg’ Berlin and Nuremberg–Leipzig corridors were the next links to be constructed (Gutiérrez 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

Table 3 Train à Grande Vitesse Construction Costs

| Line | Began Operation | Miles | Total Cost (nominal \$US billion) | Cost per Mile (nominal \$US million) |
|------------------|-----------------|-------|-----------------------------------|--------------------------------------|
| Paris–Lyon | 1981 | 264 | 1.0 | 3.7 |
| TGV Méditerranée | 2001 | 155 | 1.55 | 10 |
| LGV Est | 2007 | 186 | 4.0 | 21 |

Note: Data on cost per mile are denoted in Euro1981 for Paris–Lyon and Euro2001 for TGV Méditerranée. The exchange rate as of July 9, 2010, was used to calculate nominal U.S. dollars (1 euro = 1.27 U.S. dollars).

Sources: Adapted from Campos and de Rus (2009) for Paris–Lyon and TGV Méditerranée; for LGV Est, data are from <http://www.lgv-est.com/>.

not build a separate HST rail network but rather upgraded existing lines. This means that 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 mph to 160 mph). Nevertheless, the HST system still offers commercial speed gains of around 60 percent.

The German multipurpose HSR system was conceived to spread benefits rather than concentrate them. In fact, as Heinisch (1992) claims, the main consideration when designing the new lines was not faster passenger traffic, but 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 for passenger traffic. A further difference with the HST 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 percent, while the average net revenue per train-mile of the InterCity Express service was 1.7 times higher than the average for other long-distance services (Ellwanger and Wilckens 1993). However, from a 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 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 (see table 4), a situation that can be attributed to the more challenging nature of the terrain, its urban structure, and political and legal obstacles. Furthermore, the network serves only around 67 million passengers a year. For this reason, the utility of continuing investment in HSR is being questioned, as 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 (Vickerman 1997; Whitelegg 1993).

Operational deficits are attributable 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 was based on a complex, interlinking network of services with interchanges that provided regular hourly or twice hourly connections between most major German towns and cities and more frequent services on certain key lines (Vickerman 1997, 28). This means that there are few corridors providing sufficient demand. Compared to the 9 million annual passengers using the HST link between Cologne and Frankfurt, the Paris–Lyon link can boast 25 million passengers and the Tokyo–Osaka link 130 million—that is, more than 10 times the Cologne–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).

Spain: *Alta Velocidad Española (AVE)*

The first Spanish HST link, the *Alta Velocidad Española (AVE)*, was inaugurated in 1992 between Madrid and Seville on the eve of the Universal Exposition, held in Seville. The train covers the 293 miles between the cities in just 2 hours, 15 minutes (direct service). By choosing Seville, Spain is 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 arguably was 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 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 rail technology rather than developing its own (Vickerman 1997), which is another distinguishing feature of the projects implemented in the other countries studied.¹⁰

In spite of good occupancy rates, infrastructure utilization of this line remains under capacity given its length and relative isolation, but particularly because of the small population served (Martí-Henneberg 2000). However, the HST has had a marked impact on mobility patterns. Before the introduction of the HST 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, the HST recorded 1.4 million passenger journeys, while the number of those flying fell to 300,000. No effects have been reported for the interurban bus service, which continued to carry around 200,000 passengers annually in that period. However, the inauguration of the first HST has 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 complementary service for freight transport has 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 the French HST, 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,

Table 4 Neubaustrecken Construction Costs

| Line | Began Operation | Miles | Total Cost (nominal \$US billion) | Cost per Mile (nominal \$US million) |
|----------------------|-----------------|-------|-----------------------------------|--------------------------------------|
| Hannover–Würzburg | 1988, 1994 | 203 | 8.5 | 42 |
| Mannheim–Stuttgart | 1991 | 61.5 | 2.9 | 47 |
| Cologne–Frankfurt | 2002 | 110 | 7.6 | 69 |
| Nuremberg–Ingolstadt | 2006 | 55 | 4.6 | 83 |

Note: The exchange rate as of July 9, 2010, was used to calculate nominal U.S. dollars (1 euro = 1.27 U.S. dollars).

