High-Speed Rail Stations as Transportation Nodes and Places: Lessons for California

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ABSTRACT

What key elements can help the US high-speed rail system (HSR) blend successfully with existing rail and transit services? That question is critically important now that high-speed rail is under construction in California. The study seeks to understand the requirements for high levels of connectivity and spatial and operational integration of HSR stations and offer recommendations for seamless, and convenient integrated service in California intercity rail/HSR stations. The study draws data from a review of the literature on the connectivity, intermodality, and spatial and operational integration of transit systems; a survey of 26 high-speed rail experts from six different European countries; and an in-depth look of the German and Spanish HSR systems and some of their stations, which are deemed as exemplary models of station connectivity. The study offers recommendations on how to enhance both the spatial and the operational connectivity of high-speed rail systems giving emphasis on four spatial zones: the station, the station neighborhood, the municipality at large, and the region.
INTRODUCTION

High-Speed Rail (HSR) can have transformative effects on cities and regions, potentially increasing both mobility and accessibility in an unprecedented way. HSR systems may also have important physical impacts, altering the built environment of station-neighborhoods and affecting municipal economies. However, not all cities have witnessed positive effects from the HSR, and benefits from HSR systems have been unevenly distributed among cities (1, 2). A number of studies have examined the factors that influence the economic and development impacts of HSR projects on station-cities (3). They have observed differential impacts depending on the type of station-city (first- or second-tier) (4), its distance from other major cities on the network (5), the condition of the local economy and land market, and station location (central or peripheral) within a city (6). Additionally, most scholars agree on the importance of two factors: connectivity of the HSR station with other transportation modes and anticipatory planning (7, 8, 9).

These two factors appear critical for California as it embarks on an ambitious $68-billion program to install the first phase of a HSR network that would connect its northern and southern parts. Indeed, three top lessons for California emerged from an earlier Delphi survey of HSR experts: “provide good connections with intra-urban transportation systems,” “plan stations as intermodal nodes,” and “develop good urban design station-area plans” (10:44).

In an early article, Bertolini and Spit noted that “a railway station’s essential feature appears to be its function as an intermodal interchange, rather than a place where trains arrive and depart. The railway station is to be seen as ‘an urban exchange complex’… The railway system has to offer full connectivity in both the hard sense – the infrastructure – and the soft sense – the services… In the process the railway station turns into ‘a place to be’, not just a ‘place to pass through’” (11:31). This observation underscores the importance of a station as both a transportation node and a vibrant place. In what follows, we examine in more depth these two issues—how to best enhance operational connectivity and intermodal integration of California’s HSR stations, and how to achieve a seamless spatial integration of these stations and their surrounding context.

To do so, we turn our gaze to European HSR systems, particularly those of Germany and Spain for a number of reasons. For one, both countries have mature HSR networks that operate for a number of decades; the ICE was inaugurated in 1991 in Germany, while the Spanish AVE started operation between Madrid and Seville in 1992. A second reason is that California is considering the use of a “blended” or shared-use system (where HSR shares tracks with conventional rail) for at least some track segments. Both Germany and Spain have extensive HSR networks operating on tracks shared between high-speed and conventional trains. Lastly, a number of Spanish and German HSR stations score high in terms of connectivity and integrate both node and place qualities.

Certainly, cities in California are considerably different from cities in Europe. The urban form of European cities is typically more compact, dense, walkable, and bicycle-friendly than their California counterparts. Additionally, European cities have higher levels of intermodality than California cities, which are primarily built around the automobile. To these differences one should add that California residents are more ‘married to their cars’ than Europeans; they have higher rates of automobile ownership and more automobile miles travelled per capita. Nevertheless and despite these differences, the European experience with the HSR can provide lessons for California.
The purpose of this study is therefore to understand the requirements for high levels of connectivity and spatial integration of HSR stations and offer some guidelines for California HSR stations. The study draws data from a review of the literature on the connectivity, intermodality, and spatial integration of transit systems; a survey of 26 HSR experts from six European countries; and an in-depth look of the German and Spanish HSR systems and some of their stations, which are deemed as exemplary models of HSR station connectivity.

