KEEPING IT ON THE TRACKS

High-speed Rail Success and Lessons Learned

FINAL REPORT

JUNE 2023

URBAN INFRASTRUCTURE LAB
UNIVERSITY of WASHINGTON

CHALLENGE SEATTLE

MOBILITY INNOVATION CENTER
at
UNIVERSITY of WASHINGTON

Acknowledgments

This research was made possible by generous funding, coordination, and communications provided by Challenge Seattle. The authors wish to thank Stephanie Formas, Amy Grotefendt, and former Governor of Washington Christine Gregoire for their support. The authors would also like to thank Jason Beloso, Ron Pate, Adam Leuin, and Washington Secretary of Transportation Roger Millar for coordinating with us and providing thoughtful comments along the way.

This report was a team effort, but the person who pulled this team together was Bart Treece, of the Mobility Innovation Center, at the University of Washington. We thank you for making this happen, and for your energetic leadership every step of the way. To the global experts interviewed for this study, please know that we appreciate each moment and insight you shared with us, to further our collective knowledge of this challenging topic. Lastly, we extend our heartfelt thanks to our colleagues whose research on this topic offered countless lessons, Betty Deakin, Robert Cervero, Karen Trapenberg Frick, Matti Siemiatycki, and John Landis.

Authors

Dr. Jan Whittington, Associate Professor, Department of Urban Design and Planning, University of Washington
Dr. Qing Shen, Professor, Department of Urban Design and Planning, University of Washington
Dr. Feiyang Sun, Assistant Teaching Professor, Department of Urban Studies and Planning, University of California San Diego
Siman Ning, Interdisciplinary Ph.D. Program in Urban Design and Planning, University of Washington
Haoyu Yue, Interdisciplinary Ph.D. Program in Urban Design and Planning, University of Washington
Chin-Wei Chen, Interdisciplinary Ph.D. Program in Urban Design and Planning, University of Washington
Richard McMichael, Master of Urban Planning Candidate, University of Washington

Citation

Whittington, J., Shen, Q., Sun, F., Ning, S., Yue, H., Chen, C., & McMichael, R. (2023). *Keeping it on the Tracks: High-speed Rail Success and Lessons Learned*. Seattle, WA: Mobility Innovation Center, University of Washington.

Copyright Information

Cover Photo Credits

Vancouver: Matt Wang
Seattle: Stephen Plopper
Portland: Knopka Ivy
High-speed Railway: David Dibert

Urban Infrastructure Lab
at the University of Washington

The Urban Infrastructure Lab (UIL) at the University of Washington, under the direction of Professor Jan Whittington, brings together students and faculty with a shared interest in the planning, governance, finance, design, development, economics, and environmental effects of infrastructure. Collectively, our interests span the systems critical to economic and social well-being, such as energy, water, health, transportation, education, and communications. Across these sectors, our studies integrate empirical and applied methods of research to discover the means to obtain long-run objectives, such as decarbonization, resilience, social equity, and information security, through decisions made today.

Challenge Seattle

Challenge Seattle is an alliance of CEOs from 21 of the region's largest employers. Together, we are taking on the challenge of ensuring the greater Seattle area continues to thrive as one of the most vibrant, innovative, and globally competitive regions in the world.

First launched in 2015, Challenge Seattle's CEO members initially made a five-year investment to collectively tackle some of the region's most pressing civic challenges. In 2020, our members renewed that commitment for another five years. Led by former Washington State Governor Christine Gregoire, Challenge Seattle harnesses the committed leadership, unique resources, and world-class talent of its member companies to find innovative solutions and inspire collective action for the greater good.

Mobility Innovation Center
at the University of Washington

A partnership between Challenge Seattle and the University of Washington, the Mobility Innovation Center tackles specific transportation challenges, using applied research and experimentation. Housed at CoMotion, University of Washington's collaborative innovation hub, the multi-disciplinary center brings together the region's leading expertise from the business, government, and academic sectors to use technology and innovation to find transportation solutions.

Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

High-speed Rail Lessons Learned

In an era of accelerated urban growth and the need for greater regional sustainability, transportation systems are seen as a key element to address challenges that our communities face, such as climate change, land use and housing affordability, and economic competitiveness. With the Washington State Legislature allocating $4 million to begin planning efforts on an ultra-high-speed connection to British Columbia and Oregon, and $150 million as a state match to apply for the significant federal funding, Cascadia has an opportunity to develop travel options that set this region apart from the rest of North America.

Many parts of the world have successfully developed high-speed rail systems that serve millions of passengers each day, and connect metropolitan areas and local communities across international borders. The United States has a history of large-scale public works projects, but has not yet delivered the same achievements already witnessed in Europe and Asia. What knowledge can be gained from systems around the world for decision-makers in Cascadia today?

This study sought to learn from existing high-speed rail systems around the world, as well as new projects in development within the U.S., to provide information useful to transportation agencies, potential partners, and decision makers who seek to develop an ultra-high-speed line to connect Cascadia. After more than fifty hours of interviews with industry experts from across the globe, and drawing from case studies and literature reviews, key trends emerged that are worth keeping at the forefront of project development efforts.

Focus on the Service and Providing Value in the Transportation Market

High-speed rail is first and foremost a service, and the physical systems need to be organized and designed to deliver on targets for those services. This means operating speeds, travel time, and reliability. Operating at high speed requires expensive infrastructure that is only economically worthwhile when the service can attract ridership. Service targets must be clearly defined early in the process and cannot be sacrificed as planning and design proceed. People responsible for developing high-speed rail lines and systems have experienced the temptation to make compromises in the design and route of the system to score political points. Going down this path can leave a legacy of decisions that shackles an owner/operator with a high-cost service that doesn't meet ridership expectations, and forecasts that fall short of project goals. Doing it right means providing an appealing and competitive metro-to-metro travel option that compliments other forms of transportation and improves regional mobility.

Effective and Productive Private Sector Relationships

Successful infrastructure megaprojects rely on the strategic involvement of the private sector in design, development, and delivery of projects and services. Architecture, engineering, and construction firms will compete for publicly administered contracts and bring much-needed workforce strength to a blended team. Industry knowledge, in the form of experts with experience in high-speed rail development from Europe and Asia can help guide a public agency through a complex process that requires both technical and political acumen to keep a project on course. Their contributions can ensure fairness at each stage of procurement that allows broader competition from companies seeking to participate and will result in the best value for the public. Additionally, it is imperative to establish a "strong owner" for the agency executing contracts and consultant agreements to ensure workflow meets project timelines, which in turn, manages external expectations.

Coordinated Public Engagement

Metro-to-metro high speed service has the potential to benefit many communities along the way, over long periods of time, in ways that could be transformative. Neighboring communities and partners want to be treated fairly and must have a high-level of trust with the agencies involved to keep progress moving forward at all stages. This means that there must be transparency in the process, with consistent and coordinated public engagement throughout the corridor. Decisions made related to alignment, station area development, and linkages to local communities, can vary for a variety of reasons. Each community may seek to ensure they are receiving the highest level of investment to achieve the most economic benefit. While this is understandable, there is a tendency for communities along high-speed routes to compete with their neighbors for greater modifications and infrastructural additions to the scope of the project, which can drive up costs and slow progress. Inviting the community into the discussion early, providing an open flow for information, can help ensure project decisions reflect community values without adding unrealistic amenities and costs.

Making the Most of Dollars and Sense

High-speed rail megaprojects are developed under an umbrella of constraints as well as targets for services, with limits in the form of public funding commitments, private investment, and capacity for operations. And yet, these projects bring along a wide array of opportunities for investment, growth, and development, both within the system and in connection with the system and its development. There are opportunities to reduce potential costs to the system, such as using existing right of way, and opportunities to leverage the real estate development that will accrue over time in conjunction with the system to provide a significant return on investment and sustained revenue sources. Metro area stations, for example, are themselves megaprojects that, if designed well, serve as foundations for private investment and economic growth for decades to come. As the Cascadia region looks forward to this megaproject that spans two countries, two states, and several jurisdictions, there should be universal awareness that this is a journey over a much longer timeframe than previously experienced in infrastructure development, and the long-term benefits must be embraced by all parties.

