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Promoting Intermodal Connectivity at California's High-Speed Rail Stations

MTI Report 12-47

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REPORT 12-47

PROMOTING INTERMODAL CONNECTIVITY AT CALIFORNIA'S HIGH-SPEED RAIL STATIONS

Anastasia Loukaitou-Sideris, PhD
Deike Peters, PhD
Wenbin Wei, PhD

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16. Abstract

High-speed rail (HSR) has emerged as one of the most revolutionary and transformative transportation technologies, having a profound impact on urban-regional accessibility and inter-city travel across Europe, Japan, and more recently China and other Asian countries. One of HSR's biggest advantages over air travel is that it offers passengers a one-seat ride into the center of major cities, eliminating time-consuming airport transfers and wait times, and providing ample opportunities for intermodal transfers at these locales. Thus, HSR passengers are typically able to arrive at stations that are only a short walk away from central business districts and major tourist attractions, without experiencing any of the stress that car drivers often experience in negotiating such highly congested environments. Such an approach requires a high level of coordination and planning of the infrastructural and spatial aspects of the HSR service, and a high degree of intermodal connectivity. But what key elements can help the US high-speed rail system blend successfully with other 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.

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Mineta Transportation Institute
College of Business
San José State University
San José, CA 95192-0219

Tel: (408) 924-7560
Fax: (408) 924-7565
Email: mineta-institute@sjsu.edu

transweb.sjsu.edu

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EXECUTIVE SUMMARY

The integration of high-speed rail (HSR) with existing conventional rail in a blended system, in which high-speed rail shares the same tracks with conventional passenger or freight rail, 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 is more challenging in terms of management and operations and requires careful pre-planning to achieve a high degree of coordination in operations and passenger services. It also requires significant infrastructure planning and coordination as well as station infrastructure that accommodates smooth transitions among the different modes.

This study seeks to: 1) understand the particular operational and spatial requirements for cost-effective, efficient, and convenient intermodal connectivity at HSR stations; 2) document how such connectivity is achieved in blended HSR systems in Germany and Spain, and to extract lessons from these two systems and from some of their most successful intermodal HSR stations; 3) identify particular local conditions and expectations as evidenced in two existing multimodal transit facilities in California—Los Angeles Union Station and Burbank Airport Station; and 4) offer recommendations for seamless, efficient, and convenient integrated service in California intercity rail/HSR stations.

The study began with a review of the literature on ways to measure and improve connectivity and intermodality in transit systems. A subsection of the literature review examined blended railway systems to draw relevant knowledge and best practices for planning and developing the California HSR system. For an empirical grounding and extension of the literature findings, the authors conducted a survey of 26 HSR experts from six European countries, who gave information regarding the nature of blended HSR systems in Europe, their advantages and disadvantages, and related issues at the level of station and station-area organization and management. Additionally, the study examined the German and Spanish HSR systems to understand how their blended systems operate and what lessons one can extract from their experiences for California. The study also examined in detail six HSR stations in Germany and six in Spain, indicated by Spanish and German HSR operators as exemplary models of HSR station intermodality. The purpose of these case studies, which utilized a number of interviews with local station managers and other German and Spanish transit officials, was to extract lessons and best practices applicable to California. Additionally, the authors examined two case studies of multimodal transit stations in Southern California that are likely to host HSR services in the future—Union Station in Los Angeles and the Airport Train Station and Regional Intermodal Transportation Center (RITC) in Burbank—and interviewed some knowledgeable stakeholders (planners, architects, and city officials). The purpose of these interviews was to understand these stations' current capacities and operations and to better appreciate how lessons from international contexts can be adjusted to California realities.

Drawing from these multiple information sources, the following advantages and challenges of blended systems are presented:

Advantages

- Because high-speed and conventional rail use the same tracks, the amount of required right-of-way space is significantly reduced in blended systems. This is particularly important in highly urbanized and built-out urban areas, where there is very limited space to accommodate additional tracks. Furthermore, the narrower right-of-way prevents the creation of significant “barrier effects.” Urban designers have an easier task to physically integrate the station with its adjacent neighborhood in blended systems.

- Blended systems typically result in cost-savings in building the railway infrastructure because of their use of already existing tracks and rights-of-way and their better integration of railway infrastructure through sharing stations and facilities.

- Some experts believe that blended systems provide greater flexibility in changing or adding HSR and/or conventional rail services or routes based on passenger demand.

- Similarly, experts believe that blended systems may have higher robustness than non-blended systems because the HSR service can use conventional tracks in cases of infrastructure and service disruptions.

- In blended systems, HSR and conventional rail may share the same platform (primarily the case in Germany) or utilize separate but adjacent platforms (often the case in Spain). Both cases allow fast changes and transfers of passengers from one system to the other so the total travel time is reduced.

Challenges

- Conventional trains sharing the same tracks with HSR trains reduce the capacity of the HSR (when there are frequent services), as they force it to often operate at lower speeds. To reduce this effect, sufficient passing tracks and intermediate stations should be provided to accommodate passing HSR trains at their full velocity. If the same tracks are also used by freight trains, then passing loops for freight services should be installed.

- In addition to their capital costs, facilities such as passing tracks, grade separations, and modified platforms needed for blended systems may be difficult to accommodate in constrained urban rail corridors.

- The different speeds of the high-speed and conventional trains require that larger safety distances are kept between trains. Maintaining these distances may have a significant impact on corridor capacity and passenger volumes.

- Blended systems present more significant scheduling and coordination challenges than systems in which these two different modes use separate tracks. They require the coordination of very different technologies and are more difficult to manage than separated systems.

- Blended systems present more opportunities for delays because of the large numbers of conventional and freight trains using the same tracks. HSR trains typically have to be given priority over other trains, and this may result in inferior conventional rail services. Some European countries like France resolve this issue by building additional new tracks at high-volume stations. There may be little capacity in California for these types of modifications.[1]

The following recommendations for addressing spatial and operational issues can be drawn from the German and Spanish case studies:

Spatial

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 also be considered in planning and designing the California stations.

At the *station scale,* attention should be given to both the aesthetics and the functionality of the station building. The spatial relationship and proximity of station platforms and the pedestrian flow between them should be carefully considered. Additionally, an array of passenger services such as business class lounges, multiple information kiosks, and ticket booths, cafes, and free wi-fi should be offered at the station. Stations and their immediate vicinities should have clear and standardized way-finding signage. The possibility of integrating retail opportunities within the station building, as happens in many Spanish and German stations, should be considered. Lastly, stations should not only provide park-and-ride and kiss-and-ride lots, but also include adequate bicycle parking, bicycle stations, and bike-sharing facilities.

At the *station neighborhood level,* emphasis should be given to minimizing the barrier created by the tracks and station infrastructure, and to 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 and bicycle access to the station and vehicular linkages between the station and its neighborhood should be provided. 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. To the extent possible, existing station-adjacent facilities, such as parking lots or car rental facilities, should be utilized instead of constructing new ones.

At the *municipality level,* emphasis should be given to 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, theme parks, commercial centers, etc.).

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 particularly 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.

Operational

Coordination and collaboration among multiple parties (the transit operators of conventional and HSR services) from the very beginning of the planning process is essential. Additionally, collaboration and coordination of state and federal transportation agencies and authorities for the provision of unified design and safety standards and maintenance criteria would also help bridge potential differences among the different systems rolling on blended corridors.

Depending upon the level and types of investment in the proposed blended service, identifying and resolving real property interests among operators is also critical (e.g., maintenance, operations, trackage rights, etc.). This is especially important in or around freight corridors.[2]

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. Level boarding between commuter and high-speed rail systems should also be encouraged where possible.

Additional ways to improve the operational connectivity of HSR services with other modes include integrated ticketing options, transfer of luggage services from one mode to the other, clear and frequent way-finding signs, and advanced information systems detailing connections with other modes.

I. INTRODUCTION

High-speed rail (HSR) has emerged as a transformative transportation technology, having a profound impact on urban-regional accessibility and inter-city travel across Europe, Japan, and more recently China, Taiwan, and Korea.[3] High-speed rail connections between major and secondary cities in Europe have taken mode shares away from air and road,[4] in some cases successfully enough to eliminate regional flights altogether (e.g., between Paris and Lyon) or at least dramatically reducing them (e.g., between Madrid and Barcelona).

One of HSR's biggest advantages over air travel is that it offers passengers a one-seat ride into the center of major cities, eliminating time-consuming airport transfers and wait times and providing ample opportunities for intermodal transfers at these locales. Thus, HSR passengers are typically able to arrive at stations that are only a short walk away from central business districts and major tourist attractions without experiencing the stress that car drivers often experience in negotiating such highly congested environments or having to find parking spaces.

However, the competitiveness of HSR depends highly on the level of its intermodal connectivity as well as the rail authorities' abilities to deliver convenient and fast service into urban cores in a cost-efficient manner. Studies have shown that a high level of intermodal connectivity is a major prerequisite for robust ridership and successful operation of high-speed rail systems.[5] The integration of high-speed trains with existing intercity and commuter/regional rail systems in a "blended system" (in which high-speed rail shares the same tracks with conventional passenger or freight rail) 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 among the different modes.

Although HSR is often billed as a separate, more advanced technology than conventional rail, some form of shared-use or blended system almost always exists, particularly as the tracks approach more densely populated areas in major metropolitan districts. Compromises among speed, maximum reach, station access, and the expense and adverse impact of retrofitting existing infrastructures into complex built environments always must be carefully weighed against each other. A 2003 Mineta Transportation Institute (MTI) report investigating experiences with shared-use systems aptly summarized the key drawbacks of blended systems, namely "safety at higher speeds; lessened train capacity; reduced top speed, which increases travel times; congestion on the line, which can increase reliability problems; and fewer options for high-speed vehicle design … making the HSR systems less attractive to customers and increasing costs to operators." This compares to the key benefits of "lower costs; reduced economic, environmental, and social impacts; improved accessibility …; and network benefits."[6]

Among major HSR systems in the world, only Japan decided to build a system of dedicated lines that could be used only by HSR service, largely because there was no capacity left on its conventional network. Yet even in France, which, following the success of its first TGV line from Paris to Lyon, built a new and extensive HSR network, tracks are still largely shared-use, i.e., blended, in urban areas. Germany has a dense rail network in which its HSR trains—the ICEs—often serve the same routes as the slightly slower IC, Regional Express, and other commuter rail services, with the ICE's main distinction in service often being in-vehicle comfort levels and reliability, rather than significant time savings. Overnight trains in particular sacrifice speed for convenience of arrival times and cabins that offer a full night's sleep. In Spain, even exclusive HSR tracks for its new AVE trains are still shared by TALGO overnight trains, rolling during times when few AVE trains operate.

In fact, the real choice is typically not whether tracks will be shared within metro regions, but rather how extensively tracks will be shared by different lines, and how much the different rail services that use these tracks will be differentiated according to speed and other factors. Ultimately, what matters most from the individual passenger's perspective is the door-to-door travel experience and how the high-speed rail portion of the trip links up with other mode choices at either end of the trip. So although previous MTI-sponsored research examined various varieties of shared/blended systems in Europe,[7] this information must be updated and reevaluated, especially now that Spain has expanded its system to 2,665 km (1,655 miles) of high-speed track, second only to China, making it one of the most connected countries in Europe.[8] Moreover, there is still an urgent need to better understand the actual variety of HSR and its complementarity with other metropolitan rail services and transit options more generally. This requires the authors to focus more specifically at the level of intermodality that might be achieved and how services might best be integrated at the station environment to offer the optimal travel experience.

A BLENDED SYSTEM FOR THE CALIFORNIA HSR

In its 2012 Revised Business Plan, the California High-Speed Rail Authority (CHSRA) confirmed its commitment to a better incorporation of new high-speed infrastructure with existing services. A study commissioned by the Peninsula Corridor Joint Powers Authority that used a micro-simulation model and an associated operations analysis to provide a proof of concept, confirmed the principal feasibility of a blended approach for the corridor from San Francisco to San Jose and onward to Tamien. In particular, the study concluded that:

- "a blended operation on the Caltrain Corridor where Caltrain and high-speed trains are sharing tracks is conceptually feasible.
- an electrified system with an advanced signal system and electric trains increases the ability to support future train growth in the corridor; and,
- the blended system without passing tracks for train overtakes can reliably support up to 6 Caltrain trains and 2 high- speed rail trains … [and] with passing tracks … up to … 4 high-speed rail trains per peak hour per direction."[9]

The CHSRA expects that a blended system will be more cost-efficient. In addition, and as the investigators found in their previous research, a number of station-cities would favor the shared-track approach because they believe it would have less impact on their urban form and require fewer property acquisitions.[10] On the other hand, opposition to the blended approach has come from those who believe that the train's speed would be significantly compromised. It is clear that such an approach requires a higher level of coordination and planning of the infrastructural, operational, and spatial aspects of the HSR service.

RESEARCH PURPOSE AND RESEARCH QUESTIONS

The purpose of this study is: 1) to understand the particular operational and spatial requirements for cost-effective, efficient, and convenient intermodal connectivity at HSR stations; 2) to document how such connectivity is achieved in blended HSR systems in Germany and Spain; 3) to identify particular local conditions and expectations as evidenced in existing multi-modal transit facilities in California; and 4) to offer best practices and guidelines for seamless, efficient, and convenient blended service in California intercity rail/HSR stations.

The study seeks to answer the following questions:

1. What are the challenges of intermodality in terms of spatial and operational needs in the context of intercity rail/high-speed rail stations?

2. How are these challenges addressed in two successful blended systems—the ICE in Germany and ALVIA and ALTARIA in Spain?

3. What lessons can we learn from the German and Spanish blended HSR systems that are relevant for the California context?

4. What policies and design and planning guidelines should be in place to achieve a seamless interaction of the HSR service with other passenger railway lines?

RESEARCH METHODOLOGY

This research began with a systematic review of the planning and transportation engineering literatures about connectivity and intermodality of railway transit systems. The goal was to identify what these literatures tell us about the opportunities and challenges of blended service and blended railway systems. Additionally, the authors surveyed a group of international experts on HSR systems asking them to identify the challenges and issues related to blended railway systems. (See Appendix A for a list of interviewees and Appendix B for the interview instrument.)

To empirically ground the literature and expert survey findings and also draw lessons from existing blended HSR systems, the study examines in detail the HSR systems in Germany and Spain. The German HSR network, called ICE, is probably the most blended in the world because most of its HSR infrastructure is upgraded conventional infrastructure, which is now utilized by both HSR and conventional rail. Spain has a combination of services, from pure HSR services (the so-called AVE that rolls along new HSR infrastructure at 185-205 mph/298-330 km/h), 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 (282 km/h), to short distance commuting HSR services called AVANT, that roll only on new HSR infrastructure but with slower trains (150 mph/241 km/h).[11] The authors interviewed HSR transit operators and station managers in these two countries and also conducted six case studies of HSR stations in Germany and six case studies of HSR stations in Spain that were identified by the experts as good examples of blended systems. (See Appendix C for the interview instrument.) The purpose of the case studies was to draw lessons regarding the optimal infrastructure requirements, fare policies, transfers, and station spatial layouts for blended railway systems.

Additionally, the authors conducted two case studies of multi-modal transit stations in Southern California that are likely to host HSR services in the future—Union Station in Los Angeles and the Airport Train Station and Regional Intermodal Transportation Center (RITC) in Burbank—and interviewed some knowledgeable stakeholders, such as planners, architects, and city officials. (See Appendix D and Appendix E for a list of these interviews and the interview instrument, respectively.) Both facilities and their surrounding districts are currently undergoing extensive re-envisioning and master planning processes to optimize access, transit operations and capacity, to intensify land use in the surrounding area and to plan for the future arrival of HSR service. The purpose was to understand their current capacities and operations, and to better appreciate how lessons from international contexts can be adjusted to California realities.

REPORT ORGANIZATION

Following this introductory section, Chapter 2 presents the literature review. Chapter 3 presents the information gathered from the survey of international HSR experts. Chapter 4 presents some basic information about the development of high-speed rail systems in Europe, focusing primarily on blended systems. It also presents a typology and inventory of blended systems in Germany and Spain, two European countries that have utilized blended railway networks in characteristically different ways. Chapter 5 gives detailed information about the development, funding, management, and operation of the HSR systems in Germany and Spain, as well as details about how they achieve high levels of intermodality. It discusses about station planning and design, ticketing and other passenger services, and inter-agency coordination in these two countries. Chapters 6 and 7 present the case study stations in Germany and Spain, respectively. For each station, they discuss its context, station layout and modal integration and give factual details about the station and its intermodal services. Chapter 8 introduces the two California case studies discussing how both of these stations are being adapted for future increased use, including the addition of HSR. The final chapter of the report summarizes a number of recommendations for seamless intermodal connectivity and blended service.

II. LITERATURE REVIEW

Transit connectivity denotes the level of accessibility of a transit setting (station or transit stop) from different points of origin as well as the level of integration between a transit system and other transportation modes (including walking and cycling). The latter is also called intermodality. 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. Good public transport connectivity and high levels of intermodality are key objectives in transportation planning because they allow passengers several options for travel and thus make travel more efficient, convenient, and attractive. High levels of connectivity and intermodality are particularly important for transit passengers. In fact, in a national survey of transit experts and planners, the United States Government Accountability Office found that there is significant consensus that multi-modal connectivity can provide a wide range of mobility benefits for travelers.[12] Conversely, poor transit connectivity creates barriers to passenger mobility and may affect transit ridership.[13]

Developing or improving multimodal connectivity at transit stations, however, is highly 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, etc.) as well as operational factors, from line integration and scheduling to fare and information systems, to integrating different transportation systems (e.g., rail and airline services). Furthermore, scholars debate the optimum way of measuring and evaluating connectivity, which can have significant implications when trying to account for local contexts. In this context, this literature review explores recent research on measuring connectivity and intermodality as well as ways to improve connectivity through spatial and operational interventions.

MEASURING CONNECTIVITY AND INTERMODALITY OF TRANSIT SYSTEMS

Evaluating the level of connectivity at transit stations is problematic due to the numerous ways connectivity can be operationalized and measured. Some of the most sophisticated analyses rely on network structure, locations of activities, and service frequency as their inputs. A number of studies have sought to measure transit connectivity by utilizing unified connectivity measures that each weigh different attributes (e.g., travel time, service, spatial layout, information and transfer attributes) relative to other attributes.[14] However, as explained by Hadas and Rantjitkar, such a weighting system results in very complex modeling.[15] They propose a simpler approach that models each type of attribute separately and calibrates a weighting factor for each attribute group. They formulate a transit connectivity measure that analyzes both connectivity and transfer efficiency by incorporating travel time attributes (ride time, wait time, and walk time) and transfer attributes. Regarding travel time, ride time represents actual in-vehicle time, the wait time represents the time spent waiting at the stop/station for the next vehicle to arrive, and walk time represents the time spent walking between two stops or access/egress walks. Transfer attributes are categorized into four different types: a) street-crossing transfers, b) sidewalk transfers, c) non-walk transfers, and d) one-leg trips. They develop a model to calculate connectivity measures that inputs both spatial and service data (e.g., road network sidewalk and stop features, transit routes, type of transfers, etc.). The researchers combine data from Google Transit, a local-transport agency, and GIS-based road networks to test their model on the city of Auckland, New Zealand. The contribution of this model is that 1) it allows for a simplified measure of connectivity based on the value of time and quality of transfers; 2) the connectivity measures are calculated automatically within a GIS package, thereby making it possible to analyze large public-transit networks; 3) it allows for comparing and analyzing transit-network alternatives; 4) it enables a sensitivity analysis on transit-vehicle headways and their effect on connectivity; 5) it provides tools for analyzing the effect of improving transfers in terms of stop location; and 6) it makes it possible to simulate what-if scenarios, such as demand change.[16]

Other scholars seek to quantify measures of connectivity at the node, line, transfer center, and regional levels.[17] By combining these measures of connectivity in a single index, they create a quantitative measure of transit performance that goes beyond traditional measures of centrality, which is particularly important for large multi-modal transit systems. Taking into consideration that many models require large amounts of data, or, at times, unattainable data, the secondary purpose of such a model is to provide a strong measure of connectivity with the lowest possible data requirements. The measure is constructed through 1) node connectivity (measures the connecting power of a node as the aggregate of its inbound and outbound lines); 2) line connectivity (the total connecting power of a line is the sum of the averages of inbound and outbound lines of every node on the line); 3) transfer center[18] connectivity (takes into account the number of nodes in the transfer center and the connecting power of each node); and regional connectivity (the sum of connectivity of all nodes within a region). The researchers tested this model on the multimodal network of the Washington DC and Baltimore region and found that the connectivity of a given transfer center does not strictly correlate with the total daily passengers that pass through that center. They argue that this level of analysis can help to identify areas that are underserved by transit and connect them to areas with higher connectivity.[19]

Turning to the measurement of intermodality, Tapiador and his colleagues have used three indices to measure intermodality at HSR stations.[20] The first index is called *intermodal time*. The intermodal time for a specific mode in an HSR station is defined as the summation of the times required for this mode to reach every other mode at this station. The second index is called *intermodal integral time* and is calculated as the summation of the intermodal times for all modes at the HSR station. The third index is called *intermodal entropy* and reflects how unbalanced different modes are in an HSR station. If there is a single mode, the entropy has a minimum value of zero, and if the intermodal times for all the transportation modes are the same, the entropy reaches its maximum value. All other cases will have entropy values in between these two extreme cases. The authors use the intermodal integral time and intermodal entropy to quantify the connectivity of different modes of transportation at high-speed train stations. They classify 27 stations in Europe into four groups based on intermodal integral time and intermodal entropy: 1) stations with low intermodal entropy and large intermodal integral times; 2) stations with low intermodal entropy and small intermodal integral times, such as those small stations where one or more transportation modes are missing; 3) stations with high intermodal entropy and large intermodal integral times; and 4) stations with high intermodal entropy and small intermodal integral times.

The level of intermodality in a particular setting is an important criterion for identifying the best locations for high-speed rail stations. The higher the intermodality, the better the high-speed rail can be utilized in the multimodal transportation system. Mateus and his colleagues apply a quantitative method, called Multi-Criteria Decision Analysis (MCDA), to select the best among a set of given alternatives for the location of the central high-speed rail station in Porto, Portugal.[21] They organize all the evaluation criteria in a hierarchical structure. Each criterion is associated with an ordered set of impact levels, which can be either quantitative or qualitative. Each location alternative is first given an impact level for each elementary criterion. Then, there are three major steps in the overall process of evaluating all alternatives. First, a value function for each criterion is constructed, which can measure the relative attractiveness of each alternative. Second, based on the impact levels and the value function determined above, the local values of the alternatives on each elementary criterion are calculated. Third, a simple additive model is used to aggregate the local values on various elementary criteria. Finally, the overall value for each alternative is calculated using the additive model in the aggregation process, and the best alternative is identified.

In another study, He and his colleagues first identified five factors that influence the decisions for the best location of the park-and-ride (P&R) facilities for the rail transit network in Beijing: population density, annual household income, accessibility of P&R facilities, distance to downtown, and saving of travel time. Then they applied the Analytic Hierarchy Process (AHP) and Expert Scoring Method (ESM) to find the best site among all proposed candidate P&R facilities.[22] The AHP method was initially developed by Thomas Saaty in the 1970s and then refined and applied extensively for decision-making in various problems. It is a structural technique and quantitative method for complex decision-making problems and helps decision makers identify the decision that best suits their goals. The Expert Scoring Method (ESM) is based on the evaluation scores given by a group of experienced experts for specified project items.

Researchers have also developed route-choice models to predict passengers' choices in multimodal transportation networks that include high-speed rail. Thus, Uchida and his colleagues develop a probit-based multimodal transport assignment model in which three transportation modes (railway, bus, and automobile) and their combinations can be used by passengers to travel.[23] The factors affecting travelers' route choices include actual travel times, discomfort effects on transit systems, expected waiting times, fares, and constants specific to transport modes. A route can include different modes, and the time needed to walk to a bus stop or to a railway station is also taken into consideration in the model. The probit assignment model is built based on the assumption that a passenger's choice of a route depends on the value of the disutility function, which consists of a deterministic part (a weighted function of the five factors above) and a random component with a specific joint probability density function. Based on the proposed transport assignment model, the optimal frequency of the transit (bus or rail) can be determined through an optimization model with the objective function to minimize the total disutility of all travelers.

Hoogendoorn-Lanser and his colleagues study the overlap in multimodal transport networks.[24] In road network, overlap is defined based on the length of overlapping paths in either time or distance, while in a multimodal transport network, there are many possibilities for overlapping components, such as nodes, modes, and transport services. They find that the number of legs (defined as a pair of nodes served by the same mode or transport service) appears the best way to tackle overlaps; therefore, it is suggested that a nest approach is needed in logit modeling for route choices in multimodal transport networks.

Van Nes introduces a hierarchical approach for the design of multimodal transportation networks.[25] The transportation design problem is formulated as a bi-level optimization problem in which the upper level problem is given from an investor's or operator's perspective with the objective to maximize total profit or social welfare or to minimize total cost. The lower level problem is determined by the behavior of travelers with the objective to minimize total travel costs. In the proposed hierarchy approach, the transport networks are distinguished at different levels, each suited for covering specific distances. The highest network level, usually a coarse network, has high speeds and limited accessibility. The lowest network level serves short-distance trips and provides access to higher-level networks. It has high network densities, slow speeds, and high accessibility. The analytical transportation network design models developed in this study consist of a level of service models, demand models, and supply models. The innovative components of these models include the multilevel nature of the network design problem, the incorporation of lower-level travel choices such as route choice or access mode choice, and the possibility that different actors, such as authorities, investors or operators, are responsible for transport network design. The author concludes that multimodal transport does not require significant restructuring of transport networks because properly structured unimodal transport networks, such as the private transport networks and the multilevel line-bound public transport networks in Netherlands, are already suited for serving multimodal travel demand. Ignoring the basic rules established for the hierarchical unimodal transport networks will lead to poorer performance of all networks involved. The author claims that multimodal transport networks do not require a new design but will benefit from minor modifications for each unimodal transport network.

In summary, various quantitative metrics, methods, and models have been proposed to measure connectivity and intermodality, to identify the best locations for HSR stations, and to assess how multimodal transit networks can be better designed to operate more efficiently. Some methods emphasize holistic and in-depth analyses, while others try to cater to transit planners with limited time and data. All these metrics and methods are valid and reasonable, but future research must clearly delineate not only how, but why connectivity and intermodality have been operationalized and measured in a certain way in order to make clear the policy implications. Additionally, there is only limited research on the effectiveness of using these metrics for identifying optimal locations for HSR stations. Most researchers apply logit models to traffic assignment or route choice in multimodal transport networks, and a detailed methodology for the design of the multimodal transport network is proposed in literature. But these models and methodologies have not yet been applied or verified in practice.

IMPROVING CONNECTIVITY

Connectivity is crucial to attracting passengers because it makes travel convenient. However, many previous empirical studies have focused on transit ridership at the route level and segment level, thereby assuming homogenous service levels and land use along each route. Some scholars have recently started emphasizing the importance of also examining and seeking to improve connectivity at the transit stop or station level focusing attention on urban form elements and transit vehicle operations, as well as the information and ticketing.

Spatial Connectivity

A number of authors stress the importance of spatial connectivity and smooth linkages between an intermodal transportation facility and the surrounding neighborhood and city. Loukaitou-Sideris identifies four spatial zones that must be considered for a good connectivity of high-speed rail stations: 1) the station itself and how it relates to its immediate surroundings; 2) the station-district, generally defined as about one-half mile (0.8 km) radius around the station; 3) the municipality at large; and 4) the broader region.[26]

Recognizing that past research on connectivity and ridership analyzed transit service characteristics and urban form separately, Dill and her colleagues sought to synthesize these disparate approaches and look at their combined influence on transit ridership at the stop level. 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, matter as well. When high transit service and a good physical infrastructure co-exist, connectivity improves and ridership is the highest. They propose several policy implications based on their research: 1) improve multimodal connectivity to leverage ridership; 2) enhance street activity and encourage more pedestrian-oriented business development to promote a pedestrian-friendly built environment; 3) integrate multi-family housing and pedestrian-oriented commercial land use into transit investments; and 4) give more emphasis on planning at the transit stop level.[27] While this research does not include high-speed rail stations, it emphasizes the importance of the built environment as a major factor in improving transit's connectivity. Many of the proposed elements can also serve as vital components of establishing a robust and vibrant HSR station.

Similarly, Sando and his colleagues stress the role of the built environment in encouraging or discouraging transit use.[28] They develop a conceptual model that considers how different modes of transportation, specific user groups,[29] as well as the built environment interact, and they allow for a more nuanced analysis of how different intermodal movements and transit users face different connectivity issues. They argue that a station that accommodates all modes of transportation, including walking and cycling, will have the highest ridership rates.

With few notable exceptions, such in the Netherlands or China where cycling is prominent, the accommodation and storage of bicycles and the connectivity between bicycle and transit have often been an afterthought in the design of multimodal facilities. This may be changing.[30] Where space is limited, the development of bicycle stations, and bike sharing facilities may have significant positive impacts on access, congestion and the need for parking at HSR Stations. Thus, Pan and his colleagues examine the challenges and opportunities for improving the bicycle-rail connectivity based on a case study in Shanghai. Using the data collected from two surveys of rail transit passengers in Shanghai, they analyze the existing mode shares of rail station access and egress trips, the underlying mechanisms for choosing among alternative models, and the comparative advantages of the bicycle for trips that have certain distance and location characteristics. Empirical results suggest that the potential for travel improvement for rail transit riders lies primarily in the collection and distribution phases. Results also suggest several promising approaches, such as providing more bicycle parking spaces and a bicycle rental system for improving the bicycle-rail connection and utilizing the bicycle more fully as an efficient supplement mode for the rapidly growing urban rail transportation in China.[31]

Operational Connectivity

A number of studies have examined ways of improving operational connectivity by examining how to improve transferring services, supporting facilities, and information systems in multimodal transportation networks. The Swiss example of "clockface scheduling" is referred to as "the most streamlined delivery of public transport and Europe's best practice for bus, tram, and private railway interchange."[32] 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 past 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) as a way to improve the service of public transportation and motivate more customers to use the service.[33] Under ITT, trains, buses, boats, and other means of local and long-distance public transportation not only operate on a fixed-interval schedule, but they also connect with each other in a way to minimize transfer times. The advantages of ITT include reduction of transfer times, more frequent services, better spatial coverage, and more profit for operators. The disadvantages of ITT include the unrealistic assumption of uniform usage of the system throughout the day, longer headways, reduction of schedule reliability of the entire system due to uncertainties in operations, and being supply-driven instead of demand-driven. Using the example of the San Francisco Bay Area, the researchers demonstrate how the concept of ITT can be applied in the planning and decision-making process in the US through the coordination and integration of decisions and practices of all public transportation agencies in order to improve the service quality of public transportation.

Information and Ticketing

An additional factor that can contribute to increased connectivity of different travel modes 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, and information kiosks can also improve connectivity and thus attract ridership.[34] Sauter-Servaes and Nash examine how to increase demand for rail by improving multimodal information and ticketing practices based on lessons drawn from Switzerland's *Night&Flight* program, which enables passengers to purchase combined transport services, consisting of an overnight railway journey to a destination and a daytime flight back (or vice versa), as a complete package from a single source in Europe. The researchers surveyed users and nonusers to evaluate the barriers to intermodal transport and find out how users may be persuaded to use a new product or service. They found that an effective Internet-based multimodal transport information and reservation system is needed to successfully increase rail travel, and the system should provide accurate and complete information about all travel alternatives in a simple package and should enable customers to purchase a single ticket for the entire trip (including local public transport).[35]

Chiu and his colleagues present a Multi-modal Route Advisory System (MRAS) that supports multiple modes of public transportation services as well as mobile vehicles (taxis and on-call vans) and commuters.[36] The key components of the system include a route-based shortest path algorithm, several heuristics-based algorithms for speeding up searching, and a *Knowledge Basket*, which captures useful information for route-finding beforehand. A prototype of the system supporting users on multiple platforms has been built using the contemporary computer coding technologies and an efficient underlying database scheme, which can be used by the customers of the multiple public transportation modes. Real time transit information must also be part of this system.

Passenger and Stakeholder Perceptions

It is rarely a simple matter to plan a good transit station. Typically, different stakeholders have varying opinions about the siting, design, and operation of a particular transit facility. In this context, some scholars have focused on the perspective of passengers or other stakeholders (e.g., transit agency staff, public officials) seeking to understand their preferences regarding station design and transit experience. Thus, Carnegie and his colleagues examined which features of the transit transfer experience are the most important to New Jersey transit customers. Based on survey data, they found that transit riders were most satisfied with access to stations and customer information and least satisfied with facility maintenance, amenities, and service levels. Customers valued service features the most, and they indicated that conditions at local facilities had significant room for improvement.[37] Other passenger surveys have found that while schedule coordination and ease of transfers are important factors in passenger satisfaction, safety and security are also important concerns that should be considered in multimodal station design.[38]

A study that examined the perceptions of different stakeholders about transit connectivity in the San Francisco Bay area identified connectivity barriers in four areas: 1) in service connections; 2) lack of appropriate information and amenities in transfer points; 3) lack of adequate information for pre-trip planning; and 4) in fare policies and fare collection. In addition to expanding transit service levels and minimizing the needs for transfers, the report recommends improving information to transit riders, regional way-finding, and better planning for the last mile, connecting services through bus, shuttle, taxi, bicycle, and pedestrian connections.[39]

In summary, studies find that various methods can be applied to improve the operational connectivity of public transportation services, such as better ticketing practices, better signs and improvement of facility conditions at transfer stations, a more comprehensive and advanced information system, more coordinated transferring services, and better use of bicycles for connecting with rail. Most of these approaches are at the conceptual level or are drawn from survey results. Only a few quantitative studies have been conducted on the effectiveness of these approaches for improving public transportation or for making it attractive to customers in the multimodal transportation system.

INTEGRATED TRANSIT SYSTEMS

One particular part of the connectivity literature examines integrated transit systems. It is widely recognized that the European Union (EU) has one of the most highly integrated and extensive rail systems in the world. In reviewing EU actions over the last several decades, scholars have found that removing and/or alleviating barriers has emerged as the main objective and the precondition for overall future and smooth growth of a single-market transit system.[40] These actions can be further broken down into 1) the design and implementation of a common transport policy; 2) the introduction and promotion of sustainability for the transport sectors; and 3) integration of transport infrastructure and services (i.e., development of integrated transport systems). Janic provides an in-depth examination of the relevant research, legislation, and communication strategies that the EU underwent to achieve each of these actions. She emphasizes that “the successful development of intermodality, interconnectivity, and interoperability in each particular project (or action) needs to include the very precise identification of ‘barriers’ and related problems, an assessment of their ‘strengths’ and ‘influences,’ and creating and implementing solutions for either their alleviation or removal.”[41]

Despite several promising innovative cases of integrated transport in the EU, such as the innovative freight bundling networks and New Generation (NG) terminals, developments achieved in the EU PACT program,[42] and the cases of rail-based “freight freeways,”[43] further research and policy actions should focus on alleviating and/or removing the remaining barriers to the use of integrated transport systems in hardware, software, orgware, finware, and ecoware.[44] Such research necessarily involves dealing with different fields such as transport policy, transport technology, and transport economics.

The recent NAS-ITIP project, which sought to develop and reform intermodal transport in newly associated EU countries (NAS countries), allowed for an additional investigation of the challenges and opportunities for transit integration.[45] While this study was carried out in a particular political and geographic context, which is quite different from the one in the US, the conclusions are useful for other geo-political entities that, like the NAS countries, seek to develop an intermodal transit network while simultaneously integrating it into a larger system. Scholars emphasized 1) the need to include various NAS governmental institutional bodies in the decision making processes of the larger EU institutions; 2) the need to establish uniform standards for reliability, secure transit time, and cargo security of public intermodal transport terminals in all EU countries; and 3) the need to establish an obligatory standardized and harmonized regulation system. For NAS countries specifically, the report recommended that they prepare intermodal development national plans that include a set of information and communication tools, which would allow them to efficiently integrate intermodal terminals into existing transport chains while also ensuring financial support for the construction and reconstruction of intermodal transport facilities.[46]

Despite the useful lessons, the aforementioned studies have focused on transit integration at a transnational scale. Noting that the literature focuses primarily on intermodal competition among transit modes, Givoni and Banister have also examined intermodal cooperation and integration among operators of different transport modes.[47] Focusing on air and rail transit at Heathrow Airport in London, they defined integration as "aircraft and HST railway services provided as one complete journey with a fast and seamless transfer between the modes."[48] 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. Through an analysis of existing runway capacities, infrastructure, and market demand, the researchers show that integration would be mutually beneficial for all operators in the current transit system (airlines, airports, and railways), while also achieving the government's policy goals for Heathrow—namely preserving a competitive position, increasing services to other regions, and curbing its environmental impact. These benefits are not only enjoyed by multiple parties, but also they are greater than the benefits received from mode competition. However, the realities of the planning system and the government's decision-making capabilities mean that the private sector must play a significant role in promoting airline/railway integration. Additionally, policy makers should consider the two modes as part of one transport network rather than separate entities competing in an open market.[49]

Overall, the research on transit system intermodality and connectivity demonstrates that there is wide agreement 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, as well as issues relating to passenger safety and security, is also important to transit riders. Lastly, transit planners and transit operators need to consider not only intra- but also inter-modal connectivity and develop ways to better integrate different transportation modes, such as railway and aircraft services, so they complement rather than compete with one another.

BLENDED SYSTEMS

Another literature that is important for this study relates to the experiences of transit systems in other countries with so-called shared-use or blended systems. These terms denote that the same tracks are shared for different services (e.g., traditional and high-speed rail, freight rail). Such sharing increases the capacity of rail lines responding to the increasing demand for high-speed and on-time performance, but it also may create challenges for reliable operations and safety. The sections that follow will review the research on shared use, with a particular emphasis on high-speed rail capacity, in order to draw relevant knowledge and best practices for planning and developing the California HSR system.

The interest in blended HSR systems in the United States necessitates a closer examination of the pros and cons of shared-use capacity building. However, it is an especially complicated situation in the US because of the diverse ownership over rail corridors, which may lie with a variety of public entities, commuter rail authorities, state highway departments, and freight railroads. Nevertheless, some scholars have argued that the benefits of shared-use among HSR agencies and freight rail companies are greatest if plans maximize the use of existing rights-of-way.[50] In addition to expediting the development of HSR, this would allow owners of existing infrastructure to benefit from a number of improvements, such as service upgrades, safety upgrades, and capacity upgrades. In addition, agencies could then share information on travelers and customers, allowing joint marketing activities between transit systems and HSR and increased ridership through mutual feeding of passengers and customers. If the HSR agency can use existing public land already off the tax rolls instead of acquiring privately held land, local governments and public owners of transit corridors may also benefit by the preservation of tax revenue.

However, the impacts of HSR on existing infrastructure can be burdensome. For example, HSR can create a perceived or actual competition with existing service providers, or it can trigger heightened FRA safety requirements. Other drawbacks include the cost of negotiations, construction costs, and operational impacts. Limiting these factors will require that agencies such as the FRA and FTA play a larger role in shaping the legal environment by creating universal standards for governance. The high acquisition costs or high grade-separation costs of shared-use must also be considered for HSR development to remain cost-effective and not adversely impact existing corridor uses.[51]

Partnerships

Given Europe's extensive experience with integrating HSR systems into existing urban transportation networks, MTI published a report that sought to identify the EU's infrastructure and operating strategies regarding shared-use.[52] The report indicates the necessity of strong partnerships between transportation agencies and institutions in order to make shared-use work, which allows parties to look beyond their own parochial interests. The report then outlines a variety of strategies to improve shared-use planning, infrastructure, communications, and operations. These are summarized in Table 1. Others argue that to create the necessary partnerships, there must be financial incentives offered to freight and passenger railroads to cooperate, such as turning dormant freight facilities and land into revenue streams.[53]

Table 1. Strategies for Improving Shared-Use

Type	Description	Examples
Planning Strategies	Planning strategies identify the most effective set of improvements necessary to provide the service demanded by the market with the least economic, political, technological, and environmental cost.	-Consider a range of improvements -Maximize use of simulation -Prepare a prioritized infrastructure improvement program -Consider funding in system planning and design -Plan for maintenance

Type	Description	Examples
Infrastructure Strategies	Infrastructure strategies are presented for track, structures, stations, and grade crossings. Most of the recommended strategies are similar to those used to increase capacity and speed on any rail system.	-Add mainline tracks and universal crossovers -Build dedicated high-speed segments -Reduce horizontal curvature -Improve passenger access to trains -Improve grade-crossing and warning systems
Communications and Signal Systems Strategies	Signaling strategies help determine a rail segment's maximum speed and capacity by controlling the movement of trains. They also prevent trains from colliding and route trains on the best tracks to enable efficient railroad system operation.	-Adjust block length -Add automatic train stop and train control -Add automatic cab signaling -Add interlocking systems
Operating Strategies	There are two kinds of operating strategies — 1) operations planning; and 2) dispatching. Operations planning consists of developing a schedule for all trains. Dispatching is the process of providing trains with specific directions that account for the day-to-day operating conditions in real time.	-Limit train variation and scheduling -Add speed scheduling and eliminate local stops/trains -Add maintenance windows -Add computerized dispatching assistance

Source: Nash (2003).