SPATIAL AND OPERATIONAL CONNECTIVITY OF STATIONS

HSR station connectivity denotes the spatial integration of the station with its surrounding urban fabric, but also the level of accessibility of the station from different points of origin. Good urban design is the means to achieve the first type of connectivity, which we will call spatial connectivity. Frequent HSR services and operational integration between the HSR system and other transportation modes (including walking and cycling) are critical in achieving the second type of connectivity, which we will call operational connectivity. The latter is also related to intermodality, since a high level of intermodality denotes a passenger’s ability to use more than one transportation mode for a single trip in a convenient and “seamless” way. A high level of connectivity increases the mobility benefits for transit travelers (12). Conversely, poor transit connectivity creates barriers to passenger mobility and may affect transit ridership (13).

Good operational and spatial connectivity enhance the node qualities of a station, while good spatial connectivity also contributes to its place quality (14). Both types of connectivity are crucial to attracting passengers because they make travel convenient. This appears to be significant for the competitiveness of HSR systems (10). Indeed, one of HSR’s biggest advantages over air travel is that it can offer passengers a one-seat ride into the center of cities, eliminating time-consuming airport transfers and wait times, and providing opportunities for intermodal transfers at these locales. However, the competitiveness of HSR is highly dependent on the level of its spatial and intermodal connectivity, as well as the transit authorities’ ability to deliver convenient and fast service into urban cores in a cost-efficient manner. The integration of high-speed trains with existing intercity and commuter/regional rail systems in a “blended system” offers the advantages of higher connectivity as well as potentially lower capital costs and decreased adverse environmental and urban form impacts. However, a blended approach requires careful pre-planning to achieve a high degree of coordination in operations and passenger services. It also requires station infrastructure that accommodates smooth transitions between the different modes (15).

Many previous empirical studies have focused on transit ridership at the route-level and segment-level, thereby assuming homogenous service levels and land uses along each route. Some scholars have recently started emphasizing the importance of also examining and seeking to improve connectivity at the transit station level and in more holistic ways that focus not only on transit vehicle operations but also information and ticketing as well as the design and layout of urban form elements.

Recognizing that past research on connectivity and ridership analyzed transit service characteristics and urban form separately, Dill and Schlossberg sought to synthesize these disparate approaches and examine their combined influence on transit ridership at the transit stop/station level (16). They found that while transit service plays the most important role in predicting transit ridership, characteristics of the built environment, such as the nearby presence of bicycle paths, also matter. When good transit services and a good physical infrastructure co-
exist, connectivity improves and ridership increases. While this research is not including HSR stations, its findings emphasize the importance of the built environment as a major factor in improving transit’s connectivity. Similarly, Mbata et al. stress the role of the built environment in encouraging or discouraging transit use. They argue that a station-area design that connects to different transportation modes, including walking and cycling, will have the highest rates of ridership (17).

Developing or improving connectivity at HSR stations is complicated due to the wide range of factors that must be taken into account. These include both physical/infrastructural (e.g. station design, connection between different platforms) as well as operational factors (e.g. line integration and scheduling, fare and information systems, integration of different transportation systems).

**Spatial Connectivity**

While the importance of smooth linkages between an intermodal transportation facility and the surrounding neighborhood and city is recognized, only a miniscule part of the HSR literature discusses physical and urban design interventions that can improve spatial connectivity. Loukaitou-Sideris (18) identifies four spatial zones that must be considered for ensuring good connectivity and access to HSR stations: 1) the station itself; 2) the station-district, generally defined as about half-mile radius around the station; 3) the municipality at large; and 4) the broader region. Good urban design can enhance the station’s spatial connectivity in the first two zones; while good multimodal services can improve the connectivity of the station with the municipality and region at large.