Sources: Adapted from European Commission (1996), Deutsche Bahn, <http://www.bahn.com/i/view/index.shtml>; and International Union of Railways, High Speed Department.

commercial speed gains in Spain are more than 100 percent, with the HST 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 HST railway stations. Neither has it led to new firms establishing themselves within their vicinity. Yet the image of cities with HST 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 HSR construction. However, Albaladejo and Bel (2008) report that Ciudad Real and Puertollano, two cities served by the HST since 1992, 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 lose 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 One-third of all investment (amounting to 82.96 billion euros) in the country's Strategic Plan for Transport Infrastructure is to be devoted to HSR until 2020 (Bel 2007), when 6,200 miles of the HSR network are expected to be in service. These plans are rooted in the desire to build a rapid connection between all of the provincial capitals in the country and the political capital, Madrid, as formulated by former Prime Minister José María Aznar on April 25, 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 Spanish HST is considered a symbol of modernity, and it enjoys user support—perhaps because passengers pay low prices thanks to huge public subsidies (De Rus and Román 2006).¹² In fact, HST lines in Spain have received the bulk of European Union subsidies for regional development allocated to Spain, ranging between 30 percent and 50 percent (depending on the line) of total construction costs (ADIF 2009, 59).

Cost-benefit analyses 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 attributable to the low volume of traffic (De Rus and Inglada 1997). More recent cost-benefit analyses (De Rus and Román 2006) of the profitability of the Madrid-Barcelona route—the two largest and most 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.

According to the information delivered by De Rus (2010), the marginal cost associated with an HSR project is distributed in the following way, depending on the volume of passengers:

- HSR with 2.5 million passengers annually: 79 percent fixed costs and 21 percent variable costs
- HSR with 5 million passengers annually: 65 percent fixed costs and 35 percent variable costs

- HSR with 10 million passengers annually: 49 percent fixed costs and 51 percent variable costs

These figures imply that even covering variable costs, which implies a recognition of operating costs when charging passengers, the subsidy needed to cover fixed costs is huge for HSR projects with low demand. Even in corridors with a demand of 10 million passengers, it is needed to subsidize half of the marginal cost because of fixed costs. Because operating costs in Spain have not been covered by pricing schemes so far, it is easy to understand the important deficit that taxpayers must bear, especially if we consider that only the Madrid-Barcelona corridor is able to provide significant passenger demand.

Table 5 shows the building costs for the most recently constructed HST 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 2003, and the HST 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 (\$11 billion) is relatively lower than that for the Cordoba-Malaga and Madrid-Valladolid projects, which were completed relatively quickly between 2004 and 2007, the year in which HST service began on those routes.

With regard to the environmental impact of the HST, we are able to evaluate its carbon dioxide emissions compared to those produced by conventional trains. Using data presented by García Alvarez (2007) on distances, emissions, and passenger capacity, we can compare carbon dioxide emissions per passenger-kilometer on three Spanish HST lines and their corresponding conventional rail services. On two routes (Madrid-Seville and Madrid-Barcelona), there are no significant differences between the two services in carbon dioxide emissions per mile. However, carbon dioxide emissions per passenger-mile on the Madrid-Toledo link are almost 50 percent higher in the case of the HST. 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.

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 Milan-Naples and Turin-Venice lines. This concession was extended in 1992 to include the Milan-Genoa line. Società TAV is of mixed public-private ownership, with 60 percent of the capital

Table 5 Alta Velocidad Española Construction Costs

| Line | Began Operation | Length (miles) | Construction Costs (nominal \$US billion) | Cost per Mile (nominal \$US million) |
|-------------------|-----------------|----------------|---|--------------------------------------|
| Madrid-Barcelona | 2003 & 2008 | 413 | 11.0 | 27 |
| Madrid-Valladolid | 2007 | 114 | 5.3 | 46 |
| Cordoba-Malaga | 2007 | 96 | 3.2 | 34 |

Note: The exchange rate as of July 9, 2010, was used to calculate nominal U.S. dollars (1 euro = 1.27 U.S. dollars).