Design Standards

In addition to strategic partnerships, design and infrastructure are key elements of shared use. In order to develop official design criteria and standards governing shared use in the US, scholars have surveyed shared-use rail corridors by the Federal Railway Authority (FRA).[54] FRA's "Catalog of Common Use Rail Corridors" defines three types of shared-use rail corridors: 1) shared track, in which heavy or light rail transit (LRT) operate on the same tracks used by freight trains; 2) shared right-of-way (ROW), where transit vehicles run on separate tracks, but the separation between the centerline of the freight track and the passenger track is less than 25 feet (7.62 meters); and 3) shared corridor, which refers to tracks that are separated by at least 25 feet and no more than 200 feet (61 meters), but which share a transportation corridor. They identified a total of 20 rail systems that had either of these definitions in the general railroad system. Most notable amongst their findings was that there is a wide variation in construction standards for transit lines in shared-use corridors. The development of shared-use corridors is driven primarily (directly or indirectly) by safety concerns, particularly for passengers. Time separation, distance separation, grade separation, and constructing intrusion fences and crash walls are measures that can be taken to respond to safety concerns.

Sela and his colleagues argue for the creation of various design and operations measures to further develop standards of maintenance for shared-use corridors and roadway crossings.[55] For example, the relationships among centerline distances, operational speeds, trip frequency, and probability of derailment (amongst others) must be elucidated in order to provide more insight on the existing agency regulations and potentially update the agency requirements regarding shared-use corridors. Unified design and maintenance criteria would also help bridge potential differences between the two uses of shared-use corridors, thus providing planners and engineers the necessary tools for the planning and designing of new facilities. For example, Caltrain in California was able to introduce European-style electric multiple units (EMUs) into its already existing FRA-compliant passenger trains by adopting a European norm for crash energy management.[56,57] The ability to provide meaningful calculations and test results proved essential to enhancing hazard analysis. Ultimately, while challenges remain regarding safety concerns and considerations of existing facilities, a greater inventory of operation and design standards would serve a pivotal role in reducing risks and accidents while also helping to formulate better maintained systems.

Capacity

In developing shared-use transit systems, defining and measuring railway capacity is fundamental. However, the definition used for rail capacity in the US varies based on the techniques and objectives of the particular study.[58] Even in Europe's widely accessible and extensive transit system, the most common definition of capacity (provided by the International Union of Railways [UIC] code 406) allows variation based upon the interrelated perspectives of railroad customers, infrastructure planners, timetable planners, and railroad operators. In this sense, capacity is a theoretical construct that can be achieved by: 1) absolute train-path harmony; 2) minimum headway; and 3) best quality of service. The vast array of differences between the U.S. and Europe's rail networks regarding infrastructure, signaling, operations, and rolling stock explain this variability.[59]

The literature identifies three analytical approaches and methodologies for measuring capacity: analytical, simulation, and combined approaches. Pouryousef and his colleagues survey previous case studies utilizing one of these three approaches to assess how the chosen methodology relates to the research purpose, outcomes/ solutions, and accuracy of results. Although the majority of studies use simulation approaches—especially amongst European rail networks—the accuracy of the simulation results is a concern. They suggest that researchers apply all methods and evaluate the applicability and accuracy of each approach in the US environment.[60]

As is evident from the aforementioned studies, strong partnerships, accurate measurement of a system's capacity, and the adoption of universal design standards are crucial for the development of safe and efficient shared-use railway systems. The differing experiences also suggest that there is no silver bullet for success. Building and measuring capacity must be executed on a case-specific basis. Nevertheless, there is much to be learned from European countries regarding effective planning, operations and management, and communications strategies for blended transit systems.

SUMMARY

This chapter reviewed the literature on intermodal connectivity at HSR stations from different perspectives. It found that various quantitative metrics and models have been proposed to measure connectivity and intermodality, identify the best locations for HSR stations, and assess the design of multimodal transit networks. But more research is needed to justify the applicability of each method under different circumstances or conditions, and to evaluate the effectiveness of these methods in identifying optimal locations for HSR stations or in designing multimodal transport networks.

Secondly, the chapter explored recent literature on ways to improve connectivity through spatial and operational interventions. The literature agrees that spatial connectivity—smooth linkages between a transportation facility and the surrounding neighborhood and city—is very important in improving multimodal transit ridership. At the same time, better transferring services, better signs and supporting facilities, better use of bicycles for connecting with transit modes, and better information and ticketing practices can increase the operational connectivity of public transportation services.

Based on the examination of the literature on integrated transit systems, it is demonstrated that improved transit connectivity and intermodality, either through spatial or operational connectivity, can significantly benefit travelers and thus increase the ridership of multimodal transportation systems. It is also pointed out that transit planners and operators must consider both intra- and inter-modal connectivity in order to develop a successful integrated transportation network with different modes.

Lastly, the chapter examined the literature on blended systems, which allow high-speed and conventional or freight rail to share the same tracks. It found that strong partnerships between transportation agencies and institutions are necessary to make shared use work. A set of design and operation standards must be developed for the better safety of shared-use corridors. Various analytical, simulation, and combined approaches have been proposed to measure railway capacity, which is fundamental in developing shared-use transit systems. However, additional research is needed to evaluate the applicability and accuracy of each approach in the US context.

In what follows, the study draws from additional sources—a survey of experts and interviews with transit managers of blended systems in Germany and Spain—to examine ways that enhance the spatial and operational connectivity of HSR systems.

III. EXPERT SURVEY

To complement the findings of the literature review, a survey was sent out in November 2013 to 30 high-speed rail experts in Europe.[61] The response rate for this survey was exceptionally high, as 26 experts from six different countries (France, Germany, Italy, the Netherlands, Spain, and United Kingdom) provided responses. (See Appendix A for a list of survey respondents.) The HSR experts were asked to respond to eight open-ended questions regarding the nature of blended HSR systems and related issues at the level of station and station-area organization and management. (See Appendix B for a list of survey questions.) The following overview presents key insights from the survey.

BLENDED SYSTEMS IN EUROPEAN COUNTRIES

The surveyed experts were all very familiar with blended systems because a number of European countries are using them to different extent. As one expert noted, “The possibility to ‘blend’ is an important advantage of HSR compared to maglev, because it allows the train to call at existing, centrally located stations, and enables larger flexibility in terms of various routes.”[62]

According to the German survey respondents, Germany is generally known to have the most blended systems among the major countries with HSR. Indeed, almost all HSR lines in Germany operate as blended systems. There are a few select high-speed corridors, notably between Berlin and Hannover, and between Cologne and Bonn, but trains run primarily on conventional tracks. Also, newly built high-speed rail tracks are not exclusively dedicated to the high-speed (ICE) trains but can also be used by regional and other inter-city trains.[63]

The Netherlands has only two HSR lines. The first, from Amsterdam to Belgium and France, is on a dedicated track except for the tracks in the urban area of Rotterdam and the track from Schipol airport to Amsterdam. The second, from Amsterdam to Germany, shares tracks with the conventional trains. This service has similar speeds with the conventional rail but has fewer stops within the Netherlands. The German portion of this line then continues to Cologne on high-speed tracks.[64]

Spain[65] has an interesting system that started out as a separated system in which Spain’s HSR AVE trains and conventional services used different track gauges and different electrical systems and thus shared only minor areas at stations. Now, however, Spain has a “third rail” system that allows both systems to share infrastructure. This new, somewhat slower HSR system that also diverts to destinations along the conventional rail infrastructure is called ALVIA. The respective trains are now able to change gauge without coming to a full stop, only slowing to about 20 km/h (12 mph). One drawback is the limited number of changeover locations, making the network less flexible. It should be noted that in Spain, even the exclusive HSR tracks (AVE trains) are still shared by TALGO overnight trains.[66]

The UK has true high-speed infrastructure on the Channel Tunnel link from London to the coast (HS1) that achieves speeds of 186 mph (299 km/h). A second high-speed line (HS2) is being planned from London to Birmingham and beyond. HS1 carries the international

Eurostar trains as well as Javlin trains, a high-speed commuter service inaugurated in 2008 using Japanese Hitachi trains. It takes passengers from Kent and Ashford to London St Pancras in a mere 37 minutes. As one expert explained, “The present system of inner city services (125 mph/201 km/h) is blended throughout. The one very high-speed line (186 mph/299 km/h) (HS1 London-Channel Tunnel) is dedicated to HS trains (Eurostars, Hitachi Javelin domestic trains to Kent). The latter exit at Ashford on the classic track and also switch power (from AC to DC).”[67] Some experts suggested that the HSR can also be used for freight services at night;[68] however, freight carriers in the US are currently reluctant to operate in electrified corridors.[69]

Italy has a blended system in which “the HSR tracks are not shared by conventional trains but in the main nodes (Milan, Rome) the HSR trains use the conventional network, because the new HSR tracks start outside the urban network. The HSR lines in Italy are for passenger trains and freight trains.”[70] Historic stations such as Milano Centrale, Milano Garibaldi, Milano Rogoredo, and Roma Termini have been redesigned for high-speed trains. New stations such as Torino Porta Susa and Roma Tiburtina have been developed as multimodal nodes accommodating both traditional and HSR trains as well as underground lines. One example of an HSR-only station is Mediopadana Reggio Emilia. Another important point is that HSR trains are running on conventional lines, but not vice-versa, due to the single voltage of the slower trains.[71]

France[72] built an extensive system of new corridors dedicated to high-speed trains, but the system is still blended in the sense that the French high-speed TGV trains still “share their tracks with conventional lines in some city cores and operate as conventional trains on certain segments of their tracks.”[73] The creation of new TGV stations at the edges of big regional cities and at a distance for the conventional stations is viewed as a problem.[74] For this reason, the connectivity and compatibility of the HSR service with the conventional service (which reaches the city center) is deemed very important.[75] According to one expert:

> *The first HSR line that opened in 1981 was designed to be used only by HSR (25000 volts and 260-300 km/h) [162-186 mph],* but the high-speed trains could use any electrified line. … Only some of the newer projects envision a partial use by standard trains (particularly *for freight during the night). The main corridors (from Paris to other big cities) are equipped with dedicated HSR tracks. It is rather the tributaries of these big corridors that are blended.*[76]

Many TGV services continue out of high-speed tracks on the conventional network,[77] but “not all conventional infrastructures are electrified.”[78] To name a concrete example, “to go from Paris to Dijon, the TGV Paris runs on a conventional line, then it takes the high-speed line from Paris to Lyon to go as fast as 300 km/h (186 mph); then it gets out of the high-speed line to take the conventional line (speed of about 150 km/h or 93 mph) to go to Dijon.”[79] But “to make this system work in France, [they] only use the railway equipment that is compatible with the technical standards developed by Alstom. In Germany there is a similar system with Siemens trains, but they are not compatible with the French network (however, Alstom TGV can travel on the German network).”[80] Also, “to give you an idea of the importance of the compatibility of the HSR with the conventional network, compare the stations served by HSR to those served by the conventional network: Eighteen stations for HSR and hundreds for the conventional one.”[81]

BENEFITS OF BLENDED SYSTEMS

Overall, several experts highlighted the key advantages of blended systems. According to them, an important advantage is that:

> *Blended systems require less space, and this is mainly important in urban areas. By using existing tracks, the high-speed train can reach existing, centrally located stations in urban areas, where there is no or little space for additional tracks or platforms.*[82]

> *It seems quite logical that, particularly in urban areas, a blended system is applied. It is very difficult to find the required space to enter existing cities with a new railway system. In countries, such as France, Belgium and Germany, the HSR runs on conventional tracks within the major cities simply because there is no space available. Only underground systems are able to penetrate urban areas, however, at high costs.*[83]

Another key advantage of putting HSR trains on upgraded conventional tracks is lower cost because it uses already existing tracks and right-of-way and the better integration of railway infrastructure through sharing stations and facilities.[84] A third advantage is that blended systems may provide greater flexibility in changing or adding services or routes based on demand. As argued:

> *It seems easier to change or add services (for example adding services in the summer from Amsterdam to Avignon, or in the winter from Amsterdam to the Alps). Furthermore, if the HSR uses conventional tracks, this means a service can be set up without the need to complete the whole trajectory of HSR at once. This allows for a more incremental development. Finally, I can imagine a blended system is more robust (or resilient) because the HST can use conventional tracks for a detour in the case of disturbances.*[85]

A fourth advantage of blended systems at the station level is that most of the station infrastructure is shared. According to one expert: “This allows for fast changes between HSR and conventional rail, so that the total travel time is reduced.”[86]

Lastly, one expert argued that blended systems may have a higher robustness because the HSR service can use conventional tracks in cases of infrastructure and service disruptions.[87]

CHALLENGES OF BLENDED SYSTEMS

There was a general consensus among the experts that the most significant challenges of blended systems are operational, followed by some infrastructural challenges, while the spatial challenges were deemed less significant. There were no clearly discernible differences among experts in their opinions depending on their countries of origin, so the main issues, some of which were named by a vast majority of experts, will be discussed independently of the experts’ home bases.

As mentioned, most experts pointed out that the spatial challenges of blended systems are negligible or unimportant whenever conventional lines are upgraded to accommodate high-speed trains. On the other hand, the construction of entirely new high-speed lines is subject to NIMBY and environmental opposition. As one expert recalled, “one of the major issues on the Amsterdam-Germany high-speed link was that the people who opposed it claimed that there was no space available for a new dedicated track without destroying important natural areas in particular on the Utrecht-Germany trajectory of the link.”[88]

From an operational perspective, the different speeds of the high-speed and conventional trains require larger safety distances and present scheduling and coordination challenges.[89] Put simply and succinctly, “conventional trains on the same line reduce the capacity of HSR.[90] For infrastructure, this then means that sufficient passing tracks should be built [and] intermediate stations must be built to accommodate HSR trains to pass at full velocity.”[91]

One Dutch expert provided a particularly vivid illustration of the big operational challenges involved in blended systems and how these are closely related to infrastructure issues. As he argued:

> *Different train systems are running on the same track: HST, Intercity, all-station trains and freight trains. They are all running at different speeds, having different stops, often operated by different operators. In the Netherlands, the core network of the train system is at least two tracks, so one track is available in each direction. However, on the busiest links such as Amsterdam-Utrecht, we have four tracks. One track [is] for intercity and HST, and one track* [is] *for all-station trains and freight trains in both directions. It is only in the urban area of Amsterdam that the four-track system merges into a two-track system, leading to very low speeds for all train systems. This four-track system made it possible to run all four train types. Without the four-track system, this would be impossible.*[92]

A Spanish expert emphasized that:

> *A recent accident in Spain*[93] *has brought this [operational] issue to the frontline again … From a technical management perspective, a blended system requires the coordination of very different technologies, and sometimes [it] is not easy. Separated systems are obviously easier to manage.*[94]

Another concrete illustration of such operational challenges related to single versus multi-track corridors is in the UK. As explained:

> *On the HS1 line, Eurostar trains (186 mph) [299 km/h] and Javelins (140 mph) [225 km/h] necessitate gaps, but the line has sufficient spare capacity for this. On the West Coast Main Line, tilting Pendolinos (125 mph) [201 km/h] and non-tilting electric stock (100 mph) [161 km/h] use separate tracks.*[95]

A French expert succinctly summarized the core challenge as: “HSR supply needs generally slots with a big reliability during the peak hour. In France, the problem was solved with one or two new tracks in the main stations and for the last km.”[96] Other infrastructure challenges mentioned by the experts primarily related to gauge width, safety, and electrical systems. As a Dutch expert explained:

> *Although the gauges are similar, the Netherlands have a different electrification system than our neighboring countries (1500V instead of 15Kw). This is solved by making the trains able to run on both systems. … HST trains have an on-board safety warning systems (the track ahead of the train has to be free for 2 kilometers), whereas on conventional tracks*, the safety system is located on the *track (a new train is allowed on a specified segment of the track only after the previous train has left this segment).*[97]

The fact that many HSR trains in Europe travel in different countries complicates things because, as explained:

> *In European countries*, *many different versions of rail safety systems are in use, and international HSR trains must be equipped with the safety systems of the countries they serve. Dedicated HSR tracks commonly have a different safety system than the conventional trains, and in a blended system*, *the HSR trains must be equipped with both. Also domestic trains making use of the HSR track must be equipped with the proper safety system.*[98]

It was also explained that whenever there are high-speed operations present on a line, there is a "need to accommodate high-tech signaling/ control systems, which are however being increasingly adopted on all lines (EU ERTMS system)."[99] Experts also pointed to particulars in the gauge systems, as for example in Spain and in the UK, where the classical gauge will not accommodate Bern-gauge double-decker rolling stock.[100]

The importance of a smooth coordination of train schedules was also stressed by a number of experts.[101] As a Dutch expert explained:

> *A main challenge seems to be that trains should not hinder each other, particularly that the HST is not stopped by a large number of commuter trains or by accidents … If HSTs are not given priority, they may easily be hindered by the much larger number of local and regional trains; but if they are given priority and they are delayed, a large number of other trains may have to wait.*[102]

Additionally, the need for coordination of different services (high-speed and conventional) was also emphasized. As one French expert noted:

> *Often the TGV leads to the abandonment of secondary connections on the conventional network. The ideal is to have stops on high-speed trains, which are coordinated with local, regional trains*, *etc. … We must also think about the coordination among infrastructure managers. In France, the rail network is managed and maintained by a public authority, the Réseau Ferré de France. The network operation is supervised by the SNC.*[103]

While spatial issues were not deemed particularly challenging it was noted that "Blended systems require the installation of passing loops for freight services. The different operating characteristics limit gradients and curves, plus the need for appropriate signaling."[104]

OPTIMAL STATION LAYOUTS FOR BLENDED SYSTEMS

Asked if particular station locations and layouts (e.g., with shared or separate platforms, service, and ticketing areas) are more suitable for blended systems, the HSR experts gave a variety of responses. Their responses corresponded and related to concrete national practices in terms of ticketing and shared services, as those are handled quite differently in various countries in Europe.

Thus, regarding ticketing, whereas for a Spanish expert, "it is normal to have separate service and ticketing areas because normally they correspond to different operators providing different type of services,"[105] the situation in the Netherlands is that "tickets can be bought online or at the larger stations. The larger intercity stations offer separate ticketing areas for all international train tickets. Smaller stations offer only inland train tickets."[106] Ticketing will be more integrated in the future, however.[107] Germany, by contrast, already has completely shared service and ticketing areas – with the exception of prime waiting areas for first-class passengers.[108]

Regarding station location, both Spain and France have the policy of building new HSR stations at the edges of or even further away from the center of smaller or intermediate cities, focusing on finding the shortest possible distances and best routes to connect to the major cities, where stations are then fully integrated. This dual phenomenon of both fully separated stations in smaller cities and fully integrated stations in major cities stands in contrast with German cities, for example, where all stations are fully integrated.

There was a lack of consensus among experts 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. As explained:

> *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*.[109]

On the other hand, some experts believed that sharing station platforms as much as possible is preferable, as it maximizes interconnectivity.[110] Most experts, 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."[111] Some also argued 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."[112] Some experts also mentioned that consideration of separate or shared platforms should depend on whether or not trains have similar or different dwell times (amount of time that a train stops at the station):

> *If the trains have different dwell times (e.g., high-speed inter-city services with end-doors versus regional trains with frequent mid-car doors), they should use separate platforms; preferably, however, on the same island platforms for easy interchange. The Dutch Railways handle this brilliantly.*[113]

Lastly, some mentioned that the practice of separating high-speed and conventional services within the stations is required because of security reasons in some European stations that also accommodate international services. As explained: "For safety reasons, the Eurostar to London requires separate (and fenced) platforms. Also, ticketing is often separated for short/long distances (e.g., in France) [or] domestic/abroad (Netherlands)."[114]

INTEGRATION OF HSR SERVICES[115]

A number of factors play a role in the successful operation of an HSR system, such as the number and location of stations, the number of offered services, the linkage of the HSR station to other transportation modes, and the level of station intermodality. As explained, "You have to find the best compromise between network density and urban density. A HSR network gains in performance when situated close to places of residence and employment. The best integration results from an intelligent placement of the public transit network and from avoiding an over-abundance of parking at multimodal stations."[116]

All experts agreed on the critical importance of good intermodal connections between the HSR and other travel modes. As argued:

> *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.*[117]

> *Finding the right system depends on the opportunities of each territory. But simple rules for success exist: We must consider the new HSR lines as part of a multimodal system. We must ensure interdependencies among the rail lines. A good transportation system is a system that ensures high connectivity.*[118]

Additionally, the experts emphasized that "maximum connectivity is reached if users experience the HSR service as much as possible as one door-to-door system."[119] But how can this be achieved? The experts talked about a combination of spatial and operational measures.

Station Location

An important topic that emerged from the survey entailed the location of HSR stations and the trade-offs of having stations placed in central versus peripheral locations. 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 … 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.[120]

As was further explained, a blended system allows the HSR to reach centrally located stations, but on the other hand, stations at the urban fringe of a metropolitan area allow shorter stops and less travel time for passengers traveling to other destinations.[121] Several French experts chimed in with key insights in this regard:

Our 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 in creating dedicated high-speed railway stations*.[122]

In France, the historic station is usually the focal point for intercity bus connections and a major hub of the urban transportation system. “Integrating an HSR station in a densely built district certainly 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.”[123]

On the other hand, if an HSR station is placed at a peripheral location and away from the 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 that is served daily by 74 bus connections. In Reims or Besançon, a specific rail link was built to connect the new station to the conventional rail network; high-speed trains benefit from connections to the central station or other regional stations. In Reims, the proximity of the city has also allowed the linkage of the station with the urban transport network through the building of a new tramway service.[124]

Station Environment

Many emphasized the importance of the station environment for HSR riders so it is not simply a transportation facility but also a destination. A couple of experts spoke specifically about the station building as a real estate asset that requires careful planning and programming, pointing out elements such as:

…the adaptability of the station’s functional program, and ensuring the possibility of the evolution of station components (i.e., *different functions and activities in different spaces of the station). In general, planning 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.*[125]

It is important to bring new services into the stations to make them attractive. Such services may include retail, restaurant, and even cultural activities.[126]

Many also mentioned elements such as good information panels, good signage for way-finding, and integrated ticketing. As one expert summarized: “Signage is important and especially indicating on the ticket in advance from what platform the next train will depart. If possible, [locate] the coach station in walking distance, and have one ticket for the entire journey even when it involves a train and a coach."[127]

The importance of a station design that allows visual connections, physical proximity, and short walking distances from the HSR platform to other transport modes was also noted by many experts.[128] One expert highlighted the need for "continuity between the station and station neighborhood; easy recognition of the access path to the city and other interconnected transport networks; in relation to its location (urban or exurban), design the space of the station as an urban open avenue/space, permeable and equipped with functions and activities that integrate this space to the surrounding urban fabric."[129]

Coordination of Different Travel Modes

The easy connection with other travel modes, and the goal of "complementarity rather than competition among the different connected travel modes"[130] was emphasized repeatedly. Additionally, the need was emphasized 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 network and park & ride facilities." Operational aspects such as short transfer times were also mentioned as very important for good intermodality."[131] As argued, "the main issue is technical and regulatory coordination. An 'overall' transport authority (with multimodal functions) is crucial."[132]

As many experts noted, the promotion of intermodal connectivity at HSR stations requires multiple levels of integration. One Spanish expert explained: "You always should consider the triple integration: physical, institutional and ticketing. The best solution is to have a terminal manager with coordination responsibilities over all kinds of operators, spaces, and services."[133]

GOOD EXAMPLES OF MULTIMODAL HSR STATIONS

The experts mentioned a number of stations (with or without blended systems) as good multimodal examples. These are listed in Table 2.

Table 2. European HSR Stations Listed as Good Multimodal Environments

UK	France	Belgium	Germany	Switzerland	Netherlands	Spain	Italy
- St. Pancras International - Ebbsfleet International - Stratford International	- Besançon - Lille Europe - Lille Flandres - Gare de Lyon - Charles de Gaulle Airport - Lyon/Part-Dieu - Dijon - Valence TGV - Champagne Ardenne TGV - Aix-en-Provence	- Brussels Midi (Zuid) - Antwerp	- Frankfurt Airport - Dusseldof Airport - Hannover - Karlsruhe	- Zurich - Geneva Cointrin	- Schiphol airport - Rotterdam Central - Amsterdam Central	- Madrid Atocha - Madrid Chamartin - Córdoba - Zaragoza (Delicias)	- Roma Termini

Source: Authors Survey.

POOR EXAMPLES OF MULTIMODAL HSR STATIONS

Interestingly, a few stations characterized by some experts as problematic had been mentioned by other experts as good examples. This happened when one key drawback in the opinion of one expert outweighed other assets mentioned by others. Thus, Frankfurt station, highlighted by some experts as having a good multimodal integration, was characterized by another expert as problematic because of “massive track beds that slow down trains approaching and leaving the station.”[134] Additionally, one German expert noted how the otherwise highly desirable integrated train schedules at some German stations may turn into a disadvantage if these stations operate at or above capacity. One such example is the heavily congested station in Cologne, where “problems occur occasionally where regional trains and HSR (to Brussels) operate in a synchronized way on the same track. Small delays of one system can cause trouble for the other system.”[135] London’s St. Pancras was another station mentioned as a good multimodal example by some experts but considered problematic by one expert “because the HSR [there] is a different, separate world from the other modes, but in other respects, it is a good station.”[136]

The most frequently-mentioned poor examples were located in France, where a large number of purpose-built high-speed rail stations have been built. Thus, stations such as Gare de Lyon Perrache, Avignon TGV, Meuse TGV, Le Creusot-Montceau-les-Mines (TGV Sud-Est), Vendôme (TGV Atlantique), Haute-Picardie (TGV-Nord), Aix-en-Provence (TGV Méditerranée), Lorraine TGV (TGV-Est), Paris Orly (Airport), and Lyon (Saint Exupéry Airport) all were mentioned as exhibiting poor multimodal connections. Experts highlighted that many of these stations were set in car-dependent environments away from multimodal connections that did not offer the opportunity for riders to take transit to transit.

"Most ex-urban stations, built in the periphery, negatively affect passengers' overall journey times (while the high-speed train is supposed to save time). When the only access to the station is the car, then the system is bad."[137]

Several Italian stations, such as Milan Central Station, Roma Tiburtina, and the planned new underground HSR station in Florence were also mentioned as not well connected to local transportation.[138] Multiple experts noted that the two-station phenomenon in Lille was also controversial:

> *The city of Lille believed that a HSR line (the line Paris-London) passing by the center of the city could be a strategic advantage despite the recommendations of all the experts. ... The result is that there are now two central stations in Lille: Lille-Europe with only HS lines and HS trains, and Lille-Flandres operated with a blended system. The distance between the two stations being 500 meters (0.3 mile), Lille is the worst case of integration of the HSR service with other railway services*.[139]

A similar and equally problematic example is that of the future HSR station in Birmingham, UK**,** which is also planned 500 meters (0.3 mile) from the conventional station. As one expert noted: "This means that to change from the HSR to the conventional rail, the passengers will have to change station!"[140]

Speaking about stations in Spain, one expert said that "most of them have only rail services without connection to the buses and good integration with transit at the local level. Last-mile problems are not integrated in the management of the corridor."[141] Another Spanish expert found that the Atocha station in Madrid "can be confusing for first-time users."[142]

Stations described as problematic, or at least having some problematic aspects in accommodating multimodality, are listed in Table 3.

Table 3. European HSR Stations Listed as Problematic in Accommodating Multimodality

UK	France	Germany	Spain	Italy
- St. Pancras International - Birmingham (planned)	- Gare de Lyon Perrache (Paris) - Paris Orly (Airport) - Avignon TGV - Meuse TGV - Le Creusot-Montceau-les-Mines (TGV Sud-Est) - Vendôme (TGV Atlantique) - Haute-Picardie (TGV-Nord) - Aix-en-Provence (TGV Méditerranée) - Lorraine TGV (TGV-Est) - Lyon (Saint Exupéry Airport) - Lille two stations	- Frankfurt - Cologne	- Madrid Atocha	- Roma Tiburtina - Milan Central

SUMMARY

Drawing from their expertise and multiple experiences with European HSR systems, the 26 experts gave useful information for the California HSR about the advantages and challenges of blended systems, but most importantly about the different elements that enhance the spatial, operational, and institutional integration of high-speed rail services.

IV. BLENDED HSR SYSTEMS IN GERMANY AND SPAIN: INVENTORY AND STATION TYPOLOGY

This chapter gives some basic information about the development of high-speed rail (HSR) systems in Europe, focusing primarily on the concept of blended systems. Germany and Spain are two European countries that have utilized blended railway networks in characteristically different ways. In preparation for a detailed account and case studies of blended systems in these two countries (which will be presented in the next three chapters), this chapter presents a typology and an inventory of blended HSR stations in Germany and Spain.

HIGH-SPEED RAIL INFRASTRUCTURE IN EUROPE

Although high-speed rail systems in Europe were built by the individual countries under quite different national systems and configurations, the European Union has had a stake in integrating these systems. Most importantly, there have been efforts to build up the so-called Trans-European Transport Networks (TEN-T) from the 1980s onward, and the European Union has in fact co-financed with millions of Euros various highway and railway projects deemed of "European significance" (primarily with an overall bias toward road infrastructure).[143]

Between 1985 and 2009, the number of HSR kilometers in Europe increased from under 800 km (about 500 miles) to over 6000 km (3,728 miles) (Figure 1). As a result, significant reductions in travel times across many Western and Central European cities have been achieved in the last two decades (Figure 2).

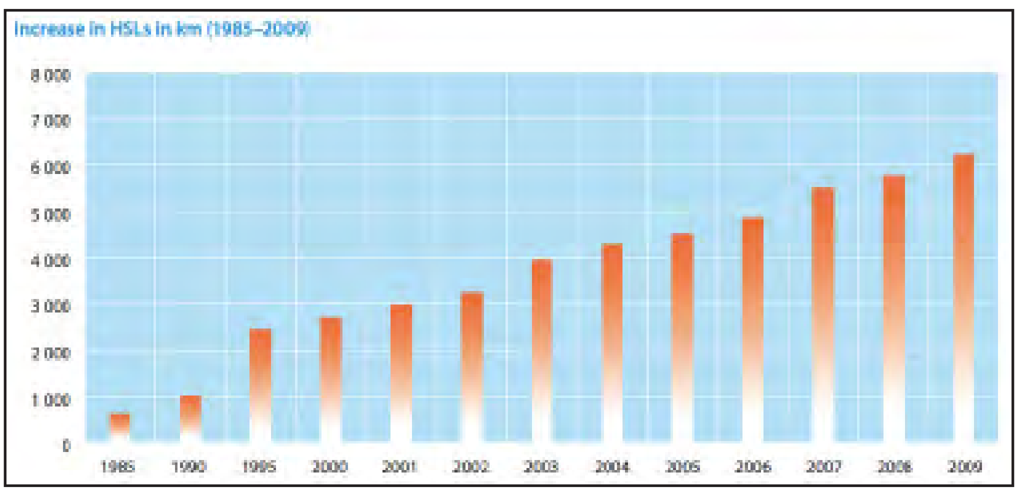


Figure 1. High-Speed Rail Lines in Europe 1985-2009

Source: "High-Speed Europe." Online at http://bit.ly/1LQZdrv, page 5, accessed August 11, 2014.

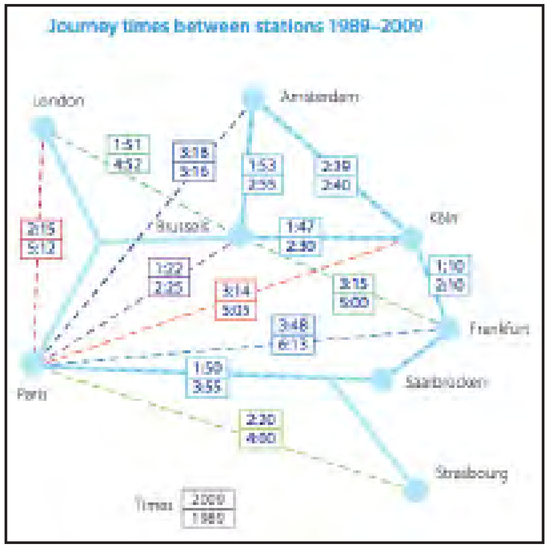


Figure 2. Reduced Rail Journey Times between Key European Cities (1989-2009)

Source: "High-Speed Europe." Online at http://bit.ly/1LQZdrv, page 8, accessed August 11, 2014.

In January 2014, a transport infrastructure policy was decided upon, and nine core rail corridors were identified as forming the most important backbone axes across the European Union (Figure 3).

Figure 3. TEN-T Core Transport Network

Source: European Commission, Online at http://bit.ly/1CF0RHF, accessed August 11, 2014.

These corridors were then broken down into more detailed infrastructure segments in the individual countries. Figures 4 and 5 show the TEN railway infrastructure guideline maps for Germany and Spain as they appear in official EU documents. Clearly, not all of the TEN-T core rail corridors are built out as high-speed rail corridors.

Figure 4. Trans-European Rail Corridors in Germany

Source: Excerpted and re-sized from http://bit.ly/1NunrZ8

Figure 5. Trans-European Rail Corridors in Spain

http://bit.ly/1Kpwo8q

BLENDED HSR SYSTEMS IN GERMANY AND SPAIN

As discussed previously, in a blended system, tracks are shared between high-speed and conventional trains, either along portions of the route or for its entirety. Blended stations stand in contrast to stations that exclusively serve high-speed trains or stations with only conventional rail service. A blended station, consequently, signifies a rail station in which high-speed trains stop alongside conventional trains. But there is significant variation among blended systems. For example, tracks within the station may or may not be exclusively reserved for the high-speed trains. High-speed trains may or may not arrive via especially dedicated high-speed tracks, and there may or may not be a bypass option for high-speed trains to skip a blended station during certain hours of operation. Many European HSR corridors represent blended systems.

As explained in Chapter 2, while blended systems may often make sense economically, they also present certain challenges operationally. In Europe, blended railway systems have presented some challenges not only in terms of intermodality but also in terms of interoperability because trains must be fitted with different signaling and control systems.

This study focused on the blended HSR systems of Germany and Spain, two countries that have utilized blended railway systems extensively in their networks but in characteristically different ways. The sections that follow present a blended system inventory and HSR station typology in these two countries. In constructing this inventory, the first step was to obtain a complete overview of the existing high-speed rail services, corridors, and stations in Germany and Spain, and to then to document the respective stations' overall characteristics in terms of size, location, and intermodality. Because the goal was to investigate blended systems, the study ultimately focused only on stations located along a newly built or at least substantially upgraded and expanded high-speed rail infrastructure corridor (now allowing for maximum speeds of 250 km/h [156 mph]). In Germany, the high-speed-branded ICE trains run on conventional or moderately upgraded lines for the vast majority of the network. This is true for many important railway stations in large secondary cities in Germany (e.g., the entire Rhein-Ruhr Valley, Hamburg, and much of East Germany), which were thus not part of these closer investigations, as no new high-speed rail corridors were built to access them.

Of Germany's 158 stations with ICE train service, only 32 are located along new or substantially upgraded corridors, which allow for speeds of 250 km/h (156 mph) or more. Spain's situation, however, is more similar to the system envisioned in California, with a substantial separate, dedicated HSR network built in addition to—or rather separate from—a conventional network, which in fact has a different gauge. Thus, this study investigated a total of 32 stations in Germany and 28 stations in Spain, collecting information on the number of daily high-speed and conventional trains, connections to local transit, and station building type.

DEVELOPMENT OF A STATION TYPOLOGY

Given that the ultimate goal is to derive comparative lessons from the European cases for the prospective California system, it did not make much sense to develop very detailed individual typologies because these would be very specific to each country's individual urbanization and settlements patterns. Rather, the effort was to develop sensible, comparable categories that would likely work across all three countries. Thus, the development of a station typology was influenced by the following initial considerations:

The two most important criteria influencing the overall character and function of a station are its location within its urban area and the character and function of the respective urban area. Is the station located at the heart of a city (within its historic core), or is it placed in a sub-center or even a peripheral location within a city? Also, is the station located in a large and populous city that extends over a sizeable geographical area and has several significant sub-centers, or is it a smaller city whose urbanized area does not extend far beyond its historic core? Thus, ultimately the study settled on a typology that distinguished stations according to:

1. The size of the city they are located in –[144] Cities were divided into four categories: a) first-tier cities (population over one million); b) large cities (500,000-1 million population); c) medium cities (100,000-500,000 population); and d) small cities (less than 100,000 population).

2. The station's geographical location within the metro area – This included five different location types: a) historic core (downtown); b) secondary center; c) peripheral location within the metro area; d) exurban location; and e) airport location.

Tables 4 and 5, respectively, present characteristics of the 23 HSR station-cities and 32 HSR stations in Germany and the 28 HSR station-cities and 29 HSR stations in Spain. Table 6 presents the summary results, assigning the 32 German and 28 Spanish stations along the 250 km/h (156 mph) corridors to the 20 (5x4) different typology categories. The airport category allowed for double listing (i.e., a station could be listed as both a peripheral and an airport station). Additionally, information was collected about each city's metropolitan population, urban density, and station types (e.g., through station, terminal station, cross station with lines intersecting, etc.). The full datasets are listed and discussed in more detail in the section entitled "Station Typologies for Germany and Spain."

The tables already indicate key differences and similarities between the two countries.[145] Thus, the population density in most of the Spanish HSR station-cities is significantly lower than the population density in the German HSR station-cities. The 28 Spanish HSR station-cities have a median population density of about 355 people per square mile, while the median density in the 23 German HSR cities of the sample is about 1,600 people per square mile.

As shown in Table 6, while 53% of Germany's newly built or substantially upgraded stations are in first-tier or large cities, only 24% of Spain's such stations are in first-tier or large cities. Indeed, 87% (31%+22%+34%) of all German stations in the database are located in cities larger than 100,000 people, and 63% of all German stations are located in the city's historic core; whereas just over half, or 52% (10%+14%+28%) of the Spanish stations are located in cities larger than 100,000 people, and less than half (48%) of all of the stations are located in the historic core of the cities. Lastly, three new German stations are built at airport locations, while Spain does not have any HSR station associated with an airport. These aggregate numbers already tell us quite a bit about the prospective intermodal capacities of the respective stations, with German stations, on aggregate, benefiting from much more central locations in larger cities. In Germany, six cities (Berlin, Munich, Koln, Frankfurt, Stuttgart, and Hannover) have multiple stations that accommodate HSR lines, while only Madrid in Spain has two stations (Atocha and Chamartin) that accommodate HSR lines. Because of the highly blended system in Germany, HSR stations there tend to have multiple platforms. With the exception of Madrid, Barcelona, Cordoba, Velladolid, and Segovia, the rest of the Spanish HSR cities accommodate only a very small number of HSR lines daily (AVE, ALVIA, ALTARIA, and AVANT), compared with the German HSR station-cities in the sample.

Table 4. HSR Rail Stations along High-Speed Rail Corridors in Germany

			Station Location							
City Size	City	Station Name	Historic Core	Secondary Center	Peripheral in Metro Area (non-airport)	Exurban	Airport	City Population (not metro area)	City Density (inh/hm²)	Station Type
First Tier City (over 1 million)	Berlin	Berlin Hbf	x					3,415,091	3,829	Crossing
	Berlin	Berlin Ostbf		x				3,415,091	3,829	Through
	Berlin	Berlin Gesundbrunnen		x				3,415,091	3,829	Crossing
	Berlin	Berlin-Spandau		x				3,415,091	3,829	Separation
	Berlin	Berlin Sudkreuz		x				3,415,091	3,829	Crossing
	Munchen	Munchen Hbf	x					1,388,308	4,468	Terminal
	Munchen	Munchen-Pasing Bf		x				1,388,308	4,468	Through
	Koln	Koln Hbf	x					1,024,373	2,528	Separation
	Koln	Koln Messe/Deutz		x				1,024,373	2,528	Crossing
	Koln	Koln Bonn Flughafen					x	1,024,373	2,528	Through
Large City (0.5 to 1 million)	Frankfurt am Main	Frankfurt (Main) Hbf	x					687,775	2,770	Terminal
	Frankfurt am Main	Frankfurt am Main Flughafen					x	687,775	2,770	Separation
	Stuttgart	Stuttgart Hbf	x					597,939	2,884	Terminal
	Leipzig	Leipzig Hbf	x					520,838	1,800	Terminal
	Leipzig	Leipzig Flughafen					x	520,838	1,800	Through
	Hannover	Hannover Hbf	x					509,485	2,500	Crossing
	Nurnberg	Nurnberg Hbf	x					495,121	2,655	Through

City Size	City	Station Name	Station Location: Historic Core	Station Location: Secondary Center	Station Location: Peripheral in Metro Area (non-airport)	Station Location: Exurban	Station Location: Airport	City Population (not metro area)	City Density (inh/hm²)	Station Type
Medium City (100,000 to 0.5 million)	Karlsruhe	Karisruhe Hbf	x					296,033	1,707	Crossing
	Mannheim	Mannheim Hbf	x					294,627	2,032	Crossing
	Wiesbaden	Wiesbaden Hbf	x					272,636	1,337	Terminal
	Aachen	Aachen Hbf	x					240,086	1,493	Separa-tion, system change, border
	Erfurt	Erfurt Hbf	x					203,485	760	
	Kassel	Kassel-Wilhelmshohe		x				192,874	1,806	Reiter
	Ingolstadt	Ingolstadt Hbf	x					127,886	959	Through
	Wurzburg	Wurzburg Hbf	x					124,577	1,422	Crossing
	Wolfsburg	Wolfsburg Hbf	x					121,758	597	Through
	Ulm	Ulm Hbf	x					117,977	994	Node
	Gottingen	Gottingen Bf	x					116,052	990	Through
Smaller City (under 100,000)	Hanau	Hanau Hbf	x					88,834	1,161	Crossing
	Fulda	Fulda Bf	x					64,779	623	Through
	Limburg an der Lahn	Limburg Sudbf			x			33,619	745	Through
	Montabaur				x					

Source: Authors' own data collection and calculations.