At the station, the flow of pedestrian movement from parking lots and adjacent bus stops to station entrances, ticketing areas, train platforms and other station facilities is important, and the connections between different station platforms should be direct, short, and legible for passengers. At the station-neighborhood, a major urban design challenge for spatial connectivity is the bridging of “the barrier effect,” the gap between the station and its neighborhood that is created by the bulky railway infrastructure and major parking facilities. The appropriate urban design intervention would vary depending on the guideway type (elevated, surface, or tunnel), and if the HSR tracks are dedicated or shared (the railway right-of-way is wider and more challenging to bridge when the HSR operates on its own dedicated track) (18).

**Operational Connectivity**

Operational connectivity can be enhanced by high levels of intermodality—the availability of different transportation modes converging at the HSR station—and the seamless integration and time-coordination of these modes, so that waiting time for passengers is minimized. A number of studies have examined ways of enhancing operational connectivity by improving transferring services, supporting facilities, and information systems in multimodal transportation networks.

The integration of HSR with both high- and low-speed modes appears to be important. A particularly interesting integration of two high-speed modes is between HSR and air travel. Noting that most studies focus primarily on intermodal competition between transit modes, Givoni and Banister have examined intermodal cooperation and integration between air and rail transit at Heathrow Airport in London. They defined integration as “aircraft and high-speed railway services provided as one complete journey with a fast and seamless transfer between the
modes.” (19:388). They suggest that achieving integration requires that 1) the railway station is
designed to offer fast and seamless travel between modes by minimizing the distance of
transfers; 2) the station has direct links to a large number of destinations with services at a
relatively high frequency (oftentimes by making the airport rail station a through station on a
main line); and 3) the travel times between the railway service and aircraft service on the same
route (achieved by taking the passenger directly from the airport to the destination city’s center)
are comparable. The researchers find that such integration is mutually beneficial for both transit
and airline operators, while also preserving the airport’s and HSR station’s competitive position,
increasing services to other regions, and curbing environmental impacts. The authors suggest that
policy makers consider the two modes as part of one transport network, rather than separate and
competing entities (19).

Developing the HSR station in close proximity to retail and tourist attractions requires its
integration with low-speed modes—walking and biking. Thus, Pan et al. examine the challenges
and opportunities for improving the bicycle-rail connectivity based on surveys of railway
passengers in Shanghai. Based on their findings, they recommend the provision of additional
bicycle parking spaces and a bicycle rental system for improving the bicycle-rail connection and
utilizing the bicycle more fully as an efficient supplemental mode for rail transportation in China
(20).

In regards to the efficient time-coordination of different modes with the HSR, the Swiss
eexample of “clockface scheduling” is referred to as “the most streamlined delivery of public
transport and Europe’s best practice for bus, tram, and railway interchange” (21:46). All Swiss
trains are programmed to arrive at the interchange stations of all major cities at exactly the same
time, at 00 and 30 minutes pass the hour. Inter-city trains arrive every 30 minutes, regional
trains and buses connecting to the station arrive every 15 minutes, while local trams and buses
arrive every 7.5 minutes.

Clever examines the concept of Integrated Time Transfer (ITT), utilized in Europe as a
way to improve public transportation services. Under ITT, trains, buses, boats, and other means
of local and long-distance public transportation not only operate on a fixed-interval schedule, but
also connect with each other in ways that minimize transfer times. The advantages of ITT
include reduction of transfer times, more frequent services, better spatial coverage, and more
profit for operators, while possible disadvantages include longer headways and the unrealistic
assumption of the uniform usage of the system throughout the day (22).

Lastly, an additional factor that can contribute to the increased operational connectivity
of HSR involves the provision of seamless information and ticketing for travelers. Noting that
building infrastructure to support connectivity can be expensive and time-intensive, some
scholars have argued that more or better-placed signage, real-time information about the
schedules of different connecting modes, information kiosks, and ticketing practices that enable
passengers to purchase combined transport services can improve connectivity and attract
ridership (12) (23). Recently, particular interest has also gone into the development of effective
internet-based platforms such as the multi-modal route advisory system (MRASD) developed by
Chiu et al. (24) that enables travelers to link with multiple modes of public transportation
services as well as taxis and shuttles in identifying the shortest, fastest or cheapest multimodal
connections. These kinds of services are expected to become standard in coming years and let
users take full and optimized advantage of a full range of connections between modes.