CHAPTER 1

Overview

1.1 The purpose of this study

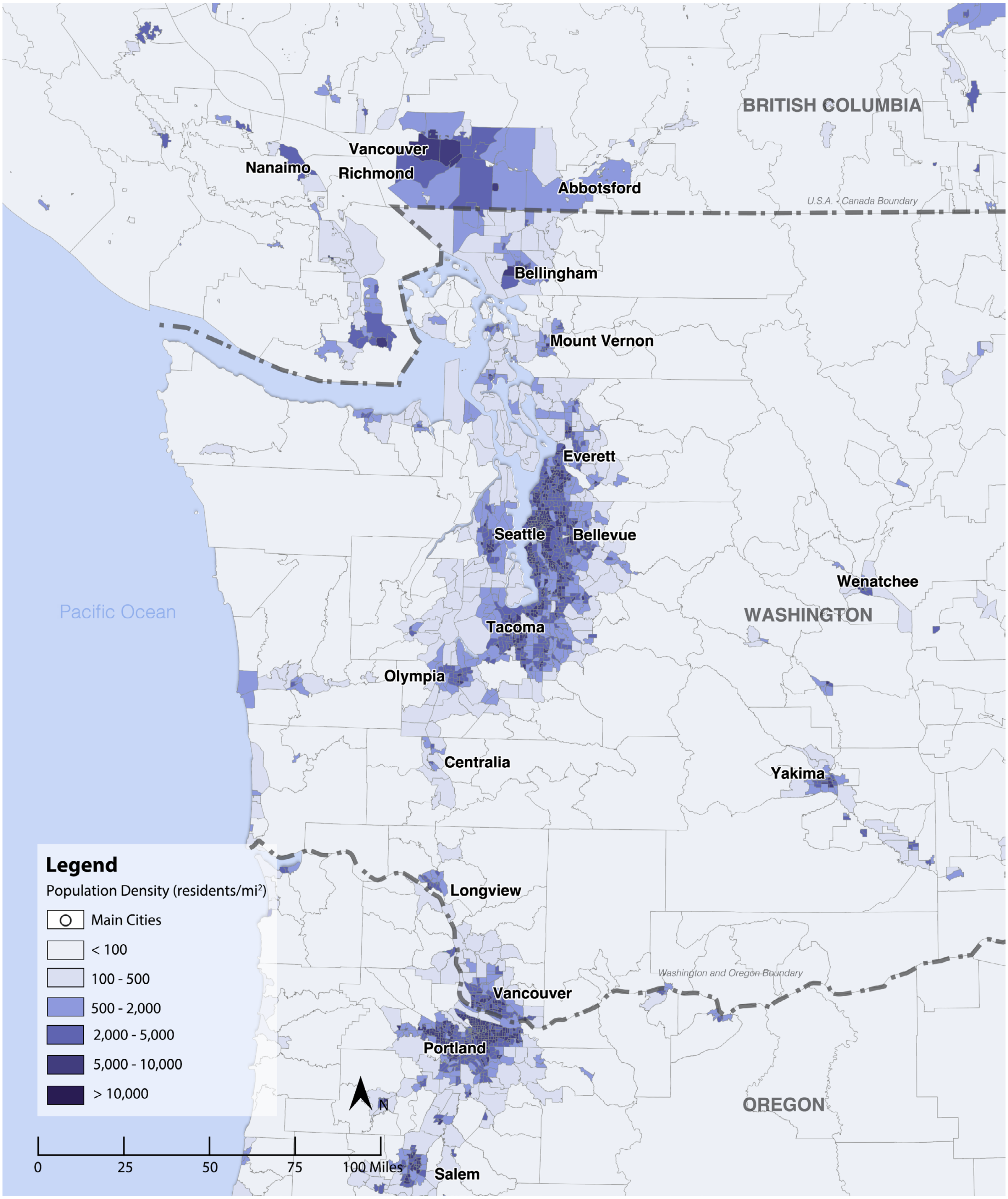
There are over 34,800 miles (56,000 kms) of high-speed rail service operating around the world (UIC, 2023). In Western Europe, Japan, and China, such developments have become commonplace for intracontinental travel. This fact has not been lost on the United States, where scholars have spent over half a century contemplating the prospect of a high speed rail network. Today, several routes are in various stages of planning and development, designed to connect major U.S. metropolitan areas. Among those is the newly considered possibility of a line flowing down west side of the Cascade Range of the Pacific Northwest, linking Vancouver, British Columbia, with Seattle and Portland.