Table 5. HSR Rail Stations along High-Speed Rail Corridors in Spain

City Size	City	Station Name	Station Location					City Population (not metro area)	City Density (inh/hm²)	Station Type
			Historic Core	Secondary Center	Peripheral in Metro Area (non-airport)	Exurban	Airport			
First Tier City (over 1 million)	Madrid	Atocha	x					3,234,000	3,595	Crossing
	Mardid	Chamartin		x				3,234,000	3,595	Crossing
	Barcelona	Sants	x					1,673,000	15,926	Crossing
Large City (0.5 to 1 million)	Valencia	Valencia Joaquin Sorolla	x					809,267	6,000	Through
	Sevilla	Santa Justa	x					703,000	5,002	Crossing
	Zaragoza	Zaragoza-Delicias		x				702,090	660	Crossing
	Malaga	Malaga-Maria Zambrano	x					568,507	1,427	Terminal
Medium City (100,000 to 0.5 million)	Alicante	Estacion de Alicante	x					334,329	1,700	Terminal
	Cordoba	Cordoba Central	x					328,488	260	Crossing
	Valladolid	Valladolid-Campo Grande		x				311,501	1,600	Crossing
	Acoruna	Estacion-A Coruna			x			246,056	6,613	Terminal
	Albacete	Albacete-Los Llanos	x					172,472	150	Through
	Lleida	Lleida-Pirineus	x					138,416	34	Through
	Taragona	Camp de Tarragona			x			134,085	2,400	Through
	Ourense	Ourense-Empalme		x				108,002	1,262	Crossing
Smaller City (under 100,000)	Girona	Estacion de Gerona	x					96,722	2,486	Through
	Santiago de Compostella	Estacion de Santiago de Compostela			x			95,671	429	Through
	Guadalajara	Guadalajara-Yebes				x		84,504	359	Through
	Ciudad Real	Estacion de Ciudad Real Central	x					74,921	260	Through
	Cuenca	Cuenca-Fernando Zobel			x			57,032	63	Through
	Segovia	Segovia-Guiomar				x		56,660,	350	Through

City Size	City	Station Name	Station Location					City Population (not metro area)	City Density (inh/hm^2)	Station Type
			Historic Core	Secondary Center	Peripheral in Metro Area (non-airport)	Exurban	Airport			
	Huesca	Estacion de Huesca	x					52,347	330	Terminal
	Puertollano	Estacion de Puertollano	x					51,842	230	Through
	Antequera	Antequera-Santa Ana				x		45,854	56	Through
	Requena-Utiel	Estacion de Requena Utiel				x		43,087	25	Through
	Calatayud	Estacion de Calatayud			x			42,379	17	Through
	Puente Genil-Herrera	Puente Genil-Herrera				x		30,033	180	Through
	Toledo	Estacion de Toledo			x			23,365	101	Terminal
	Tardienta	Estacion de Tardienta	x					944	11	Through

Source: Authors’ own data collection and calculations.

Table 6. Station Typology with Summary Results for Germany and Spain

				Station Location				
	City Size	**# of Cities in this category**	**# of Stations in this category**	**Historic Core**	**Secondary Center**	**Peripheral within Metro Area**	**Exurban**	**Airport**
Germany	First Tier City (over 1 million)	3	10 31%	3 30%	6 60%	0 0%	0 0%	1 10%
Spain	First Tier City (over 1 million)	2	3 10%	2 67%	1 33%	0 0%	0 0%	0 0%
Germany	Large City (0.5 to 1 million)	5	7 22%	5 71%	0 0%	0 0%	0 0%	2 29%
Spain	Large City (0.5 to 1 million)	4	4 14%	3 75%	1 25%	0 0%	0 0%	0 0%
Germany	Medium City (100,000 to 0.5 million)	11	11 34%	10 91%	1 9%	0 0%	0 0%	0 0%
Spain	Medium City (100,000 to 0.5 million)	8	8 28%	4 50%	2 25%	2 25%	0 0%	0 0%
Germany	Smaller City (under 100,000)	4	4 13%	2 50%	0 0%	2 50%	0 0%	0 0%
Spain	Smaller City (under 100,000)	14	14 48%	5 36%	0 0%	4 29%	5 36%	0 0%
Germany Totals		23	32 100%	20 63%	7 22%	2 6%	0 0%	3 9%
Spain Totals		28	29 100%	14 48%	4 14%	6 21%	5 17%	0 0%

Source: Authors' own data collection and calculations.

SUMMARY

To better understand the context and facilitate the later comparison among the German, Spanish, and California HSR systems, this chapter created an inventory and a typology of HSR station-cities in Germany and Spain. While Germany tends to locate HSR services primarily at the historic cores of its first-tier and large cities, about one-half of Spain's HSR stations are located in small cities. The core differences in the urban networks of the two countries have generated different patterns of HSR development that will be discussed in detail in the next chapter.

V. BLENDED HSR SYSTEMS IN GERMANY AND SPAIN: INTERMODALITY

Germany and Spain have followed different strategies in HSR development. Spain, which did not have a very dense or efficient conventional rail network, focused on building a very impressive new network of high-speed corridors that allow speeds of 250 km/h (155 mph) or above. In contrast, Germany, which had one of the densest railway networks in the world prior to the advent of high-speed rail technology in the 1980s, focused more on speeding up its overall network by selectively investing in few strategic new connections alongside substantial upgrading efforts across its entire conventional network.

This key difference ultimately has to do with the political and geographic differences in the two countries, which have resulted in the development of two dissimilar settlement patterns over time. Figure 6 is a 2012 European Commission Eurostat map that provides an overview of population densities across Europe, grouped at the EU region level. Germany has a significantly more multi-nucleated and denser settlement structure than Spain and California (Table 7). So in discussing the two different countries' approaches to optimizing intermodality and accessibility in their respective urban environments, one needs to bear in mind that Germany is more focused on optimizing high-speed connection across a complex interconnected web of poly-centric regions, while the Spanish system has a hub-and-spoke form with the capital city Madrid at its center. So while neither is completely akin to the planned system in California, where the original impetus for instigating high-speed rail has been focused around connecting two large coastal regions that lie roughly 400 miles (644 km) apart, Spain is much more similar in population size and settlement structure to California than to Germany. As the two systems in Spain and Germany are quite different, the two case study countries will be discussed separately.

Table 7. Settlement Structures in Germany, Spain, and California

	Population (million)	Size (square km)	Density (pop/square km)
Germany	81.8	357,021	233
Spain	46.8	505,782	92
California	38.3	423,970	95

Source: http://en.wikipedia.org/wiki/Area_and_population_of_European_countries (2010 figures) and http://en.wikipedia.org/wiki/California (2014 estimates).

THE GERMAN HSR SYSTEM

Germany's HSR system privileges connectivity before speed. Germany has a balanced polycentric settlement structure without one single dominant metropolis (Figure 6). Only four cities – Berlin, Hamburg, Cologne and Munich – have more than one million inhabitants, but many have 100,000 inhabitants or more, and large portions of the country are part of what the Federal Spatial Planning Office calls "urbanized regions." At over 10 million, the Rhein-Ruhr region is Germany's largest mega-region, rivaling Paris and London in size. Germany's historic East-West orientation for the movement of goods and people was interrupted with the partition of the country into two separate states after World War II.

Reunification in 1990 provided Germany an exceptional opportunity to embark on an ambitious program to reconnect metropolitan regions in the East with those of the West.

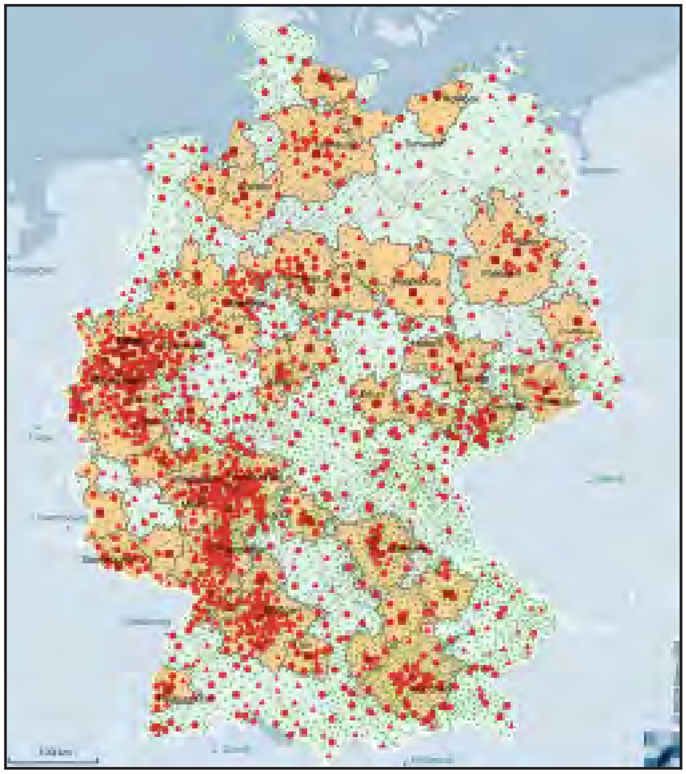


Figure 6. Germany's Polycentric Settlement Structure

- Large city over 100,000 inhabitants
- Medium city over 20,000 inhabitants
- Δ Small city, typically under 20,000 inhabitants
- Settlement areas of primarily rural character
- Urbanized region

Source: German Federal Institute for Construction, City and Spatial Planning at http://bit.ly/1dsXIUy, last accessed November 15, 2014.

Unlike in Japan, France or Spain, Germany's high-speed service, the ICE system, was not developed primarily via the construction of new rail corridors but rather through the integration of new generations of specially branded ICE trains into the existing system, coupled with the construction of only a few select new high-speed lines, and a larger number of upgraded lines. This approach resulted in a system that includes 130 stations across Germany and another 50 in neighboring countries. At 80 of the domestic and 15 of the international stations, ICE service occurs in at least two-hour intervals. While the network generally privileges stations in larger cities, the service is uneven across the country. This leaves large cities such as (the former capital) Bonn, Gelsenkirchen, Moenchengladbach, Krefeld, and Chemnitz, all of which have more than 200,000 inhabitants, without any ICE service. Meanwhile, small cities such as Montabaur (12,500 inhabitants) and Züssow (1400 inhabitants) enjoy ICE access. The average distance between ICE stops in Germany is only 70 km (44 miles). Because so few rail lines in the network have received maximum upgrades, average speeds across the network are comparatively slower than in other international networks. But what the network lacks in maximum speed, it makes up in overall connectivity, with multiple and convenient transfer possibilities at each station. Passengers can often transfer from one ICE train to another, or to a slightly slower Inter-City (IC) or Regional Express (RE) train simply by walking across the platform, with comparatively short transfer times.

Today, the ICE is the flagship of German Railway services. Within Germany, the brand name recognition nears 100%. By 2013, annual ridership had exceeded 80 million, up from 76.6 million in 2012, when this figure constituted about 58% of all long-distance travel within German Railway's network. It is interesting to note that while the ICE accounts for only about 8-10% of the company's sales volume, it is responsible for 90% of its reputation.[146]

DEVELOPMENT AND FUNDING

ICE was officially inaugurated in Germany on May 29, 1991, a mere half-year after the nation was reunified. Germany Railways (DB) had been conducting trials around what was then called the Inter-City Experimental (ICE-V) since 1985, but none of the high-speed corridors had been finished yet. The original impetus for developing high-speed rail service in Germany also included considerations for improving conditions for freight traffic. Germany's first two new high-speed rail corridors, planned long before Germany's reunification, linked Hannover to Würzburg and Stuttgart to Mannheim. After reunification in October 1990, neglected or abandoned East-West links needed to be re-established. The Federal Government financed several high-profile infrastructure projects called Transport Projects Germany Unity (*Verkehrsprojekte Deutsche Einheit*, or VDE in German). These included funding for several high-speed rail connections, as well as a complete multi-billion Euro overhaul of the entire rail network in Berlin, whose infrastructure networks had been divided by the Wall for three decades. The projected overall costs for the VDE were about EUR40 billion, of which EUR34 billion were spent until the end of 2013. Of this sum, EUR16.9 billion were spent on rail projects, and much of it went to improving high-speed rail connections between Germany's East and West.[147]

In Germany, railway infrastructure funding is allocated at the federal level. All transport investment is allocated according to the so-called Federal Transport Infrastructure Plan, or BVWP (*Bundesverkehrswegeplan* in German), for which individual states are permitted to rank their priority projects. The government then releases five-year Framework Investment Plans, listing all road, rail and waterway projects. Even with German unification prompting many new construction projects, the maintenance and upgrading of existing infrastructures are always receiving higher priority in Germany. For example, for the 2011-2015 period, EUR50.1 billion was to be invested in transport infrastructure, of which EUR28.1 billion were slated for maintenance. German Federal Railways received around EUR20.6 billion, of which only EUR6.4billion went to upgrading and new construction compared to a full EUR12.6 billion for maintenance (leaving EUR1.5 billion for other measures).[148]

Due to the country's geological characteristics and its complex project approval procedures, including comparatively diligent spatial and environmental appraisal, construction costs are high in Germany, setting the bar for new rail corridors relatively high. Stakes are high for accurately estimating both the costs and benefits for new high-speed projects. Albalate and Bel insist that:

> *If there is a feature that distinguishes the German experience from others, it is precisely the network's capacity to function for two forms of mobility: passengers and freight. Passenger services primarily use the network during the day, while freight is transported at night. […] [T]he choice of a mixed model of passengers and freight meant renouncing greater commercial speeds (with a maximum of >150-160 mph, [241-257 km/h] in order to gain the stability and safety required for adapting the infrastructure to the restrictive characteristics of high-speed freight transportation. […] [The Ministry of Transportation's] position in favor of the mixed model was greatly influenced by the significant volume of income freight traffic generated for the state railway company.*[149]

Box 1 gives a short overview of Germany's new high-speed rail corridors, or NBS (*Neubaustrecken* in German), that are either completed or under construction.[150] Many of them are planned in close connection with upgraded sections at either end, called ABS (*Ausbaustrecken* in German). It should be noted that many of the NBS and ABS projects have met with strong resistance from local environmental and citizen groups, often with significant planning delays.

Box 1: Germany's New High-Speed Rail Corridors

1. Hannover–Würzburg

At 327 km (203 miles), this was Germany's first and longest NBS, planned since the 1970s and representing the backbone of the country's North-South rail network.

2. Stuttgart–Mannheim

This 100 km (62 mile) stretch is an example of a new corridor that is also being used by non-ICE trains and even freight trains (at night). Stuttgart main station is a terminal station but there are major and highly contested plans for turning it into a through station.

3. Hannover–Berlin

Plans for a fast rail connection from West Germany to West Berlin originated in the West Germany Transport Ministry in the 1980s, but actual construction did not begin until 1992, and the line opened in 1998. This route is unusual in that it does not connect the two state capitals of Magdeburg and Potsdam (just outside Berlin) to the line. Up until Wolfsburg, the line is in fact an upgraded version of the old line, which allows maximum speeds of 200 km/h (124 mph), whereas the 190 km (118 miles) of new construction from Wolfsburg to Berlin allows maximum speeds of 250 km/h (155 mph) through comparatively sparsely settled regions.

4. Koln–Frankfurt (Main)

This new line cut the distance traveled between these two major cities by 110 miles (177 km). It includes 18 bridges and 26 tunnels and largely follows the A3 Autobahn. Only the special ICE 3 series trains can service this route because of steep gradients of up to 40%. It is the first HSR line in Germany that routinely reaches top speeds of 300 km/h (186 mph). The NBS included a crucial new long-distance train station at Germany's major airport in Frankfurt, as well as a subterranean (non-high-speed) loop to the regional Koln/Bonn airport. It has become very popular with business travelers, vacationers, and tourists and has led to a substantial reduction of domestic air travel between Dusseldorf, Koln, and Frankfurt. German Railways operates several AIRail trains along this route, which feature code-share arrangements with Lufthansa, with airport-style check-in options at the Koln, Dusseldorf, and Stuttgart stations.

5. Nürnberg–Ingolstadt (Munich)

This is another NBS that largely follows a freeway, in this case the A9, to create 89 km (55 miles) of new high-speed track. Opened since 2006, the NBS reduced travel times between Nürnberg and Munich from 105 to 80 minutes, and coupled with the upgrading of the line from Ingolstadt to Munich, this time was further reduced to 62 minutes. This NBS also allows maximum speeds of 300 km/h (186 mph). Critics of the line are unhappy with its high price tag of EUR3.6 billion, calculating that every minute of saved time costs about EUR100 million.

6. Nürnberg–Erfurt

This 107km-section (65 miles) is part of the larger VDE (Transport Projekt German Unity) #8, and construction began as early as 1996 but was halted in 1999. Only after the allocation of additional necessary funds did construction seriously continue in 2006, with DB intending to complete the project by 2017.

7. Erfurt Leipzig/Halle

Part of the same VDE #8, this 123 km (76 mile) section is supposed to be completed in 2015. A 23 km-long (14-mile) portion was completed in 2003, ensuring network connectivity for the new long-distance train station at Halle/Leipzig airport.

8. Stuttgart–Wendlingen (Ulm)

This is another combined NBS and ABS project following a freeway right of way, in this case along the A8. Construction for the NBS to Wendlingen started in 2012, and completion of the line is expected for 2021.

9. Karlsruhe–Basel

A highly trafficked route to Switzerland for freight trains was upgraded and renewed along a 183-km stretch (113-mile). The most significant individual piece of infrastructure, the so-called Katzenberg tunnel, was opened in 2012.

Source: Assembled by authors using misc. Internet sources.

MANAGEMENT AND OPERATIONS

German Railways, or *Deutsche Bahn* in German (and DB for short), is a legally privatized but 100% publicly owned company, crafted out of the merger of East and West Germany's respective state railway companies in 1994, four years after reunification. Following this merger, DB radically reduced its staff and focused on increasing its profitability, with a renewed rail-sector focus on boosting high-speed operations for business travelers, often at the expense of decentralized local services in less urbanized areas with lower passenger volumes. As detailed below, DB's ICE service is highly integrated with the company's other operations, including not only lower-speed rail operations, but also services such as car rental and bike share operations. In fact, DB's own self-image is that of an all-around mobility provider rather than that of a national railway company. Note, for example, the company's carefully crafted LinkedIn profile, which reads:

> *Deutsche Bahn is an international provider of mobility and logistics services and active in over 130 countries. We design and operate the transport networks of the future. With the integrated operation of transport and infrastructure and the intelligent linking of all modes of transport, we move people and goods – on the rails and roads, by sea and by air.*[151]

DB has more than 1,000 sub-companies, of which the most important ones are *DB Schenker Rail,* managing and operating all of DB's rail freight; *DB Regio*, managing and operating regional passenger rail operations; *DB Netz*, managing and operating 87% of Germany's railway network; DB Station & Service, managing and operating all of the approximately 5,400 railway stations across Germany; and finally *DB Fernverkehr*, managing and operating DB's long-distance rail services including the ICE, IC and EuroCity high(er) speed trains, amounting to about 1,300 trains per day, as well as five long distance IC bus lines to select international destinations.

BLENDED SYSTEM AND INTERMODALITY

As apparent from the previous discussions, Germany's rail operations are highly blended, and the optimization of intermodality lies at the very heart of the system. High-speed operations were originally designed to blend seamlessly intro 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, especially when travelling from major business destination to business destination. Depending on their popularity, ICE lines operate at half-hour, one-hour, or two-hour intervals, depending on location and time of day. There are no exclusive ICE stations or even concourses in Germany, and major stations across the country are all located in city centers, with the key exception of the newly built ICE station at Frankfurt Airport, Germany's most important airport hub.

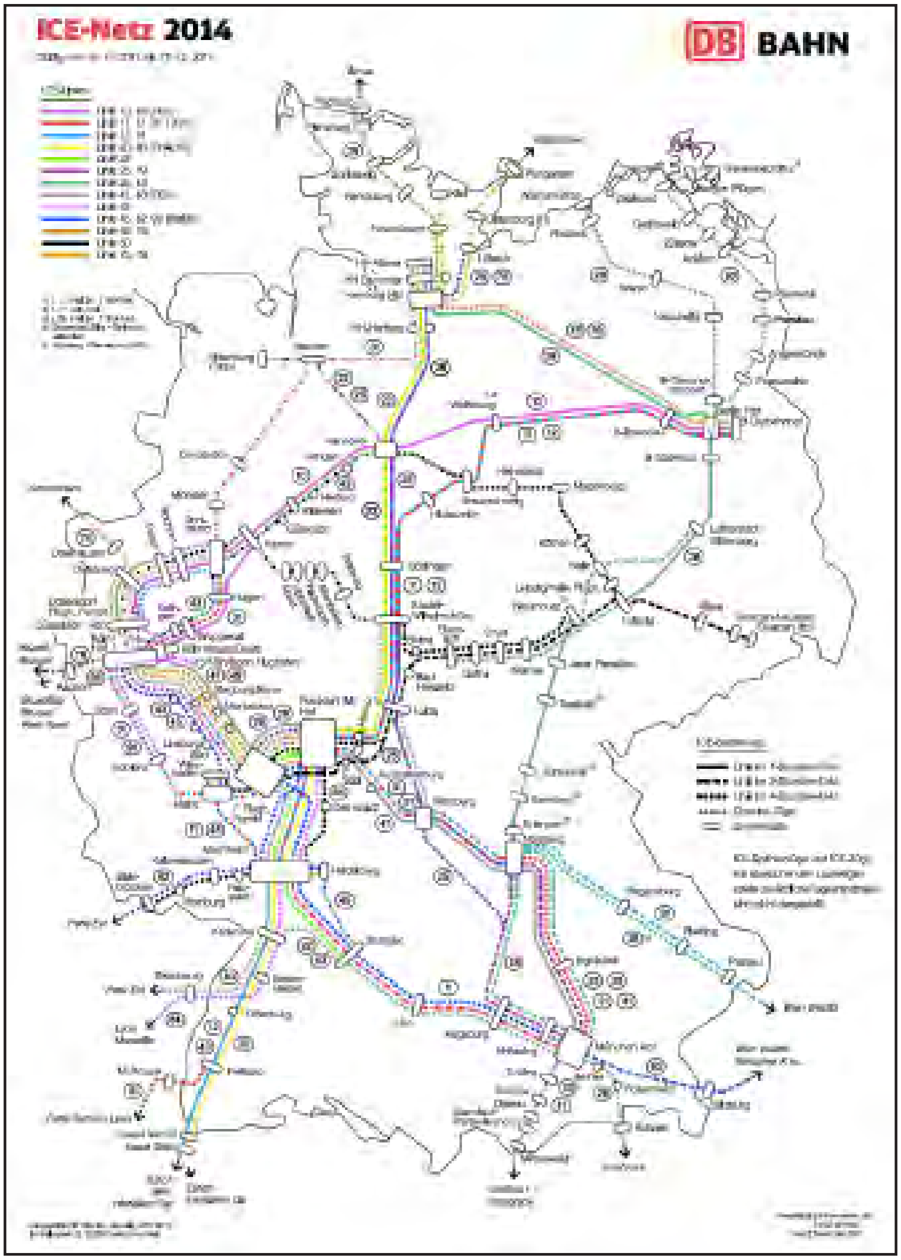


Figure 7. ICE Network Map 2014

Source: http://bit.ly/1GIpP9H, accessed August 8, 2014.

Figure 7 provides an overview of Germany's ICE network in 2014, with different ICE lines highlighted across the network and stations clearly visible. Figure 8, by contrast, gives a good schematic overview of how few new HSR corridors had been developed until 2009 in the core ICE network. The major new HSR route that is not yet included is the new connection between Leipzig and Nuremberg, described as (a section of) Transport Project German Unity # 8 (*VDE 8* in German).

Figure 8. Main German High-Speed Rail Corridors (until 2009)

Source: http://commons.wikimedia.org/wiki/File%3AICEtracks.png, attributed to Classical geographer (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0

Other than the ICE, there are two additional domestic rail services that achieve high speeds of up to 200 km/h (124 mph): the Inter-City or IC service and portions of the Regional Express, or RE service. While both RE and IC service have generally suffered at the expense of expanded ICE service, there are certain RE routes that have benefited from the construction of the NBS because their trains, too, are now using the faster rail infrastructures.

Station Design

In 2011, DB Station & Service reorganized the system by which all stations under its management are categorized and organized. As a result, Germany now has a seven-tier system of stations, with Category 1 consisting of the 21 most important stations in the country and Categories 6 and 7 together consisting of about 3400 minimally serviced stops in low-density rural areas. Box 2 provides an overview of the different types of stations, and Figures 9a-g give a visual impression of their typical look. The categories are formed according to the following set of criteria:[152]

- number of tracks at the station
- maximum length of platforms
- number of passengers
- number of trains stopping
- presence of barrier-free technical conditions
- availability of service personnel

High-speed rail service (ICE) is not solely constrained to the top category stations. For example, the ICE station in Montabaur is only a Category 4 station, yet it still boasts a multitude of ICE arrivals and departures every day. By contrast, there are several important Category 2 stations in the Rhein-Ruhr region, such as Bonn, Gelsenkirchen, Moenchengladbach and Krefeld, which do not have ICE high-speed rail service but only feature IC/EC and regional service. Thus, train station design in Germany is organized not according to the kind of rail service the station carries, but rather according to a more complex mix of categories that together to more accurately reflect the station’s importance within the national network.

Box 2: German Railways (DB) Official Station Categories

Category 1
The 21 stations of Category 1 are considered traffic hubs. They are permanently staffed and carry all sorts of railway-related facilities as well as usually featuring a shopping mall in the station. Most of these stations are the main stations of large cities with 500,000 inhabitants and above, though some in smaller cities are regarded as important because they are at the intersection of important railway lines. Berlin, Hamburg, Munich, and Koln, the four biggest cities in Germany, have more than one Category 1 station.

Category 2
Most of the about 80+ stations of Category 2 are either important junctions of long-distance traffic or offer connections to large airports. InterCity and EuroCity trains generally call at these stations. All railway-related services, like a ticket hall and a service desk, are present at the station, and the station is staffed during the usual times of traffic. The service is similar to Category 1 stations.

Category 3
Category 3 includes 230 stations. These stations will usually feature a station hall where travelers can buy tickets and groceries, but these stations are usually not permanently staffed. They are often main stations of cities with about 50,000 inhabitants.

Category 4
Category 4 includes 600 stations. Most of these stations have frequent connections with RegionalExpress and RegionalBahn trains. Their service level is comparable to a bus station, and they offer services to commuters. This category also includes stations situated in major cities that see high usage of S-Bahn or RE/RB services.

Category 5
Category 5 includes 1070 stations. These stations either belong to smaller, rural towns or to outlying suburban areas of major cities. Their inventory normally is vandal-proofed due to the lower number of passengers. They normally have only local trains calling at the station.

Category 6
Category 6 includes 2500 stations. These stations have low passenger numbers, and only the most basic equipment needed is present at the station. They are akin to bus stops.

Category 7
Most of the 870 stations of the lowest Category 7 are in rural areas. Only several local trains call at these stops, which usually have not more than one platform.

Source: Slightly shortened from http://en.wikipedia.org/wiki/German_railway_station_categories.

Figure 9. a-g: Sample Pictures of German Rail Stations in Categories 1-7

Source: Rearranged from http://en.wikipedia.org/wiki/German_railway_station_categories

DB has been criticized for its often minimalistic basic branding of lower-category stations, using the same red, blue, white, and silver materials for in-station way-finding and interior decorating, often negating the impressive tradition of identity-building local station architecture that existed in Germany in the 19th and 20th centuries, and replacing it with bland non-place corporate design. Contrary to the fate of the less important stations, several of the country's most important stations continue to be cherished and highlighted as architectural landmarks, often with expensive restoration programs in place to upgrade the historic city-center stations with modern amenities and services. As the vast majority of Germany's ICE stations are historic city-center stations, station designs vary greatly from city to city, depending on whether they are terminal or through stations, whether they were destroyed in the war or not, and whether the historic station buildings have been restored or amended. Dresden's Main Station is a good example of a station where historic elements have been very successfully mixed with modern upgrades. As part of a major renovation that lasted from the late 1990s until 2006, Lord Norman Foster added a "striking new 30,000-square-metre translucent roof." As he noted:

> *Our redevelopment of Dresden Station represents a true celebration of the 19th century original through the means of our times. The dramatic roof structure has been specially engineered to rest comfortably on the original station arches revealing the fine historic detailing while flooding the space below with natural light, reducing energy consumption and reinventing the station for the 21st century.*[153]

Despite the comparatively modest daily rail passenger volumes of 60,000 passengers, Dresden Main station is still a Category 1 top station that exemplifies the German approach to intermodality. Located at the intersection of two major long-distance routes and a gateway to international lines to Prague, Budapest, and Vienna (going East) or Basel and Amsterdam (heading West), it is complemented by Dresden Neustadt Station within the city for high-speed ICE service to Leipzig. Figures 10a-d and 11 show the renovated station and give a good impression of the ease with which passengers can transition from high-speed to regional and local commuter trains simply by switching platforms in the main train hall within minutes, or, alternatively, find many light rail/tram lines at the Northern and Eastern sides of the station, coupled with multiple bus lines. The platforms are located on two levels, making the station a combined through and terminal station. Given its central location, many passengers simply walk to their final destinations in the city core.

Figure 10. a-d: The Redeveloped Dresden Main Station (after 2006)

Source: Foster and Partners at http://www.fosterandpartners.com/projects/dresden-station-redevelopment/

Figure 11. Dresden Central Station. Central Hall with Railcars DB 143, DB 612 and ICE

Source: Kai Körner (available under Wiki Commons at http://bit.ly/1g38uTg).

Figure 12. Integrated Intermodality, Exemplified at Dresden Main Station

Source: Allianz Pro Schiene Pressefoto (available at http://1drv.ms/1GVBSDZ).

Figure 12 captures the wide range of connecting transit options that a high-speed rail passenger arriving or departing on an ICE train, such as the one visible on the left side of the picture, has at her fingertips. A long-distance IC train is just arriving or departing from the other train hall on the right side of the picture, while a taxi is waiting right in front of the station, at the same time as a tram and two articulated buses are also passing through the picture. Voted Station of the Year in 2014 by the German pro-rail group Pro Rail Alliance (*Allianz Pro Schiene* in German), Dresden Main Station also offers the full variety of services that are typically available at Germany high-speed stations. About 540 trains arrive and/or depart at the station every day on its 15 platforms. There are about 1,100 car parking spaces in the direct vicinity, as well as 118 bike parking spaces. DB's service point is open from 6 am to 10:30 pm, and it also features a lounge, mobile service, lockers, a lost-and-found, serviced restrooms, WiFi (free for the first 30 minutes), as well as 43 shops, cafes, and restaurants distributed over 14,000 square meters (46,000 square feet) that employ about 380 people. DB has 87 employees working at the station.[154]

Ticketing and Other Passenger Services

Ticketing for high-speed rail services is fully integrated with all other rail ticketing by DB. Tickets can be purchased in many different ways: They can be bought in person at the station, either at one of the fully staffed DB Travel Centers (Figure 13), at select *DB Mobility Centers*, or at the automated ticket machines located throughout the stations. Tickets can also be bought in advance at various travel agencies, via the DB Internet portal, or by phone. For smartphone users, there is the DB Navigator application. It is also possible to purchase tickets on the train itself. The pricing system is complex and includes a great variety of special discounts for early booking, frequent travelers, and groups. So as a general rule, the later you book, the smaller your party, and/or the more flexibility, comfort, and travel speed you require, the more expensive your ticket becomes.[155] All children under the age of 6 and older children under the age of 14 accompanied by parents or grandparents travel for free. Otherwise, older children pay 50% of the ticket price. Online and smart phone booking allows both self-printing of tickets as well as online tickets. About one-third of all tickets are booked online, and another one-third are bought at automated kiosks.

For calculating the normal ticket price, DB distinguishes among three different product categories: 1) ICE high-speed; 2) IC/EC and night trains; and 3) all other regional/commuter travel. For the ICE category, the normal ticket price is a relative price with a set base price for any connection between two destinations. This price is not dependent merely on distance but also on comfort level and travel time. Besides the annual discount cards *BahnCard 25* and *BahnCard 50*, which give holders an additional 25% or 50% discount off the ticket price, DB also offers a *BahnCard 100*, which allows unlimited travel on all high-speed and other trains across the country. As an added bonus, all commuter travel at one's home or travel destination is included as well. This network card costs EUR4090 per year or EUR379 per month in second class and EUR6890 or EUR639 in first class. It is an attractive option for many business people and academics, who frequently travel outside their home regions and/or must maintain a second home in a different city.

Additional passenger services are available at DB Information counters at all Category 1 stations and many Category 2 stations. Besides train information, these staffed counters as also offer:

- Information flyers about regional destinations;
- Information about ongoing local construction projects DB is involved in;

- Hotel booking for nearby destination;
- Distribution of hotel and taxi vouchers for delayed passengers;
- Fax services and miscellaneous other services for delayed passengers;
- Booking of DB car-rental, car-sharing, bike-sharing services;
- Way-finding assistance;
- Assistance with lost and found items; and
- Selected courier services.

Figure 13. DB Travel Center in Trier, with Automated Ticket Machine (visible in front)

Source: Craig 2007 (Own work), via Wikimedia Commons (available at http://bit.ly/1Kl7cyi).

Inter-agency Coordination

DB collaborates with a number of other mobility providers. For high-speed service, the following are of most interest:

AIRail

AIRail is a cooperation between DB and Germany's major airline Lufthansa. Introduced in 2001, the system originally concentrated on designating ICE trains with three-letter flight codes to transport passengers from Koln to Frankfurt, thereby making flights between these two cities increasingly unnecessary. Passengers can board the trains with their luggage and then check in at Frankfurt at a special check-in counter in the transition area between the Frankfurt Airport station and the Lufthansa terminal (Figures 14 and 15). At this special counter, passengers can also check in for connecting flights with 23 other participating airlines.[156] AIRail is also possible from Stuttgart, Dusseldorf, Siegburg/Bonn, Kassel Wilhelmshöhe, and Karlsruhe.

Rail & Fly and Rail Inclusive Tours (RIT)

Rail & Fly and Rail Inclusive Tours (RIT) are two other ways in which DB cooperates with other travel and tourism agencies to promote seamless integration of travel chains for passengers' arrival and departure to long-distance destinations, offering discounted fares. DB has cooperation agreements with airlines such as Germanwings and Condor, with tour operators such as Ameropa, with the AIDA cruise operator, and with several others.[157]

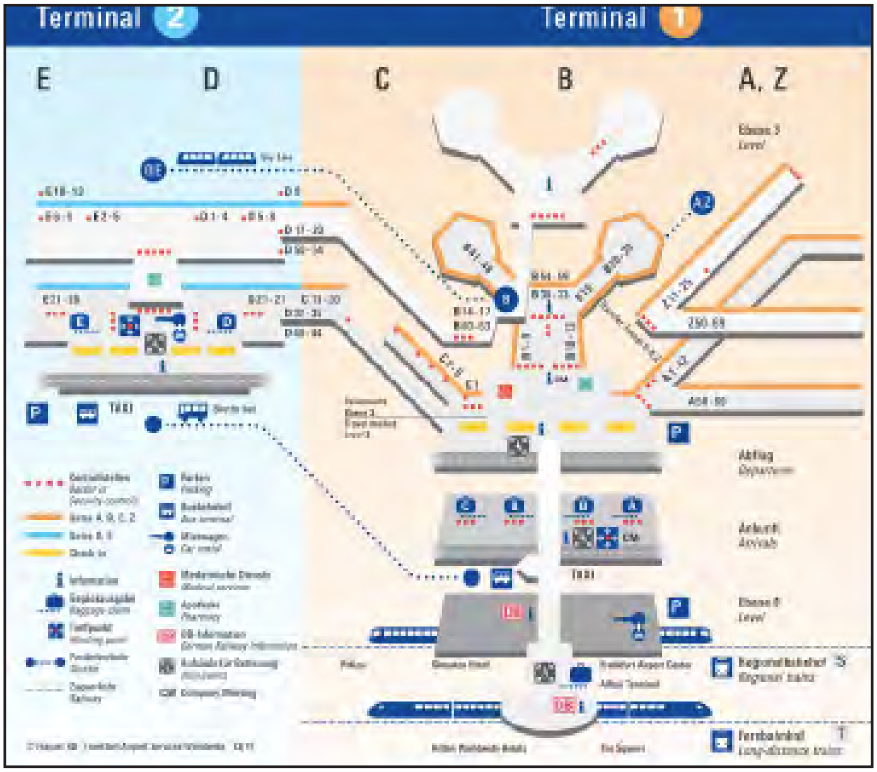


Figure 14. Seamless Integration of Railway Station and Terminals at Frankfurt Airport

Source: http://bit.ly/1DIKkE6 p.6 (accessed December 27, 2014).

Figure 15. Frankfurt Airport Station

Source: Deike Peters.

THE SPANISH HSR SYSTEM

Spain's HSR system is focused on connecting its capital, Madrid, to provincial capitals.

Spain's urban settlement structure is not as polycentric as Germany's, but rather it is dominated by two major poles: Madrid and Barcelona, with several other major population centers located along the coastline. With a population of 3,255,944 in 2009, Madrid, ranks as the third-largest city in the European Union in population size and is the undisputed administrative, political, and economic center of Spain. Spain's second pole is Barcelona, the capital city of the Catalonia region; it has a population of 1,621,537 and is a major cultural center and tourist destination. All other cities in Spain are significantly below the one-million-population mark, though a number of them have 100,000 inhabitants or more. Over the course of the last two decades, Spain has built an impressive network of new high-speed lines across its territory, and the expansion continues regardless of the fact that its system carries significantly fewer passengers per kilometer than comparable systems in France, Germany, or Japan. Some scholars are adamant that Spain explicitly disregarded more rigorous economic analyses in favor of a large, economically less viable hub-and-spoke system that privileges access to the national capital.[158]

DEVELOPMENT AND FUNDING

In 1986, Spain made the decision to invest in modernizing its railways, building a new infrastructure for high-speed service as well as suburban rail lines (Cercanías) in its main cities. Today, Spain has most enthusiastically adopted HSR technology with the goal of building a network that by 2024 would allow 90% of Spaniards to live within a 50-km (31-mile) distance or less from an HSR station.[159] In 2005, Spain issued its *Strategic Plan for Transport Infrastructures (PEIT),* which allocated 48% of its transportation budget to railways. More recently, in 2012, a new Strategic Plan – *The Infrastructure, Transport, and Housing Plan 2012-2024 (PITVI)* – was issued, which out of a total budgeted EUR137 billion of investments, allocates EUR53 billion to the rail sector, and EUR40 billion to roadways.[160] Figure 16 clearly indicates the importance given to railway investment in Spain over other transportation modes.

According to the Spanish railway construction company ADIF (Administrador de Infraestructuras Ferroviarias), the Spaniards have achieved the lowest HSR construction cost in Europe at an average of EUR16 million per kilometer, while the cost of building an HSR station in Spain has ranged from EUR15-50 million for medium-sized stations, and from EUR50-200 million for large stations.[161]

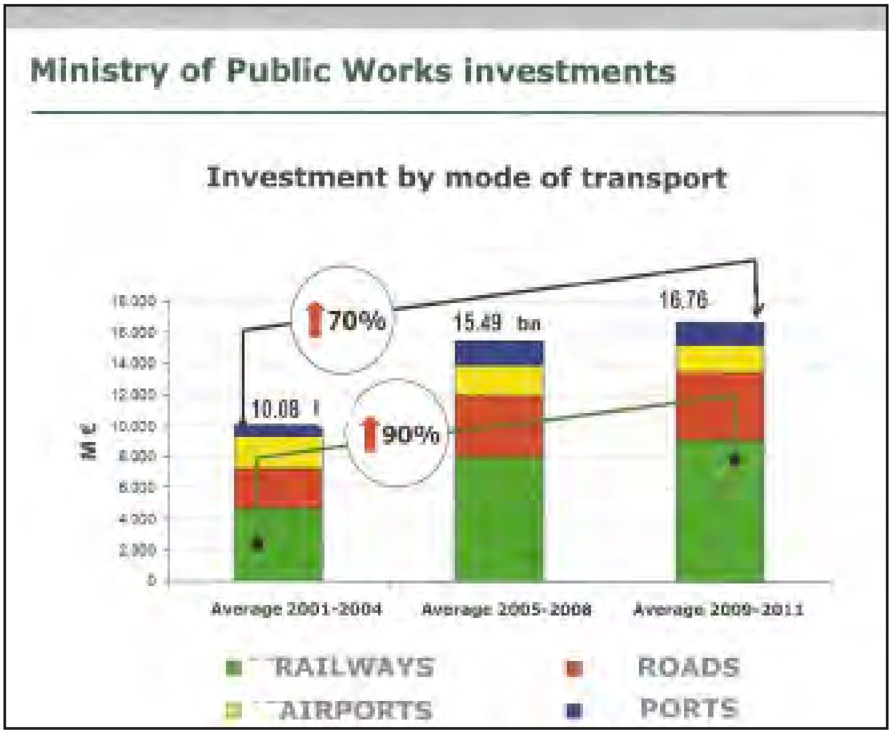


Figure 16. Transportation Investment in Spain (2001-2011)

Source: ADIF (2013) Developing a Successful High Performance Rail Network: The Spanish Case.