Overall, the existing research demonstrates that transit connectivity and intermodality can
provide a wide range of mobility benefits for travelers, and thus increase ridership. While many
argue that improving the built environment is crucial to improving connectivity, others have shown that operational connectivity is also important. Lastly, HSR planners need to consider the integration of the HSR with low- and high-speed travel modes for intra- and inter-city travel.

**EXPERT SURVEY**

To complement the findings of the literature and identify the factors that should be considered for the good integration of the California HSR network and the high connectivity of its stations, we consulted with 26 HSR experts from Europe. All experts had positions at universities or think-tanks, had conducted research and had significant publications on HSR development and evaluation. There was an overall consensus among the experts of the critical importance of HSR connectivity and network integration. As reasoned:

“Finding the right system depends on the opportunities of each territory. But simple rules for success exist: You must consider the new HSR lines as part of a multimodal system. You must ensure interdependencies among the rail lines. A good transportation system is a system that ensures high connectivity” (25).

“The HSR is an important long-distance mode of transport and its integration with the rest of the transport network is probably one of the most, if not the most, important element in its planning” (26).

Additionally, it was noted that “maximum connectivity is reached if users experience the HSR service as much as possible as one door-to-door system” (27). But how can this be achieved? The experts talked about a combination of spatial and operational measures and ways to enhance the nodal and place qualities of HSR stations.

### Station location

An important topic that emerged from the survey entailed the location of HSR stations and the trade-offs of having stations in central versus peripheral city locations. In Spain and France, new HSR stations were often built peripherally, at a distance from city centers in small and intermediate cities, while they are centrally located in large cities. In contrast, Germany integrated almost all its HSR connections into pre-existing stations in central urban areas. There are trade-offs involved. As explained:

“There are two scenarios: The first is that of stations in the city center. It is easier to integrate different services and modes of transportation there. Be careful though because it requires a lot of work to adapt to different modes in the area of the station. Capital works are cumbersome and complex. The second scenario is of stations located on the outskirts of cities. Here it is essential to organize the transportation of passengers to the city center where the station is located” (28).

Historic stations are usually the focal point for intercity bus connections and a major hub of the urban transportation system. As argued: “Integrating an HSR station in a densely built district hinders access by car, because of the congestion of the urban street system, but allows access by walking or cycling. Thus, the choice to serve a central station encourages intermodality and sustainable mobility” (29).
On the other hand, if a HSR station is located at a peripheral location and away from conventional railway services, then a dense network of intercity buses should connect it to different parts of the metropolitan area. This is the case in Valence, France—a new station built exclusively for the HSR—which is served daily by 74 bus connections. In Reims and Besançon, a specific rail link was built to connect the new HSR station to the conventional rail network. Additionally, in Reims, the new HSR station is integrated into the urban transport network through the building of a new tramway service (29). Despite these examples, the assessment of a French expert is that:

“The experience in France shows that where TGV stations have been created at a distance from conventional (central) station, the TGV station is not well served from the center and fails to attract services. It also impacts the central station, which becomes less attractive. Therefore, one has to be very careful when building dedicated HSR stations” (30).

Station Design and Connections

Many experts emphasized the importance of station planning, design, and programming for enhancing the place qualities of HSR stations for both travelers and non-travelers:

“Plan functions and activities which express mix, flexibility and versatility of the spaces to ensure the presence of different populations and different practices not only related to the trip or for temporal use” (31).

“It is important to bring new services into the stations to make them attractive. Such services may include retail, restaurant, and even cultural activities” (30).

Experts referred to the “need for continuity between the station and its neighborhood; easy recognition of the access path to the city and other interconnected transport networks” and recommended to “design the space of the station as an urban open avenue/space, permeable and equipped with functions and activities that integrate it to the surrounding urban fabric.” (31). As noted, “the best integration results from an intelligent placement of the public transit network and from avoiding an over-abundance of parking at multimodal stations” (25).