Sources: Authors' calculations based on information from the Spanish Ministry of Transportation; and ADIF (2009, 29, 50).

in private hands and the remaining 40 percent belonging to the State Railways, the Gruppo 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 percent of all passenger transit, while the trains are responsible for carrying just 12 percent of the nation's freight (GFDS 2007b). Both figures are well below European averages. Moreover, air transport cannot guarantee the intermediate stopover 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 an 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 toward a more integrated conception of the network, and so the Alta Velocità plans were replaced with the Alta Velocità/Alta Capacità (high-speed/high-capacity) 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 percent of this private share was acquired by the Gruppo Ferrovie dello Stato in 1998.

Contrary to the HST strategy adopted in Japan, France, and Spain, the Italian HST was conceived to spread the benefits of high-speed rail—linking up with the conventional lines—rather than concentrating them. However, this strategy caused an increase in projected costs. The decision to shift from a high-speed strategy to a high speed/high capacity one caused projected costs to rise by about one-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 Rome–Naples in 2005 and Turin–Novara and Modena–Laveno in 2006. Today, the Italian HST network covers 411 miles, with additional HST services running between Turin–Milan–Bologna–Florence,¹³ and Rome–Naples–Sorrento. Construction costs, provided by the Gruppo Ferrovie dello Stato (GFDS 2007a), are shown in table 6.

Table 6 Alta Velocità/Alta Capacità Construction Costs

| Main Line | Began Operation | HST Miles | Connecting Lines (to conventional network, miles) | Construction Costs (nominal \$US billion) | Cost per Mile (nominal \$US million) |
|------------------|-----------------|-----------|---|---|--------------------------------------|
| Rome–Naples | 2006 | 129 | 16 | 7.2 | 49 |
| Turin–Milan | 2006 | 78 | 12 | 9.9 | 110 |
| Milan–Bologna | 2008 | 115 | 25 | 9.1 | 65 |
| Bologna–Florence | 2009 | 49 | 5 | 7.5 | 138 |

Note: The exchange rate as of July 9, 2010, was used to calculate nominal U.S. dollars (1 euro = 1.27 U.S. dollars).

Sources: Authors' calculations based on Gruppo Ferrovie dello Stato (2007a); and International Union of Railways, High Speed Department.

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

The cost per mile of HST lines in Italy is much higher than those reported in the other European countries reviewed. On average, the cost per mile of the lines currently operating in Italy has been \$77 million. This marked price differential is attributable mainly 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, as air routes between the Italian cities that so far have been linked to the HST network are of limited importance because of the short distances involved.

Lessons from Worldwide Experience

Based on the case studies reported here, 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. Linking with other corridors to promote regional equity or to foster regional development only seems to result in the economic failure of the project.

Still, within the domain of general motivation, an interesting issue emerges from the reviews conducted: political objectives do not appear to be a main driver of HSR development, with the relevant exception of Spain. In that country, “HSR political supply” from the national government has been fostered by huge foreign subsidies for construction from the European Union. In addition to this, “HSR political demand” from regional and local governments has been encouraged by the fact that the full costs of construction have been born by the central government budget (with the help of the foreign subsidies). This might explain the ambitious plans for HST extension in Spain. We do not think this is likely to happen in the United States to the same degree. First, no foreign subsidies are available in this case. Second, the U.S. federal government is typically offering subsidies for 25 percent of construction costs, while the remaining costs have to be born by state (and eventually local) governments. Still some degree of “political demand” can be expected from local governments as long as they are not required to confront large expenditures, as shown by the activism of the mayors of Los Angeles, Chicago, Orlando, and Albany in the United States Conference of Mayors (2010). However, we expect public debate on the cost–benefit implications of HSR in the United States to grow, particularly in a time of strong fiscal restrictions, as in the present.

Structure: Design and Functions

Perhaps the first major decision to be made 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 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 United States, where a much higher share of freight is transported by rail than is the case in Europe and Japan. However, we must be cautious regarding the suitability of joint operation of passenger and freight traffic in the United States, as rail network and institutional structure for freight transportation in the United States is much different from those countries reviewed earlier. In the United States, the freight network traditionally has been under private ownership.¹⁴ However, if HSR projects are supported only by passenger traffic, they will produce little—whether or not irrelevant—impacts on most areas served, unless traffic density HSR projects consider the private lines for freight.