As shown in Figure 17, a number of dedicated HSR lines are today spiking out of Madrid, connecting the Spanish capital to other Spanish cities and regions throughout the country. The first HSR line started operation in 1992, connecting Madrid to Seville at the country's southern edge and covering a distance of 293 miles (472 kilometers). The second line, covering a similar distance, opened in 2003 and connected Madrid to Lleida, through Zaragoza. Since then, the Spanish railway construction company ADIF (Administrador de Infraestructuras Ferroviarias) has continued to build additional segments filling in the country's HSR network. Figure 18 shows the completed and under construction HSR lines (operating on International Union of Railways [UIC] gauge) as of June 2013. Unlike in Germany, where the HSR lines connect many similar cities, every Spanish line typically connects two major cities with smaller cities in between.[162]

As shown in Figure 19, the introduction of HSR has led to dramatic reductions in travel time. For example, the trip from Madrid to Seville was reduced from almost six hours to two hours and 20 minutes, a reduction of 58%. The trip from Madrid to Barcelona witnessed a similar 58% reduction in time.

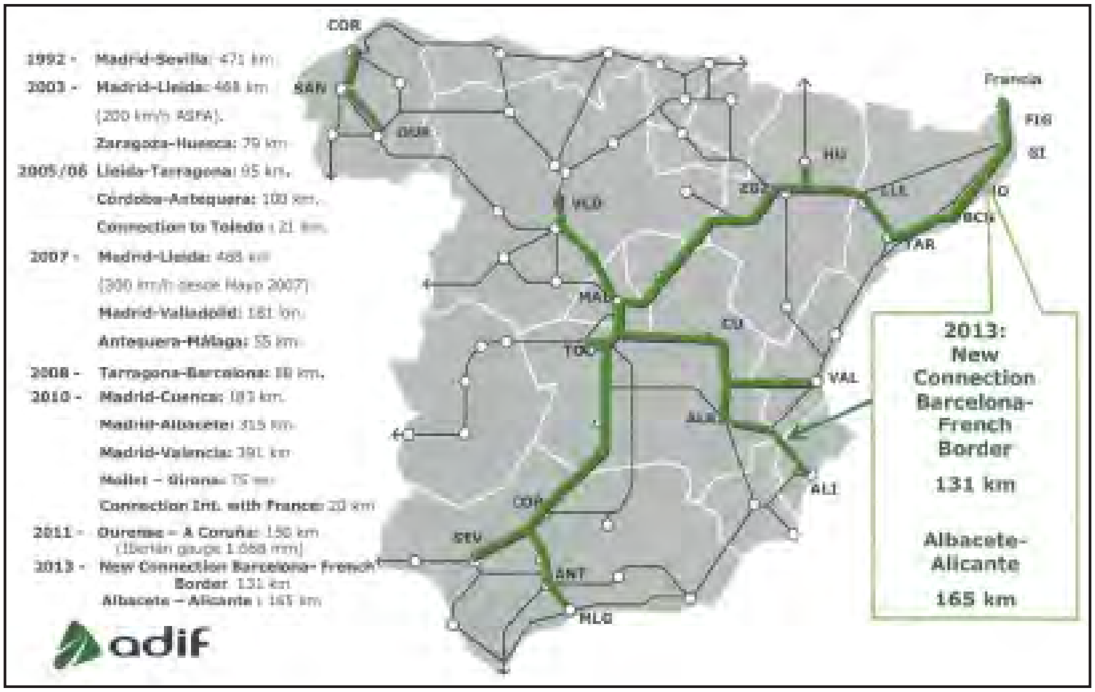
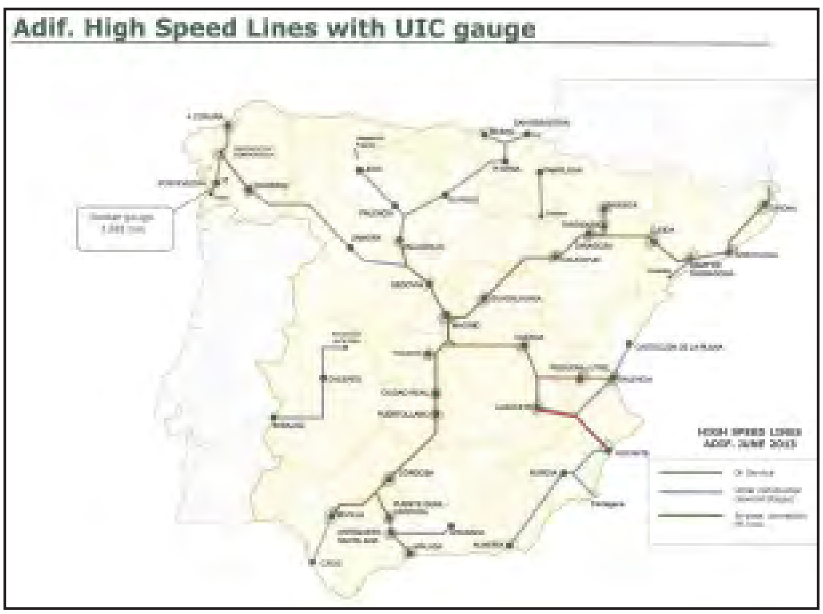


Figure 17. Development of the Spanish HSR Network

Source: ADIF (2013) *Developing a Successful High Performance Rail Network: The Spanish Case.*



On service
Under Construction

Figure 18. Spanish HSR Network: Completed and Under Construction HSR Lines

Source: ADIF (2013) *Developing a Successful High Performance Rail Network: The Spanish Case.*

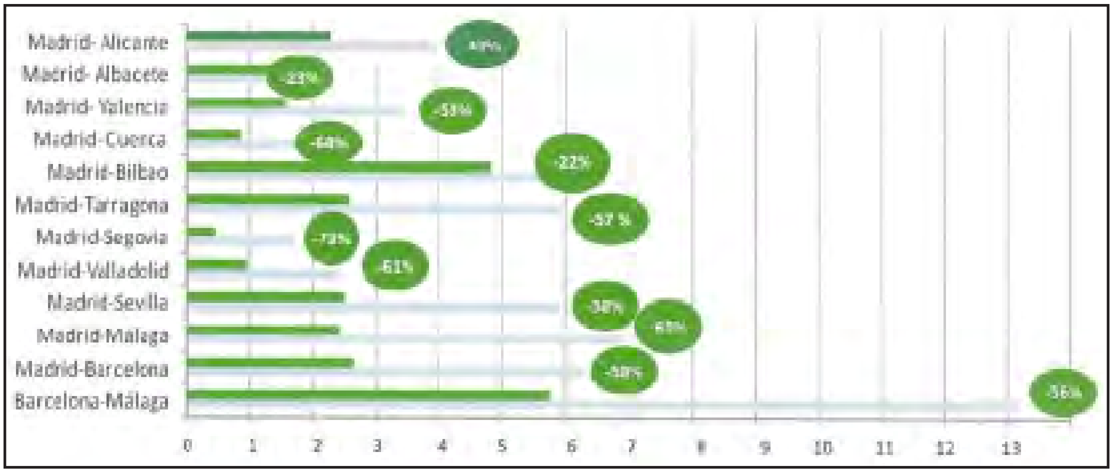


Figure 19. Reductions in Travel Time on the Spanish HSR

Source: ADIF (2013) *Developing a Successful High Performance Rail Network: The Spanish Case.*

Spain has two types of HSR infrastructure: 1) new HSR lines designed for 300-350 km/h, which typically only serve passenger services since the conventional railway infrastructure is maintained along the same (parallel) corridors, and 2) upgraded railway infrastructure designed for 200-250 km/h (124-155 mph), which accommodates both passenger and freight services because there is no parallel conventional infrastructure. The new HSR lines accommodate trains running on three different speeds:

1. Long distance, pure HSR services (AVE) currently reaching 310 km/h (193 mph) maximum speed

2. Mixed HSR services (called ALVIA or ALTARIA) that roll on the new HSR infrastructure for part of their journeys but continue on conventional railway infrastructure (with lower speeds) to reach their destinations

3. Short-distance commuting HSR services (called AVANT), covering distances between 70-200 km (50-125 miles), which roll only on the new HSR infrastructure with maximum speeds of 250 km/h (155 mph)

The mix of these three types of high-speed services may vary, but Spanish HSR expert José Maria de Ureña estimates that their distribution is about 60% AVE, 25% AVANT, and 15% ALVIA-ALTARIA services.[163]

It is also interesting to note the coexistence in the Spanish system of two networks with different gauges: 1) high-speed network with standard European gauge (1,435 mm or 4 ft 8½ in); and 2) conventional network with Iberian gauge (1,668 mm or 5 ft 5 21⁄32 in). As explained in an internal ADIF document: "102 of the 231 High-speed trains in service currently have double gauge, using two different technologies (CAF and TALGO). These trains switch from one network to the other without stopping, by only slowing down the speed to approximately 20 km/h, using a unique gauge exchanger system owned by ADIF."[164]

MANAGEMENT AND OPERATION

Prior to 2005, there was only one railway company in Spain – RENFE (*Red Nacional de los Ferrocarriles Españoles* – National Network of Spanish Railways). Prompted by European Union requirements to separate the monopoly of infrastructure management from the competitive operations of running a transit system (thus allowing the possibility of competition from other transit operators), RENFE was split on January 1, 2005 into two different state-owned companies with discrete missions. These are under the supervision of the Ministry of Transport and Public Works: ADIF that owns the railway infrastructure and is responsible for its management, and RENFE Operadora that owns the trains and is responsible for their circulation.

More specifically, ADIF is a public company responsible for the construction, renovation, and maintenance of Spain's railway infrastructure (both conventional and high-speed), including railway tracks, stations, and signaling. Additionally, ADIF enters into Public-Private Partnerships with private companies for the development of commercial facilities such as shopping centers in its station areas. The company also provides consulting and training to other infrastructure management companies around the world. ADIF is organized in two general divisions: 1) Construction and Operations and 2) Passenger Services.[165] It has a staff of more than 14,000 employees and manages more than 15,000 km (9,300 miles) of railway network. These include 2,381-km (1,480-mile) high-speed with UIC gauge, where trains can run at maximum speeds of 250-310 km/h (155-193 mph), and 737-km (458-mile) high performance with Iberian Gauge that have been improved to reach high-speed parameters, with current maximum speeds of 200-220 km/h (124-138 mph). The company also manages about 4,800 km (2,982 miles) of conventional network (with maximum speed of 140-160 km/h, or 87-100 mph), and 1,566 stations; 29 of these stations accommodate HSR services. ADIF operates about 1.8 million services annually, with more of 20% of them on high-speed trains. There are 324 high-speed trains running every day carrying 102,836 passengers.[166] RENFE Operadora is a railway transit operator that owns the rolling stock and is responsible for planning, marketing, and operating passenger and freight services (though no longer with a legal monopoly).

BLENDED SYSTEM AND INTERMODALITY

Spain's HSR system started out as a separated system in which high-speed AVE trains and conventional services used different track gauges and different electrical systems and thus shared only minor areas at stations. Now, however, Spain has a "third rail" (ALVIA) system that allows both systems to share infrastructure. As discussed in the previous section, ALVIA trains are able to change gauge without coming to a full stop (only slowing to about 20 km/h) and to continue their journey along the conventional railway tracks. Where the HSR trains use the same tracks with conventional rail, the HSR typically has priority, with some exceptions during commuter train peak hours. While the system draws high marks by the Spanish operators (ADIF), who indicated that they do not encounter more delays in the shared parts of their network,[167] one drawback is the limited number of changeover locations, making the network less flexible.

According to the ADIF and RENFE managers interviewed, a high level of intermodality and a smooth level of transition from one mode to the other are achieved in Spain through:

- Careful placement and design of stations
- Coordinated signage
- Integrated ticketing and other passenger services
- Agency coordination among RENFE and ADIF and other travel operators and municipal authorities.

The following sections discuss these areas in more detail.

Station Planning and Design

Station planning in Spain is undertaken by the Ministry of Transport and Public Works but also in coordination with local and regional governments. ADIF officials refer to three kinds of sustainability that their station buildings should promote: environmental sustainability through energy efficient design, good building orientation, and good illumination; social sustainability through the creation of a setting that is not only for transportation but also for commercial and cultural activities (such as concerts); and economic sustainability through the integration of commercial/office space at the station for leasing. Indeed, about 41% of station revenue comes from private businesses (retail stores, malls, hotels, offices, parking, and advertising).[168] As shown in Table 8, a number of Spanish railway stations incorporate substantial amount of commercial space for lease.

Table 8. Commercial and Parking Space in Selected Spanish Stations

Station	Available space for lease (sq. m)	Number of shops
Madrid-Chamartín	21,847	49
Madrid-Atocha	6,081	46
Barcelona-Sants	3,143	30
Valencia Joaquín-Sorolla	1,857	21
Alicante	1,113	16
Girona	917	11
Cordoba	888	19
Sevilla-Santa Justa	2,530	31
Malaga	35,000	102
Albacete	12,766	43

Source: ADIF (October 2013). *Gestión de Estaciones de Viajeros.*

In addition to the economic revenue from leasing commercial and office space, the incorporation of several uses at the HSR station, other than those strictly related to travel, helps to achieve the station's better integration with the surrounding city. This is also helped by good station-building aesthetics. While some Spanish stations are rather boxy utilitarian buildings (Figure 20), other stations benefit from more eye-catching designs (Figures 21 and 22).

Importantly, good integration is also achieved by ensuring good station connectivity with other travel modes. Most HSR stations have easy access (within 1/8 of a mile) to buses and taxi services.[169] Most stations provide park-and-ride spaces. While parking costs and parking discounts differ from station to station, HSR passengers typically receive discounts to leave their cars at the station parking lots. Some stations also have bike-sharing and car-sharing services. Access of bicycles to the trains is not allowed for the long-distance trains (AVE). For the medium-distance (AVANT) trains, bicycles that can be folded and do not exceed a certain size can be transported in the train.

Figure 20. Station Albacete Los Llanos

Source: ADIF website http://bit.ly/1GVC4CZ

Figure 21. Station Cuenca Fernando Zóbel (Brunel Award 2011)

Source: http://bit.ly/1IGTMZ2

Figure 22. Zaragoza Delicias Railway station

Source: http://bit.ly/1IopQoJ

The movement of passengers throughout the station is helped by good interior station layout, appropriate platform placement, and good signage. As shown in Figure 23, there is an effort in many stations to use natural lighting. HSR trains typically use different platforms from conventional trains when they run along UIC-gauge tracks. These platforms are in close proximity to the platforms used by conventional trains. Only in a few cases, the same platform is used for conventional and high-speed trains. Lastly, ADIF regulation determines station signage, which is also coordinated with local authorities.

Figure 23. Zaragoza Delicias Railway Station

Source: http://bit.ly/1LEebUX

Ticketing and Other Passenger Services[170]

Tickets for HSR services can be purchased at station ticket windows and ticket vending machines, but also by phone, through the Internet (RENFE website) and travel agencies. Ticket sales at the station for AVE and long-distance services are typically sold in the same ticket window, while commuter trains within cities have their own ticketing windows. The use of electronic tickets – via internet or cellular phones – which can be automatically read by optical devices at station access points, are rapidly gaining ground over conventional ticket formats. For all services, tickets may be purchased in advance with some discount. Tickets for HSR and long-distance conventional trains and medium-distance or regional conventional trains have assigned seats.

Fares are seamlessly integrated between high-speed and conventional train services. Purchase of a long-distance HSR ticket allows free access to the commuter rail network of the origin or destination city, but it does not allow free access to the subway or buses. RENFE, however, offers combined travel packages. Thus, if a passenger wants to make a trip that requires riding both HSR and conventional trains, he or she can purchase one ticket for the whole itinerary. Tickets for long-distance AVANT services may allow passengers to ride commuter trains at no extra cost. On the other hand, there is no single mobility card integrating tickets of different modes. There are passes for the medium distance HSR trains and passes for commuter trains (for one week, one month, 10 trips, etc.), and passes to all urban transport modes of a specific city (monthly or annual).

Passengers cannot access the train without a ticket. For the HSR service, the ticket check-in takes place before boarding the train and before accessing the platform at a point that is usually located in a dedicated zone of the station's passenger boarding area that is specific for HSR services. Entry into this zone takes place through a security control point that is equipped with scanners for baggage check and random person check. Access always takes place through a boarding gate, where the ticket check-in is performed (the tickets have a bar code allowing optical identification). For HSR services, boarding of passengers (access to platform and train) starts 30 minutes before departure for single-composition trains (200 m long; 656 feet) and 40 minutes for double-composition trains (400 m long; 1,312 feet). Access to the boarding platform is closed two minutes before the scheduled departure time.

In terms of other passenger services, each station has a customers' corridor that encompasses car parking, customer service centers, assistance centers for disabled passengers, boarding zones, lockers, waiting lounges with information boards, video-screens, seating, and a special first-class travelers' lounge. Most HSR trains have private meeting rooms that can be used by passengers holding the most expensive fare ticket (Club ticket) and by government officials.

Inter-agency Coordination[171]

There is frequent contact and coordination between the two public Spanish companies, ADIF and RENFE. There is also considerable coordination with municipal governments (in terms of station area land uses and future development) and managers of other transportation modes (local and national). For such coordination to happen, a public authority is created with members from RENFE, ADIF, and local, regional, and national government representatives. There is constant contact among station managers and those entities responsible for other modes of transportation (city councils, regional government, taxi collectives, etc.) to make the stations more accessible. Although not compulsory by the legislation, there is usually an agreement between ADIF and the city council about the station land uses. For new stations or when the impacts of an existing station's retrofit are important, the Railway Regulatory legislation asks that a feasibility study is reviewed by the city council.

Overall, the Spanish HSR system achieves a good level of physical and operational integration in most of its stations. When asked what recommendations they have for achieving good integration in the California HSR system, the RENFE manager chose to emphasize the importance of seamless integration of different transportation modes, while the ADIF manager stressed the importance of communication among different agencies.

> *I just would like to add that the integration of all transportation modes (metropolitan networks, buses, commuter trains, etc.) in the HST station is essential for people's mobility. The availability of public parking at the station is also essential. Stations that feature both HSR and conventional rail services should ensure their seamless integration, avoiding transfers from one station to the other*.[172]

> *It is very important to create the necessary communication networks among the different public agencies, railway operators, and managers of other transportation modes, as well as to establish appropriate budget allocations.*[173]

SUMMARY

The extensive discussion in this chapter of the different types of blended systems in Germany and Spain and the means by which these systems achieve intermodality provide useful lessons for California that will be further summarized in the concluding chapter of this report. Both countries have been able to achieve a high degree of integration of their HSR systems with the rest of their transportation networks by following spatial strategies that enhance station connectivity and operational strategies that facilitate seamless travel for passengers.

VI. CASE STUDIES OF GERMAN HSR STATIONS

This chapter presents case studies of six German high-speed rail stations. These stations were indicated as exemplary models of intermodality by a number of German high-speed rail experts. They range from large station complexes in inner city areas such as the Berlin Central station, to thoroughly remodeled station nodes in the centers of medium-sized cities such as Erfurt, to rare examples of new ICE stations in secondary locations such as the Berlin South Cross or Kassel Wilhelmshöhe. The case studies give information about each station's context, layout, and integration with other travel modes, as well as the number of rail passengers travelling through the station and the number of HSR services serving each station.

Data for this chapter were gathered from a variety of sources. The authors interviewed representatives of German Railways, and one of the authors also conducted field research in Germany. A great deal of information on new high-speed corridors and station construction projects was publicly available as part of DB's vast spread of promotional and informational materials on websites, but it had to be gathered, re-assembled, and translated from German. Additional information came from European and national transport ministry websites and a number of other documents such as travel guides, station itineraries, and Wikipedia and Wikitravel articles for each station. Lastly, Google Earth or Google Maps were used for aerial photographs for each station.

BERLIN CENTRAL STATION (BERLIN HAUPTBAHNHOF)

Figure 24. Aerial View of Berlin Central Station

Source: Google Maps.

Context

Berlin Central Station is Germany's most high-profile rail mega-project of the last decade. Not only was the entire station re-built from scratch from 1995 to 2006, but also the German capital's entire rail system was completely re-thought and re-railed after German unification in 1990. It is therefore the most extreme and most interesting German example of a newly built station with the highest level of blended service and modal integration. Not only was the station rebuilt, but also were the surrounding rail corridors, covering both conventional rail and high-speed rail segments, all for a total of more than EUR5 billion.

Like many other major European metropolises that underwent rapid industrialization and urban expansion in the late 19th century, Berlin ended up with many different terminal rail stations scattered across its urban core. These terminals were eventually connected via an outer suburban rail ring and an inner-city east-west connection, which formed the basis of Berlin's expanding local rail network. But the city never constructed a north-south axis. So the decision to build the new Hauptbahnhof as a new central crossing station at the approximate location of the former Lehrter Urban Rail Station, right at the intersection of the East-West elevated city rail corridor and a new north-south connection, was the realization of a long-time dream of Berlin transport planners and engineers. A key decision was made in the early 1990s to construct a new tunnel underneath the Spree River and the Tiergarten Park as the centerpiece of a comprehensive restructuring of both the metropolitan and the long-distance rail transport infrastructure system.[174]

No central crossing station had ever existed for regional and intraregional travel. Figure 25 shows the Central Station (*Hauptbahnhof* in German) at the center of a mushroom-shaped system of stations that is further complemented by Spandau station to the west, Gesundbrunnen to the north, Ostbahnhof to the east, and Suedkreuz to the south. All five stations became high-speed rail stations, and all were thoroughly renovated or even rebuilt from scratch. Much has been written about the advantages and disadvantages of the mushroom concept and of the multi-layered combined transport and urban redevelopment megaproject that is Berlin's new Central Station, but it is not necessary to reiterate all those discussions in detail in this particular report.[175] The following section will concentrate on the current functioning of the station as an intermodal transportation hub.

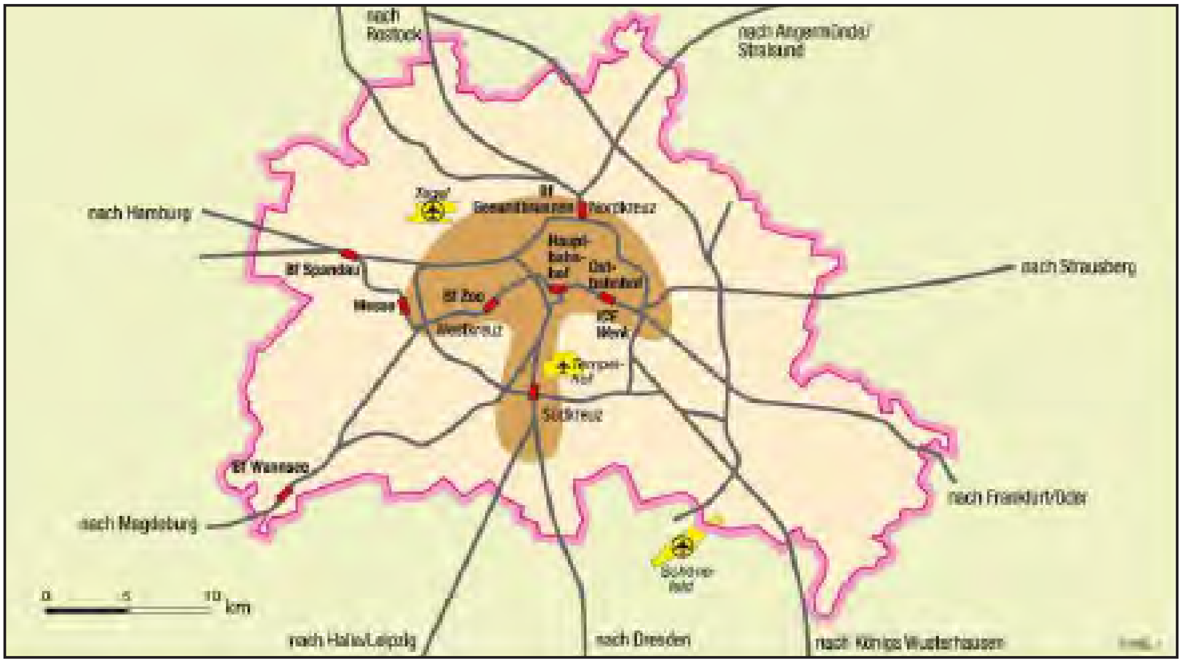


Figure 25. The Berlin Mushroom Concept (*Hauptbahnhof* = Central Station)

Source: http://bit.ly/1Ioq4fM, accessed September 26, 2014.

Figure 26. a-c: Inside and Outside Views of Berlin Central Station

Source: http://bit.ly/1BRnQEd

Station Layout and Modal Integration

The Berlin Hauptbahnhof was built for EUR1.2 billion as a new flagship rail station designed to impress as a piece of architecture and engineering. It was officially opened after years of delays in May 2006, coinciding with Germany's hosting of the Soccer World Cup that year. The new station, with 14 platforms at two different levels, is frequented by 300,000 passengers and by 1,100 long-distance and regional trains per day. It is also home to 161,000 square feet (14,957 square meters) of retail space on three levels with extended shopping hours.

The station is laid out as a crossing station with high-speed, conventional, and local rail transport running in both east-west and north-south directions. Figures 26-30 give a good impression regarding its overall layout. The architects von Gerkan, Marg & Partner conceived the building as a symbolic intersection of a unifying Europe. It is a 1053-feet long glass structure covering the East-West city viaduct, intersected by a 525-feet long (160-meters) and 131-feet wide (40-meters) station hall running in a north-south direction, which is flanked by two glassy towers offering up to 473,000 square feet (43,943 square meters) of office space (Figure 30). All platforms are flooded with daylight. The station has two levels below ground, a ground level, plus two above-ground levels. Trains traveling north-south arrive and leave below ground, while trains traveling each-west arrive on Berlin's *Stadtbahn* viaduct above ground.

The new North-South tunnel accommodates both high-speed and conventional trains but currently no S-Bahn commuter trains. ("S" means *Stadt* = city.) There is a separate tunnel still to be built for a new S-Bahn line. A costly and therefore highly controversial new metro line stub, the U55, also leaves from a separate below-ground metro station. The above-ground tracks are arranged in parallel order, with the northernmost tracks reserved for local S-Bahn travel and the other tracks accommodating a great variety of conventional and high-speed trains. (For a full list of local connections, see Figure 31) One can often see a regional train arriving and leaving on the same track on which an internationally-bound ICE pulls in two minutes later. There are multiple staircases leading down from the top level to the mezzanine and further below, along with several panorama round-shaped elevators, but because they move across so many different floors, they are always slow to arrive and quite cumbersome for people arriving with luggage. The space between the tracks is narrow near the staircases, leading to crowding on high-volume traffic days.

Buses and taxis leave from the northern and southern entrances of the station, and bike parking is available at several locations around the building. Modal integration is thus very high by international standards—although local experts criticized specific aspects of modal integration as having sub-optimal solutions. Although urban redevelopment around the station is slowly gaining speed, and a number of new hotels have been built on the adjacent lots, both the southern and northern plazas still appear empty on many days, especially when rainy and windswept.

Figure 27. Panorama View of the Southern Side of Berlin Central Station, facing the Federal Government Quarter across the River Spree

Source: Deike Peters.

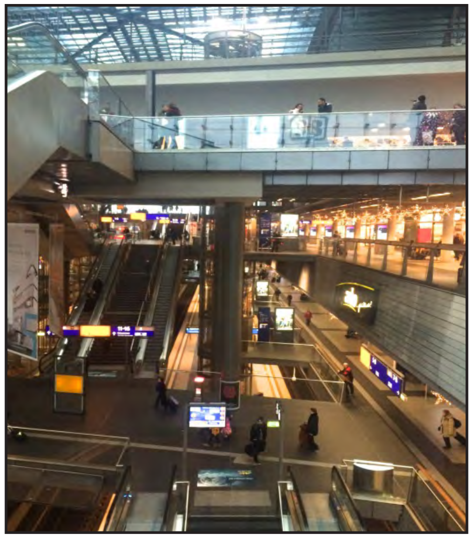


Figure 28. Berlin Central Station Interior

Source: Deike Peters.

Figure 29. Taxicabs at Southern Exit

Source: Deike Peters.

Figure 30. Aerial View of Berlin Central Station at Opening (2006)

Source: © dpa @ http://bit.ly/1ef0fT0

S-Bahn:	S+U Berlin Hauptbahnhof S5, S7, S75	0km
U-Bahn:	S+U Berlin Hauptbahnhof U55	0km
Bus:	S+U Berlin Hauptbahnhof 120, 123, 142, 147, 245, EV, M41, M85, N20, N40, TXL	0km
	Lehrter Str./Invalidenstr. 120, 123, 245, N40	0.2km
	Washingtonplatz/Hauptbahnhof 147, M85, TXL	0.2km
	Seydlitzstr. 120, 123	0.3km
	Döberitzer Str. 142	0.5km
Tram:	S+U Berlin Hauptbahnhof M5	0km
	Clara-Jaschke-Str. M5	0.2km
Regional-bahn:	S+U Berlin Hauptbahnhof IRE IRE, RB14, RB21, RB22, RE1, RE2, RE7	0km
	S+U Berlin Hauptbahnhof (tief) Ausfl, IRE IRE, RB10, RB19, RE2, RE3, RE4, RE5	0.1km

Figure 31. Berlin Central Station Local Connections

Source: http://bit.ly/1NupUCX

Figures 32 and 33 give a good overview of the five-level layout of the station, indicating the precise location of various service points as well as modal connections. The station layout shown on Railteam Europe's website also indicates the location of the business lounges and the car rental service.[176]

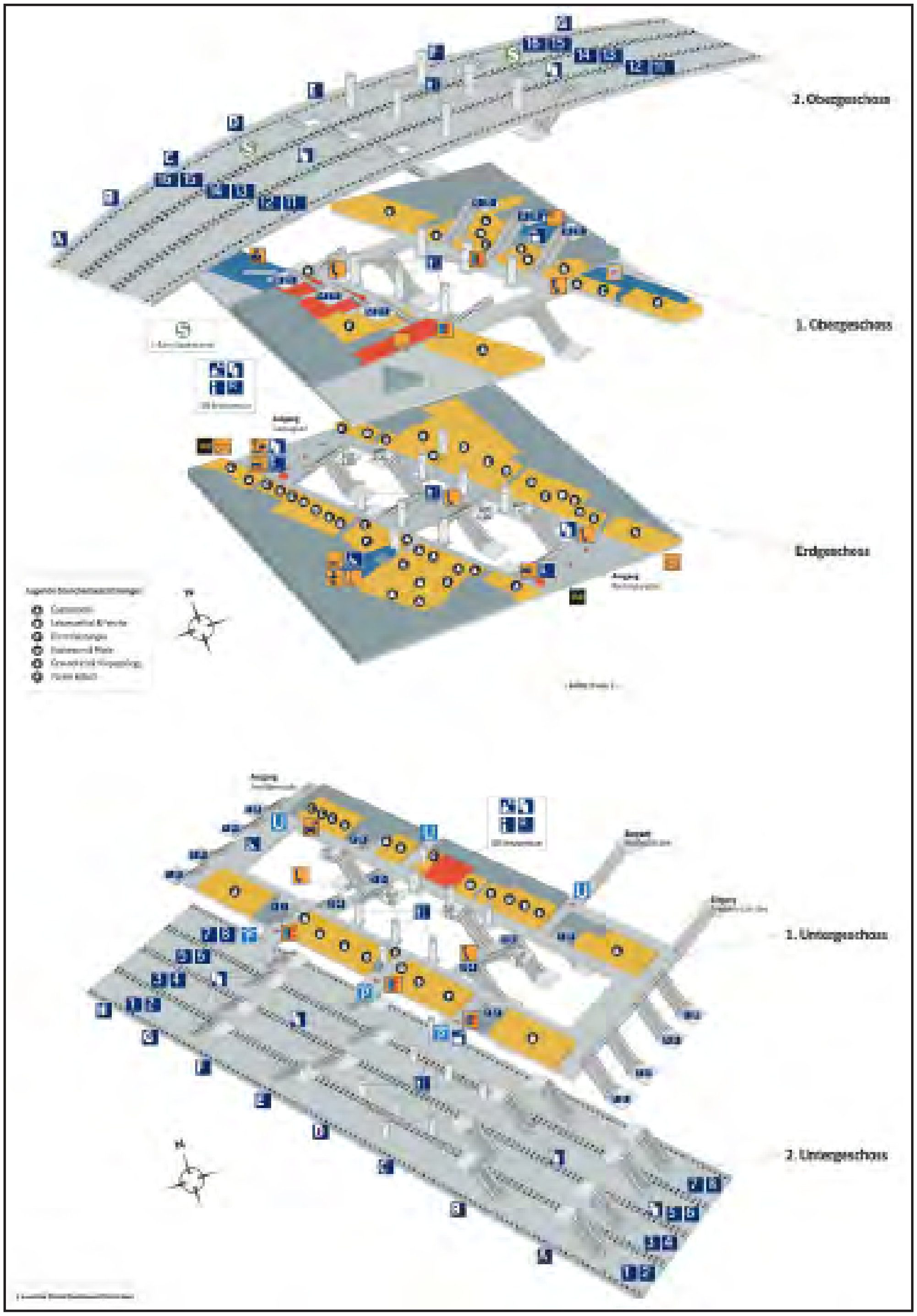


Figure 32. Berlin Central Station Layout

Source: http://bit.ly/1HtslHr, accessed September 20, 2014[177]

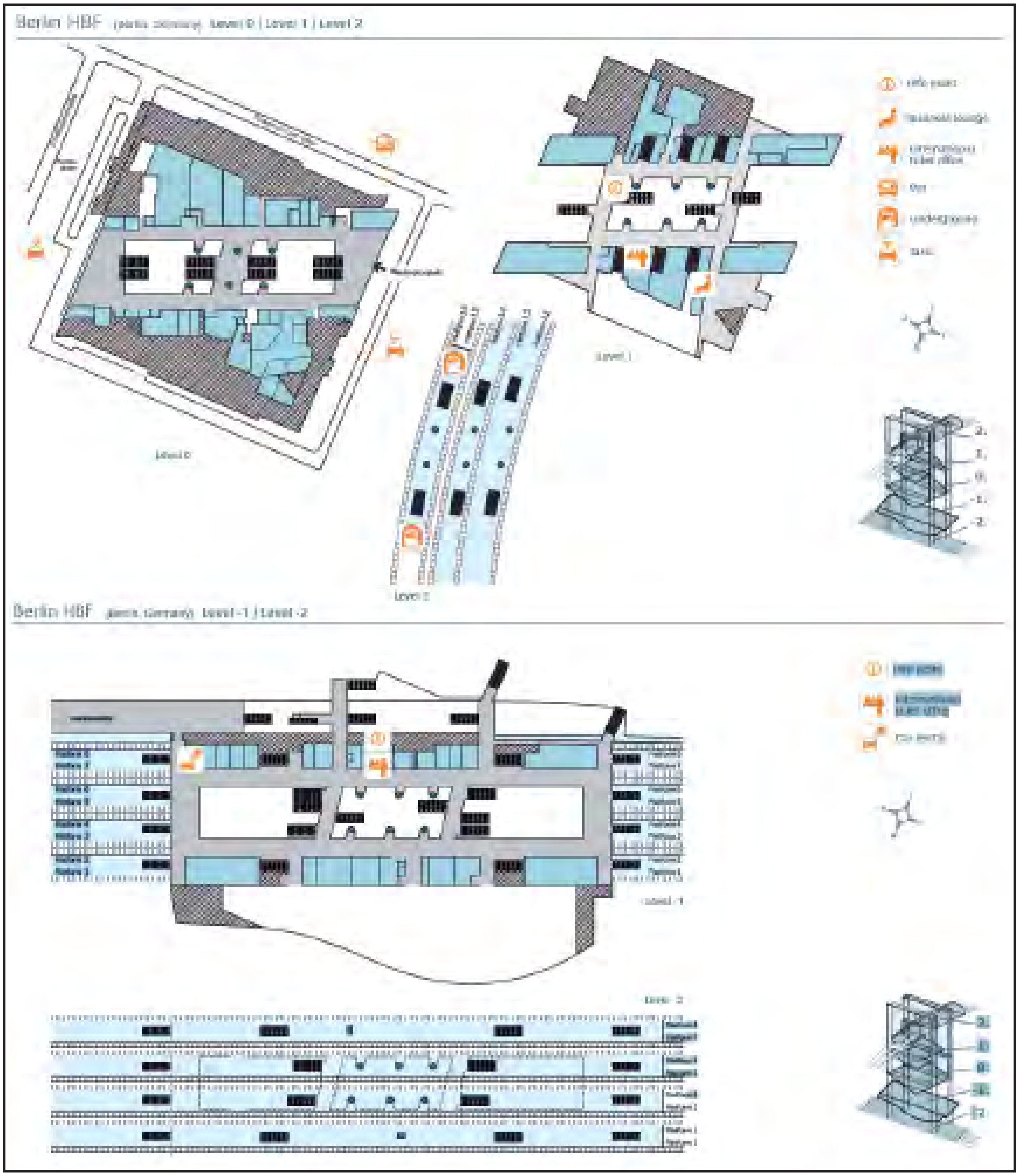


Figure 33. Berlin Central Station Layout (Railteam Europe)

Source: www.railteam.eu via https://www.nsinternational.nl/en/stations/station-maps-floor-plan, accessed September 25, 2014.

Parking

Parking at Berlin Hauptbahnhof has been a controversial issue. The station was deliberately planned to minimize private automobiles, and the vast majority of travelers do indeed arrive at the station via transit. Almost no parking is visible adjacent to the station. There is in fact ample parking in a multi-level parking structure adjacent to the station, but its entrance is relatively hidden. Above ground, it can be accessed via Clara Jaschke Street, but its main access is quite hidden via the underground B96 tunnel. The underground structure has 860 spaces, parking is free for the first 15 minutes, then costs EUR2.50 per hour or EUR22/day (EUR18 at the discounted rate for BahnCard customers) or EUR180/month.

Airport Connections and HSR/Air Competition

Until the new highly controversial Berlin Brandenburg International Airport (BBI) can finally be opened after years of delay and hundreds of millions of dollars of cost overruns, the city still has to operate two international airports, which are accessed from the Central Station. Berlin Tegel airport never had direct rail access, but the TXL Airport bus passes the Central Station every 10 minutes and reaches Tegel Airport in about 20 minutes. Travel to Schoenefeld airport (the future BBI) is possible via the Airport Express Regional trains traveling along the city viaduct, leaving every 30 minutes and reaching this airport 30 minutes later. The cost is EUR3.30 (as of 1/1/2015). The walk from the Airport Express to the terminal is barrier-free but takes about10 minutes.

Summary Evaluation

Berlin Central Station was DB's post-reunification flagship megaproject and is now established as a widely admired architectural attraction in the German capital, strategically located in an area along the former death strip that divided East and West Berlin. Due to Berlin's unique history as a city divided by a heavily militarized wall for many decades, the station had the unusual distinction of having been built in a geographically highly central location in Berlin, yet in an area that was completely undeveloped in the 1990s. Urban development is slowly playing catch-up with the station, which sits in the middle of an area that is over-endowed with expensive rail transport infrastructure and offers strategic advantages for future development.

Box 3: Berlin Central Station Profile

City Population: 3.5 million

Metro Population: 4.5 million

Year Station Opened: 2006

Station Type: DB Category 1

Passenger Volumes: 300,000 passengers/day

Trains: ICE, IC/EC, RE, RB, S-Bahn

Tracks: 16

HSR trains use same platforms as conventional rail

Proximity to other modes:

- Bus, metro or tram (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: train to SFX (30 min) and bus to TXL (20 min)

Parking: subterranean, at station, +860 spaces

Bike Parking: Yes (DB call-a-bike)

BERLIN SOUTH CROSS STATION (BERLIN SÜDKREUZ)

Figure 34. Aerial View of Berlin Southern Cross Station

Source: Google Maps.

Context

Since the early 1900s, this station, which used to be called Papestrasse Station after the nearby street, was a simple changing station for regional commuters, linking the ring rail road, traveling in east-west direction, to the north-south lines for the Anhalter and Dresdner rail roads. The station was significantly upgraded in importance when DB decided to built its new multi-billion-euro long-distance high-speed rail tunnel and make Papestrasse its southern long-distance hub within the mushroom concept described above. After some initial delays prompted by NIMBY opposition, and three years of construction, the station opened concurrently with the new Central Station and took its place in Berlin's new rail hierarchy as its second busiest long-distance station. According to DB, as early as 2006, up to 200,000 travelers per day used the station, including local commuters.

Station Layout and Modal Integration

The station (Figure 35) covers roughly 538,000 square feet (49,982 square meters) of the total station area of 1,500,000 square feet (139,355 square meters). It is conceived as a crossing station with two station plazas and two entrance halls. In addition to the regular commuter S-Bahn, about 120 regional trains and 50 long-distance trains stop at the station every day, with a total of about 500 trains every day. In addition to the S-Bahn, Regional Express lines stop at South Cross, as well as EC/IC lines and ICE lines. The smaller station plaza at the north-east corner and the two station plazas toward the west are home to several bus stops. The north-west entrance is not open to the public but used only by the federal police, who have a station there.

The railway station was supposed to overcome the barrier effect that the old commuter station had, separating the districts Tempelhof and Schöneberg. The station building is notable for its lack of commercial development inside the station, especially compared with other high-use stations. It is located in close proximity to one of Berlin's major big-box store areas, however, with the southern exit nicknamed "IKEA exit" by locals.