Others referred to the importance of allowing visual connections, physical proximity and short walking distances from the HSR platform to other transport modes, including conventional rail (32, 33). There was a lack of consensus, however, as to the desirability of shared or separate station platforms between HSR and conventional trains. Some believed that separate train platforms at stations are preferable:

“It seems important to try and separate the slow and fast trains as much as possible in the stations to allow easy transfer between the services. If the services share a platform, the change between them will necessitate waiting at the platform for one service to depart and the next to arrive” (26).

On the other hand, some experts believed that sharing station platforms as much as possible is preferable because it maximizes interconnectivity (27). Most, however, qualified their response on the basis of particular contexts. Thus, the number of trains that arrive or depart from a station should influence the number of required platforms. As explained: “In Dutch stations there are only a small number of high-speed trains, and separate platforms seem a waste of space,
but this is different in Brussels Midi where there are many more high-speed trains” (34). Some
also emphasized that the type of station (intermediate or terminal) plays a role: “Separate
platforms are essential at intermediate stations where high-speed trains pass through at high
velocities. At endpoints they are helpful and convenient, but not essential to ensure efficient
service” (35). Some experts mentioned that the decision about separate or shared platforms
should depend on whether trains have similar or different dwell times (36).
Lastly, experts referred to the importance of information panels and good way-finding
signage for achieving good connectivity. As mentioned, “Signage is important and especially
indicating on the ticket in advance from what platform the next train will depart” (26). Much of
that information will become even more available in the future via real-time smart phone apps.

**Coordination of different travel modes and services**

A third major theme that emerged related to the coordination and seamless connection between
the HSR and other travel modes and the goal of “complementarity rather than competition
among the different modes” (37). Additionally, the need was noted for “the HSR to stop at
airports and have the endpoint within a city transport-hub (intersection of several metro lines), as
well as ensure integration into local tram and/or bus networks and park-and-ride facilities” (38).
Operational aspects such as short transfer times were deemed very important for good
intermodality. Experts stressed the importance of smooth coordination of HSR and conventional
rail schedules and services (28, 39). As argued: “Often the TGV leads to the abandonment of
secondary connections on the conventional network. The ideal, however, is to have stops on
high-speed trains which are coordinated with local, regional trains etc.” (28).

According to the experts, integration and coordination should extend to the ticketing of
different transportation modes, as already happens in Germany. As recommended: “Have one
ticket for the entire journey even when it involves a plane, a train and a coach.” (26).
Lastly, institutional coordination was mentioned among the managers of HSR and other
transportation services (28). There was even the suggestion for “an overall transport authority for
multimodal functions” (40) and “a terminal manager with coordination responsibilities over all
kind of operators, spaces and services” (41).

In the end, as most experts noted, the promotion of connectivity at HSR stations requires
multiple levels of integration: “You always should consider the triple integration: spatial,
operational and institutional” (41).

**CONNECTIVITY IN GERMAN AND SPANISH STATIONS**

To better understand the aforementioned issues are handled in German and Spanish HSR
stations, we examined six stations in Germany (Berlin Hauptbahnhof, Berlin Südkreutz,
Hannover Hauptbahnhof, Kassel Wilhelmshöhe Fernbahnhof, Leipzig Haußbahnhof, Erfurt
Hauptbahnhof) and six stations in Spain (Madrid Puerta de Atocha, Barcelona Sants, Zaragoza
Delicias, Málaga María Zambrano, Córdoba Central, and Lleida-Pirineus station). The HSR
experts recommended these stations as exemplary models of connectivity and intermodality.

Data for the case studies was gathered from a variety of sources. In Germany, we visited
the case study stations, interviewed representatives of German Railways (DB), and reviewed
publicly available information on new HSR corridors and station construction projects. In Spain,
we interviewed representatives of the HSR operator RENFE, as well as the managers of the case
study stations. The Spanish station owner ADIF provided us with relevant data such as station plans, annual number of HSR services, available parking spaces at each station, etc. We also consulted European and national transport ministry websites and other documents such as station itineraries for each case study station. In what follows, we synthesize our findings per system.