High-speed rail lines in the U.S. are not commonplace. For public departments of transportation, such projects are novel and yet monumental in scale, bringing with them a host of complexities that threaten to stall otherwise successful projects. For those in the high speed rail industry, such projects represent opportunities to export high cost and potentially high value services to a country with the unquestioned economic capacity to pay for such services. This study explores the barriers that high-speed rail projects have faced, in the U.S. and beyond, to understand how such complex projects have emerged triumphant.

Renewed attention to high-speed rail in the U.S.—the Cascadia Region included—is bolstered by several recent shifts in policy that have arisen against the backdrop of the climate crisis. The passage of federal legislation, such as the Infrastructure Investment and Jobs Act (2021), offers the promise of funding to engage in enough planning to compare the value of high-speed services in relation to the estimated cost of their development. In Washington State, $150 million has been set aside as potential matching funds toward an ultra high-speed ground transportation line that would reach speeds as high as 250 mph or more, moving passengers between British Columbia, Washington, and Oregon (State of Washington, 2022). Since 2018, studies commissioned by the Washington State Department of Transportation have sketched out arguments, concepts for corridors, and road maps for decision-making in favor of high-speed rail. With the publication of Cascadia Vision 2050, the Cascadia Innovation Corridor partnership of Challenge Seattle and the Business Council of British Columbia offer the prospect of high-speed rail as a centerpiece in a constellation of potential solutions to overcome long-term problems of affordable housing, traffic congestion, and greenhouse gas emissions (Cascadia Innovation Corridor, 2020).

What knowledge can be gained from systems around the world for decision-makers in Cascadia today? The purpose of this study is to inform the nascent consideration of high-speed rail in Cascadia with key facts and the opinions of experts distilled from other active and successful projects. The focus is to identify topics which, if taken up today, hold the promise of improving the prospects of project success. For many interviewees, this line of questioning led to expressions of regret over early errors. All were generous with their time, revisiting the means by which barriers were ultimately overcome or reconsidering options that have been shown elsewhere to have such an effect.

Figure 1.1: Population Density along the Cascades in the Pacific Northwest



1.2 The methods of research

This report is the result of six months of academic and industry research. The academic literature review spans the topics of high-speed rail in general and a set of cases in particular, including prominent sources on the broader subject of megaproject development. This literature was supplemented by interviews with international experts in the field, with experience in the early stages of development of high-speed rail systems successfully operating today in other countries, as well as several that are in development in the U.S.

The methods for this study were deployed in steps:

(1) This study began with a review of the literature on high-speed rail planning and operations, and the identification of a short list of high-speed lines and systems of interest for their comparability to conditions relevant for early-stage consideration of high-speed rail in the Pacific Northwest.

(2) Experts were identified to be interviewed on the basis of their discipline-specific knowledge of the early stage development of the high-speed systems short-listed during step one. While on-the-job participation in the early stage development of high-speed rail was shared by all of the interviewees, participants differed in their disciplinary knowledge and perspective. This selection of variation in expertise was purposeful, to capture key perspectives of experts in politics, business, finance, planning, engineering, operations, power, station design, real estate, and government.

(3) With the approval of the Institutional Review Board of the University of Washington's Human Subjects Division in the Office of Research, interviews were conducted that centered on a set of 12 questions, sent to each expert in advance. Interviews were conducted with 12 participants, resulting in 50 hours of anonymized interview transcripts. Together with the literature review and the field experience of the authors of this report, these interview results elevated a set of key facts and opinions of merit.