Figure 35. Close Up Aerial View of Berlin Southern Cross Station

Source: © Denis Apel via http://bit.ly/1SYycqr

In early 2014, DB Station and Service opened its first long distance bus station at Südkreuz, with about 500 departures per week. Car and bike sharing are also available, and both are soon to include electric options. By mid-2015, the 204 bus line is to feature an emission-free electrical vehicle linking South Cross to Zoo station in the center. In 2014, DB also installed two wind turbines on the station roof and an 8,000kWh solar mover to create an autonomous micro smart grid (MSG) that can now power ten charging stations for electric vehicles, five charging stations for electric bicycles, and the inductive charging system for the electric bus.[178] These and other initiatives are part of a federally funded project called Intelligent Mobility Station: Thematic Train Station 'Networked Mobility and Energy (Figures 36-38).[179]

Figure 36. New Solar Mover at the Southern Exit

Source: http://bit.ly/1Lyt0r3

Figure 37. Covered Bicycle Parking

Sources: http://bit.ly/1LEeDCk

Figure 38. New Wind Power

Sources: © Deutsche Bahn AG/Pablo Castagno.

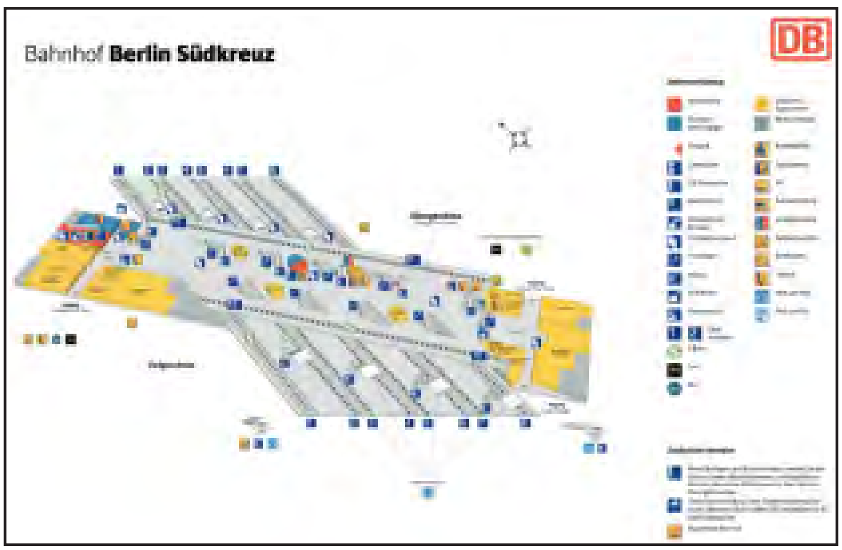


Figure 39. Berlin Southern Cross Station Layout

Source: http://bit.ly/1LR0Y84

Figure 40. a-b: New Electric Vehicle Charging Stations / EVlink

Source: http://bit.ly/1JtnHd4

Parking

There are about 200 parking spaces at the station, located in a parking structure above the tracks. The station was always intended as a drivers' station for people accessing the HSR routes to the north and south. The station has good automobile access via the southern ring road, visible in the aerial of Figure 34. So, initial plans envisioned many more parking spaces, but so far demand for them has not materialized. As explained:

> *When Suedkreuz Station was ultimately built, only the lower level of each of these parking garages was built, and only one of the two platforms was equipped with an access ramp for cars. The other currently sits vacant and can only be accessed by foot. Each of these platforms was built in order to be able to accommodate four additional stories of parking at a later date, if demand warranted it.*[180]

Airport Connection and HSR/Air Competition

To get to Tegel Airport (TXL) in the north of Berlin, passengers can either take the regional train until Berlin Central Station and then an Express Bus, which stops directly at the airport, or take a local train to the S-Bahn Station Jungfernheide and then change to bus that takes them to Tegel Airport. Each version takes about 35 minutes. To reach Schoenefeld airport (SFX), passengers should take a local train for a 30-minute ride.

Summary Evaluation

DB is trying hard to further increase the station's attractiveness as an intermodal mobility hub at the southern tip of the urban core. The station is used by many passengers but is regarded as a functional station only. It is not nearly as beloved as the much more attractive Central Station that has ample commercial, retail, office and hotel development nearby.

One of the interesting recent developments is DB's participation in the federally funded e-mobility pilot project, as well as its decision to become its own competition by co-operating with several new long-distance bus services from the station. The choice here is comparable to what the Megabus service in California might offer in comparison with a future high-speed rail service. For example, while DB offers high-speed rail service from Berlin to Dresden in about two hours, a regular one-way rail ticket costs about EUR40, while tickets for the long-distance bus, which travels the same distance in about 2 hours 45 minutes, start at around EUR5, thus representing a clear advantage for the price-conscious travelers.

Box 4: Berlin South Cross Station Profile

City Population: 3.5 million

Metro Population: 4.5 million

Year Station Opened: 2006

Station Type: DB Category 1

Passenger Volumes: 200,000 passengers/day

Trains: ICE, IC/EC, RE, RB, S-Bahn

Tracks: 10 (six for long-distance rail, plus two upstairs and downstairs, each for S-Bahn)

HSR trains use same platforms as conventional rail (IC/EC/RE/RB)

Proximity to other modes:

- Bus, metro, or tram (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connections to airports: 1-seat S-Bahn ride to SFX (~30min) and a train-to-bus connection to TXL airport (~35 min)
- Multiple long-distance buses (less than 5 min)

Parking: Yes (200 spaces in adjacent structure)

Bike Parking: Yes (DB call-a-bike)

HANNOVER MAIN STATION (HANNOVER HBF)

Figure 41. Aerial View of Hannover Main Station

Source: Google Maps.

Context

Hannover Main Station is a Category 1 station strategically located at the center of Germany's poly-centric structure. In fact, although Hannover is a city of modest size and importance, it may be legitimately considered Germany's most central rail hub. As Albate and Bel[181] find in their recent study:

> *In contrast to other experiences, such as those of the Japanese or French, we find that the primary hub in terms of centrality has a value of only 14 percent. This means that of all the origin-destination pairs of the German high-speed rail network, [only] 14 percent pass through its station. This hub is Hanover, which plays an important role in the connections between the east and west of the country. The rest of the hubs all have values lower than 10 percent. It should be remembered that in the case of Japan the primary hub [Tokyo] has a value of 70 percent, and in the case of France, Paris enjoys a centrality value of 54 percent. There is no question that the design of the network reproduces the existing decentralization found in the system of German cities.*

The construction of the new high-speed rail corridors (NBS) from Hannover to Berlin and from Hannover to Wuerzburg have significantly reduced travel times in both directions. For trips to Berlin, the new corridor saved a full hour off the trip, reducing it to an (almost) commutable time of about 1hour and 45 minutes to the German capital.

Station Layout and Modal Integration

Hannover Main Station (*Hannover Hauptbahnhof*, or Hbf, in German) features all the related amenities and services that Category 1 stations demand. It has six platforms with 12 platform tracks and two through tracks without platforms (Figure 42). It is used by 250,000 passengers per day, with 622 trains arriving and departing every day. The entrance to the station was completely rebuilt as part of the preparations for the EXPO 2000 World Fair, which took place in Hannover that summer. The Hannover S-Bahn also opened that year. Additional elevators were added at that time and additional daylight was brought into the station. Moreover, a large new 75,350 square feet (7,000 square meters) shopping promenade (Figure 44) was created extending outward from the entrance, with additional modifications carried out between 2004 and 2006. The passageway now transitions into Niki-de-Saint-Phalle promenade, creating 215,278 square feet (20,000 square meters) of retail on two levels.

To the north, at Raschplatz, the Central Bus Terminal (ZOB in German) is also the central terminal for the so-called *RegioSprinter* regional bus lines. Many other buses and tram/light rail lines also stop at Ernst-August Plaza. The underground passageway to Fernroder Street is home to a bike station where customers can rent, store, and have bicycles repaired. Another bike station is located at the Raschplatz parking structure. The underground parking structure is also home to a car-sharing station. Taxis are available both at the Ernst-August-Platz and the northern exit (Figure 43).

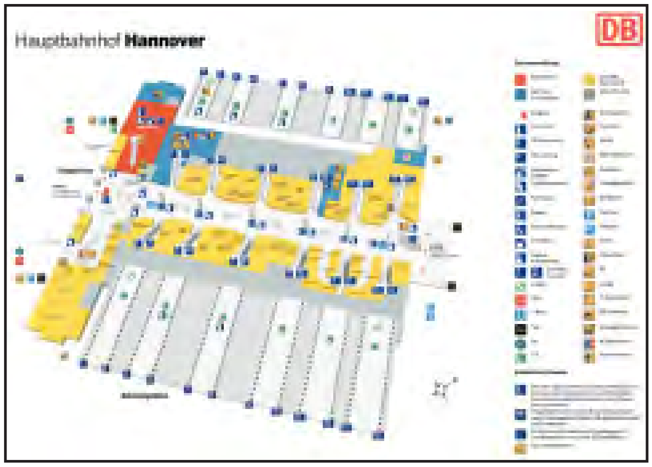


Figure 42. Station Plan Hannover Station

Source: http://www.bahnhof.de/file/6504612/data/Hannover%20Hbf_de_PDF.pdf

Figure 43. Taxicabs and Bike Parking in front of Hannover Station

Source: © Ra Boe (accessed via Wiki Commons at http://bit.ly/1dsYXTG).

Figure 44. View of the Pedestrian Promenade in front of Hannover Station
Source: © Heidas (accessed via Wiki Commons at http://bit.ly/1JtnOFp).

Parking

The parking structure at Raschplatz has about 1000 parking spaces, and several additional parking structures are nearby.

Airport Connection and HSR/Air Competition

The new S-Bahn that opened in 2000 also linked the airport with the main station, leaving once every 30 minutes and reaching it in about 20 minutes. Hannover airport is not one of Germany's major airports, and it primarily offers regional connections and service to major European holiday destinations for the Lufthansa subsidiary Germanwings.

Summary Evaluation

Hannover Main Station is a good example of a well functioning intermodal station. It is also Germany's most central hub, although this feat is not as meaningful in this poly-centric system as it would be in a country with a clear primate city such as Paris in France or London in the UK. Hannover was heavily bombed in WWII and is not considered an attractive city, so it does not interest many tourists. However, it does become a major international destination every March when it hosts the CeBit, the largest annual computer/tech exhibition in the world. Locals and visitors alike can take advantage of the city's excellent public transport system using the Hannover Card. The main station lies right at the center of this well-integrated local system.

Box 5: Hannover Station Profile

City Population: 0.5 million

Metro Population: 1.1 million

Year Station Opened: 1879, last rebuilt 2000

Station Type: DB Category 1

Passenger Volumes: 250,000 passengers/day

Trains: ICE, IC/EC, RE, RB, S-Bahn

Tracks: 12

HSR trains use same platforms as conventional rail (IC/EC/RE/RB)

Proximity to other modes:

- Bus, metro or tram (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connections to airports: 1-seat S-Bahn ride (~20min)
- Multiple long-distance buses (less than 5 min)

Parking: Yes (1000+ spaces in nearby structures)

Bike Parking: Yes (DB call-a-bike), and additional bike services as well.

KASSEL WILHELMSHÖHE STATION (KASSEL WILHELMSHÖHE FERNBAHNHOF)

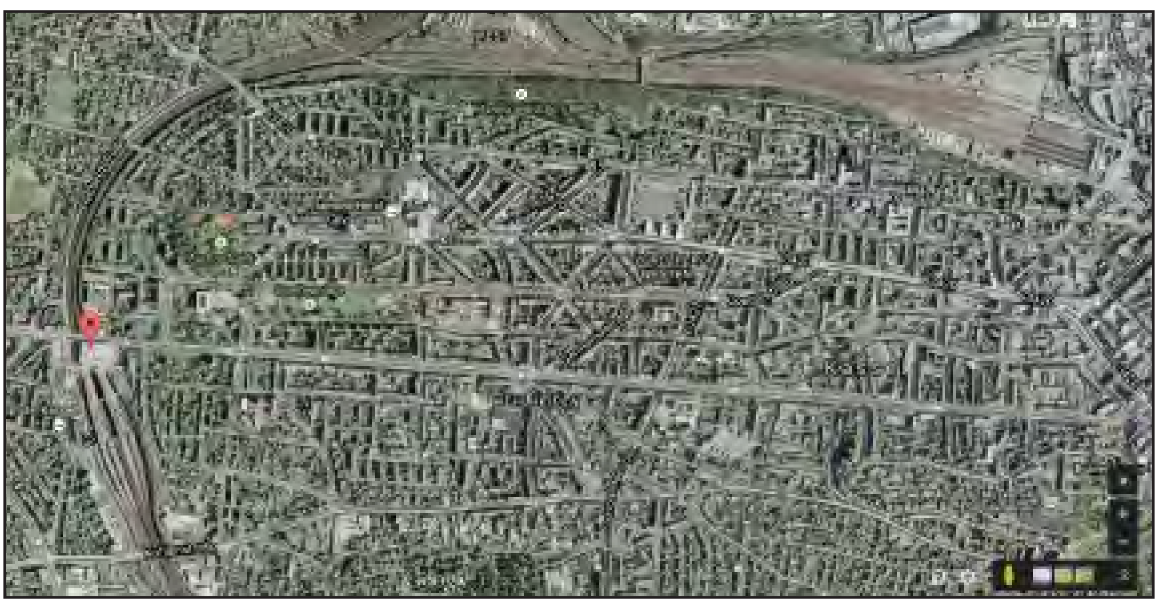


Figure 45. Aerial View of Kassel Wilhelmshöhe Station

Source: Google Maps.

Context

The Kassel Wilhelmshöhe Station, visible on the left side of Figure 45, is the most important modern new station built as part of the inaugural high-speed rail network in Germany. There were plans for a new station in Kassel as early as 1971, when the country first discussed the new high-speed rail line from Hannover to Wuerzburg. The Kassel Main station, visible on the upper right corner of the same map, is a terminal station. Connecting this station to the new line would have been possible only via a very expensive and controversial underground approach that was discussed as a parallel option. When it finally became clear that Wilhelmshöhe, which had always been favored by DB, was going to win over the Kassel Main Station, the city acted smartly and sought to re-enliven the underutilized parts of its central station with a variety of cultural functions. These include theater and movie studios, concert venues, restaurants, and meeting rooms. Thanks to the new high-speed train station, Wilhelmshöhe, on the other hand, successfully developed into a vibrant secondary center with excellent local, regional and long-distance transit options. The new station, which opened in 1991, was originally planned to be an ICE-only station. However, once the decision in favor of Wilhelmshöhe was made, the city no longer sought to curtail operations there and committed to operating regional rail from that location. There is another key piece to understanding the evolving puzzle of inter-modality in Kassel. By 2007, planners turned Kassel Main station into a partial through station, thus enabling a unique connection between the regional heavy-rail network and the local tram network, creating a new RegioTram tram-train system that follows the famous Karlsruhe model. This is a combined tram/commuter train system that allows urban trams to use regional commuter tracks outside the city to extend their reach.[182] Kassel is thus in the unique situation of featuring a main station. Despite its remaining hub function for local/regional rail travel, it is in fact only the city's secondary station, with Kassel Wilhelmshöhe now being the more important train stop and the only one for ICE trains.

Station Layout and Modal Integration

The station is a through station with four tracks for boarding and two bypass tracks (used for/by freight trains). The western tracks are used primarily for long-distance trains, whereas the eastern tracks are used primarily for regional trains.

Figure 46. Aerial Close Up of Kassel Wilhelmshöhe
Source: © P Krause at http://www.fotocommunity.de/pc/pc/display/21073296

The platforms are long and function as long ramps that lead up to the 722-feet (220-meter) long entry building at the northern end that runs perpendicular to the platforms. Additional stairs and elevators are at the northern end, leading to the two-level parking structure. The entry plaza, an extension of Wilhelmshöhe Allee, is covered by a 295-by 213-feet (90-by-65-meters) roof that is about 50 feet (15 meters) high. This is where the trams and all buses (local and long-distance) depart.

Figure 47. Station Layout Kassel Wilhelmshöhe

Source: http://bit.ly/1QZSYIt

Parking

Ample parking is available at this station. In fact, DB originally wanted to design the station with long ramp platforms so cars could drive all the way up to the platforms, but luckily, this concept was dismissed. But the long ramps remained an integral part of the overall station design.

Airport Connection and HSR/Air Competition

As noted in Box 6, Kassel has only a very small airport that serves few destinations. So the ICE presents an excellent access mode for visitors and residents wishing to access the city to and from the international airports at Dusseldorf, Frankfurt, and even Berlin and Hannover. As described in more detail in Chapter 5, DB and Lufthansa have recently expanded their AIRail cooperation to include additional cities from which Frankfurt Airport can be accessed via a direct ICE train. This train carries a Lufthansa LH flight number, and service to and from Kassel opened in 2014. The one-seat ride from Kassel Wilhelmshöhe to Frankfurt Airport takes 92 minutes.

Summary Evaluation

Kassel Wilhelmshöhe is second only to Hannover in its centrality within Germany (Figure 48). This new station was always an integral part of the country's new ICE system, sitting right at the intersection of the initial north-south and east-west ICE corridors. The station was opened on the same day that ICE service was officially initiated in Germany on May 29, 1991. On that day, Germany's first five ICE trains left Bonn, Hamburg, Mainz, Stuttgart, and Munich, all timed to reach Kassel Wilhelmshöhe at the same time. This created the historic moment when "German President Richard von Weizsäcker symbolically switched the exit signal to green at 12:00 noon and declared high-speed traffic in the Federal Republic of Germany open."[183]

Normal times in 2009 from Kassel-Wilhelmshöhe via Intercity-Express and InterCity		
City	**Intercity-Express**	**InterCity**
Amsterdam	5:22	--
Basel	4:18	--
Berlin	2:29	4:10
Brussels	4:54	--
Frankfurt	1:23	2:02
Hamburg	2:11	2:59
Hanover	0:53	1:28
Cologne	2:37*	3:28
Copenhagen	7:36	--
Leipzig	--	2:45
Munich	3:15	4:08
Paris	5:39	--
Stuttgart	2:56	3:52
Vienna	6:56	--
Zurich	5:23	7:21

Figure 48. ICE Travel Times from Kassel

Source: http://en.wikipedia.org/wiki/Kassel-Wilhelmsh%C3%B6he_station

Box 6: Kassel Wilhelmshöhe Station Profile

City Population: 200,000

Metro Population: 1.2 million

Year Station Opened: 1991

Station Type: DB Category 2

Passenger Volumes: 53,000 passengers/day

Trains: ICE, IC/EC, RegioTram

Tracks: 6 + 4 (local)

HSR trains can use same platforms as conventional rail (IC/EC/RE/RB)

Proximity to other modes:

- Bus and RegioTram (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min) [Flinkster, Sixt]
- Connections to airports: AIRail ICE service to Frankfurt Int'l Airport (with LH flight number) since December 2014 (98 minutes); bus connection to the local Kassel-Calden Airport (40 minutes). This new, small, already failing regional airport offers only select flights to a handful of holiday destinations.
- Multiple long-distance buses (less than 5 min)

Parking: Yes (365 spaces in adjacent structures for longer terms and 17 short-term [1hr] spaces)

Bike Parking and Renting: Yes

LEIPZIG MAIN STATION (LEIPZIG HBF)

Figure 49. Aerial View of Leipzig Main Station

Source: Google Maps.

Context

The historic Leipzig Main Station opened in December 1915 as a new central rail terminal that unified rail operations in this rapidly growing industrial East German city. The massive station once boasted as many as 26 tracks. Together, the entry and train halls covered 893,400 square feet (83,000 square meters), making it the largest station in Europe (and perhaps the world) in terms of building volume. The station was heavily damaged in WWII but rebuilt by the East German government. With about 120,000 daily travelers, it is the twelfth-busiest long-distance station in Germany (along with Bremen Main Station). Its 21 current tracks now include two through tracks.

The station forms an integral part of the Transport Project German Unity 8 (VDE8) already described in Chapter 5 as one of the few new high-speed rail corridor projects currently still underway in Germany. This megaproject has important impacts on the current functioning of the station due to ongoing construction, but DB consoles customers with the promise of significant future time-savings (Figure 52). VDE8 is also supported by the EU as part of the Trans-European Rail Network #1 extending from Scandinavia to Sicily (Figure 50).[184] Within Germany, DB is particularly focused on being able to offer a high-speed ride from Berlin to Munich in less than four hours, thus making rail competitive with air (~3hr) and automobile (~5 1/2hr) for downtown to downtown travel. Rail currently has a 20% mode share for this connection, but DB officials are hopeful that they could potentially double this to capture 40% of all Berlin-Munich trips once VDE8 is completed.

Figure 50. The Leipzig and Erfurt Nodes within the Context of VDE8 and TEN-T1

Source: http://www.vde8.de/

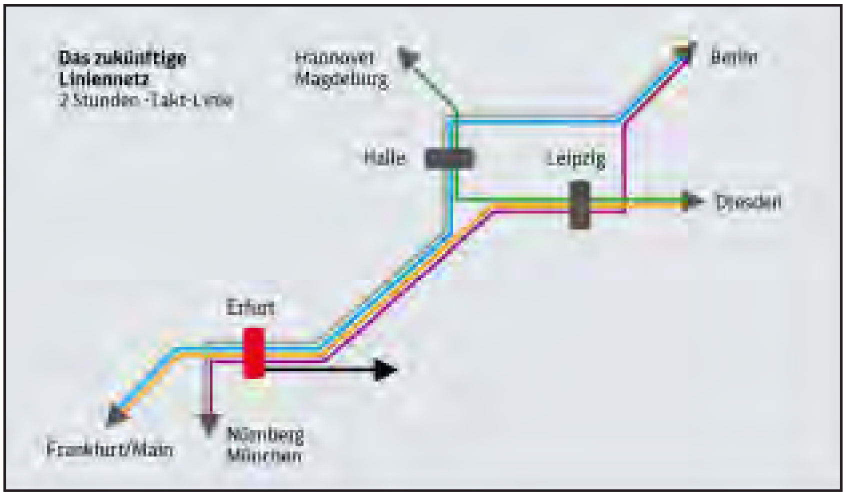


Figure 51. DB's Plans for a Faster, Integrated ICE Network along VDE 8

Source: DB Netze (2014) p.4 and http://www.vde8.de/---_site.project..ls_dir._likecms.html

As much as 6.8 miles (11 kilometers) of track and 75 switches are being replaced around the Leipzig station for more than EUR30 million, part of a larger EUR120 million investment in this construction phase. Further investments are planned for a second phase until 2017. Overall federal investments for the integration of the Leipzig rail node into the new high-speed corridor will go up to EUR350 million, ultimately resulting in significantly reduced travel times to Erfurt (45 minutes), Munich (3:10 hours) and Frankfurt/Main (3 hours) (Figure 51). Upon completion of the VDE8, Leipzig will become a major node in DB's new integrated ICE train schedule (*Integraler Taktfahrplan* or ITF in German), with ICE trains converging in Leipzig at 15 and 45 minutes past the hour.

Figure 52. DB Advertizing Reduced Travel Times After Full Completion of VDE8

Translation: Fahrzeiten = travel times; heute = today; zukünftig = future; Ersparnis = saved time; ab/seit = from/since; Sprinterzüge = express ICEs (making no interim stops)

Source: DB Netze (2014) p.3[185]

Station Layout and Modal Integration

The massive station façade facing Leipzig's city center is 978 feet (298 meters) wide. Four years after reunification, in 1994, the station, along with Koln Main Station, was selected for a national pilot project promoting the transformation of high-use stations into multi-functional nodes including increased commercial opportunities. The area near several platforms, which were no longer in use, was repurposed. A large section of the cross platform was taken out to insert a large multi-story shopping mall into the station, offering over 753,000 square feet (69,956 square meters) of retail space distributed across many different shops. Retail operator ECE supervised the construction and still manages the center today. DB leased the space to ECE for 70 years. Many people feared that the large mall would kill commercial development in the rest of the city center. But despite additional competition from greenfield development, the inner city remains vibrant. As part of the ICE upgrading, two platforms are being extended by 262 feet (80 meters) and raised by six inches (0.15 meter) so that they can accommodate trains as long as 1,378 feet (420 meters) in the future.

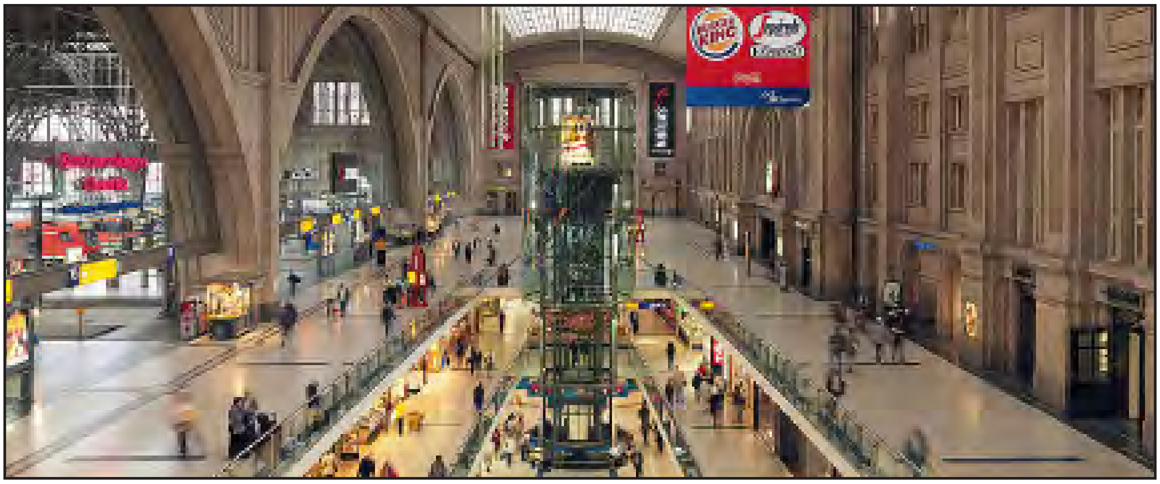


Figure 53. Inside View of Leipzig Main Station with Promenaden Shopping Mall

Source: © *HPP* @ http://bit.ly/1g3bm2B

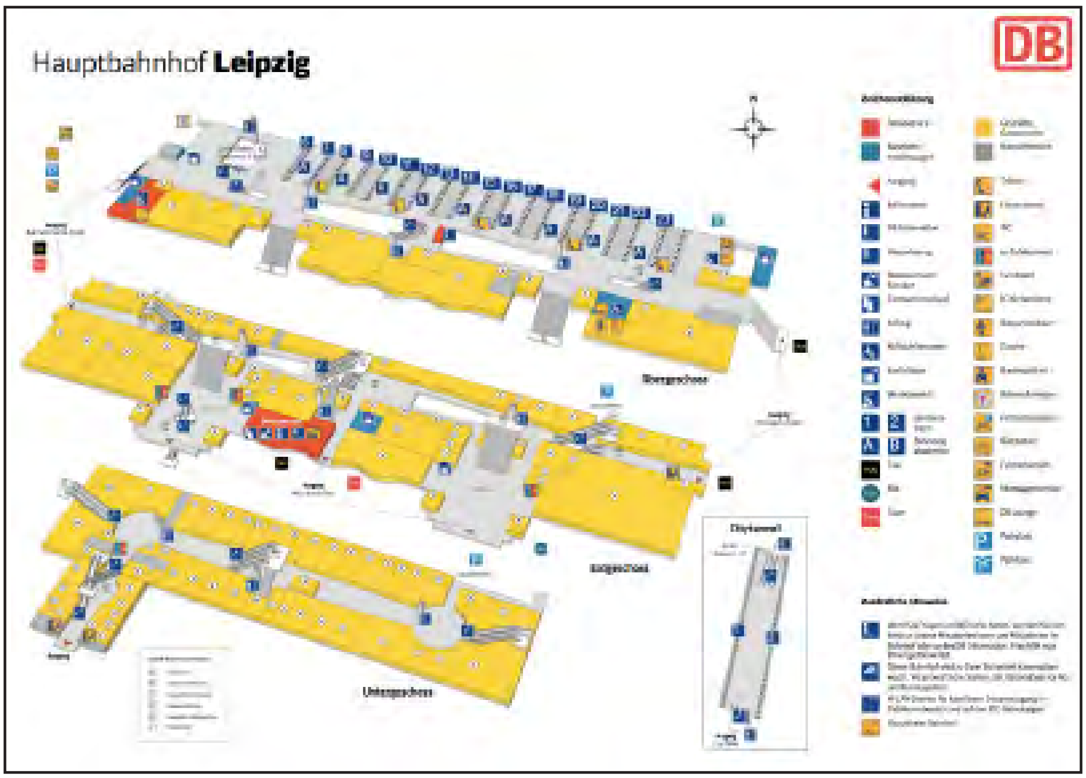


Figure 54. Leipzig Station Layout

Source: http://www.bahnhof.de/file/6501290/data/Leipzig_Hbf_de_PDF.pdf

Besides its future enhanced role within the ICE network, Leipzig is also a key hub in DB's regional southeastern S-Bahn network for central Germany. This regional network was also substantially enhanced recently by the completion of the so-called *City-Tunnel,* opened in December 2013, which provides a new through connection from Leipzig Main station to Bayrische station and onward into the region. Additional local transit is provided by the Leipzig Transit Operators (LVB), who operate various tram and bus connections leaving from the station.

Parking

As part of the comprehensive remodeling in the second half of the 1990s, a 600-space parking structure was built near the platforms. The original plans for a multi-story structure met with intense resistance from the public and preservation advocates resulting in a compromise. In order to create a visual transition between the station building and the parking structure, an exhibition of several historic rail cars was placed along the old track 24, featuring a steam locomotive and several electric engines.

Airport Connection and HSR/Air Competition

The integration of the regional airport Leipzig/Halle into the ICE network was always an integral element of the VDE8 plan, but ICE connections to the airport are currently operating only twice a day. Most of the time, passengers must still take the hourly ICE trains to Halle or Leipzig and then change to one of the local trains that make the journey out to the airport in about 20 minutes. The airport is of regional significance and provides decent connections to other major German cities and vacation destinations. It served around 2.2 million passengers in 2012.

Summary Evaluation

Leipzig Main Station was comprehen-sively remodeled in the late 1990s to house a major shopping mall. Its local and regional multimodality was enhanced in 2013 with the opening of the Leipzig City Tunnel that provided a hitherto impossible through connection underneath the city center for local trains. The station's multimodality will be further enhanced once the new VDE 8 HSR corridor is completed, providing significant additional time saving for national and international destinations.

Box 7: Leipzig Station Profile

City Population: 550,000

Metro Area Population: 1 million

Year Station Opened: 1915/1997

Station Type: DB Category 1

Passenger Volumes: 120,000 passengers/day

Trains: ICEs 28, 50, ICs 50, 55, 56, REs 6, 13, 50, RBs 57, 110, 125, MRB 113, EB, S-Bahn # 1, 2, 3, 4, 5, 5x (to airport)

Tracks: 21 (19 terminal, two through)

HSR trains use same platforms as conventional rail, but tracks are/will be pre-designated.

Proximity to other modes:

- Bus, metro or tram (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: S-Bahn 5/5x, ICE

Parking: inside station, 600+ spaces

Bike Parking: Yes (DB call-a-bike, Nextbike)

ERFURT MAIN STATION (ERFURT HBF)

Figure 55. Aerial View of Erfurt Main Station

Source: Google Maps.

Context

Erfurt Main Station is located atop the city's old 14th century fortification wall, just south of the center of the old city. Erfurt features one of the best-preserved medieval city centers in Germany. Its first station was built in 1846 and remains standing today but was replaced by a new station 100 feet away in 1893. After that, Erfurt station became an "island station" (*Inselbahnhof*) with a station entry hall at the station plaza that featured shops and ticket counters and an arrival hall set between the tracks. Due to the elevated nature of the tracks, car and pedestrian traffic was always able to flow easily under the tracks. This second station was comprehensively renovated between 2002 and 2008 to function as a key node linking the new ICE high-speed corridor from Berlin to Munich with the high-speed line between Frankfurt and Dresden. Figure 57 shows the alignment of the new high-speed corridor in relation to the existing rail corridor.

Figure 56. Erfurt Main Station Façade

Source: CC Michael Sander @ http://de.wikipedia.org/wiki/Datei:Erfurt_Hbf_Front.JPG

Figure 57. The New High-Speed Corridor's Alignment through Erfurt Main Station

Source: DB AG Graphic @ http://www.vde8.de/de/knoten-erfurt

Station Layout and Modal Integration

Concerned citizens and historic preservationists were strongly opposed to the razing of the historic arrival hall sitting in the middle of the tracks, but DB prevailed and today the historic entry hall at the station front is all that remains of the historic station (Figure 56). A 32,000 square-feet (2,973 square-meters) retail and commercial space was created underneath the tracks, with an underground parking structure below. The station is undercut by the station street, which offers excellent local transit connections via tram lines and bus lines. Additional local buses leave from the bus terminal at Bürgermeister-Wagner-Straße. The adjacent Kurt-Schumacher-Straße provides car access to the station and its parking spaces as well as the taxicab waiting area.

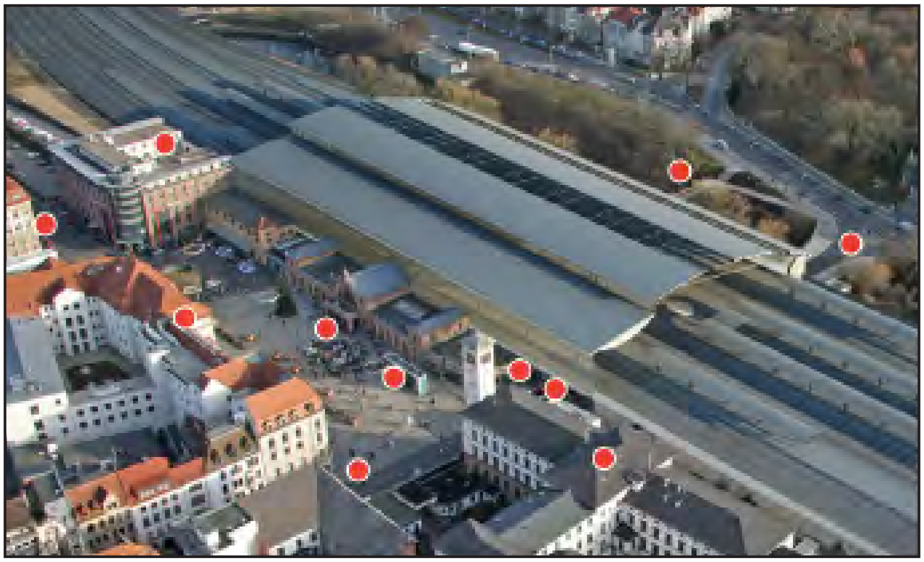


Figure 58. DB's Interactive Overview of Erfurt Main Station Intermodality

Pop up' dots from left to right: Bus terminal, InterCity hotel, Erfurter Hotel, old (20th century) Station Hall, Way Towards City Center, Entry to Underground Parking Structure, Tram/Bus Stop, Bike Station, original (19th century) Station Building, Moat, Way Towards South City

Source: DB AG @ http://www.vde8.de/de/knoten-erfurt/hauptbahnhof

Figure 59. Erfurt Main Station Layout

Source: http://www.bahnhof.de/file/6503766/data/Erfurt%20Hbf_de_PDF.pdf

Parking

The parking structure underneath the station has more than 100 spaces. It was conceived as an integral part of the station renovation.

Airport Connection and HSR/Air Competition

Erfurt has a small, seasonal airport that was renamed Erfurt-Weimar Airport in 2011. A tram leaving from the station reaches the airport in about 20 minutes, also offering stops at the city center. This airport, located in the suburb of Binderleben, has only a few hundred thousand customers per year, primarily serving a handful of Mediterranean holiday destinations. Rail travel to the bigger Leipzig/Halle Airport takes 1:45 to 2 hours and currently requires a connection either from the ICE to the S-Bahn in Leipzig or a transfer from a regional train to a ICE/IC train in Halle/Saale. Travel to Frankfurt Airport, however, is a convenient one-seat ride via IC or ICE train. Departures are about once every hour, and the trip takes 2:30 hours by either IC or ICE.

Summary Evaluation

Erfurt station is a good example of a high-speed rail node in a medium-sized city where substantial track, building, and other complex infrastructure upgrades were fitted into and around historic station structures at the edge of a well-preserved medieval city center. The station was reconfigured to allow for a high-degree of inter-modality with local trams and buses (Figure 60). Passengers enjoy barrier-free and/or elevator access to all tracks as well as a number of services inside the station.

Box 8: Erfurt Station Profile

City Population: 200,000

Year Station Opened: 1846 / 1893 / 2008

Station Type: DB Category 2

Passenger Volumes: 34,000 passengers/day

Trains: ICE 50, IC 50, CNL, REs 1, 2, 3, 7, 10, 45, 55, RBs 20, 52, 59, EB23, 46, STB44

Tracks: 10. HSR trains use the same platforms as conventional rail.

Proximity to other modes:

- Bus, metro or tram (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connections to airports: 20 min to Erfurt-Weimer via tram, 120 min to Leipzig/Halle via 2-seat rail, 2:30 hrs to Frankfurt Airport via 1-seat ICE ride.

Parking: Subterranean, at station, 100+ spaces

Bike Parking: Yes (DB call-a-bike)

Figure 60. Erfurt Station Inter-modality

Source: cc Magnus Manske @commons.wikipedia.org

CONCLUSIONS FROM THE GERMAN CASE STUDIES

Germany has built very few new HSR stations but has remodeled and adapted many historic stations to better accommodate its HSR services since the early 1990s. Berlin is a high-profile example of a city that underwent a multi-billion euro restructuring effort to optimize local, regional, and long-distance rail operations in the 21st century. One of the biggest lessons from Berlin's five-station mushroom concept that placed a new Central Station amidst four additional secondary stations is that in larger metropolitan areas, time savings achieved by laying new high-speed tracks into and/or through the center of a city are appreciated only by those whose final destination lies in the most central areas adjacent to the destination station. In the case of Berlin, residents and visitors alike are frequently better served by one of the four other stations, all of which offer excellent intermodal connections with local rail and bus operations. All other German cities of more than one million inhabitants, namely Hamburg, Cologne, and Munich, also feature more than one HSR station. Germany's largest metro area, the Rhein-Ruhr, has more than 15 stations with ICE services and many more with IC/EC services, all in a region of 10 million people with a size comparable to the Los Angeles metro area.

The German case studies provide some examples in which the construction of a new HSR line has promoted the re-purposing of secondary rail stations into new, well-linked high-speed rail nodes (Berlin South Cross and Kassel Wilhelmshöhe). In addition, other and overall more common examples of historic inner-city rail stations have undergone vast transformations into multimodal hubs with amplified commercial and retail functions (Berlin Central Station, Hannover, 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. High-speed rail enthusiasts enamored with DB's integrated rail system often forget that Germany is also the land of the 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 also interlinks this with various car- and bike-sharing offers. At times, it 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. They also provide some insights for California:

- In Germany, ICE stations are *never* exclusive to high-speed rail but are always also served by regional and/or local rail.
- 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 the city's central core or at a secondary center, but rarely outside the urban core.
- DB consistently practices the joint/adjacent use of station tracks for both ICE/IC/EC trains and local RB/RE/S-Bahn trains.
- High emphasis is placed 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, local planners copied the Karlsruhe model to develop a RegioTram system in which 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 other German cities.
- DB has long practiced integrated ticketing services, easy online booking and rebooking, early booking discounts, etc.
- DB Station & Service 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. Thanks to the availability of strong transit networks, German cities do not typically promote park- or kiss-and-ride lots at inner city stations, as U.S. cities do, with the unique exception of Berlin South Cross station, which has a strong car-orientation.

- Station remodeling has sought to promote smooth passenger flows within the stations, ideally via barrier-free access and/or high-capacity elevators and escalators. However, Berlin Central Station has often received negative attention in this regard because of slow elevators and narrow platforms. As stations also have become shopping malls on rails, 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 inside the station, including those commonly found in airports (first-class and business lounges, boarding areas, information kiosks, travel agencies, free WiFi).

VII. CASE STUDIES OF SPANISH HSR STATIONS

This chapter presents case studies of six Spanish high-speed rail stations. Spanish high-speed rail experts indicated these stations as good examples of intermodality. They range from large station complexes in high-density urban areas such as the Madrid Atocha to small stations in lower-density smaller towns such as Lleida. The case studies give information about each station's context, layout, integration with other travel modes, and passenger services. They also present information regarding the annual number of HSR passengers travelling through the station as well as the annual number of HSR services serving each station.

Data for this chapter were gathered from a variety of sources. These included interviews with representatives of the high-speed transit operator RENFE as well as the managers of each of the case study stations. The Spanish station owner ADIF provided number of relevant data such as station plans, annual number of high-speed services, available parking spaces at each station, etc. Additionally, data were drawn from a number of other documents such as travel guides, station itineraries, and Wikipedia and Wikitravel articles for each station. Lastly, Google Earth provided aerial photographs for each station.

MADRID – PUERTA DE ATOCHA

Figure 61. Aerial View of Atocha Station

Source: Google Earth.

Context

Madrid Puerta de Atocha[186] is the largest railway station located at Madrid's city center. It is a major transportation hub where different railway networks converge—commuter trains (Cercanías), intercity and regional trains, as well as high-speed trains from Barcelona, Zaragoza, Seville, Málaga Valencia, Valladolid, and Toledo. The station is named for the nearby Royal Basilica of our lady of Atocha. The Atocha station is a railway complex formed by the Madrid Atocha Cercanías and Madrid Puerta de Atocha stations of the Spanish national railways and the Atocha Renfe station of the Madrid Metro, which operates two underground stations there, *Atocha* and *Atocha Renfe*. Hotels, restaurants, a museum (Reina Sofía Museum), and other tourist attractions are within walking distance from the Madrid Puerta de Atocha station.