**Germany**

Germany’s rail operations are highly blended, and the optimization of connectivity and intermodality lies at the heart of its transit system. High-speed operations were originally designed to blend seamlessly into pre-existing rail operations, and high-speed corridors are not exclusive to high-speed passenger rail operations under the ICE label. The overall slower top speeds of the system are usually out-weighed by the good overall connectivity of the integrated system, still allowing for impressive door-to-door connections. Depending on location, route and time of day, ICE lines operate at half-hour, hour or two-hour intervals. With the exception of the special case of Limburg-South, there are no exclusive ICE stations or even concourses in Germany. With the exception of the newly built ICE station at Frankfurt Airport, major stations across the country are all located in city centers.

Relying mostly on upgrading existing routes to higher speeds, Germany has built comparatively few new HSR corridors or completely new HSR stations. Instead, German Railways (DB) remodeled and adapted many historic stations and locations to better accommodate its HSR services since the early 1990s. All German cities of over a million inhabitants, namely Berlin, Hamburg, Cologne and Munich, have more than one HSR station, and Germany’s largest metro area, the Rhein-Ruhr, features more than 15 stations with ICE services, all in a region of 10 million people with a size that is comparable to the LA metro area.

In the cases where new HSR lines were constructed, German Railways promoted the repurposing of secondary rail stations into new, well-linked HSR nodes (Berlin South Cross and Kassel Wilhelmshöhe). Historic inner-city rail stations, meanwhile, underwent vast transformations into multi-modal hubs with amplified commercial and retail functions (Berlin Central Station, Hanover, Leipzig, Erfurt). The related planning processes have integrated national, regional and local redevelopment efforts at multiple levels.

The German approach of privileging modal connectivity at the station level over achieving top speeds at the corridor level has clearly resulted in a system that is optimally suited to the country’s poly-centric settlement pattern. HSR enthusiasts enamored with DB’s integrated rail system often forget that Germany is also the land of speed-limitless Autobahnen, Audi, BMW, Mercedes-Benz and Porsche, and a country where large portions of the population hardly ever use trains. This has forced DB to re-invent itself as a one-stop mobility provider that not only offers integrated and price-competitive ticketing for rail travel but interlinks this with various car- and bike-sharing offers, and at times even issues flight numbers and Lufthansa boarding passes for its fastest metro connections.

The following factors are key reasons why and how Germany achieves high inter-modality at its HSR stations:

- With the exception of Limburg, Germany’s 150+ ICE stations are *never* exclusive to HSR but are always also served by regional and/or local rail. DB consistently practices the joint/adjacent use of station tracks for both ICE/IC/EC trains and local RB/RE/S-Bahn trains.
Stations are located so that they provide quick access to other travel modes and good pedestrian connections to surrounding neighborhoods. Good intermodal access can be provided either in city’s central core or at a secondary center, but rarely outside the urban core.

There is high emphasis on good connectivity with local metro and tram systems. In the case of Berlin Central Station, this meant the expensive new construction of the new U55 metro stub. In the case of Kassel, regional train tracks directly extend and connect into the local light rail system. Several stations achieve short pedestrian connections by layering tracks atop each other (Berlin Central Station, Berlin South Cross, Erfurt).

Most cities provide direct and convenient connections to nearby airports, ideally via rail, but at minimum via frequent and regular bus service.

Whenever possible, DB cooperates rather than competes with major airlines. As a case in point, DB and Lufthansa created the DB/LH joint AIRail service for select high-speed routes from Frankfurt Airport to several German cities.

DB has long practiced integrated ticketing services, and easy online, early booking discounts. Its DB Navigator app lets smartphone users check time tables, receive real time information on arrivals, and book tickets.

DB has long standardized its easy-to-read signs for in-station way-finding. Good way-finding often extends into surrounding neighborhoods.

All major stations have good availability of bicycle parking and bike-sharing programs next to or inside the station.

All major stations offer car rental services and provide day use and longer-term parking near the station. Due to the availability of strong transit networks, German cities do not typically promote park- or kiss-and-ride at inner city stations the way U.S. cities do, with the unique exception of Berlin South Cross station, which has a strong car-orientation.