1.3 Organization of report

This report is organized into four chapters. Topics considered critical at this early stage of high-speed rail de-

Table 1.1: Case Study Interview Questions

- Describe your role in the HSR project through its development.
- In your opinion, what were/are the key milestones for project development?
- What kinds of barriers arose during project development and how were they overcome?
- Describe the ways in which the project was introduced to the public, or engaged the public during its development.
- What were the most meaningful aspects of the project for public decision-makers?
- How dependent would you say the project is on private funding, finance, concessions and/or ownership, and why is that the case?
- What public funding sources were required to plan and/or construct the project?
- What were the most meaningful aspects of the project for private firms in the HSR industry?
- How did you recognize and/or address the problem or concern over the choice of technologies and what that could mean for a lack of competition in procurement?
- Describe the project-related strategies for route selection, station area selection, and station area development.
- Describe the basis for ridership forecasts.
- Describe the project's perspective on safety.

velopment are introduced in Chapter 2. Many of these topics came about as a result of examining high-speed rail projects successfully operating elsewhere or in development in the U.S. All such projects are briefly described in Chapter 3. The report concludes with recommendations in Chapter 4.

In Chapter 2, the key facts and opinions from this research are organized into the following topics, salient at this time because they suggest directions for critical decisions that have not yet been made for high-speed rail in the Pacific Northwest:

- Success is defined by high-speed service
- Megaproject risks magnify project financial impacts
- Efficiency requires a competitive market for the delivery of public goods
- Effective high-speed rail development requires thorough and deliberate public engagement coupled with planning and engineering
- High-speed rail is increasingly discussed as a form of climate action

Chapter 3 offers a closer factual breakdown of a small set of international and domestic cases of high-speed rail development. The proliferation of high-speed rail creates many opportunities for case studies. Cases in this report represent systems developed in areas with institutional and geographic attributes comparable to the Pacific Northwest. While this objective for research did not preclude study of the Chinese, Japanese, and full European networks, it did lead to the selection of the following cases:

International

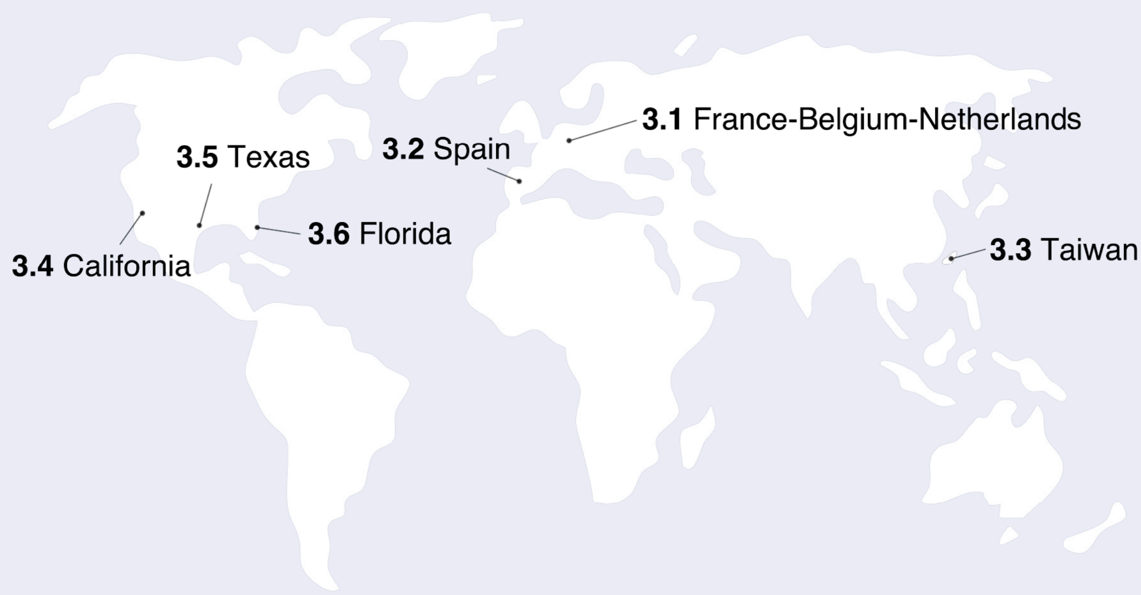
- The corridor linking Paris, France to Amsterdam in the Netherlands
- The high-speed rail systems of Spain
- Taiwan high-speed rail, linking Taipei to Kaohsiung