Madrid's first railway station was built at this site in 1851. It was destroyed by fire and rebuilt in 1892 in the form of two long brick buildings bridged by a steel-and-glass roof. The façade of this original complex faces the Plaza del Emperador Carlos V (Figure 62), a site where a number of streets converge (Figure 63). Over the years, this complex expanded to accommodate the increased railway services.

Station Layout and Modal Integration

A major remodeling project was carried out in 1985, based on designs by well-known Spanish architect Rafael Moneo. The railway tracks were moved out of the old station to a new modern terminal built nearby to serve both the new high-speed AVE trains and local commuter lines. In 1992, the original station ceased to operate as a terminal and was converted into a concourse with retail stores, eateries, a nightclub, and a tropical garden. A new metro station—*Atocha Renfe*—was added when the new terminal building was constructed and is directly linked to the railway station. This new terminal quadrupled the capacity of the Atocha Station. The main lines end in the new terminal; commuter train platforms are located underground, at the beginning of a rail tunnel that extends northward. Atocha station is reminiscent of a modern airport. Check-in and boarding procedures are similar to those at airports, and passengers can wait to enter their trains at boarding lounges. Ongoing work will create a terminal for arrivals and a different terminal for departures, similar to an airport.

Figure 62. Façade of the Historic Atocha Station
Source: http://bit.ly/1GIrVq6

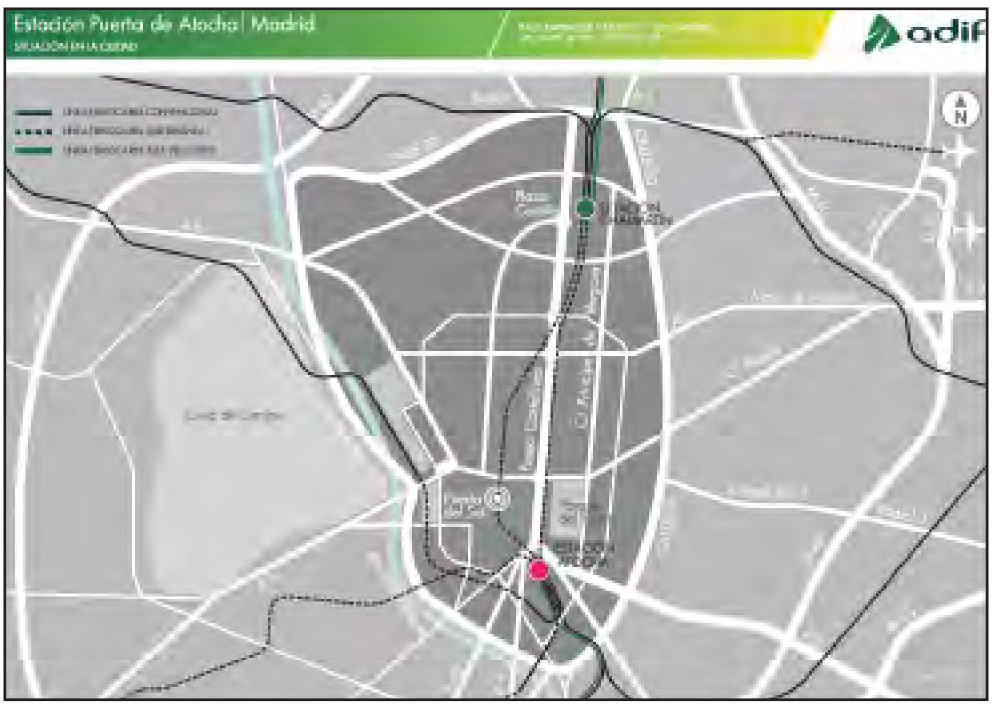


Figure 63. Atocha Station Location
Source: http://bit.ly/1HqHdoe

Atocha Station has an underground and three above-ground levels. The top level (Figure 64) features the 3-11 Memorial and has ample parking space. A bus to the Madrid airport leaves from this level. Escalators lead to a lower level (Figure 65), which features a boarding lounge, car rental facilities, eateries, and tourist information. Escalators from this level take passengers down to the lower level, which has the train platforms and tracks for the long-distance trains to the west and for Cercanias commuter trains to the east, along with more eateries and retail shops. This level also features the old station building (now converted into a mall) and tropical gardens (Figures 66, 67).

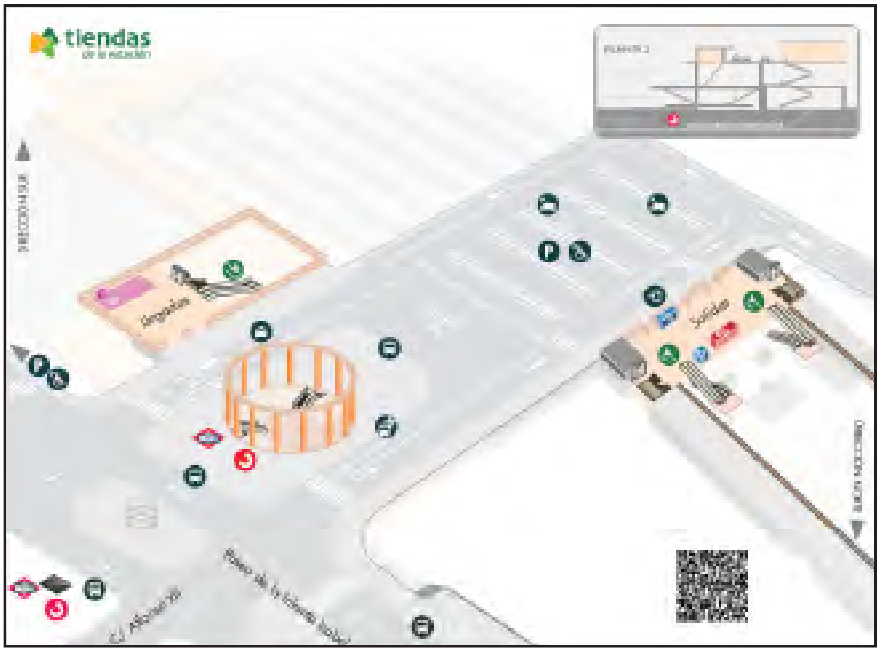


Figure 64. Top Level of Atocha Station

Source: http://bit.ly/1IGVSrL

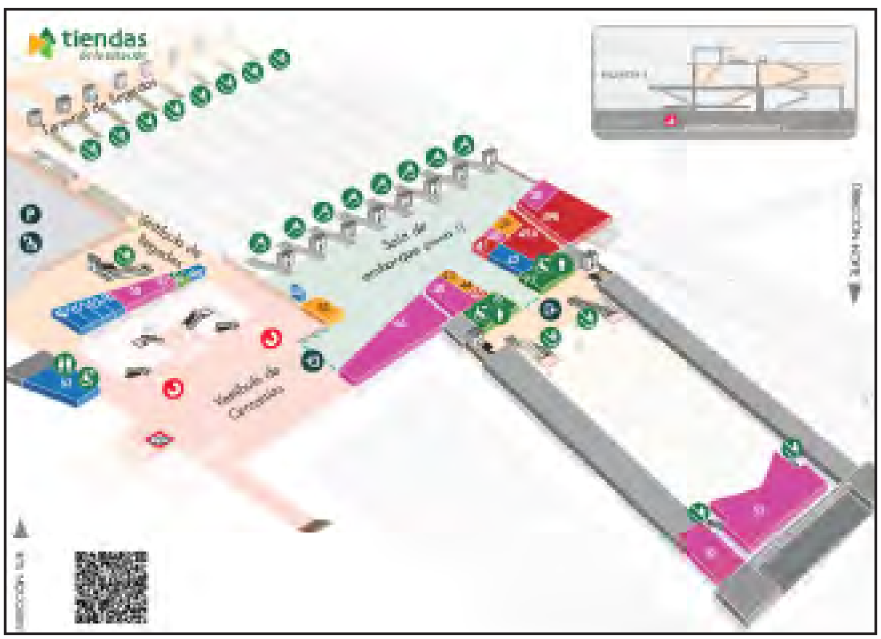


Figure 65. Second Level of Atocha Station

Source: http://bit.ly/1HqHdoe

Figure 66. Ground Level of Atocha Station

Source: http://bit.ly/1IGVSrL

Figure 67. Tropical Gardens Inside Old Atocha Station Building

Source: http://en.wikipedia.org/wiki/Madrid_Atocha_railway_station

Figure 68 shows the co-existence and seamless integration of different transportation modes: Public bus transit (including a bus to the airport), metro and commuter lines, high-speed lines, taxis, and private automobiles. Not visible in Figure 68 are reserved areas for bicycle parking that exist outside the station.

Figure 68. Atocha Station—Coexistence of Different Modes

Source: http://bit.ly/1IGVSrL

Box 9 shows the different types of trains as well as the number of different train services that connect Madrid with other Spanish cities. More than 10,000,000 passengers boarded or alighted high-speed trains at the Atocha station in 2012.

When asked about challenges or issues they face with intermodality, the ADIF station managers interviewed talked about the spatial challenge resulting from increased ridership and the need for further expansion of the station's departure lounges. They also referred to the necessity of separating the flows of arriving and departing passengers.

Box 9: Atocha Station Profile

City Population: 3,234,000 (2012)

Metro Population: about 6.5 million

Year Station Opened: 1851; rebuilt 1892; expanded 1985

Trains: AVE, Altaria, Alaris, Alvia, Cercanias, Madrid Metro

Number of passengers on AVE and AVANT trains in 2012: 10,179,200

Number of annual AVE and AVANT services from Madrid

- Madrid-Cuenca-Valencia: 8,391
- Madrid-Albacete-Alicante: 1,049
- Madrid-Toledo: 8,245
- Madrid-Puertolano: 6,782
- Madrid-Sevilla: 11,424
- Madrid-Málaga: 7,606
- Madrid-Zaragoza-Lleida-Barcelona: 23,282
- Madrid-Huesca: 928
- Madrid-Valladolid: no data

Platforms: 13; **Tracks**: 23

HSR trains use same platforms as conventional rail.

Proximity to other modes:

- Bus or metro (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: Airport bus or commuter rail (Cercanias) to Nuevos Ministeros station, then Metro Line 8; Commuter rail line C

Parking: Four park-and-ride lots

Bike Parking: Yes (reserved areas outside station)

BARCELONA SANTS STATION

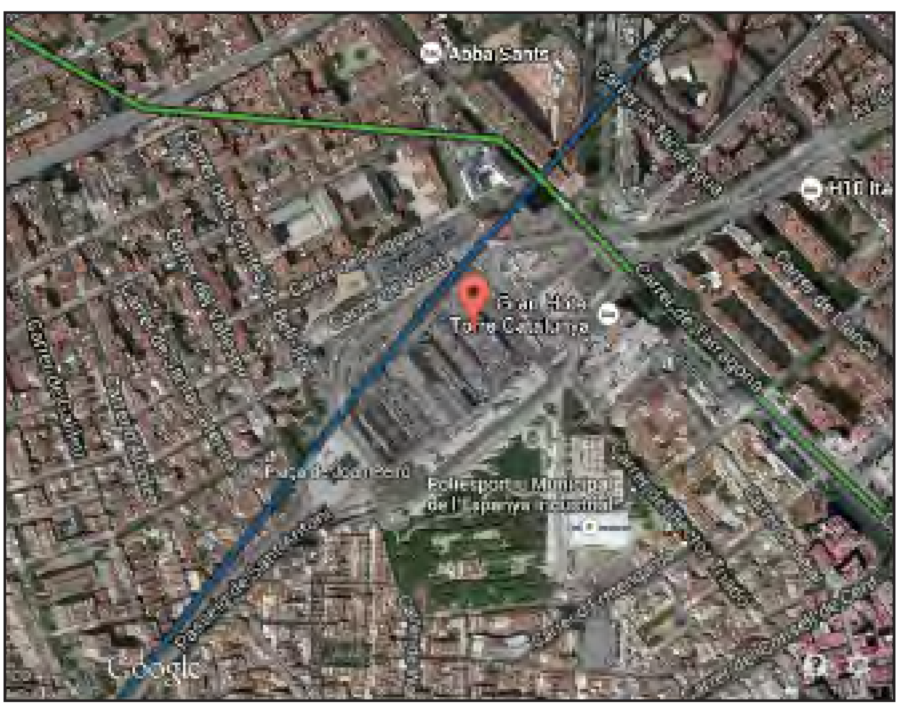


Figure 69. Aerial View of Sants Station

Source: Google Earth.

Context

Barcelona Sants[187] is the main railway station in Barcelona. It is the Catalan region's most important transportation hub. Different railway networks converge here, including commuter trains (Cercanias), intercity and regional trains, and high-speed trains reaching international and domestic destinations. This is also the location of the Sants international bus station as well as a Barcelona metro station serving the Sants railway complex (Figure 70).

The station is in the Sants neighborhood, adjacent and to the west of the city center. Sitting at the end of Avinguda Roma between two squares—Plaça dels Països Catalans and Plaça Joan Peiró—the station has two entrances, one from each square (Figure 71). It is highly accessible from different parts of the city by public transportation (buses and metro).

Since 2008, the Sants station has become Barcelona's hub for the Spanish high-speed trains (AVE), which connect the city to Madrid in only 2 hours and 40 minutes. Extension of this line into France was completed in 2012, with TGV services reaching Barcelona in December 2013. A second major railway station in Barcelona, Estació de la Sagrera, is currently under construction and is planned for completion in 2016. This new station will give the northern parts of the city a better connection and access to high-speed and long-distance train services.

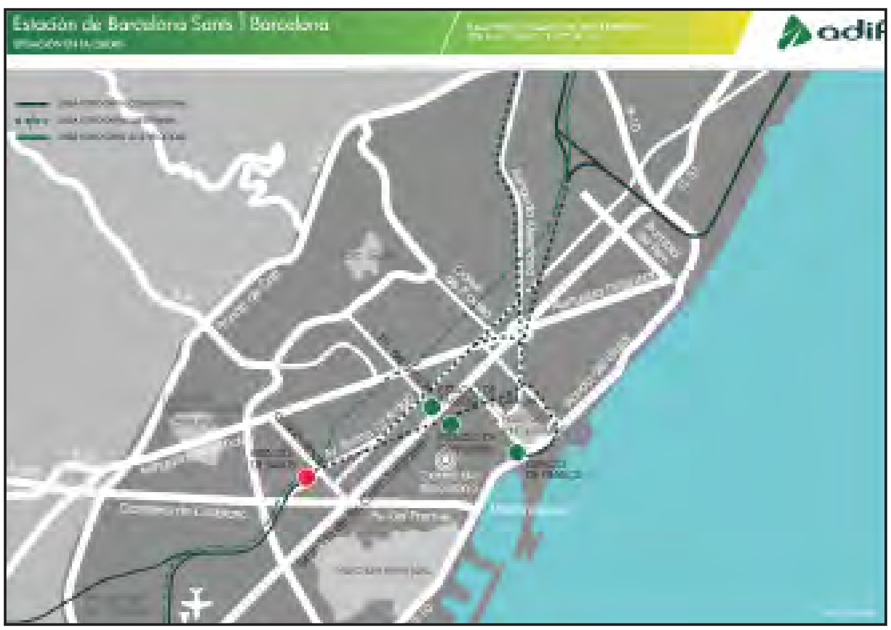


Figure 70. Sants Station Location

Source: http://bit.ly/1QZTDtw

Figure 71. Sants Station—Coexistence of Different Modes

Source: http://bit.ly/1QZTDtw

Station Layout and Modal Integration

The complex that houses the station was built in 1975 as a modern structure using materials such as steel, concrete, and glass. It hosted the first east-west regional line running under the center of Barcelona. Over the last 30 years, Sants became the city's main railway station, replacing in importance and traffic another railway station (Barcelona Estació de França) that had been built in the 1920s. In 2007, parts of the Sants station were remodeled, and new parts were added to accommodate the coming of the high-speed train AVE, which began operations in the city in 2008.

The station complex is composed of two levels. An underground level houses the station's seven platforms and 14 tracks. The high-speed service uses platforms 1 to 6, which have been converted to the European standard gauge, while the remaining 8 platforms serve other RENFE services and are using the Spanish (Iberian) gauge tracks. High-speed-rail passengers enjoy their own departure area and customer service, while first-class passengers can utilize the first-class lounge called Sala Club. From the underground level, escalators lead to a surface level (Figure 72) that houses a wide range of facilities, such as shops, eateries, car rental services, ticket booths, multiple information desks, tourist information, lockers, and even a police station. Above this level extends a multi-story building, most of which is occupied by a four-star hotel (Hotel Barceló Sants).

The station has four underground levels of a park-and-ride lot with 900 spaces of covered parking, as well as two short-term (15 minutes free) kiss-and-ride lots. It also has parking for bicycles and motorcycles. Because of the successful integration of different modes, many passengers reach or leave from the station utilizing public transit.

Figure 72. Sants Station Surface (Street) Level

Source: http://bit.ly/1QZTDtw

Box 10 shows the different types of trains as well as the number of different train services that connect Barcelona with other Spanish cities. More than 4,000,000 passengers bordered or alighted high-speed trains at the Sants station in 2012.

The ADIF station managers interviewed emphasized that a planned station expansion will provide “a new direct, comfortable, and secure connection with the metro and bus station.” They also believed that integrating tickets (combining railway tickets with tickets for other modes of transportation in one package) and more frequent services to the Barcelona airport would further enhance an already high level of station intermodality.

Box 10: Sants Station Profile

City Population: 1,673,000 (2012)

Metro Population: About 4.5 million

Year Station Opened: 1975 (2007 new construction)

Trains: AVE, AVANT, ALVIA, TGV, Regional, Estrela, Cercanias, Barcelona Metro

Number of passengers on AVE and AVANT trains in 2012: 4,069,300

Number of annual (2012) AVE and AVANT services from Barcelona

- Barcelona-Lleida: 3,448
- Barcelona-Madrid-Cordoba-Malaga: 1,066
- Barcelona-Madrid-Sevilla: 1,443
- Barcelona-Lleida-Zaragoza-Madrid (Atocha): 14,889
- Barcelona-Lleida-Zaragoza-Madrid (Atocha): 609

Platforms: 7 island platforms; **Tracks**: 14

HSR trains use different platforms, which are adjacent and very close to the platforms used by conventional rail.

Proximity to other modes

- Bus (less than 5 min; regional bus station located at the station)
- Metro (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: By conventional and commuter rail or taxi

Parking: Park-and-ride structure with 900 parking spaces; two kiss-and-ride lots with 15-minute maximum time for stops.

Bike Parking: Reserved areas outside station

ZARAGOZA DELICIAS STATION

Figure 73. Aerial View of Delicias Station

Source: Google Earth.

Context

The Zaragoza-Delicias station[188] is located in Zaragoza, a city of about 700,000 inhabitants in Aragon, Spain. The station opened in May 2003 and was followed by the opening of the

Zaragoza Central Bus Station four years later in May 2007. Different railway services—high-speed, regional and commuter trains—are housed in this station. It is also served by the AVE high-speed trains that bring passengers from Zaragoza to Madrid in approximately 1 hour and 20 minutes and to Barcelona in about 1 hour and 30 minutes.

The station is located only 1.25 mile (about 2 kilometers) from the city center, which lies to the west, and about the same distance from the University of Zaragoza to the south (Figure 74). It has easy access to major motorways but is also highly accessible from different parts of the city by public transportation, on foot, and by bicycle (Figure 75). Indeed, the city of Zaragoza has a bike-sharing program, and for a small annual charge, participants can pick up a bike from particular points (including the station), ride it, and leave it at another part of the city.

HSR services started operating at the station on May 7, 2003, and presently there are up to 19 daily HSR trains in each direction for Madrid and 12 for Barcelona. Fewer conventional rail services connect Zaragoza to other cities, such as Huesca, Teruel, Pamplona, Logroño, Bilbao, and Valencia.

Figure 74. Delicias Station Location

Source: http://bit.ly/1GVDCNj

Figure 75. Delicias Station—Coexistence of Different Modes

Source: http://bit.ly/1GVDCNj

Station Layout and Modal Integration

The station, which is quite massive compared with the rest of the city fabric, was built in May 2003, when the HSR services began operating. In 2008, just prior to the opening of the International Exhibition in Zaragoza, the station also started receiving the first commuter trains of the newly created line C-1 of Cercanías Zaragoza.

Delicias has an interior space that hosts five platforms (about 250 feet long) and eight tracks. Two of the tracks have the Iberian gauge, while six tracks have the European standard gauge. The large interior space is covered with an impressive roof, with large arches placed diagonally across the station building and filled in by pyramidal structures that bring much natural light to the interior space (Figures 76 and 77). The roof is 1,214 feet (370 meters) long with a span of 492 feet (150 meters). It is considered to be the largest pillar-free space in Spain. In the platform area, the ceiling height is almost 46 feet (14 meters), with no interrupting pillars, which results in a roomy, airy space (Figure 78). The station building received the FAD Architecture Prize in 2004 and the Brunel Award in 2005.

Figure 76. Exterior of Delicias Station
Source: http://bit.ly/1LR1LG6

Figure 77. Interior of Delicias Station—Lounge Area
Source: http://bit.ly/1Kl9uxn

Figure 78. Interior of Delicias Station—Platform Area
Source: http://bit.ly/1dsZCoh

The main station entrance is on the north and faces the River Ebro. On the station's north side, there is a hotel and the city's central bus station. Plans for building a railway museum on the south side of the station have not yet been realized, and the area remains vacant (Figure 76). Other facilities present at the station are a few eateries and shops, as well as rental car services, information and ticketing booths, a lounge for first-class HSR passengers, about 1800 spaces of covered parking, and two kiss-and-ride lots for passenger pick up or drop off (Figure 79).

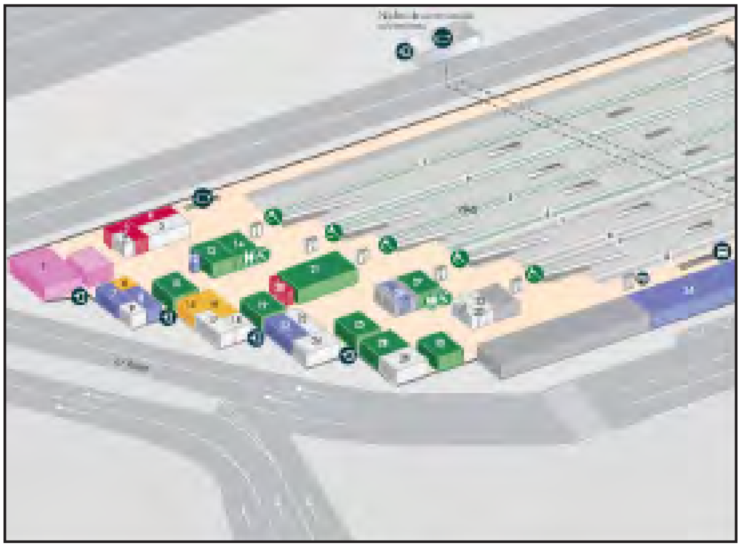


Figure 79. Delicias Station Layout

Source: http://bit.ly/1GVDCNj

Box 11 shows the different types of trains as well as the number of different train services that connect Zaragoza with other Spanish cities. More than 2,000,000 passengers boarded or alighted high-speed trains at the Delicias station in 2012.

The ADIF station managers interviewed emphasized that the intermodality of the Zaragoza station is greatly helped by the fact that the station also includes the city's main bus station, a hub for local, intercity, and even international buses. They indicated that their future challenge would be to achieve similar seamless connections with the services of a future new east-west tram system.

Box 11: Delicias Station Profile

City Population: 702,090 (2012)

Metro Population: About 785,000

Year Station Opened: 2003

Trains: AVE, AVANT, ALVIA, MD, Estrela, Regional, Cercanias

Number of passengers on AVE and AVANT trains in 2012: 2,042,700

Number of annual (2012) AVE and AVANT services through Zaragoza

- Zaragoza-Calatayud: 2,132
- Madrid-Zaragoza-Huesca: 928
- Madrid-Zaragoza-Lleida-Barcelona-Figueres: 502
- Madrid-Zaragoza-Lleida-Barcelona: 11,342
- Barcelona-Zaragoza-Madrid-Sevilla: 1,430
- Barcelona-Zaragoza-Madrid-Córdoba-Málaga: 1,072

Platforms: 5; **Tracks**: 8

HSR trains use their own platforms, which are adjacent and very close to the platforms used by conventional rail.

Proximity to other modes

- Bus (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: By bus or taxi

Parking: Park-and-ride area with 1800 parking spaces. Outside the station, there are also two kiss-and-ride areas for passenger pick-up, with 15-minute maximum time for stops.

Bike Parking: Reserved areas outside the station

MALAGA MARIA ZAMBRANO STATION

Figure 80. Aerial View of María Zambrano Station

Source: Google Earth.

Context

The María Zambrano Station[189] is located in Málaga, a city of about 570,000 inhabitants in Andalucía, Spain. The station, which is built on the site of a former historic station in Málaga, was completed in 2006 and was further renovated in 2009 and 2010. Different railway services—high-speed, regional and commuter trains—are housed in this station. It is also served by the AVE high-speed trains that bring passengers from Málaga to Madrid in 2 hours and 30 minutes and from Barcelona in 5 hours and 40 minutes.

HSR services started operating between Málaga and Madrid in December 2007 with the opening of the Antequera-Málaga stretch of the Córdoba-Málaga line. AVE trains leave Málaga for Madrid every 60–120 minutes, stopping at Antequera, Puente Genil, and Córdoba on the way. Since February 2008, Málaga is also connected by AVE high-speed trains to Barcelona with two trains each way daily, with stops at Antequera, Puente Genil, Cordoba, Zaragoza, and Tarragona. AVANT services passengers directly from Seville to Málaga and vice-versa. The station is also served by conventional (Alaris) trains, Middle Distance trains (MD and Avant), and commuter trains (Cercanías Málaga).

Station Layout and Modal Integration

The station is located on Explanada de la Estación, just southwest and within an easy walk of Málaga's city center. The station's multimodality is helped by its strategic location. It is situated approximately 1.25 mile (2 kilometers) from the Málaga Port and 5.6 miles (9 kilometers) from the Málaga airport (Figure 81), and it has easy access to the city's major motorways (A-357 and MA-20). A railway station at Málaga Pablo Picasso Airport links to the María Zambrano railway station, which is only four stops away. Airport passengers can also board the Málaga Airport bus to the Málaga central bus station adjacent to the María Zambrano station (Figure 82). Additionally in July 2014, the metro station El Perchel opened adjacent to the María Zambrano railway station, making the transfer between the metro and conventional or high-speed train services very easy.

Figure 81. María Zambrano Station Location

Source: http://bit.ly/1g3cCTo

Figure 82. María Zambrano Station—Coexistence of Different Modes

Source: http://bit.ly/1g3cCTo

In addition to the platforms, tracks, and passenger-elated services, María Zambrano station also features a four-star, 222-room Barcelo Málaga Hotel and Convention Center on its southeast end and the ADIF-owned shopping center Vialia that occupies the north side of the station. It offers 30,000 square feet (2737 square meters) of commercial space and 121 different stores, including a number of movie theaters (Figures 82, 83, 84).

Figure 83. María Zambrano Station Ground Level

Source: http://bit.ly/1g3cCTo

Figure 84. María Zambrano Station Upper Level

Source: http://bit.ly/1g3cCTo

The station has seven platforms and eleven tracks, some with the Iberian gauge and some with the European standard gauge (Figure 85). Underground platforms serve the Cercanías commuter trains.

Figure 85. María Zambrano HSR Platforms

Source: http://bit.ly/1g3cSlg

The station is bright and airy, with two levels above ground. High-speed rail platforms are on the ground level, which also includes a number of services for passengers—ticket windows, information desks, automatic check-in kiosks, travel and tourist information center, storage lockers, car-rental services, VIP lounge, and many eateries and retail stores (Figures 83). The Vialia mall extends to a second level (Figures 84, 86). There is parking at the front of the station for 1,500 vehicles: 1,250 underground and 250 on ground-floor level. Visitors travelling by long distance or high-speed train on Preferential, First, and Club Class receive 24 hours free parking. This means a return ticket to Madrid comes with 48 hours of free parking.

Figure 86. Vialia Mall at María Zambrano Station
Source: http://www.panoramio.com/photo/82811028, Google Maps.

Box 12 shows the different types of trains as well as the number of different train services that connect Málaga with other Spanish cities. Almost 2,000,000 passengers boarded or alighted high-speed trains at the María Zambrano station in 2012.

The ADIF station managers interviewed emphasized that the intermodality of the Málaga station is greatly helped by the new metro stop that opened under the station in 2014, as well as the bus station adjacent to the railway station. The fact that the station is so close to the port (a major stop for cruises), and that it also has a direct connection to the airport increases its connectivity and intermodality. In the future, managers hope to offer plane and cruise passengers HSR connections with the possibility of luggage check-in.

Box 12: Maria Zambrano Station Profile

City Population: 568,507

Metro Population: 1,046,279

Year Station Opened: 2005-2007

Trains: AVE, AVANT, ALARIS, MD, Regional, Cercanias

Number of passengers on AVE and AVANT trains in 2012: 1,962,200

Number of annual (2012) AVE and AVANT services through Malaga

- Málaga-Madrid: 7,606
- Málaga-Córdoba-Sevilla: 3,767
- Málaga-Córdoba-Madrid-Barcelona: 1,420

Platforms: 7; **Tracks**: 11

HSR trains use their own platforms, which are adjacent and very close to the platforms used by conventional rail.

Proximity to other modes

- Bus (less than 5 min), main bus station across the street from train station
- Subway stop
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: By bus (Malaga airport bus), commuter rail, or taxi

Parking: 1,500 spaces in three park-and-ride areas; two kiss-and-ride areas to pick up passengers (with 15-minute maximum time for stops free of charge).

Bike Parking: Reserved areas outside station

CORDOBA CENTRAL STATION

Figure 87. Aerial View of Córdoba Station

Source: Google Earth.

Context

The Córdoba Central Station[190] is the main railway station of Córdoba, a city of about 330,000 inhabitants in Andalucía, Spain. The station opened in 1994, replacing a much older railway station in the city, which was built in 1859. The new station was built to facilitate easy access to the Andalucía region and accommodate high-speed trains. The station houses HSR services that connect Córdoba to Madrid, Barcelona, and Málaga. AVE trains that leave from the station every hour connect Córdoba to Madrid in 1 hour and 45 minutes, to Seville in 45 minutes, and to Málaga in 50 minutes. Two daily AVE services to Barcelona make the trip in about 5 hours. Additionally, the station is served by middle-distance AVANT and MD services and conventional (Altaria and Alivia) trains. More than 20 trains every day connect Córdoba to Málaga María Zambrano station, which also provides connection to the Málaga Airport because Córdoba does not have an airport for commercial flights. Because of the operation of high-speed trains, the travel time between the two major cities of Andalucía—Seville and Córdoba—has been cut to just 25 minutes, allowing many tourists to visit Córdoba on a day trip from Seville, and boosting tourism in both cities.

Station Layout and Modal Integration

Córdoba Central Station is off the Avenida de America, at the northern end of the city's central district (Figure 88). The advent of high-speed rail led to the burial of the old railroad tracks that had divided the city in two, freeing up more than 42 acres (7 hectares) for commercial and office space construction and housing.

This is a small station compared with the stations examined so far, but similar to the previous examples, it has a high level of intermodality. The station is quite busy with 22–30 daily trains from Madrid and extensive regional connections to other parts of Andalucía. As shown in Figure 89, the station is adjacent to the city's main bus station and can be easily reached from different parts of the city via public bus, taxi, private car, and bicycle. A bus runs between the train station and the city's historic core.

Figure 88. Córdoba Station Location

Source: http://bit.ly/1eVGLno

Figure 89. Córdoba Central—Coexistence of Different Modes

Source: http://bit.ly/1eVGLno

The Córdoba station is a boxy and non-distinctive structure (Figure 90). It has four tracks with European standard gauge for high-speed trains and four tracks with the Iberian gauge for the conventional train services. The station has high traffic because of the multiple daily connections with Madrid and Barcelona as well as other destinations in Andalucía, especially to Seville and Málaga. On the ground level, one finds the typical passenger services (ticket windows, travel and tourist office, first-class lounge, office for lost-and-found), as well as a few restaurants, cafés, and retail stores. Escalators lead to an underground level, where the platforms and tracks are located (Figure 91).

Figure 90. Façade of Córdoba Central Station

Source: http://bit.ly/1RMHuDg

Figure 91. Córdoba Central Station Ground Level

Source: http://bit.ly/1eVGLno

Box 13 shows the different types of trains as well as the number of different train services that connect Córdoba with other Spanish cities. More than 800,000 passengers boarded or alighted high-speed trains at the station in 2012.

The ADIF station managers interviewed emphasized that one of the challenges they are facing is the high automobile traffic in the station area that is not related to the station. To achieve a higher level of intermodality, they believe that they should divert this traffic away from the station, improve the coordination between local/intercity buses and train timetables, and improve the communication between the transit operators of regional and long-distance transport services in order to avoid competition.

Box 13: Cordoba Central Station Profile

City Population: 328,488

Year Station Opened: 1994 (HSR platform 2003)

Trains: AVE, AVANT, ALTARIA, ALIVIA, MD (Media Distancia)

Number of passengers on AVE and AVANT trains in 2012: 803,000

Number of annual (2012) AVE and AVANT services through Cordoba:

- Barcelona-Madrid-Córdoba -Málaga: 1,420
- Barcelona-Madrid-Córdoba-Sevilla: 1,779
- Jaén-Córdoba-Sevilla-Cádiz: 710
- Málaga-Córdoba-Sevilla: 4,957
- Madrid-Córdoba-Málaga: 5,785
- Madrid-Córdoba-Sevilla: 9,768

Platforms: 5; **Tracks**: 8

HSR trains use their own platforms, which are adjacent and very close to the platforms used by conventional rail.

Proximity to other modes

- Bus (less than 3 min)
- Taxis or shuttles (less than 3 min)
- Car rental or car-sharing services (less than 2 min)
- Bike sharing (less than 5 min)
- Connection to airport: The closest airport for commercial flights is in Malaga.

Parking: 2 park-and-ride areas (with 15-minute maximum time for stops free of charge).

Bike Parking: Reserved areas near station entrance

LLEIDA-PIRINEUS STATION

Figure 92. Aerial View of Lleida-Pirineus Station

Source: Google Earth.

Context

The Lleida Pirineus station[191] is in Lleida, a city of about 140,000 inhabitants in Catalonia, Spain. It is a center for agriculture and agribusiness and has a University of about 10,000 students. Thus, the city resembles the city of Fresno, along the California HSR corridor, although Fresno has a much larger population (about 509,000 people), and its university enrolls a larger number of students.

The station is housed in a historic structure built in 1927. It was renovated in 1997, and its south façade was restored to its original state. Work continued at the station in 2003 with new additions and modification of the station layout in preparation for the advent of the high-speed services, which started in the same year. During the peak summer months, up to 41 AVE daily services connect Lleida to Madrid in two hours and to Barcelona in one hour. Because of its strategic location, the station has also a number of Middle Distance regional railway services operated by RENFE to other cities in Catalonia and the Aragón regions.

The Lleida station was originally planned as a peripheral station on the Barcelona-Madrid high-speed corridor, with the HSR train bypassing the city's center. However, after the Lleida City Council's considerable pressure on the national government, the Ministry of Public Works finally agreed in 2002 to the use of the city's historic station as a hub for HSR services. The city proceeded to rehabilitate its railway station as part of a strategy that intended to reinvigorate a declining urban center by promoting Lleida as a gateway to the Pirenee Mountains, encouraging investment at its city core and increasing tourism.

Station Layout and Modal Integration

The station is at the north edge of the city center across from the Ramón Berenguer Plaza (Figure 92). It is composed of two distinct parts: the historic building and new extensions that were made in 2003. The historic building is 223 feet (68 meters) long and 62 feet (19 meters) tall and has a tower at each end. The new section features a large glass-and-metal canopy that covers the platforms and tracks (Figure 94).

Figure 93. Lleida-Pirineus Station Location

Source: http://bit.ly/1CF5JfC

Figure 94. Façade of Lleida's Historic Railway Station

Source: http://bit.ly/1SYAN3u

The city planned its renovated railway station as an intermodal transit center and has made significant investments to strengthen multimodal connections to the station, including intercity buses, regional railway lines, car rental services, and taxis, all of which are hosted at the station (Figure 95). Additionally, the station renovation project decreased the barrier effect between the station and its surroundings by putting a segment of the tracks underground and creating a new urban park on top of them. Other improvements included pedestrian amenities and streetscape beautification. These design interventions have resulted in an improved pedestrian connection between the station and the city center. Importantly, scholars have found that the new HSR station in Lleida has served as a catalyst for more growth and economic development in the city.[192] It has triggered the development of a nearby industrial park, a new convention center, and an increase in tourism because the HSR brought the city much closer to Barcelona and Madrid.

Figure 95. Lleida Pirineus Station—Coexistence of Different Modes

Source: http://bit.ly/1CF5JfC

The station is equipped with four platforms, all covered and accessible through escalators and elevators. It has eight tracks, some with the European standard gauge for high-speed trains and some with the Iberian gauge for the conventional trains. In addition to the passenger services (ticket windows, travel and tourist office, first-class lounge, office for lost-and-found), the station also has a hotel, a few cafés and restaurants, and some small retail stores (Figure 95). A park-and-ride area can host 650 automobiles.

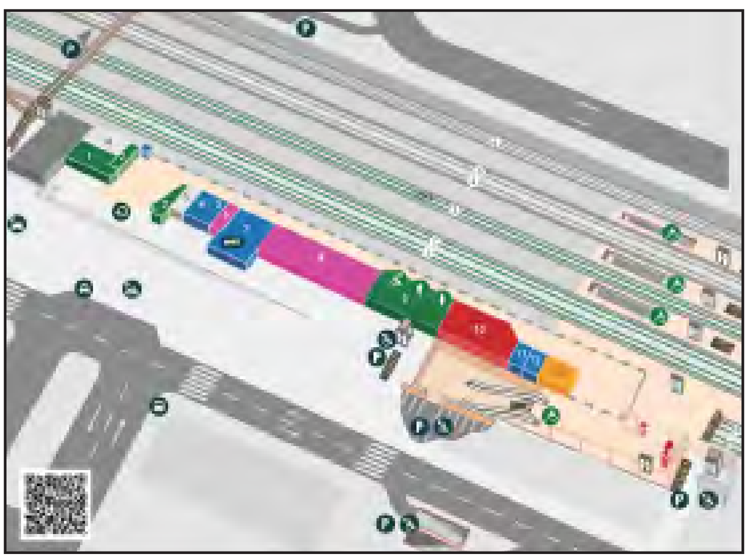


Figure 96. Lleida-Pirineus Station Layout

Source: http://bit.ly/1LR2mHW

Box 14 shows the different types of trains as well as the number of different train services that connect Lleida to other Spanish cities. More than 800,000 passengers boarded or alighted high-speed trains at the station in 2012. The ADIF station managers interviewed emphasized that the station expansion has facilitated the station's better operation and services. They believed that the combination of tickets for different travel modes in one package would further increase the seamless integration among travel modes.

Box 14: Lleida-Pirineus Station Profile

City Population: 138,416 (2012)

Metro Population: About 250,000

Year Station Opened/Renovated: 1927; 1997; 2003

Trains: AVE, AVANT, ALVIA, Regional

Number of passengers on AVE and AVANT trains in 2012: 802,000

Number of annual (2012) AVE and AVANT services through Lleida

- Lleida-Barcelona: 3,448
- Barcelona-Lleida-Madrid-Cordoba-Malaga: 1,066
- Barcelona-Lleida-Madrid-Sevilla: 1,420
- Barcelona-Lleida-Zaragoza-Madrid: 5,911
- Figueres-Barcelona-Lleida-Zaragoza-Madrid: 264

Platforms: 4; **Tracks**: 8

HSR trains use their own platforms, which are adjacent and very close to the platforms used by conventional rail.

Proximity to other modes

- Bus (less than 5 min)
- Taxis or shuttles (less than 5 min)
- Renting or car-sharing services (less than 5 min)
- Connection to airport: By taxi

Parking: Park-and-ride area with 650 parking spaces and 15-minute maximum time for stops free of charge.

Bike Parking: Reserved areas outside station

CONCLUSIONS FROM THE SPANISH CASE STUDIES

The six Spanish HSR stations discussed above are arguably among the best examples of intermodality of the Spanish HSR network. In the Spanish cases, intermodality is achieved through several factors:

- A good station location that has easy access to other travel modes and good pedestrian connections to its surrounding vicinity. The 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 central bus terminal inside the station or directly adjacent to it.

- For cities that have a metro system, a metro stop inside the station.
- Close proximity and common boarding heights (Common Level Boarding) 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-ride and kiss-and-ride lots. However, the high level of station intermodality decreases the need for large amounts of parking.
- Good information panels in the station and standardized, easy-to-read signs for way-finding in the station and its vicinity.
- Smooth passenger flows within the stations and proximity of different station platforms.
- A variety of passenger services inside the station, typical of those seen in airports (such as first-class lounges, boarding areas, information kiosks, travel agencies, car rental facilities, etc.).

Additionally, all six case study stations serve not only as a transportation hubs 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 preservation and expansion of significant historic buildings (such as in Madrid Atocha and Lleida Pirineus) or building a new structure (such as in Zaragoza–Delicias)—intends to reclaim or create a new architectural landmark in the city. Indeed, these six case studies exemplify how a railway station can become both a route for seamless travel and a place for a variety of other urban activities.