DB remodeling of stations has sought to promote smooth passenger flows within the stations, ideally via barrier-free access and/or high-capacity elevators and escalators. As stations also include shopping malls, there is a conflict of interest between quickly moving passengers through the stations versus encouraging potential retail customers to linger near shops and attractions.

All major stations offer a variety of additional passenger services, including those commonly found in airports (first class and business lounges, boarding areas, information kiosks, travel agencies, free WiFi).

Spain

Spain has a combination of systems, from pure HSR systems (the so-called AVE that rolls along new HSR infrastructure at 185-205 mph), to blended HSR services called ALVIA and ALTARIA that in certain segments roll along new HSR infrastructure and at other segments along the conventional infrastructure at 175 mph, to short distance commuting HSR services called AVANT, that only roll on new HSR infrastructure but with slower trains (150 mph). In Spain, the HSR started as a separate system using mostly dedicated tracks, but technology has developed that now allows HSR trains to share conventional train infrastructure by changing gauge at certain locations, slowing down but not having to stop. This system allows Spanish HSR trains to typically travel at higher speeds than the German ICE trains. One serious drawback is the limited number of changeover location that makes the network less flexible.
In the Spanish cases, intermodality is achieved through:

- A good station location that has easy access to other travel modes and good pedestrian connections to the vicinity. Such a location is either at the city’s central core or at a secondary center, not far from the core and linked to the core via a frequent and direct bus line.
- A location of a central bus terminal inside the station, or directly adjacent to it.
- For cities that have a metro system, a location of a metro stop inside the station.
- Close proximity of HSR platforms to the platforms of other railway services to regional destinations.
- Direct connection to the city airport through a “fly-away” bus, metro line or both.
- Availability of bicycle parking, and bike-sharing programs in the station.
- Integration of ticketing services
- Availability of park- and kiss-and-ride lots. However, the high level of station intermodality decreases the need for large amounts of parking.
- Good information panels within the station and standardized, easy-to-read signs for wayfinding
- Smooth passenger flows within the stations and proximity of different station platforms
- Availability of a variety of passenger services inside the station, more often seen in airports (such as first class lounges, boarding areas, information kiosks, travel agencies, car rental facilities)

Additionally, all six case study stations serve not only as transportation nodes for travel but also as social destinations and vibrant places in the city, incorporating retail stores, cafes, restaurants, and sometimes hotels, museums, and gardens. In some of these stations, good station architecture – either through the preservation and expansion of significant historic buildings (such as in Madrid Atocha and Lleida Pirineus) or the building of a new structure (such as in Zaragoza –Delicias)-- aims to reclaim or create an architectural landmark in the city. Indeed, these six case studies exemplify how a railway station can become both a route for seamless travel but also a place for many other urban activities.

CONCLUSION: LESSONS FOR CALIFORNIA

The German and Spanish case studies as well as the survey of experts and literature review help us draw lessons and recommendations for the California HSR stations. In terms of spatial connectivity, the studied European examples do a good job in their consideration of four spatial zones: the station, the station-neighborhood, the municipality at large, and the broader region. These four zones should be considered in the planning and design of the California stations.

At the station scale, attention should be given to both aesthetics and functionality of the station building. In some of the case study stations, existing historic buildings were renovated and expanded – as was the case with Madrid’s Puerta de Atocha Station, Lleida Pirineus Station, or Leipzig Main Station-- or as in the case of Erfurt, partly retained. In other cases, completely new buildings have been built, and many feature significant new architecture. This attention to station aesthetics signifies a desire to create a landmark building in the city, one that serves as both a transportation node and a social place.

Station architecture is not only about aesthetics but also functionality. Thus, the spatial relationship and proximity of train platforms and the pedestrian flow between them should be carefully considered. A variety of passenger services should be easily available at the California
HSR stations. The Spanish and German cases feature an array of such services, such as business
class lounges, multiple information kiosks and ticket booths, cafes, and free wi-fi. Some Spanish
and German HSR stations feature full-fledged malls within the station structure. The possibility
of marrying retail with station activities should be considered for some California HSR stations.