Lower construction costs have been reported for 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 learned 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 that European and Japanese downtown areas are denser than their American counterparts. 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 earlier, concerns the complementarity of carrying passengers and freight. Complementarity with freight transport increases costs because the track gradients have to be more carefully controlled. However, making freight carriage compatible with passenger travel 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 is the political pressures that are brought to bear and can lead to incremental costs and decreasing benefits.

One issue that certainly should not be ignored is the political pressures that are brought to bear and 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. On the demand

side, local and regional governments might exert pressure for an HST railway station, even if this runs contrary to sound transportation rationale. All of these factors can combine to raise construction costs and lower the average commercial speed.

According to estimates calculated by De Rus and Nombela (2007, 21), investment in HSR is difficult to justify when the expected first-year demand is below 8 million to 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.¹⁵ In line with this criterion, the European Commission stated in 2008 that "only under exceptional circumstances (a combination of low construction costs plus high time savings) could a new HSR line be justified with a level of patronage below 6 million passengers per annum in the opening year; with typical construction costs and time savings, a minimum figure of 9 million passengers per annum is likely to be needed" (European Commission 2008, 84).¹⁶ 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 when there is high demand expectations for rail travel (i.e., routes connecting densely populated metropolitan areas), severe road congestion, and a deficient air connection. In this regard, the economic rationale for the four HST lines that have been given priority in the United States (see table 1) is by no means clear, with the exception of that in California, for which the demand forecast is above estimated thresholds estimated in Europe, but expected costs are much higher, by far.

This economic framework casts doubts on the use of public-private partnerships in HSR projects. This is clearly illustrated by the Italian case, where the HSR was originally conceived as a public-private partnership but was later nationalized because of 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 compared to conventional rail services, but similar door-to-door timings are reported

Table 7 Modal Share Change Before and After Introduction of First HST Corridor

| Mode | Paris–Lyon (1981–84) 264 Miles | Madrid–Seville (1991–94) 292 Miles |
|----------|--------------------------------|------------------------------------|
| Airports | –24 | –27 |
| Rail | +32 | +35 |
| Road | –8 | –8 |
| Total | 37 | 35 |

Source: European Commission (1996).

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—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 100 miles 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 of the cases studied, with the greatest impact on the airline industry in France and Spain. As table 7 highlights, immediately following the inauguration of 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 5 million passengers per year in 2007), show that after a year of HST service, one-third of air traffic has switched to rail.

Environmental Advantages

There has yet to be a detailed, systematic evaluation of the impact of an expanding HST network on the reduction in carbon dioxide emissions at either the aggregate or country level. However, information is available on the environmental effects of HSTs, particularly with regard to their energy consumption. According to estimates conducted by Van Essen et al. (2003), energy consumed (in megajoules per seat-kilometer) by air transport is 240 percent higher than that attributable to HSTs. However, the energy consumed by HSTs is 12.8 percent higher than a petrol-driven car when traveling on the motorway, 55.9 percent higher than a diesel-driven car on the motorway, and 140.9 percent higher than an intercity train. Similarly, a recent paper by Anderson and Lukaszewicz (2009) finds a 32 percent difference between conventional and HSR using kilowatt hours per seat-kilometer as a measure. 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, whether it replaces cars or buses). However,

HSR is not a particularly useful tool for fighting carbon dioxide emissions, as it is less environmentally efficient than conventional modern trains. Further, building a new and separate HST line involves significant carbon dioxide emissions that environmental HST analyses do not take into account (together with the environmental impact caused by land take, noise, and visual disruption). In fact, Kageson concludes, after presenting evidence comparing the environmental impact of different transport modes, that the reduction of carbon dioxide through HSR building “is small and it may take decades for it to compensate for the emissions caused by construction Indeed, it will take too long for traffic to offset the emissions caused by building the line. Under these circumstances it may be better to upgrade an existing line to accommodate for somewhat higher speeds as this would minimize emissions from construction and cut emissions from train traffic compared to HSR” (2009, 25).

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 ongoing processes as well as to facilitate intraorganizational journeys for those firms and institutions for which 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-sized 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 sometimes comes 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 lack of attention given to an 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 because of 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.