VIII. CALIFORNIA CASE STUDIES

This chapter examines in detail two future HSR stations on the California system—Union Station in Los Angeles, and Burbank station in Burbank—to better understand the current infrastructural characteristics and future needs of intermodal stations in California. The chapter also seeks to transfer lessons learned from the European case studies to some of the future station sites of the California HSR project.

The chapter begins with a general descriptive overview of both stations as they currently serve conventional regional and long-distance rail. Then it moves on to a discussion of how these two stations are being adapted for future increased use, including the possible addition of high-speed rail. The information in this section was gathered through a series of stakeholder interviews as well as the review of technical reports, planning documents, and other material related to the two stations.

LOS ANGELES UNION STATION

Figure 97. View of Los Angeles Union Station

Source: Metro's The Source post on June 28, 2012.

In 2014, its 75th anniversary year, Los Angeles Union Station is at a critical junction of its storied history. It was completed in 1939 as the "last of the Great Stations"(Figure 97), just 18 months before the Arroyo Seco Parkway opened. It quickly faded away in importance as automobile use grew, the 101 Freeway cut the station off from downtown, and rail passenger numbers started plummeting. For the last three decades, however, the station has undergone multiple renaissances that have now converged to a full-scale rebirth for one of the city's most iconic buildings.

After the demise of the Red Cars, rail went into a temporary hiatus in Los Angeles, but, as Elkind[193] eloquently describes, a number of key politicians in the county fought for Metro Rail and a re-railed future. This led to the opening of the Blue Line in 1990, the Metrolink commuter rail system in 1991, the Red Line in 1993, and the Gold and Purple lines in 2003, all of which end or pass through Union Station. The Los Angeles metro area rail system was further enhanced by various extensions to these lines, such as the Green Line's opening along the Century Freeway in 1995, the Exposition Line in 2012, and the prospective opening of the new Crenshaw Line and Downtown Regional Connector around 2020.

Union Station is the transit hub in a region of 17 million people. The station is currently accessed by 60,000 travelers every day, boarding trains, buses, and other transportation modes from and to different directions. With the numerous planned transit expansions, Union Station's use is projected to increase to more than 100,000 daily boardings, which is still small by European comparisons. The Los Angeles County Metropolitan Transportation Authority ("Metro") purchased the station and the 38-acre (15-hectare) site it sits on, along with 5.9 million square feet (548,128 square meters) of development entitlements, from the Catellus Development Corporation for $75 million in 2011. The intention is to significantly re-think the overall functioning of this hub, including its future role as a high-speed rail terminal. As Roelof van Ark, CEO of the California High-Speed Rail Authority (CHSRA) at the time, noted in a press release, "Union Station is a critical transportation hub for the high-speed rail system, providing passenger access and intermodal connectivity. The High-Speed Rail Authority will be working with Metro to, ultimately, determine the details behind this partnership."[194]

Station Design

The original station at the western end of the site at Alameda St., was built in 1939 and designed by John and Donald D. Parkinson architects. Entering the station from Alameda St., one finds the original ticket concourse with its 62-foot (19-meter) high ceilings on the left and the former Harvey House restaurant on the right. Both spaces will be revived for commercial and retail activity as part of Metro's new Los Angeles Union Station Master Plan. The architectural style of the station is a combination of Colonial and Mission Revival architecture with some modern elements, with parts of the walls covered in marble and some terra cotta elements. The station building features several enclosed patios around the central waiting room. The tracks behind this building are actually at grade but give the impression of being elevated, with access to all tracks gained via a tunnel-like access corridor that leads underneath the tracks all the way to the East Portal. A handful of food and drink vendors are located in the transition area between the waiting room and the track access, and there is access to the Red Line metro from either end of the track access corridor. The East Portal at the other end of the track access corridor is a more recent addition. Figure 98 gives an overview of the station current layout.

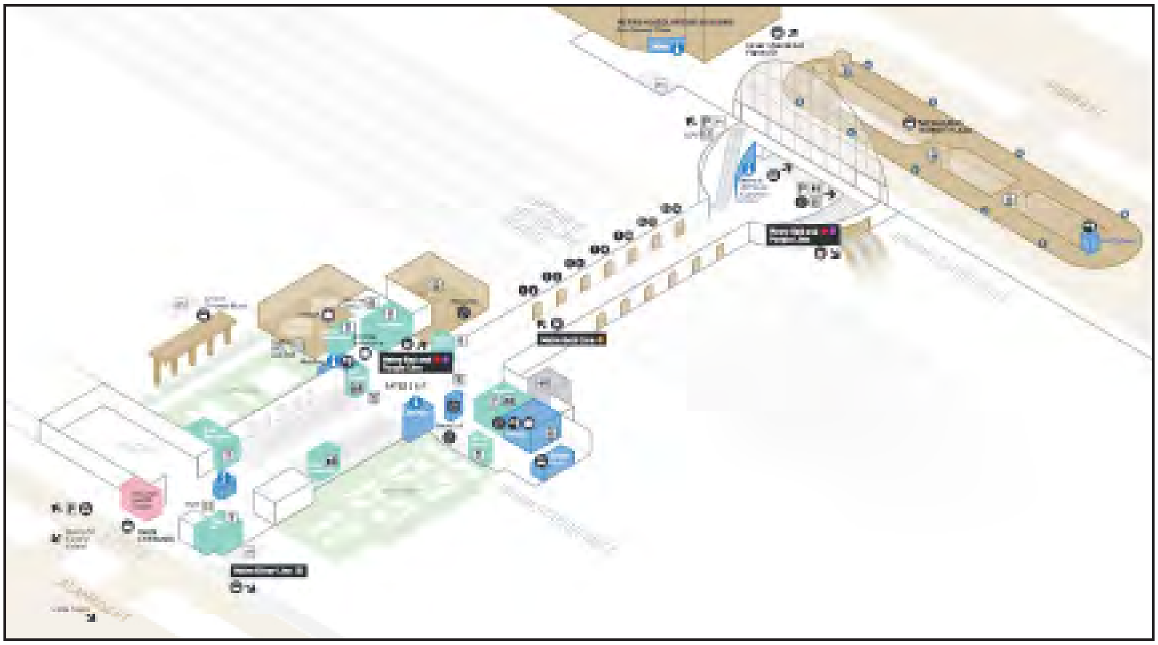


Figure 98. Los Angeles Union Station Current Layout

Source: http://bit.ly/1Htwxaa accessed August 14, 2014.

The Los Angles Union Station Master Plan Effort

Just over a year after purchasing the station and surrounding site, Metro launched the Los Angeles Union Station Master Plan (LAUSMP) effort in June 2012. Table 9 presents the schedule for this effort, while Figure 99 presents its scope. This plan comprehensively envisions the entire station as a future multimodal mobility hub.

Table 9. Los Angeles Union Station Master Plan Project Schedule

June 2012	Consultant contract award
September 2012	Project kick-off
Fall 2012	Data collection and analysis Stakeholder engagement Union Station Technical Advisory Committee meeting
Winter 2012	Community kick-off Presentation of program to the Metro Board of Directors
Spring-Summer 2013	Development of conceptual alternative plans Union Station Advisory Committee meeting Public workshop #1 (preliminary conceptual alternatives) Public workshop #2 (refined conceptual alternatives)
Fall 2013	Metro Board of Directors to select preferred conceptual alternative
Fall 2014	Final Master Plan presented to Metro Board of Directors for adoption

Source: LA USMP Website at http://www.metro.net/projects/LA-union-station/, accessed August 14, 2014.

Figure 99. The Scope of Metro's LAUSMP Effort (orange area)

Source: LAUSMP presentation at http://bit.ly/1JtoMl0 (slide 5), accessed August 14, 2014.

According to its overview fact sheet, the LAUSMP will "develop Metro's vision and plan to guide future development at the station, including transit operations, enhanced pedestrian access and new private and/or public real estate development." Figure 99 provides an illustration of the re-envisioned station. The plan's four core project goals are to:

- Celebrate the site's history: "The Master Plan will celebrate the station and embrace the rich history of neighboring communities."
- Improve the Union Station passenger experience: "A program of … upgraded signage to expanded services will be designed to enhance each passenger's visit."
- Create a great destination: "… The Master Plan will consider combination of public space enhancements, access and circulation improvements, and new development."
- Prepare for High-Speed Rail: "The Master Plan will be flexible to accommodate the future arrival of high-speed rail serving Union Station."[195]

Several improvements, such as better way-finding and signage, have already been implemented. Also, two other important projects are running concurrently with the Master Plan effort. First, the so-called *Linkages Study*, carried out in partnership with SCAG and the City of Los Angeles, will start with "a neighborhood-level assessment of arterial and collector streets, with an emphasis on bicycle and pedestrian mobility." This will result in "an Action Plan and … a community-prioritized list of improvement projects to strengthen bicycle and pedestrian (active transportation) connectivity."[196] Second, the *Southern California Regional Interconnector Project* (SCRIP) will add long-term rail capacity at

Union Station to accommodate increased Amtrak, Metrolink, and eventually high-speed rail service.[197]

The Southern California Regional Interconnector Project (SCRIP)

Metro planners have been eager to fund SCRIP for more than a decade, and with CAHSRA's consideration of a "blended system," this project has become more important, as it will expand the capacity of Union Station. Figure 100 gives an overview of the SCRIP project elements. The specific Union Station improvements associated with the SCRIP are: "1) Extending several of the tracks to the south, crossing over US 101 and some local city streets; 2) Adding a new loop connection to the north along the Los Angeles River; and 3) Reconfiguring the tracks at Union Station, including elevating some alignments."[198] Currently, the CHSRA is helping to fund some SCRIP improvements.[199]

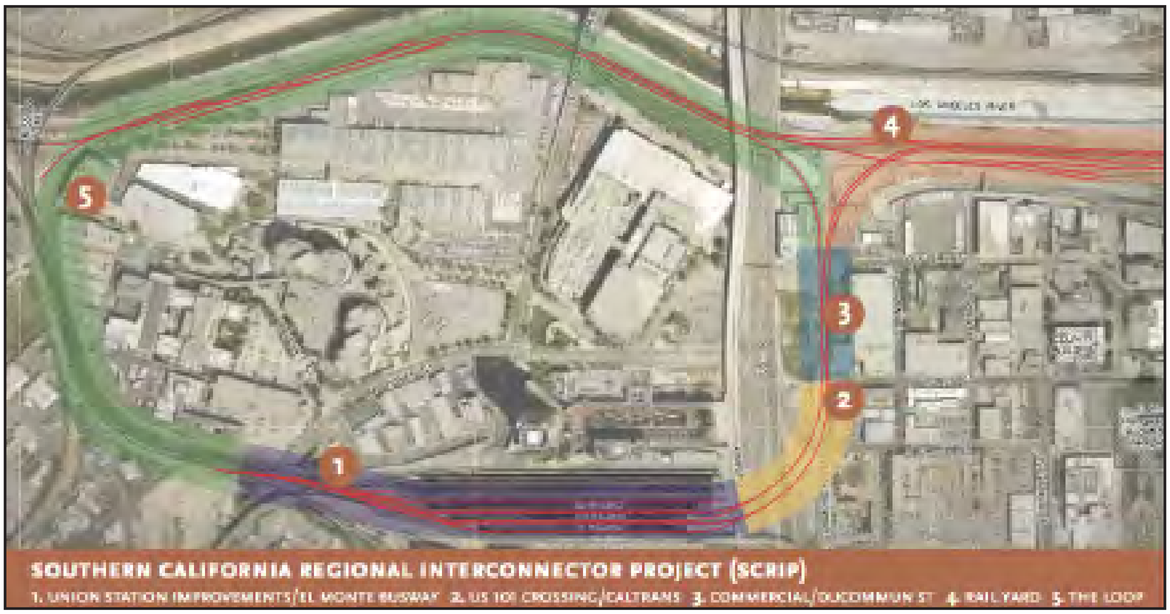


Figure 100. Overview of Metro's SCRIP Project

Source: SCRIP Fact Sheet, http://bit.ly/1U1lwk0

Options for High-Speed Rail Intermodality at Los Angeles Union Station

The LAUSMP process was to some extent carried out as independent from the arrival of HSR at Union Station, but the plan had to account for the possibility of accommodating HSR in the future. So as part of the planning process, the LAUSMP team evaluated several alternatives for (co-)locating HSR at the station. None of these alternatives considered the option of blended operations at the station, meaning that although there are plans to share tracks at different sections north and south of the station, there are no plans to blend operations and tracks at the station level itself. One of the major obstacles is that, unlike Caltrain in the San Francisco Bay Area, the regional rail operator Metrolink is currently firmly opposed to electrification. The LAUSMP process considered four alternative locations for HSR at or near the Union Station site: 1) under Alameda St.; 2) over the rail yard; 3) above Vignes St.; and 4) under Vignes St.

The “under Alameda” option was later dropped, primarily because it would be difficult and costly to build underground tracks in this area because the Red Line subway tracks are in the way. The other three options were deemed feasible, but Metro elected not to prepare any renderings for the “over the railyard” option, relegating HSR to the eastern end of its site near Vignes in all its final design renderings. Figures 101 a and b show the “under Vignes” and “above Vignes” options in the LAUSMP, while Figure 102 shows Metro’s final redesign at the concourse level, with the “New HSR Portal” located east of Vignes.

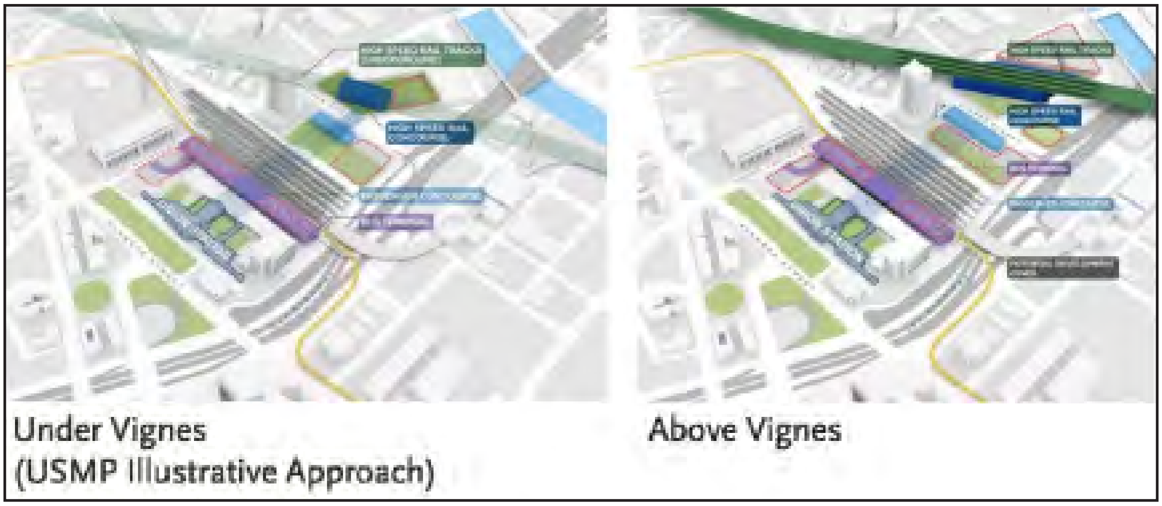


Figure 101. a-b: Under and Above Vignes Options for HSR Placement in LAUSMP

Source: http://bit.ly/1JtoMl0, Slide 23, accessed August 14, 2014.

Figure 102. LAUSMP Proposed Re-Design of the Station Complex

Source: http://bit.ly/1JtoMl0, Slide 24, accessed August 14, 2014.

As Matthew Parent of Gruen Associates, the lead agency for the LAUSMP noted:

> *We worked with HSR very closely when we were planning this station. And they said that [according to] their standards, the minimum is roughly 1400 ft. We are showing it to be an underground alignment, below Vignes street, but mostly for illustration purposes, so we could make renderings. But we have also evaluated two other HSR options, one that is above Vignes and roughly the exact same alignment as the one below, and then one over the yard. We don't believe the one that is over the yard will actually function as well as it could. But we are not doing anything to preclude it either. There are other considerations for why we believe it cannot be above the yard. But again, we are not precluding that from eventually happening.*[200]

When asked why, Parent noted several reasons:

> *[It] is hard for SCRIP to plan for having tracks that would be above the rail. Because there technically just isn't enough room to have separate tracks for HSR. They are asking for six tracks, and if they were to come at grade and using the same platforms, and they operate pretty short headways, it would take up capacity for other tracks. … Other than the constraints of the site … the SCRIP project would have to engineer any structures that would be above the rail right now, and pay for the foundation of the structure above the railroad track immediately, and it is not something they are prepared to do. … And then the other reason is that having the east side off Metro's property allows things to be relatively independent. So, HSR is able to come and service Union Station, but planning for it in terms of engineering and all these things doesn't have to happen now; it can happen at a later date. And it will also serve as a means of helping to recreate the neighborhood. By having that station over there it gives incentives for other things to happen. … It is an economic development tool as well.*[201]

The Master Plan team carefully considers a number of different scenarios of how locals, commuters, long-distance travelers, or visitors might use the redesigned station, but these renderings also make it clear that optimizing future integration with HSR is but an afterthought in this effort. Figure 103 shows the team's illustration of a potential long-distance (purportedly Amtrak) traveler using the station. There is no HSR concourse visible in this rendering. A potential HSR customer arriving at the western entrance would have to walk another 500 feet (150 meters) or more to reach the prospective HSR tracks at Vignes, making a very long walk from the main entrance of the station to the HSR tracks.

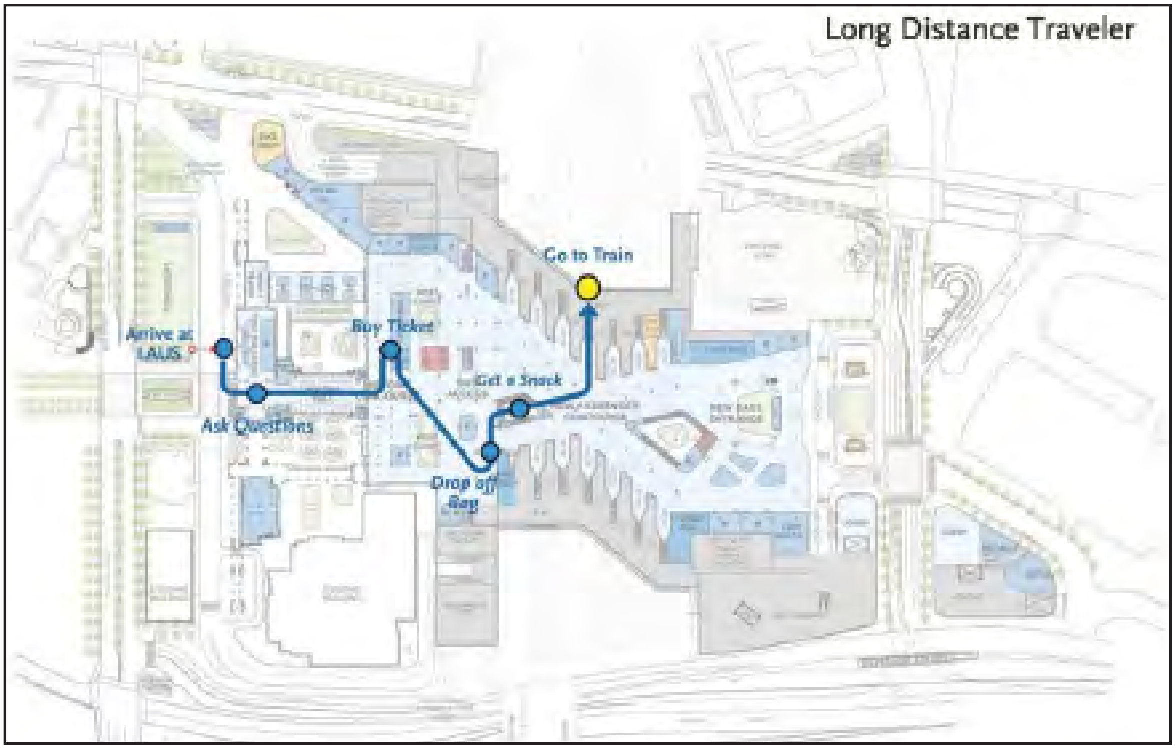


Figure 103. Envisioned Long-Distance Traveler Use of LAUS—without HSR

Source: LAUSMP presentation http://bit.ly/1JtoMl0, slide 23, accessed August 14, 2014.

Parking

The LAUSMP team also reconsidered the parking situation at Union Station. Figure 104 presents an overview of their future vision. In principle, Metro is not planning to accommodate additional parking for the new HSR concourse but only to consider the station's changing needs as a growing mobility hub. A total of 5,480 spaces are planned.

Figure 104. A Future Vision for Parking at LAUS

Source: LAUSMP presentation http://bit.ly/1JtoMl0, slide 29, accessed August 14, 2014.

The Station Area / Neighborhood

The LAUSMP effort included two parallel initiatives specifically aimed at re-thinking neighborhood connections for the station: the so-called *Linkages Study* (now rebranded as *Connect US)* and a *Neighborhood Sustainability Assessment* carried out by Global Green.

As Matthew Parent noted:

> *We really want the station to be part of the neighborhood. So we are considering long term any type of land use that you would find in a neighborhood: residential, commercial, business. We are showing in our illustrations, in a 50-year time frame, that there would be a better connection to the Los Angeles River, so there may be public facilities and parks. But we really feel that the area is very underutilized, and it really could be the center of a new neighborhood that we connect, the Arts District, Chinatown, Boyle Heights, the rest of downtown, together.*[202]

These comments were echoed by Vincent Chang, lead designer with Grimshaw Architects, who were also part of the Master Plan Team.

> *[O]ne of the designing principals from the outset for the Union Station Master Plan has been a desire to create a vibrant and mixed-use destination. Increasingly we are seeing that intermodal transportation centers are not just the portal to the city, but can also become potentially very strong anchors in neighborhoods. And so, with greater emphasis on public transportation and accessibility, then it stands to reason that it*

> *can sustain on its doorstep a range of amenities and a range of typologies of land-use, from residential to commercial, hotel accommodation, and certainly a great deal of retail. Now at Union Station, because you are on the cusp of some very revered historic neighborhoods, and you are also very proximate to what we hope will be a reimagined and revitalized LA River, there seems to be really strong opportunity for all sorts of civic and more social oriented gathering spaces. So if you were to examine the Master Plan, there is a range of very diverse uses, both those that are clearly for transit users, a convenience amenity, all the way through the kinds of uses that will be visible for the emerging district in terms of its connection to existing neighborhoods, and then furthermore to the idea that it could be a great contributor to new economies in the area, with a better connectivity to the river, or the Toy District, or other adjacent properties.*[203]

He also explained how relocating parking was directly linked to the effort of making the entire forecourt area of the station near Alameda more welcoming:

> *So you know if you can imagine LA Union Station, it is directly next to El Pueblo, and an area principally devoted to surface parking. Our investigation led us to believe that there is sufficient capacity on station property in other structures, to really liberate the concord for civic use, and to form a much more welcoming environment to improve the connectivity, especially to El Pueblo, and that entire forecourt could be reimagined for a market, a gathering space, a kind of recreational amenity, it could be curated for different kinds of events. So that is one example of how we would intent to connect to the neighborhoods. We also, in a concurrent project, the Linkages Study, just looked at the improvements to the streetscape in and around the station address the barrier effect. Journeys across the station seem to be perceptually far longer than they truly are in distance terms, and that is largely again a result of their being little visual interest or little amenity offer or diversity along those edges. So the Linkages Study is very much looking at improving the streetscape, improving its environment for cyclists, for example, and different traffic calming ideas, and those are very much incorporated into the forecourt planning that we've done at the station.*[204]

In addition, the Master Plan has specific recommendations for reconfiguring bicycle and pedestrian access to the station, illustrated in Figures 105a and b. There are also plans for a bike station at the main entrance and additional enhancements. Figure 106 presents the station area context, showing the potential for future development and densification at the eastern end of the station, but once again not resolving the question of HSR access.

Figure 105. a-b: Reconfigured Pedestrian and Bicycle Access in LAUSMP

Source: LAUSMP presentation http://bit.ly/1JtoMl0, slides 30 and 31, accessed August 14, 2014.

Figure 106. LAUS Master Plan Neighborhood Context Rendering

Source: http://bit.ly/1GItEvy, accessed August 14, 2014.

What Can We Learn From the European Examples for LAUS?

Los Angeles Union Station is clearly a unique situation, with Metro planning its future growth as a major regional mobility hub. From a basic station integration perspective, either blending the tracks or having HSR arrive above the conventional rail yard is clearly a preferable solution, especially with the SCRIP project creating the new through tracks. The entire rail yard will be reconfigured as part of this project, which is partially supported by HSR funds. However, unless the yard is rebuilt in a way that its foundations can support a future additional elevated structure, ironically the above-the-yard option would appear less feasible after SCRIPs implementation than before.

At the time of this writing, high-speed rail is not being integrated into the existing Union Station complex, but it is rather relegated toward the eastern side of the station complex, outside the area that Metro controls. If this happens, walking time between the HSR tracks and conventional rail will be quite substantial, at least compared with all the European examples studied, and the bus concourse will be relocated to the western side of the conventional tracks, thus requiring an even further walk. The main focus of Metro's current station reconfigurations concentrate primarily around the western entrance that points to downtown and the civic center. It is true that those linkage enhancements are crucial from a city-wide perspective. It is only a brisk ten-minute walk from the city hall to the (western) front of the station, and with all the suggested improvements, this walk will become significantly more pleasant. Unfortunately, it would take almost another ten minutes to reach any HSR tracks located under, above, or east of Vignes. Comparing this with the situation in Germany and Spain, where nationally funded rail companies achieve station complexes with high levels of integration, it seems that Union Station is not headed toward an optimal level of intermodal integration between high-speed rail and other modes.

To be sure, many issues relating to station intermodality and integration with the HSR remain yet to be resolved. The interviewees did not give any detailed information about issues such as HSR prioritization, operational infrastructure, ticket pricing, integrated fares and ticketing, booking options, etc. Many able professionals are working on these complex issues, however, so just as the LAUSMP is still an evolving document, so are the plans for Los Angeles's major HSR station and its precise location.

Box 15: Los Angeles Union Station Hub Intermodality

Station Size:

14 tracks (surface), 2 underground (Red Line)

Station Type:

Union Station was constructed as a terminal station (but through tracks are being constructed as part of the SCRIP Project).

Long-distance rail (Amtrak)

Coast Starlight to Seattle (service began 1971)

Southwest Chief to Chicago (service began 1971)

Sunset Limited to New Orleans (service began 1971)

Texas Eagle to Chicago via San Antonio (service began 1982)

Pacific Surfliner from San Diego to San Luis Obispo via Los Angeles.

Connections to the San Joaquin train to Oakland or Sacramento are provided through Amtrak Thruway Motorcoach services. (see v.)

Commuter Rail (Metrolink, six of seven lines serve the station)

Antelope Valley Line to Lancaster

Riverside Line to Riverside

Orange County Line to Oceanside

San Bernardino Line to San Bernardino

Ventura County Line to East Ventura

91 Line to Riverside via Fullerton

Metro Rail:

Metro Red and

Metro Purple subway lines

Metro Gold Line

Long distance bus (misc. operators):

Amtrak Thruway Motorcoach to San Joaquin trains to and from the Bakersfield Amtrak Station and south to Los Angeles San Pedro and Long Beach Catalina Island Ferries.

Along Pacific Surfliner route (to Santa Barbara, San Diego, and select intermediate stations) during overnight times when trains are not running

Thruway service to Las Vegas, Nevada from Union Station.

BoltBus **(***long-distance motorcoach routes from a bus stop at on the western side of Union Station near the Mozaic apartment complex):*

Los Angeles–Oakland (via San Jose & San Francisco)

Los Angeles–Las Vegas

Megabus (operates several long-distance motorcoach routes from Berth 1 at the Patsaouras Transit Plaza):

M10 to Las Vegas

M11 to San Francisco via Oakland

M12 to San Francisco via San Jose

California Shuttle Bus (provides service to San Francisco, Oakland, and San Jose from a bus stop across from the Patsaouras Transit Plaza at the corner of Vignes and Ramirez Streets).

Rapid Bus, Express Buses & University and Game Shuttles:

@ El Monte Busway & Alameda St:

Metro Silver Line

Metro Express: 487, 489*

Foothill Transit: Silver Streak, 481*, 493*, 497*, 498*, 499*

@ Patsaouras Plaza:

- Berth 3: LADOT Commuter Express: Bunker Hill Shuttle*, 431*, 534*, City of Santa Clarita Transit: 794*, Dodger Stadium Express (during baseball season, home games only)
- Berth 4: Foothill Transit: 699*, University of Southern California shuttles: UPC, HSC, ICS, Orange County Transportation Authority: 701*
- Berth 5: Metro Express: 442, Metro Rapid: 704
- Berth 6: Metro Rapid: 728, 733
- Berth 7: Metro Express: 485, Metro Rapid: 745, Citadel Outlets Express

@ Cesar Chavez Avenue & Vignes Street

Metro Rapid: 770

LADOT DASH: Lincoln Heights/Chinatown

@ Alameda Street & Los Angeles Street

Big Blue Bus: Rapid 10

LADOT DASH: B (weekdays only)

Torrance Transit: 4

Regular Bus/DASH/Local Shuttles

@ Patsaouras Plaza:

- Berth 2: LADOT DASH: D (weekdays only)
- Berth 5: Metro Local: 40
- Berth 6: Metro Local: 33 (late nights only)

@ Cesar Chavez Avenue & Vignes Street

Metro Local: 68, 70, 71, 78, 79, 378

Freeway Access:

Adjacent to the 101 Freeway, proximity to the 110 and 5 Freeways

Pedestrian Access:

Pedestrian access to the west is via Alameda, to the north via Cesar Chavez, and to the east via Vignes. A comprehensive “linkages study” was recently done documenting access, suggesting comprehensive improvements especially to the western access to the station.

Bike Access

Bike access largely parallels pedestrian access, there are bike lanes on Main St. and Los Angeles St. leading to the station from downtown, but the current bike environment leaves much to be desired. This, along with pedestrian improvements, will be a focus for improvements under the Los Angeles Union Station Master Plan.

Bike Storage/parking

Currently, no bike lockers are in the station, but some bike racks are at the western entrance and additional bike parking near the East Portal by the underground car park.

Car Access & Parking

Car access is possible from multiple sides, with short-term parking and drop-off at the western and northern ends of the station, accessible via Alameda and Cesar Chavez entering Union Station Driveway, and more difficult car access and drop-off at the Eastern Portal. The Patsaouras Transit Plaza is not accessible to cars.

Car Rental

Budget and Hertz rental places are at the northern end of the main station building, near the parking areas.

Airport Connections (rail or bus)

For access to LAX, see the info about the FlyAway bus above. Future plans include rail access from Union Station to LAX via the Expo and new Crenshaw.

Access to Bob Hope Burbank Airport via Metrolink and Amtrak.

There is no direct link to Ontario Airport; the closest stations are East Ontario or Pomona.

BURBANK AIRPORT TRAIN STATION[205]

Figure 107. View of Burbank-Bob Hope Train Station

Source: http://en.wikipedia.org/wiki/Burbank%E2%80%93Bob_Hope_Airport_(train_station).

The Burbank-Bob Hope Airport train station that opened in 1992 is a small, unstaffed railway station serving Metrolink and Amtrak trains (Figure 107). The station is next to Bob Hope Airport in the southeastern San Fernando Valley, in Burbank, California. It is a through station for Metrolink's Ventura County Line that connects Downtown Los Angeles (Union Station) to east Ventura. Additionally, Amtrack's *Pacific Surfliner* trains connecting San Luis Obispo to San Diego, and *Coast Starlight* trains connecting Seattle to Los Angeles stop at this station (Table 10).

Table 10. Daily Long Distance (Amtrak) and Commuter Rail (Metrolink) Services through Burbank Airport Train Station

Direction	Line	Daily Frequency (weekdays)
Northbound	AMTRAK Coast *Starlight* toward Seattle	1
	AMTRAK Pacific *Surfliner* toward San Louis Obispo	6
	METROLINK *Ventura County Line* toward East Ventura	17
Southbound	AMTRAK Coast *Starlight* toward Los Angeles	1
	AMTRAK Pacific *Surfliner* toward Los Angeles	5
	METROLINK *Ventura County Line* toward Los Angeles	16

The station has two tracks (northbound and southbound) and two side platforms (600–660 feet long, or 183–201 meters long). In terms of passengers, Amtrak listed the station as its 34th busiest station (out of 74 California stations), with 51,998 passengers boarding or alighting the train from this station during FY2013.[206]

Intermodality: From Plane to Train

The station's intermodality and connectivity are enhanced by the fact that it is located only a short walking distance from the terminals of Burbank's Bob Hope Airport. For those not willing to walk, a free airport shuttle connects the station to the airport terminals. The airport also provides free shuttle service to Metrolink's downtown Burbank station and to Metro's North Hollywood station, which in turn connect with the Metro Red Line to Los Angeles and the Metro Orange Line to Warner Center.

Every weekday, 31 Metrolink trains connect arrivals from the Burbank airport to downtown Los Angeles's Union Station in about 30 minutes. A number of MTA buses also stop at the station.

Two new infrastructure developments—a new Metrolink station (scheduled to open in 2015) and a recently opened intermodal transportation center—will enhance the intermodality of both the airport and railway station and strengthen the plane-to-train connectivity. The new Metrolink station located at San Fernando Boulevard and Hollywood Way on the Antelope Valley Line, less than a mile away from the airport terminals, will make it easier for travelers arriving at the airport to reach the San Fernando Valley, Santa Clarita, and Antelope Valley, and vice versa. The new station will have one platform, with both northbound and southbound Metrolink trains stopping on the same platform. A free shuttle will cover the one-mile distance between the new Metrolink station and the airport terminals. Currently, the Antelope Valley line has only one station at Downtown Burbank, and only Metrolink passengers on the Ventura County Line and Amtrak passengers can reach the airport by train. Both the Airport Authority and Metrolink perceive this enhanced connectivity of the airport and railway station as greatly beneficial.

> *When you look at Metrolink's system, our lines essentially run parallel with every major thoroughfare in the region. This dynamic allows people to complete a trip to the airport without leaving their car at the terminal. It's an outstanding opportunity*.[207]

> *Metrolink connectivity with the airport is a key element of our vision for the airport as a partner in regional transportation. It's great to see plane-to-train becoming a reality at Bob Hope Airport*.[208]

The Regional Intermodal Transportation Center (RITC) is the second important piece of transportation infrastructure that enhances airport and station intermodality and connectivity (Figures 108 and 109). The facility, which opened recently, is a three-level, 456,000-square-feet (42,364-square-meter) structure that costs around $112 million and serves rail (Amtrak and Metrolink), air, and bus travelers, as well as houses rental car facilities. RITC also includes two bicycle stations (about 630 square feet, or 59 square meters, each and accommodating a total of 64 bicycles) for secured bicycle parking for railway passengers and airport employees who commute to both facilities by bicycle. A planned pedestrian bridge will connect the existing Metrolink station to RITC and airport terminals so pedestrians will not have to cross railroad tracks at grade.

Figure 108. North and East Façades of RITC

Source: http://bit.ly/1QZVuyl

Figure 109. South and West Façades of RITC

Source: http://bit.ly/1QZVuyl

As described by the airport's executive director, Dan Feger:

> *…If you're talking about intermodal connectivity to various modes of transportation, we have an existing combined Amtrak and Metrolink rail station, and they're typically 600 ft long, and they have two tracks so there is a platform on each side of the track. There is a walking path, across that train station, to our regional intermodal transportation center. It is basically about half million square foot building, and on the ground floor of this building, tucked away in the corner, is a new bus station that accommodates Metro, Amtrak Bus, will accommodate Burbank bus, and we are trying to get Santa Clarita bus in here, if we can. And then, if you go up the escalator to the second level of this Regional Intermodal Transportation Center, the bulk of which is a consolidated rent-a-car facility, there is a connecting walkway, about 900 ft long. It has moving sidewalks on it, and they connect to a point that is to the South and to the East of the existing terminal complex at the airport. So when you get off the elevator walkway, you have a choice, you can walk about 200 ft to terminal B, or about 400 ft to terminal A, and you're there. So we've linked our existing Airport Terminal, a Bus Station, a consolidated rent-a-car facility, and an Amtrak Metrolink station. We are also working with Metro, and Metro is in the process of building a second train station for Metrolink, on the north side of the airport, to serve the Antelope Valley line. By the way the Metrolink Amtrak service in the south serves Ventura County and connects up with Union Station. The Antelope Valley line in the north serves Santa Clarita and the northern part of Los Angeles County, and that station will be served by an airport bus that is coordinated for pick-up time with the Metrolink schedule.*[209]

***Link*Burbank: A Land Use–Transportation Coordination**

In addition to the infrastructural projects, the City of Burbank, in collaboration with the Airport Authority, has initiated the *Link*Burbank project—a multimodal ground access planning and land use study that has the following goals:

> ***Transportation**: Develop ground transportation improvements that will allow the Airport to serve as a multi-modal regional transportation hub.*
>
> ***Land Use**: Identify transit-oriented development opportunities in the Airport area to take advantage of ongoing transportation connection improvements*.[210]

The study area depicted in Figure 110 is composed of 540 acres (219 hectares) of land that is within a ten-minute walk from the airport and railway stations.

Figure 110. ***Link*****Burbank Study Area**

Source: www.LinkBurbank.com

As depicted in a slide shown by the *Link*Burbank study team during a public workshop on August 13, 2014 (Figure 111), planners hope to expand the traditional understanding of transit-oriented development and take advantage of the synergy and close proximity of different types of rail (commuter, passenger, high-speed), bus, and airport in order to boost commercial and office development around the emerging major transportation hub (Box 16).

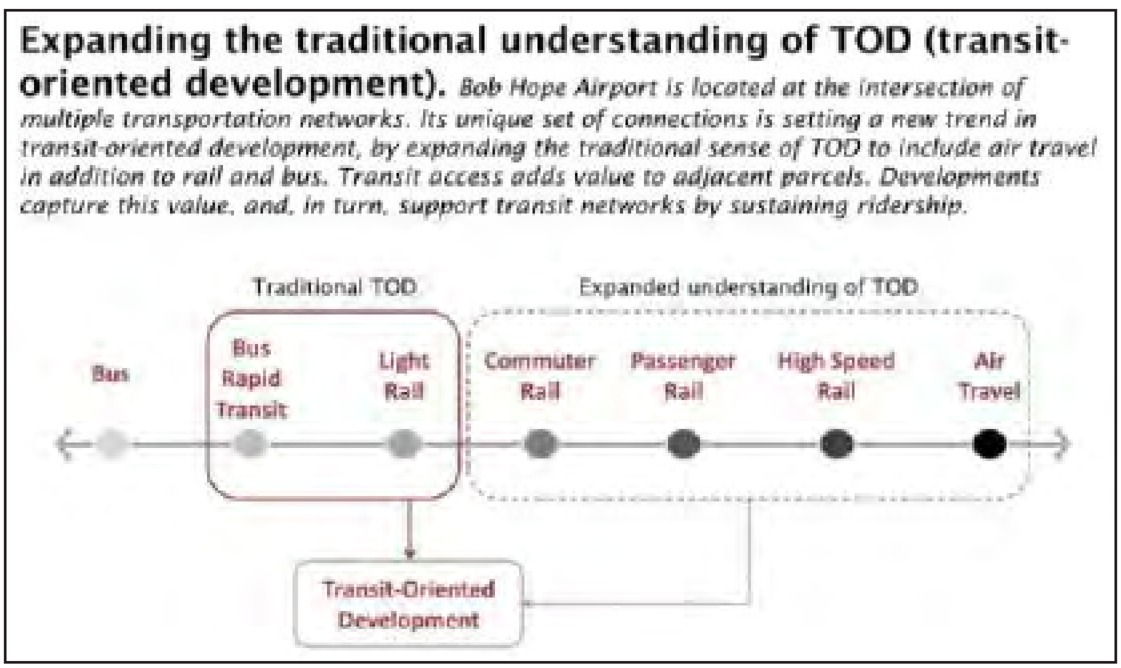


Figure 111.Slide from *Link*Burbank Public Workshop

What about High-Speed Rail?