For complex buildings such as railway terminals, where passengers have to catch
different connections, move from one platform to the other, or access other spaces (ticketing,
eateries, restrooms) inside and outside the station, clear, easy-to-read, standardized, and frequent
signage becomes important. Lastly, stations should not only provide park-and-ride and kiss-and-
ride lots but also include adequate bicycle parking.

At the station-neighborhood scale, emphasis should be given to minimizing the barrier
created by the tracks and station infrastructure, and integrating the station to the surrounding
urban fabric and street network. The case study examples have employed different design
strategies, depending on the particular context, including consolidating, covering, trenching or
bridging over the rail tracks. Regardless of the physical intervention, easy and safe pedestrian,
bicycle, and vehicular linkages between the station and its neighborhood should be provided.
Additionally, the placement of station entrances and the relationship between the station and its
surrounding streets and parking structures should be important considerations of station
planning.

In terms of operational connectivity, an important operational aspect is the level of
connectivity and intermodality of the HSR service with other travel modes. This entails both the
location of other transportation modes in close proximity and easy access from the HSR platform
as well as the coordinated scheduling of different modes for easy links and short transfer times.

At the municipality level, emphasis should be given on station connectivity via public
transit and/or via metro with different areas in the city that represent important destination points
(airports, downtown and other sub-centers, universities, hospitals, theme parks, commercial
centers, etc.). The case study stations scored high in regards to their connections with public
transit. In almost all cases, an airport bus connects the HSR station to the local airport. All
studied cases have rental car facilities, and many included car-share and bike-share facilities.
Because of this good connectivity with transit and the availability of alternative transportation
modes, the amount of parking space in the studied stations is considerably lower than the
projected parking needs for HSR stations in Southern California. It is, therefore, important to
consider the major destination points in the city connect them with direct transit lines to the HSR
station, and consider ways to boost the utilization of alternative means of transportation to and
from the HSR station.

The new high-speed infrastructure compresses time and space making some of these
cities much more accessible. Thus, at the regional level, the possible complementarity of the
station with the neighboring stations along the HSR line should be considered in determining the
desirable land uses around the station. This is likely more important for second-tier cities that
may attract more visitors and tourists if they are only 60-90 minutes away from the first-tier
cities. Thus, in Spain, after the advent of the HSR, it became much easier for tourists arriving in
Madrid to visit places like Toledo, Córdoba, or Seville.

Additional ways to improve the operational connectivity of HSR services with other
modes include integrated ticketing options and transfer of luggage services from one mode to the
other. Ticketing for HSR services in Germany is fully integrated with all other rail ticketing, with
certain tickets even including local fares from and to a passenger’s origin and final destination.
German transit operator DB has also managed to coordinate its ticketing and services with the
services of Lufthansa Airlines. Ticketing and travel service integration and possible discounts for passengers, who plan to use more than one transportation mode, can make the HSR services more appealing and increase the market for HSR; they should be considered by the California HSR.

Lastly, operational connectivity requires the coordination and collaboration among multiple parties (the transit operators of conventional and HSR services) during the planning and operation process. Additionally, collaboration and coordination of municipal, state and federal entities for the provision of unified design and safety standards, signs, and maintenance criteria would also help.

In conclusion, high levels of HSR station connectivity result in seamless travel and mobility benefits for travelers. The German and Spanish case studies are exemplary in their achieved levels of intra-city and inter-city connectivity, and have found ways to integrate local and regional railway services, buses, and even airline services in ways that complement rather than compete with one another. This entails both an operational aspect involving coordinated scheduling of different modes for easy links and short transfer times, as well as a spatial aspect (easy physical access from one mode to the other, visual connections between platforms).

Additionally, while the HSR stations in Germany and Spain often incorporate services similar to those found in an airport (e.g., first-class lounges, boarding areas, luggage services, etc.), the most successful European stations are not designed as airports (inward-oriented and cut-off from the rest of the city). Instead, they are designed as both functional transportation nodes but also outward-oriented, social hubs with high levels of connectivity and good integration to the surrounding city fabric. The California HSR stations should aspire for nothing less!

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