However, demand pressure for receiving HST projects still arises from the territory, affecting the network’s design, cost and mobility impacts. In fact, in Japan and Spain, economic expectations led to political pressure for HST stations, while in France, officials were immune to this. The political and electoral system could explain these differences. For a long time, rural districts were allocated more seats per resident than urban areas in the Japanese electoral system (Baker

Table 8 Summary of Country Reviews

| | Japan | France | Germany | Spain | Italy |
|--|--|---|--|---|--|
| Motivation | Reduce travel time in congested links between large cities | Solve congestion between large cities | Connect northern ports with southern industrial territories | Regional equity and administrative objectives: connect provinces to Madrid | Promote rail passenger travel, which is more appropriate than air transport because of the Italian geography (short distances) |
| Design and functions | Separated track; passenger orientation; large nodes connected; geography of the island constraints design | Separated track only in high-demand corridors; use of conventional track in low-demand corridors; large nodes connected to Paris; centralized network | Mixed system for both passengers and freight; lower speeds; large nodes connected; decentralized network | Separated track only for passengers; all capital provinces connected to Madrid; centralized network | Integrated network of HSR and conventional rail; large cities connected; decentralized network |
| Economic cost: latest available figure | \$US32 million (nominal) per mile (1985) | \$US16 million (nominal) per mile (2001) | \$US31.5 million (nominal) per mile (1996) | \$US48 million (nominal) per mile (2007) | \$US138 million (nominal) per mile (2009) |
| Mobility impacts | Time savings estimated at 400 million hours per year; no effect on regional dispersion; slightly increased population growth around lines | Flights and rail trips to Paris increased more than from Paris; favors intraorganizational journeys | 11 percent average increase in market share of freight transportation | Harms the airline industry; no effects on bus operators; low passenger volumes; little time savings with respect to aviation | — |
| Environmental cost ¹ | — | — | — | Carbon dioxide emissions per passenger-kilometer are 50 percent higher than conventional rail for short distances; no relevant differences for long distances | — |
| Economic and regional effects | Favored service and retail sectors but became concentrated in large nodes; tourism and intraorganizational journeys increased, but decline in pernoctation | Paris receives benefits; improves service sector in other big cities such as Lyon; impact on industrial activities is irrelevant; no effect on localization decisions | — | Negative cost-benefit analyses; not designed to promote economic dynamism; no firm location effects; no population growth around AVE lines | — |

¹ Little information is obtained from the experiences reviewed regarding environment issues. However, there are different articles—already referenced in the text—that focus on the comparability among transportation modes. Several analyze Scandinavian countries with high awareness on environmental impacts. These countries have not been reviewed here because their HSR projects are less significant in terms of length, and only short links.

and Scheiner 2007). The same happens in the Spanish electoral system (Márquez and Ramírez 1998). However, electoral systems do not favor rural and less populated areas in France (Criddle 1992), Germany (Manow 2007), and Italy (Ortona, Ottone, and Ponzano 2005). Because of this, political incentives for central governments to extend the HSR network to rural and less populated areas are higher in Spain and Japan than they are in France, Germany, and Italy. In the same way, pressure from local politicians demanding the extension of HSR networks may be more effective in Spain and Japan.

We summarize in table 8 the experiences described by implementation issue, and in table 9, we provide a summary of the main lessons learned.

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 are notoriously high. In addition, political factors (on both the supply and the demand sides) can contribute to further increase costs. This political pressure can be important when rural districts are favored by the electoral system in terms of seats per inhabitants. However, benevolent politicians could also accommodate the project's balance between citizen (potential user) needs and taxpayer welfare, but this requires the absence of private interests in the design of their policy. Also, the execution of efficient projects needs bureaucrats and policy makers without private interests.