The aforementioned transportation investments and planning studies intend to create a major intermodal transportation hub at Burbank. However, they make very little reference to the future HSR station. Likely, this is because the CHSRA has studied different alternatives for a station location in the San Fernando Valley; Burbank has been a possible but not certain stop on the HSR corridor. Even if there were to be a high-speed rail station at Burbank, it is not certain if this is to be located near the Bob Hope Airport or at downtown Burbank. As explained by Burbank's transportation planner David Kriske:

> *The LinkBurbank study was sort of agnostic about HSR. Yeah, they are saying it is coming, we know we need to find a place for it. But, it is not imminent. So we need to focus on land use and transportation as we know it now.*[211]

At the time of this writing, however, Burbank appears to be the primary station location in the San Fernando Valley. The Burbank HSR station will likely be located at an airport-adjacent location near or at the site of Metrolink's new station on San Fernando Valley and Hollywood Way (Figure 112). It is believed that the HSR will roll on separate tracks than Amtrak and Metrolink, but still ambiguities remain such as the number of daily high-speed trains likely to stop there, the station's parking needs, and the station's size and layout (though CHSRA has indicated that they would need 1,500 feet (457 meters) for the HSR platform). As emphasized by Dan Feger:

> *The high-speed rail will presumably follow the same corridor as the Antelope Valley line, though that is not on the south side of the airport, it is on the north side of the airport. And the CaHSRA, as I understand it right now, will require four tracks, two through tracks and two station tracks. And, it is completely unclear how the Metrolink service and the HSR service will be integrated. We don't know. And I think that is something California HSR hasn't figured out either.*[212]

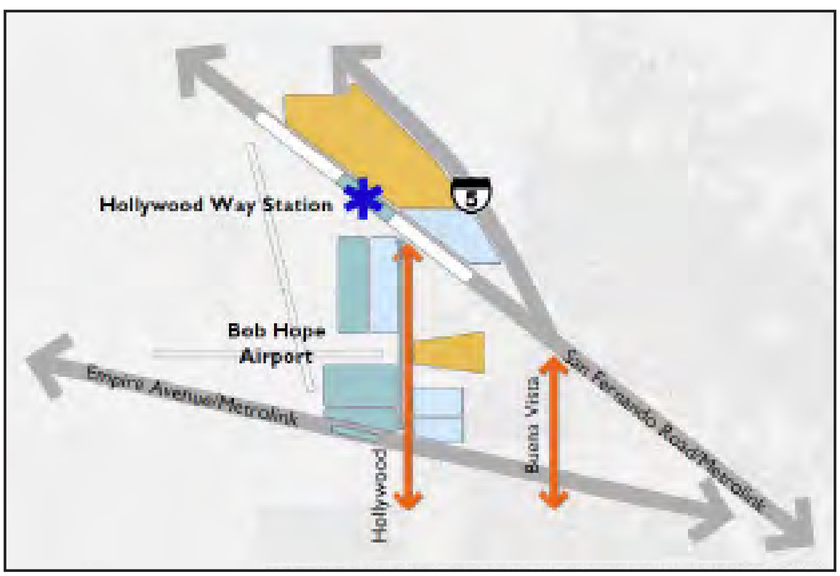


Figure 112. Possible HSR Station Location at Burbank

Source: http://www.burbankca.gov/home/showdocument?id=6884

Despite these feelings of ambiguity, Burbank city planners see the future HSR station as an opportunity. As noted by Patrick Prescott, who is in charge of the *Link*Burbank study:

> *If you look at where HSR is suggested, where the station might go, you can see that, well the city would want to capitalize on the proximity just as we do with the airport. So you might have office, even where appropriate, residential, but you don't want to put those residential too close to the airport or the rail station. We anticipate the opportunity–our council is looking at workforce development–so educational institutions and things like that. … So it would be a mix of office, commercial, and hotel, likely, and then probably some modest restaurant and service to serve the needs of travelers and business people. Maybe even a conference space, so people can fly in and ride the train in for meetings.*[213]

Burbank planners and the airport's executive director view the coming of the HSR as complementary rather than competitive to the airport:

> *Our observation from other places, where they have HSR and airport, is they sort of feed off each other. Some people think the presence of HSR would diminish the demand for flights, but what we've seen is that is not necessarily the case.*[214]

Similarly, the airport's executive director, Dan Feger, does not believe that the HSR will affect the airport business, but it will rather promote it:

> *For this particular airport, the biggest volume of business is up to the [San Francisco] Bay Area. And, opening up a HSR station next to an airport, on the surface, would appear to be direct competition with the air service that is offered here. And to some extent there would be some competition. But, in reality, the bulk of the people that California HSR hopes to attract, are not existing airline passengers. They are people that get in their car, and spend 6 to 8 hours driving up to the Bay Area. They may think that they are in a competition, but in reality they are not. If it takes 3 hours to go by train, and one hour to fly, and depending on what they charge for a ticket, and what Southwest charges for a ticket—whether or not there is competition is really a function of what the ticket price will be for HSR. Right now you can buy a $69 ticket on Southwest; it is not clear to us that California HSR can match that.*
>
> *We as an airport authority, promote connectivity to all forms of ground access, including rail, including HSR to make it easier for people to get to this airport. People will probably use HSR instead of an automobile to get to this airport. … It is just a different way to reduce traffic on I-5, which is another reason we support rail connectivity, to keep people out of their cars.*[215]

HSR Station Integration

The interviewees discussed the importance of both spatial and operational integration for the new HSR station. In terms, of spatial integration, they noted the importance of establishing a good station relationship with the surrounding streets, minimizing any barriers created by the railway tracks and infrastructure, and ensuring that the station structure is not closed off from the rest of the city (like an airport) but rather well integrated, inviting, and accessible.[216] The importance of pedestrian connections was also noted:

> *How do we get people who might be staying or working around the airport, or HSR in this case, to that station? What are good design principles for sidewalks, safe access for pedestrians as well as cyclists? Pedestrian crossing, continuous street tree canopy, appropriate lighting, etc.— those kinds of really simple, basic stuff.*[217]

Seamless operational integration was also emphasized—the idea that passengers can reach the HSR station and/or airport easily by different means of transportation, and not have to only rely on private automobiles. As noted:

> *How do people get to the HSR station? If all are arriving by car, and most people do so at the airport, that presents a challenge as far as it impacts our infrastructure, the ability of our streets to handle that, and not just the HSR facility, or the proposed new airport terminal, but the commercial development that is anticipated to follow. So there is this side-effect. So it is not just the presence of the station that presents a challenge to the infrastructure, but the development that follows. It puts a demand on our streets. How do we make this a multimodal hub for transit and transportation, and minimize the need for people to use their car to get to the airport, and the HSR station. It is something we haven't studied yet, though we have assumptions about it.*[218]

> *Current bus/rail service is inadequate to serve the HSR … Transit service to the HSR station should be frequent, have good headways, and should operate throughout the day and evening. [There should be] hourly Metrolink Service (with 30 minute service during peak periods). Metro buses should have high frequency as well, and there should be an easy connection between HSR and Airport, through either a shuttle or by physically locating HSR close to the terminal.*[219]

A seamless operational integration also involves integrated ticketing—the ability to purchase one ticket from one location for different transportation modes. However, specifics on tickets are uncertain. Dan Feger speculated that "the ticketing process for HSR will be different than the ticketing process for Metrolink, but, there will likely be co-located ticket vending equipment." He commented on the difficulty of coordinating ticketing across counties to prevent the scenarios in which passengers must constantly purchase tickets as they move through different counties.

> *The technology that Metro has is over 20 years old, obsolete, and it is not a good technology. They are trying to figure out how to install a new technology that integrates with all the types of modes of transportation that are available, i.e. Metro buses, Metro light rail, Amtrak through bus, Amtrak Metrolink. And it is a pretty complicated task, because as they explained it, they serve 6 counties. But, Metro only serves one. And each county has its own platform of other rail and transit services. So, to truly make things intermodal in the transit system that expands over several counties, there has to be intense coordination of ticketing platforms. … The compartmentalization by county of transit is a big impediment to multimodal transportation.*[220]

Lastly, the need for interagency coordination, collaboration, and co-funding was stressed as an important prerequisite of intermodality:

> *Of all the things that it would take to really make multimodal transportation work, it is breaking down the funding silos [that is most important]. There has to be a commitment by the various agencies that provide their share of the transit, i.e., CAHSRA, Metro, Union Pacific, Metrolink, the airport, Metro bus, the other bus operators. Each service provider has got to be committed to being part of this intermodal solution. … You also got to break down the funding silos and the bureaucratic silos, and say okay, we believe there should be this connectivity. If you look individually at each of the federal organizations, that are all sibling organizations of the Department of Transportation, whether it be FTA, FRA, or Federal Highways, each of these organizations is lip service and recognition of the value of intermodal connectivity. But, they don't practice it. And their grants actually prohibit cross matching. You can't use federal money from FTA at an airport; you can't use airport money for rail station. I mean it goes on like that ad nauseam. So that is the big challenge here. Until you get government bodies that say, we are going to do this, we are going to break down our rules that prevent it, and then we are going to allow public agencies, including airports, to spend their money as part of the intermodal solution, it won't happen effectively.*[221]

Box 16: Burbank Station Intermodality

Bob Hope Airport

Flights to San Francisco, San Jose, Oakland, San Diego, Sacramento, Portland, Seattle, San Diego, Phoenix, Las Vegas, Salt Lake City, Denver, and New York.

Long Distance Rail (Amtrak)

Coast Starlight, to Seattle and Union Station
Pacific Surfliner, from San Diego to San Luis Obispo via Los Angeles

Commuter Rail (Metrolink)

Antelope Valley Line, to Lancaster and Union Station
Ventura County Line, to East Ventura and Union Station

Rapid Bus, Express Buses

Metro 794
Possible express bus from NoHo Red Line station

Regular Bus

Metro Local: *94, 169, 222*

Bicycle Storage

Currently for 64 bicycles

Freeway Access

Proximity to 5 and 134 Freeways

Car Parking

Airport has 6,600 parking spaces

Pedestrian Access
Walking path connecting Airport Train station to RITC Walkway with moving sidewalks connecting

LESSONS FROM THE GERMAN AND SPANISH CASES

The case studies of the exemplary German and Spanish stations discussed in the previous chapters indicate some good lessons for the Union Station and Burbank HSR stations on how to achieve an integrated transit system spatially and operationally.

Spatial Integration

The studied European examples do a good job in their consideration of four spatial zones in planning and designing the HSR station: 1) the station itself; 2) the station-neighborhood; 3) the municipality at large; and 4) the broader region.

The Station

In the most successful examples, a particular attention is given to both the aesthetics and functionality of the station building. In some cases, 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 (but not all) of them 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.[222] Union Station is a landmark building in Los Angeles, while the Bob Hope Airport Station and new Regional Intermodal Transportation Center (RITC) are architecturally quite mundane structures. Particular attention should be given to the architecture of the new HSR station terminals at Union Station and Burbank. At Union Station, the new HSR structure or station expansion should be of analogous quality to the historic Union Station building. At Burbank, the HSR station could become a new architectural landmark signifying the importance of HSR for the city.

Station architecture is not only about aesthetics but also about functionality. If a blended system approach is adopted for Union Station and/or Burbank, where HSR trains use different platforms than conventional or commuter rail and metro, the spatial relationship and proximity of these platforms and the pedestrian flow between them should be carefully considered. Therefore, it is quite problematic that, as it currently stands, the walking time from the conventional rail platform to the HSR platform at Union Station would be substantial.

All Spanish and German examples studied feature an array of passenger services at the station, such as business-class lounges, multiple information kiosks and ticket booths, lockers, cafes, and free wi-fi. All such services should also be easily available at the California HSR stations. In many Spanish stations, there is also an effort to take advantage of the centrality of the HSR station to develop retail opportunities, and a number of stations feature full-fledged malls within the station structure. The possibility of marrying retail with station activities should be considered in both stations, possibly as a retail corridor along Hollywood Way fronting the Burbank Station and as part of the station and its surroundings at Union Station.

All German and Spanish examples studied give particular attention to way-finding signage inside and outside the station building. This signage is standardized for all stations to make it easier for passengers. 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, and frequent signage becomes extremely important.

The Station Neighborhood

The Spanish and German case study stations gave particular attention to their connection to the station-neighborhood, generally defined as a half-mile around the station. How the barrier created by the railway tracks and station infrastructure is bridged, where the station entrances are placed, and how the station relates to the surrounding streets and parking structures are important considerations. The issue of urban form connectivity must be addressed by both Union Station and Burbank HSR station. Currently, Union Station is largely cut off from the rest of downtown by freeway ramps and railroad tracks. Consolidation of existing railway tracks, trenching, and covering should be considered in efforts to better connect the station with its surrounding neighborhood and the Los Angeles River. At Burbank, it is very important to ensure easy pedestrian routes and moving sidewalks connecting the new HSR station to the airport’s two terminals and the RITC.

The Municipality at Large

All the studied stations scored very high regarding their connectivity via public transit and/or metro, providing excellent links to different areas in the city. In almost all cases, an airport bus connects the station to the airport. Additionally, all studied cases have rental car facilities, but many also include car-share and bike-share facilities as well. Because of this good connectivity with transit and the availability of alternative transportation modes other than the private car, the amount of parking space provided in the European HSR stations is considerably lower than the projected parking needs for HSR stations in Southern California. As mentioned by both David Kriske and Patrick Prescott, good HSR connections with buses, metro, and conventional rail would minimize the need for people to drive and park their cars at the HSR station.

Of course, Los Angeles is a huge urban area, and it is impossible to ensure direct transit connections between the HSR station and the myriad destination points in the city. Nevertheless, it is important to consider the major destination points in the city (for example, downtown and other sub-centers, theme parks, commercial centers, airports, etc.), seek to connect them with direct transit lines to the HSR station, and also consider ways to boost the utilization of alternative means of transportation to and from the HSR station.

The Region

An earlier MTI-sponsored study discussed the importance of complementarity among HSR station-cities because the new high-speed infrastructure compresses time and space, making some of these cities much more accessible.[223] 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 landing in Madrid to visit places like Toledo, Córdoba, or Seville. While Burbank is quite close to downtown Los Angeles, the station's physical proximity to the Burbank Airport may mean that travelers from the San Joaquin Valley in central California could use the HSR to Burbank in order to catch a flight from the Burbank airport. It is maybe for this reason that the airport's executive director, Dan Feger, is welcoming HSR's close proximity with the airport facility and sees complementarity rather than competition.

Operational Integration

The German and Spanish examples indicate that a high degree of operational integration happens when there is a high level of service, with frequent daily connections and a good coordination of train schedules. High-speed train schedules should be well coordinated with local and regional trains.

Another area in which coordination is important is integrated ticketing. As discussed in Chapter 5, ticketing for high-speed rail 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. The California HSR planners should consider them.

IX. CONCLUSIONS AND RECOMMENDATIONS

This study utilized knowledge and drew data from the literature, high-speed rail experts from academia and practice, case studies of two different types of blended systems in Germany and Spain, as well as case studies of HSR stations in these two countries. The purpose was to better understand the advantages and disadvantages of blended systems and the lessons that California can learn from the ways intermodality is practiced in the German and Spanish stations through spatial, infrastructural, and operational means. Thus, this study not only examined blended systems from the narrow perspective of how high-speed and conventional rail can share the same tracks, but it also took the broader perspective of how high-speed rail services and infrastructure can integrate with other transportation modes and better fit into the surrounding neighborhood and city. This chapter summarizes the study findings.

This study examined two different types of blended systems:

1. The German HSR system, which is almost completely blended, with HSR trains running on pre-existing conventional tracks. Where new tracks have been built in Germany, these are not exclusively dedicated to the high-speed (ICE) trains but are also used by conventional trains. As we emphasized, this system privileges connectivity over speed.

2. The Spanish HSR system that started as a separate system using primarily dedicated tracks (with the exception of short areas at stations), but which has developed technology that now allows HSR trains to share conventional train infrastructure by changing gauge at certain locations. This permits trains to slow down without stopping. Further, this system allows Spanish HSR trains to typically travel at higher speeds than the German ICE trains, but one drawback is the limited number of changeover locations that makes the network less flexible.

Advantages of Blended Systems

Regardless of these differences, a wide consensus emerged among experts that blended systems have the following general advantages:

- Because high-speed and conventional rail use the same tracks, the amount of required right-of-way space is significantly reduced in blended systems. This is particularly important in highly urbanized and built-out urban areas, where there is very limited space to accommodate additional tracks. Furthermore, the narrower right-of-way prevents the creation of significant “barrier effects.” With blended systems, urban designers have an easier task to physically integrate the station with its adjacent neighborhood.

- Blended systems typically result in cost-savings when building the railway infrastructure because they use already existing tracks and rights-of-way, and they better integrate railway infrastructure by sharing stations and facilities.

- Some experts believe that blended systems provide greater flexibility in changing or adding HSR and/or conventional rail services or routes based on passenger demand.

- Similarly, experts believe that blended systems may have a higher robustness because the HSR service can use conventional tracks in cases of infrastructure and service disruptions.

- In blended systems, HSR and conventional rail may share the same platform (as is primarily the case in Germany) or utilize separate but adjacent platforms (as is often the case in Spain). Both cases allow fast changes and passenger transfers from one system to the other, so the total travel time is reduced.

Challenges of Blended Systems

However, blended systems are not without their challenges. Experts seem to agree that the most significant challenges of blended systems are operational. The following provides a list of the most important challenges.

- Conventional trains sharing the same tracks with HSR trains typically reduce the capacity of the HSR, as they often force it to operate at lower speeds. To reduce this effect, sufficient passing tracks and intermediate stations should be provided to accommodate passing HSR trains at their full velocity. If the same tracks are also used by freight trains, then passing loops for freight services should also be installed.

- The different speeds of the high-speed and conventional trains require that larger safety distances are kept between trains.

- Blended systems present more significant scheduling and coordination challenges than systems in which these two different modes use separate tracks. They require coordination of very different technologies and are more difficult to manage than separated systems.

- Blended systems present more opportunities for delays because of the large numbers of conventional and freight trains using the same tracks. HSR trains typically must be given priority over other trains, and this may result in inferior conventional rail services. Some European countries like France resolve this issue by building additional new tracks at high-volume stations.

Recommendations

The study found much to be learned from Germany and Spain regarding the planning, design, and operation of blended transit systems. At the planning stages, it is important that the existing and desired capacities of the conventional and HSR systems are accurately understood and agreed upon because the simultaneous operation of HSR on the same tracks as conventional rail will impact both systems. It is also recommended to model these impacts to help decide more accurately to what extent and at which corridor the system will be blended and where additional tracks should be provided. Thus, coordination and collaboration among multiple parties (the transit operators of conventional and HSR services) from the very beginning of the planning process is essential. Additionally, collaboration and coordination of state and federal transportation agencies and authorities for the provision of unified design and safety standards and maintenance criteria would also help bridge potential differences among the various systems rolling on blended corridors.

But the joint use of the same tracks by two different railway systems is not the only aspect of blended systems that should be considered. Other operational aspects that should be addressed involve a high level of connectivity and intermodality with other travel modes, integrated ticketing, and good communication/information strategies. Connectivity and intermodality with other transportation modes offer seamless travel and mobility benefits. The German and Spanish case studies are exemplary in their achieved levels of intra-city and inter-city connectivity. They also 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. One suggestion from an HSR expert was to have an HSR station manager with coordination responsibilities over all categories of operators, joint-use spaces, and services.

Additional ways to improve the operational connectivity of HSR services with other modes include integrated ticketing options (as discussed in the previous chapter), luggage transfer services from one mode to the other, clear and frequent way-finding signs, and advanced information systems about connections to other modes.

Lastly, the importance of spatial connectivity should not be underestimated. Without repeating the recommendations of the previous chapter, this report will underscore the importance of a station layout that allows physical proximity, short walking distances, and visual connections among platforms, as well as among station platforms and bus terminals or bus stops. 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), 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 not only as functional transportation nodes, but also as 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.

APPENDIX A: LIST OF INTERNATIONAL EXPERTS

1. Ahlfeldt, Gabriel, London School of Economics (UK)
2. Aveline, Natacha, CNRS (France)
3. Berion, Pascal, Université de Franche-Comté (France)
4. Bertolini, Luca, University of Amsterdam (Netherlands)
5. Bonnafous, Alain, University of Lyon (France)
6. Bruinsma, Frank, Vrije Universiteit (Netherlands)
7. Campos, Javier, University of Las Palmas (Spain)
8. Edwards, Michael, University College London (UK)
9. Facchinetti-Mannone, Valerie, University of Burgundy, Dijon (France)
10. Garmendia, Maddi, University of Castilla La Mancha (Spain)
11. Ghivoni, Moshe, University of Oxford (UK)
12. Hall, Peter, Bartlett School (UK)
13. Klein, Oliver, ENTPE, University of Lyon (France)
14. Menerault, Philippe, University of Lille (France)
15. Monzón, Andrés, Universidad Politécnica de Madrid (Spain)
16. Münter, Angelika, ILS Dortmund (Germany)
17. Plowden, Stephen (UK)
18. Ponti, Marco, Politecnico University of Milan (Italy)
19. Pucci, Paola, Politecnico University of Milan (Italy)
20. Richer, Cyprien, Équipe de Recherche Associée (ERA), Lille (France)
21. Rothengatter, Werner, Karlsruhe Institute of Technology (Germany)
22. Thierstein, Alan, TU Munich (Germany)
23. Trip, Jan Jacob, TU Delft (Netherlands)

24. De Ureña, José Maria, University of Castilla La Mancha (Spain)

25. Vickerman, Roger, University of Kent (UK)

26. Willigers, Jasper, Significance and RAND Europe (Netherlands)

APPENDIX B: SURVEY INSTRUMENT FOR HSR EXPERTS

Dear Colleague,

California is in the process of building a new High-Speed Rail (HSR) system. For parts of the HSR corridor, the high-speed trains will share the tracks of the conventional railway. We call this a "**blended system**." This research, which is funded by the U.S. Federal Transit Administration, seeks to identify successful practices from blended HSR systems that will provide good lessons for California. We would like to ask you a few questions about **blended systems** as well as **multimodal train stations** (serving HSR and conventional rail, as well as other travel modes). We will be grateful for your responses!

Blended systems

1. Are the HSR trains in your country sharing any part of their tracks with conventional trains (intercity, commuter or regional)? In other words does your country have a "blended system"?

2. If yes, do you have a "blended system" for the full corridor or only for some segments of it?

3. What would you say are the biggest challenges of "blended systems" in terms of:
   (a) space/spatial requirements:
   (b) infrastructure:
   (c) operations:

4. Are there particular station layouts that can better accommodate blended systems (e.g. with shared or separate platforms, shared or separate service areas, shared or separate ticketing areas, etc.)

Multimodal Stations

1. From your experience, what recommendations do you have for achieving a seamless integration of the HSR service with other railway services and other travel modes?

2. Can you pinpoint to good examples of multimodal HSR stations (regardless of them being part of a blended system)?

3. Can you pinpoint to bad examples of multimodal HSR stations?

4. Please let us know if you have any other comments about blended systems of multimodal train stations.

THANK YOU VERY MUCH!

APPENDIX C: SURVEY INSTRUMENT FOR EUROPEAN HSR STATION MANAGERS

Dear Sir or Madame,

California is in the process of building a new High-Speed Rail (HSR) system. For parts of the HSR corridor, the high-speed trains will share the tracks of the conventional railway. This research, which is funded by the U.S. Federal Transit Administration, seeks to identify successful practices from Spanish and German HSR systems that will provide good lessons for California. For this reason, we will be grateful if you could respond to the questions that follow.

Sincerely,

Anastasia Loukaitou-Sideris
Associate Dean, UCLA Luskin School of Public Affairs
Professor, UCLA Department of Urban Planning
Email: sideris@ucla.edu

RAIL INFRASTRUCTURE

1. Do your HSR trains share track with conventional trains (intercity, commuter or regional)?

2. If yes, for the full corridor or only for some segments of it?

3. Does HSR serve the same overall routes as conventional trains?

4. Who owns the track infrastructure along the route?

5. If HSR uses shared tracks within metro areas, then:
   a. Does HSR have priority?
   b. What is the maximum speed in this metro area?
   c. Are there plans to upgrade the corridor in the future?
   d. Do you encounter any challenges by having HSR and conventional rail share the same tracks?
   e. Do you encounter more delays in the shared parts of the tracks?

TICKETING & HSR-SPECIFIC AMENITIES

6. Is ticketing service for HSR separate from regular rail ticketing (i.e. HSR ticketing booths are different or at different spaces of the station; do they have integrated or separate website for booking)?

7. Does it cost more to ride HSR than conventional rail? Are there special conditions that apply to HSR tickets such as advance booking or higher reservation fees?

8. Do intercity HSR rail tickets allow passengers to ride urban public transportation at no additional cost?

9. Are combined travel packages (for both HSR and conventional rail trips) offered to HSR riders at discounted prices?

10. Do you use integrated fare tickets for high-speed and other forms of intercity rail? For example, is there a single “mobility card” that passengers can use to access a range of transportation options? If so, which modes can be accessed with this single fare ticket? (i.e. public transit, bike share, car share, bicycle parking, car parking, etc.)

11. Does HSR service offer special services that other rail services don’t? (e.g. baggage control services, boarding services, on-board meeting spaces, lockers)

STATION LAYOUT/MODAL INTEGRATION

12. Do HSR trains arrive on different platforms than other trains?

13. If platforms are separate, how far apart are HSR tracks from conventional rail? (How many minutes to walk?)

14. If platforms are separate, is this for technical or service-related reasons?

15. What are the primary modes of access to your HSR station?

16. How far (how many minutes walk) are the HSR platforms from connecting services?
    a. Bus
    b. Metro
    c. LRT
    d. Taxi/Shuttles
    e. Car rental and/or car share facilities
    f. Bike share

17. Are bikes allowed on high-speed trains? What are the restrictions? Are there special accommodations for bikes (on-board racks, lockers)?

18. Are bikes allowed on other trains? What are the restrictions? Are there special accommodations for bikes (on-board racks, lockers)?

19. Are the HSR and the conventional tracks wheelchair accessible?

20. Do you offer specific services or programs to facilitate door-to-door access via high-speed rail, and especially by non-auto modes?

21. Has your city/region made coordinated improvements to transit stations that have the goal of increasing use of transit as an access mode to HSR?

22. Do you offer any connections to activities that are traditionally associated with auto travel (i.e. activities such as visits to wineries, ski areas, etc.)?

23. Do you have a coordinated way-finding and signage program for the station? Or are way-finding and signage standards determined by another entity (such as the national railway, regional government)?

PARKING

24. Do you provide park-and-ride spaces for cars at your station(s)? How many?

25. Is there free parking at the station? If it is paid, how is the pricing structured?

26. Has your city/region developed a regional remote parking plan that provides incentives for park-and-ride passengers to park their cars in more peripheral locations, away from main HSR stations?

27. Have you developed policies for transitioning station sites away from car access and toward more sustainable modes (walking, cycling, transit)?

28. Do you use surface parking lots as interim land uses for land-banking purposes?

STATION DISTRICT

29. Is there an official definition of the 'station area' and if so, how is it defined?

30. In defining the station area, do you use a standard distance such as an 800-meter radius? Or do you instead consider the amount of time that it takes to access the station by various modes?[224]

31. Is there a special station planning district in place?

32. What specific land uses are you seeking to attract within station areas?

33. Are transit-oriented development (TOD) plans/policies in place for HSR station areas?

AIRPORT CONNECTIONS AND HSR/AIR COMPETITION

34. Is your main regional airport served by HSR?

35. If not, how is the airport connected to your HSR stations?

36. How would you characterize the relationship between HSR and air travel? Are there coordinated policies in place to manage intercity travel demand by diverting trips below a certain distance away from airports and toward HSR?

GOVERNANCE

37. Who owns your HSR stations?

38. Who manages your stations?

39. Who is responsible for planning/maintaining the immediate station area (plaza)?

40. Are there conflicts of interest between station management and rail service operations?

41. Are there cooperation/service agreements between the rail authorities, transit agencies, station management bodies, or municipalities that serve your station?

42. Please name the citywide/metropolitan entities that are involved in planning your HSR station? What agreements are in place between those entities and the bodies that manage the station and station area?

GENERAL EVALUATION

43. What would you say are the biggest challenges of station intermodality in terms of: (a) spatial; (b) infrastructural; and (c) operational needs?

44. From your experience, what recommendations do you have for achieving a seamless integration of the HSR service with other railway services and other travel modes?

45. If you are knowledgeable about the proposed California system, do you have specific recommendations with regard to station access?

APPENDIX D: LIST OF INTERVIEWEES

United States

1. Vincent Chang, Partner, Grimshaw Architects

2. Dan Feger, Bob Hope Airport, Executive Director

3. David Kriske, Transportation Planner, City of Burbank

4. Casey Couchois, Los Angeles Metro

5. Matthew Parent, Gruen Associates

6. Patrick Prescott, Burbank City Planner, Director *Link*Burbank *study*

Spain

1. Juan Ignacio Campo Jori, Manager International Projects, ADIF

2. Jose Javier Diaz Diaz, International Projects, ADIF

3. Juan Matias Archilla Pintidura, Gerente de Área de Proyectos Internacionales Dirección Internacional, RENFE

4. Jose Maria de Ureña, Profesor of Regional Planning, Universidad de Castilla-La Mancha

5. Carlos Venutra, Director of Passenger Stations, ADIF

Germany (Interviews conducted by Eric Eidlin in November 2013)

1. Constantin Pitzen, Director, Berlin Fahrplangesellschaft

2. Andreas Knie, Frank Christian Hinrichs, Frank Wolter, and Jens Lehman (INNOZ Berlin)

3. Nils Hartwig, German Transport Ministry (BMVBS)

4. Markus Hoffmann, DB Mobility Networks Logistics

5. Marc Ulrich and Philip Luy, DB Station and Service

6. Jens Christian Gertsen, Inno-mobil

APPENDIX E: QUESTIONS FOR CALIFORNIA STATION INTERVIEWS

A. STATION

1. What is the size of the station building and station site?

2. How many platforms will the station have?

3. What will be the size (length and height) of the platform?

4. Where will be the entrance to the station?

B. RAIL INFRASTRUCTURE

5. How many trains will stop daily at the station?
   a. Amtrak
   b. Metro
   c. Metrolink
   d. HSR

6. How many trains will pass through daily (without stopping)?

7. Will the HSR trains share tracks with Amtrak trains as they enter the station?

8. Will the HSR trains roll on separate or shared tracks with Metro and Metrolink trains?

9. If HSR will use shared tracks, then:
   a. Will HSR have priority over the other trains?
   b. What will be the HSR maximum speed in the LA metro area?
   c. Are there plans to upgrade the corridor in the future?
   d. Do you anticipate any challenges if HSR and conventional rail share the same tracks?
   e. Do you anticipate more delays in the shared parts of the tracks?

C. TICKETING & HSR-SPECIFIC AMENITIES

10. Will ticketing service for HSR be separate from regular rail ticketing (i.e., HSR ticketing booths are different or at different spaces of the station; do they have integrated or separate website for booking)?

11. Do you anticipate offering:
    a. Regionally integrated fares for HSR and conventional rail?
    b. Automatic ticketing
    c. Online/Cell phone booking
    d. Monthly fare plans

12. Do you anticipate that HSR will offer special services that conventional rail services do not (e.g., baggage control services, boarding services, on-board meeting spaces, lockers)?

D. STATION LAYOUT/MODAL INTEGRATION

13. What will be the type and number of connecting transit services?
    a. Metro
    b. Light Rail
    c. Rapid Bus/Express Bus
    d. Regular Bus

14. Do you anticipate that HSR users will use which modes to access the station (in order of importance)
    a. Airplane
    b. Private automobiles
    c. Taxis/shuttles
    d. Bicycles

15. Will HSR trains arrive on different platforms than other trains?

16. If platforms are separate, how far apart will HSR tracks be from conventional rail? (How many minutes to walk?)

17. If platforms are separate, is this for technical or service-related reasons?

18. What will be the primary modes of access to the HSR station?

19. How far (how many minutes walk) will the HSR platforms from connecting services?
    a. Bus
    b. Metro
    c. LRT
    d. Taxi/Shuttles
    e. Car rental and/or car share facilities
    f. Bike share

20. Will there be special accommodations for bikes (on-board racks, lockers)?

21. Do you anticipate offering specific services or programs to facilitate door-to-door access via high-speed rail, and especially by non-auto modes?

22. Will you have a coordinated way-finding and signage program for the station?

E. PARKING

23. How many park-and-ride spaces for cars will the station have?

24. Are they going to be in structures or in surface parking lots? Where?

25. Do you anticipate developing remote parking sites? If so, do you plan to provide incentives for park-and-ride passengers to park their cars in more peripheral locations, away from the station?

26. Do you have any plans to encourage access to the station through more sustainable modes (walking, cycling, bus transit)?

27. Do you use surface parking lots as interim land uses for land-banking purposes?

F. STATION DISTRICT

28. Is there a special station planning district in place?

29. What specific land uses are you seeking to attract around the station?

30. Are transit-oriented development (TOD) plans/policies in place for the station areas?

31. Are there plans to enhance the walkability and pedestrian-friendliness of the station area?

32. What design means will you use to better connect the station to its surroundings and avoid the barrier effect?

G. AIRPORT CONNECTIONS AND HSR/AIR COMPETITION

33. How will the airport be connected to the HSR station?

34. How would you characterize the relationship between HSR and air travel? Are there coordinated policies in place to manage intercity travel demand by diverting trips below a certain distance away from airports and toward HSR?

H. GOVERNANCE

35. Please name the entities involved in planning the HSR station.

36. Who owns the station?

37. Who manages the station?

38. Who is responsible for planning/maintaining the immediate station area?

39. Are there conflicts of interest between station management and rail service operations?

40. Are there cooperation/service agreements between the rail authorities, transit agencies, station management bodies, or municipalities that serve the station?

I. GENERAL EVALUATION

41. What would you say are the biggest challenges of station intermodality in terms of: (a) spatial; (b) infrastructural, and (c) operational needs?

42. What recommendations do you have for achieving a seamless integration of the HSR service with other railway services and other travel modes?

ENDNOTES

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62. Jan Jacob Trip.
63. The German experts were Gabriel Ahlfeldt, Angelika Münter, Werner Rothengatter, and Alan Thierstein.
64. The Dutch experts were Luca Bertolini, Frank Bruinsma, Jan Jacob Trip, and Jasper Willigers.
65. A detailed description of the Spanish blended system is provided in de Ureña, J.M. (2012). "High-Speed Rail and its Evolution in Spain," in de Ureña, J.M. (Ed.) (2012) Territorial Implication of High-Speed Rail: A Spanish perspective, Ashgate, 29-44.
66. The Spanish experts were: Javier Campos, Maddi Garmendia, Andrés Monzón, and José Maria de Ureña.
67. Peter Hall.
68. The UK experts were: Michael Edwards, Moshe Givoni, Peter Hall, Stephen Plowden, and Roger Vickerman.
69. Ben Tripousis.
70. Paola Pucci.
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72. The French experts were: Natacha Aveline, Pascal Berton, Valerie Facchinetti-Mannone, Alain Bonnafous, Olivier Klein, Philippe Menerault, and Cyprien Richer
73. Natacha Aveline.
74. Ibid.
75. Valerie Facchinetti-Mannone.
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79. Pascal Berton.
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81. Cyprien Richer.

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88. Frank Bruinsma.

89. According to Ben Tripousis, in the Peninsula Corridor this issue will be addressed by having both the commuter and HSR trains operate at 110 mph (177 km/h).

90. This is true when the line carries very frequent services.

91. Gabriel Ahlfeldt.

92. Frank Bruinsma.

93. For information about this accident see: http://elpais.com/elpais/2013/09/06/inenglish/1378468502_039832.html

94. Javier Campos.

95. Peter Hall.

96. Alain Bonnafous.

97. Frank Bruinsma.

98. Jasper Willigers.

99. Peter Hall. Also for more information see: http://en.wikipedia.org/wiki/European_Rail_Traffic_Management_System

100. Peter Hall.

101. Natacha Aveline, Pascal Berion, José Maria de Ureña.

102. Jan Jacob Trip.

103. Pascal Berion.

104. Roger Vickerman.

105. Andrés Monzón.

106. Frank Bruinsma.

107. Jasper Willigers.

108. Gabriel Ahlfeldt.

109. Moshe Givoni.

110. Luca Bertolini, Roger Vickerman, Marco Ponti.

111. Jan Jacob Trip

112. Gabriel Ahlfeldt.

113. Peter Hall.

114. Jan Jacob Trip.

115. According to Peter Hall, researchers spent a great deal of time on this issue in the EU Interreg SINTROPHER and SYNAPTIC studies. See in particular the final reports of SYNAPTIC, *S-Map 2030* and *S-Map 2030 North West* and the movie clip accompanying the latter, all downloadable from the project websites, and also the final report of the SINRROPHER Word Package 3 on interchanges http://www.sintropher.eu, http://www.synaptic-cluster.eu/.

116. Cyprien Richer.

117. Moshe Givoni.

118. Cyprien Richer.

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120. Pascal Berion.

121. Jan Jacob Trip.

122. Natacha Aveline.

123. Valerie Facchinetti-Mannone.

124. Ibid.

125. Paola Pucci.

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127. Moshe Givoni.

128. Alain Bonnafous, Michael Edwards, Maddi Garmendia, Oliver Klein, Andrés Monzón. Marco Ponti, José Maria de Ureña.

129. Paola Pucci.

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144. As mentioned, however, by one reviewer: “Caution should be exercised when making a similar evaluation within the California system. San Jose, with a population of over 1 million, for example, will have a significant multi-modal station. However, the city itself is much more suburban in nature. By comparison, San Francisco has hovered at roughly 700,000 to 850,000 population but is much more urban in nature.”

145. Germany has four cities with population exceeding one million (Berlin, Hamburg, Munich, and Cologne). Spain has two cities with population exceeding one million (Madrid and Barcelona). Germany has eight and Spain has 12 cities with population between 0.5 and 1 million, while Germany has 66, and Spain has 41 cities with population between 100,000-500,000.

146. See Hartmut Mehdorn, "*Diplomat wollte ich nie warden.*" (I never wanted to become a diplomat.) Hoffmann und Campe, Berlin 2007, ISBN 978-3-455-50047-9, S. 112 f., cited in http://de.wikipedia.org/wiki/Intercity-Express#cite_note-mehdorn-2007-112-8 [Mehdorn is the former CEO of German Railways.]

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151. See https://www.linkedin.com/company/8108?trk=vsrp_companies_res_name&trkInfo=VSRPsearchId%3A144720151419677553645%2CVSRPtargetId%3A8108%2CVSRPcmpt%3Aprimary

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162. Carlos Ventura, ADIF interview.

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200. Matthew Parent, Gruen Associates, interview.

201. Ibid.

202. Ibid.

203. Vincent Chang, Grimshaw Architects, interview.

204. Ibid.

205. Data for this station came from interviews with Patrick Prescott, Deputy City Planner, City of Burbank; Dan Feger, Bob Hope Airport Executive Director; and David Kriske, Transportation Planner, City of Burbank; as well as from the following documents: *Environmental Assessment for Proposed Construction of a Regional Intermodal Transportation Center and Runway 33 Runway Safety Area Restoration*—Bob Hope Airport| Burbank, Los Angeles County, California http://www.burbankairport.com/images/stories/AirportAuthority/pdf/ritc/bur_final_ea_dec2010.pdf. City of Burbank, California. *California High-Speed Rail Project*. http://www.burbankca.gov/departments/community-development/planning-transportation/transportation-planning/california-high-speed-rail-project. LinkBurbank project website www.

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ABOUT THE AUTHORS

ANASTASIA LOUKAITOU-SIDERIS

Anastasia Loukaitou-Sideris is a professor of urban planning and associate dean of the UCLA Luskin School of Public Affairs. She holds degrees in architecture and urban planning. Her research focuses on the public environment of the city, its physical representation, aesthetics, social meaning, and impact on the urban resident. It includes documentation and analysis of the social and physical changes that have occurred in the public realm; cultural determinants of design and planning and their implications for public policy; quality-of-life issues for inner city residents; and transit security, urban design, land use, and transportation issues. She has served as a consultant to the Transportation Research Board, Federal Transit Administration, Southern California Association of Governments, South Bay Cities Council of Government, Los Angeles Neighborhood Initiative, Project for Public Spaces, Greek Government, Portuguese Foundation for Science and Technology, and many municipal governments on issues of urban design, land use, and transportation. Her projects have been supported by the U.S. and California Departments of Transportation, Federal Transit Administration, Mellon Foundation, Haynes Foundation, Gilbert Foundation, Archstone Foundation, Sound Body Sound Mind Foundation, and the Mineta Transportation Institute. Her books include Urban Design Downtown: Poetics and Politics of Form (UC Press: 1998); Jobs and Economic Development in Minority Communities (Temple University Press: 2006); Sidewalks: Conflict and Negotiation over Public Space (MIT Press: 2009; Companion to Urban Design (Routledge: 2011); and The Informal American City: Beyond Taco Trucks and Day Labor (MIT Press: 2014).

DEIKE PETERS

Deike Peters is an assistant professor of environmental planning and practice at Soka University of America. Prior to her appointment at Soka, she was German Research Foundation Research Fellow and Adjunct Professor at USC's Sol Price School of Public Policy. She holds Master Degrees in urban planning and international affairs from Columbia University and a PhD in urban planning & policy development from Rutgers University. Her experience combines 20 years of sustainable transportation policy advocacy and consulting for major international institutions (World Bank, UN Habitat, UNEP) with a 15-year transatlantic career in academia. Prior to relocating to Los Angeles, she was director of the Urban Megaprojects Unit (2008-2011), DFG Post-Doctoral Research Fellow (2005-2008) and lecturer/researcher in city and regional planning (2000-2005) at the Technical University Berlin. From 1996 to 2000, she was director of Environmental Programs at ITDP, an international environmental advocacy organization headquartered in New York City. Her publications most relevant to this research project include articles on rail station redevelopment and transport infrastructure investment in Built Environment, TRR: Journal of the Transportation Research Board, European Journal of Transport and Infrastructure Research, and European Planning Studies.

WENBIN WEI

Wenbin Wei is a professor and director of aviation in the Department of Aviation and Technology in the College of Engineering at San Jose State University. He is also an affiliated professor in the department of Industrial and System Engineering and the director of the Human Automation Integration Lab (HAIL) at San Jose State University. He has a PhD from University of California Berkeley in transportation engineering and management. Before joining the faculty at San Jose State University, Dr. Wei was a research analyst in the department of Operation Research and Decision Support at American Airlines. Dr. Wei's research interests include: transportation planning, urban transportation, public transportation, air traffic control and management, airline operations and management, airport planning and management, and logistics and supply chain management. Dr. Wei's research projects have been funded by FAA, NASA, California Department of Transportation, and others.

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