United States

- California, linking San Francisco and Sacramento to Los Angeles and San Diego
- Texas, from Dallas to Houston
- Florida, linking Tampa to Orlando and Miami

Chapter 4 concludes the report with 40 recommendations for consideration, placed in the context of the Pacific Northwest's desire to develop an ultra high-speed service linking Vancouver, British Columbia, Seattle, and Portland.

Figure 1.2: Cases Studied for this Report



CHAPTER 2

Critical Topics for Early High-Speed Rail Decision-making

This chapter organizes the facts and expert opinions collected from this research into five topics of importance in early decision-making for high-speed rail, as currently experienced in the Pacific Northwest's consideration of ultra high-speed connections between Vancouver, British Columbia, Seattle, and Portland. Early decision-making is pre-planning and pre-design, prior to the establishment of preferred technology, a preferred route, station locations, a budget, and a cost estimate.

The topics that shape this chapter are as follows:

1. **Success is defined by high-speed service:** explains how competitive intracontinental metro-to-metro service determines the success of high-speed lines.
2. **Megaproject risks magnify financial impacts:** examines how the scale, scope, and timing of projects create extraordinary risks and call for institutional safeguards.
3. **Efficiency requires a competitive market for the delivery of public goods:** discusses the roles of the public and private sector in efficient delivery and operations.
4. **Effective high-speed rail development requires thorough and deliberate public engagement coupled with planning and engineering:** explains how effective delivery demands deliberate engagement with the public in route, station area, and urban hub design.
5. **High-speed rail is increasingly discussed as a form of climate action:** examines measures used to review the impact of projects on climate and the impact of climate on projects.

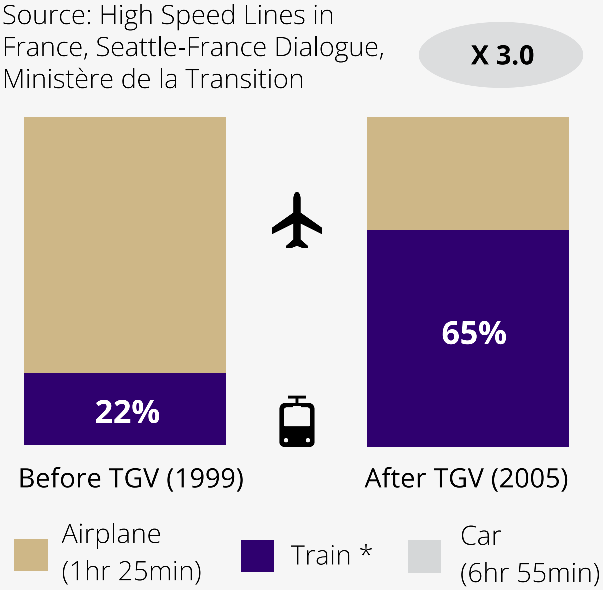
2.1 Success is defined by high-speed service

Summary. *High-speed rail is a service, defined by its competitive success in intracontinental passenger transportation, including air travel. Success is so defined by competition for metro-to-metro air travel that international experts uniformly use this factor to explain why some lines are successful and to examine why others are not. When rail operations became competitive, air transport services found ways to cooperate, further expanding the market for both rail and air services. Competition with air travel supports the concept of first class or premium pricing, along with standard and discounted services. To succeed, however, requires central and unflagging attention to the myriad ways in which decisions can detract from the competitive operational requirements of high-speed service. This imperative places expertise in operations and business planning for rail service at the forefront of early high-speed rail decision-making, providing critical guidance to political leadership. Failure to compete in metro-to-metro service leaves public agencies paying for inordinately expensive rail systems that mainly serve local commuters.*