Therefore, the potential demand for HSR services must be particularly high in order to make investment in HSR socially profitable. This means that its main targets must be those corridors linking densely populated metropolitan areas, suffering from severe road congestion, and having deficient air links. These constraints also hinder the use of public-private partnerships, 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 carbon dioxide

Table 9 Summary of Lessons Offered by International Experiences

| | Summary of Lessons |
|-------------------------------|---|
| Motivation | HSR has to be devoted to solving congestion in corridors between large populated cities. Political or administrative objectives and extension of lines for regional equity and development lead to the economic failure of the project. |
| Design and functions | In spite of the characteristics of the American rail structure, the international experience shows that passenger-oriented HSR has a minimum economic impact on the territory served. Lower construction costs are associated with combining HSR and conventional rail. Routes have to be established according to demand (commercial basis). Adequate multimodal connections are needed. |
| Economic cost | The development of an HSR network entails huge construction and operation costs (especially important land expropriation cost, bridges, and tunnels). The key decision that affects cost concerns complementarities (passenger/freight) and the extent of combination with existing conventional rail. Political pressures (connection and station costs) can increase HSR cost and constrain its profitability because of opportunism or private interests from both politicians and bureaucrats. |
| Mobility impacts | Provide 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. Modal distribution of traffic is affected when HST starts operation, with the greatest impact on the airline industry. |
| Environmental cost | Energy consumption and carbon dioxide emissions are lower for HST than for air transportation. However, they are also greater for HST than for conventional rail per seat mile. In fact, it is necessary to wait more than three decades to compensate energy and pollution generated during construction. |
| Economic and regional effects | HSR does not generate any new activities, nor does it attract new firms and investment, but rather it helps to consolidate and promote ongoing processes as well as to facilitate intraorganizational journeys, for which mobility is essential. For regions and cities whose economic conditions compare unfavorably with those of their neighbors, a connection to the HSR may even result in economic activities being drained away and an overall negative impact. Medium-sized cities may suffer the most because of the centralization of activities in large nodes. Tourism and the services sector are the only activities favored, while no effects are reported for industrial and agricultural activities. |

emissions than conventional intercity trains. For this reason, HSR is not a very useful tool for fighting carbon dioxide 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-sized cities, which might see economic activities being drained away and suffer an overall negative impact.

The present article was based on a review of the main HSR experiences around the world. Future research should draw on recent developments in U.S. transportation planning, which provides an increasing number of project analyses, including those already under way in California. 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, and fiscal constraints) with the experiences and contexts of other countries around the globe.

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Notes

1. The term “high-speed rail” is typically used to mean railways that are capable of speeds close to or above 155 miles per hour on purpose-built track (De Rus and Nash 2007).
2. See *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.
3. See official report DOT 51-09, April, 16, 2009, at the Federal Railroad Administration Web site, <http://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.
5. 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 provides a very useful up date on cost considerations and data up to the mid-2000s.

6. Although the high-speed train was proposed in 1957 and inaugurated in 1964 to coincide with the Olympic Games, construction work actually began in 1940 but was halted by World War II (Taniguchi 1992).
7. A new dedicated line was required because the conventional railway network ran on a narrow gauge that could not support HSTs (Givoni 2006, 595).
8. Social profitability is defined as the net social return, in terms of economic welfare of the society, of an investment project. It results from the comparison of social costs and social returns instead of private costs and private revenues, which is the traditional financial analysis of a private project evaluation. The social rate of return is the rate of return achieved by society—this is considering all externalities generated—as a result of a given investment project.
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 ALTSOM.
11. See “España tendrá en tres años la mayor red de AVE del mundo, según Zapatero,” *El País*, February 15, 2007, <http://www.elpais.com>.
12. In the first year of operation (beginning in October 1992), price reductions of 30 percent on the Madrid–Seville route and 50 percent on the Madrid–Ciudad Real line were introduced to offset the effects of the closure of the Universal Exposition. According to De Rus and Nash (2007), these low prices 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.
13. The Florence–Rome 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.
14. Except for the transitory period in which Consolidated Rail Corporation, commonly known as Conrail, was operating under government ownership; Conrail was created in 1976 to take over the potentially profitable lines of bankrupt carriers and was privatized in 1987.
15. De Rus and Nombela’s (2007) 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 percent discount rate.

The largest cities in the network might receive limited gains, but this is not the case for intermediate-sized cities, which might see economic activities being drained away and suffer an overall negative impact.

16. This is the minimum level of demand from which a positive economic net present value can be expected when new capacity does not provide additional benefits beyond time savings from diverted and generated demand. This exercise implies several assumptions on demand growth, value of time, and traffic diversion generated.

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