High-speed rail is a service, defined by its competitive success in intracontinental passenger transportation, including air travel. Rail transport can be many things, but the service that defines high-speed rail is passenger transportation between metropolitan city centers at a speed, convenience, frequency, and reliability competitive with air travel. Every international expert interviewed for this study defined the success of existing high-speed rail routes on the basis of competition with intracontinental air travel. In the literature, the same definition stands. Evidence from established systems in Europe and Japan proves that high-speed rail is and therefore should be designed to become the dominant transport mode for travel distances between 180 and 440 mi (290 - 710 km; 160 - 380 nmi) (Adler et al., 2010, Europe; Fu et al., 2022, Japan; Román et al., 2007, Spain), while air transport will dominate at distances greater than 620 mi (1000 km; 540 nmi) (Givoni, 2006, Global Literature Review; Givoni and Perl, 2020). For trips between 440 and 620 mi (710 - 1,000 km), the two modes compete for travelers, with the most successful rail routes winning market share. For example, for travel times of 2.5 hours or less, Japanese and European rail networks serve 70% or more of the market compared to air travel, and for travel lasting 2.5 to 4.5 hours, rail competes with varying degrees of success for 30 to 70% of market share (Anguera and Esparrich, 2020; e.g., Figure 2.1). This emphasis on competition with air travel may appear to have limited relevance in the U.S., especially when today's air travelers are likely to comprise a small portion of the overall ridership of a new rail line. The reasons for the focus on competition with air travel in defining high-speed rail success, however, are more broad and indirect than the number of passengers that can be attracted from air travel.

Figure 2.1: Paris to Marseille Market Share before and after High-Speed Rail

Source: High Speed Lines in France, Seattle-France Dialogue, Ministère de la Transition



* The train travel time after TGV is 3hr 50min.

Success is so defined by competition for metro-to-metro air travel that international experts uniformly use this factor to explain why some lines are successful and to examine why others are not. Experts offered accounts of experience with decisions that, in retrospect, left systems unable to compete, regardless of the amount of funds poured into their improvement after the fact. These were cautionary tales drawn from real-world comparisons of lines and systems that have been operating for years, told by our interviewees to emphasize the fact that the success or failure of high-speed rail service is determined in the earliest period of decision-making. Door-to-door competition with intercity air travel is the only form of competition that requires high-speed service. It is an exacting priority in the design of a service and the system it relies on, and it has to be maintained as the first priority in all decisions. The selection of the route, the number and location of stations, and the interoperability of technologies, were all described as having a direct impact on the chance of establishing competitive advantage in metro-to-metro operations, and therefore creating a successful high-speed rail line. Small compromises—decisions that would at first appear to offer political gain with little impact—such as reducing the construction cost of metro stations by placing them on the urban fringe, or diverting a metro-to-metro route to place stations within the centers of suburban and rural cities and towns, constrain operations in ways that reduce the ability of the system to be a competitive mode of travel. Allowed to accumulate, these seemingly benign decisions, each chipping away at the operational competitiveness of high-speed service, leave communities with a system that is incapable of performing as promised.

Table 2.1: High Speed Rail Ticket Pricing Structures

High-speed Rail Route	Examples of Pricing Structure (U.S. Dollar, as of October, 2022)
Texas Source: Texas Central, 2023	Based on a variable pricing model. On the high end, tickets will be competitive with the cost of flying, and with the cost of driving on the low end.
Florida: Miami - West Palm Beach (1.5 hr drive) Source: Brightline*, 2022	Smart / Standard: $15 ($145 for 10) one-way pass Premium: $37 ($257 for 10) one-way pass
Spain: Madrid-Barcelona (7 hr drive) Source: ACP Rail, 2022	Standard: $12 ($47 for 7-day pass) Premium: $30 Prices fluctuate depending on travel time
France-Italy: Paris-Milan (10 hr drive) Source: Eurail, 2022	Standard: $31 Premium: $45
Japan: Shinkansen Source: JapanRailPass, 2023	Standard: $205 for 7-day pass Premium: $274 for 7-day pass

* As of May 2023, Brightline had not yet operated any qualified high-speed line (speed > 124 mph/200kph).

When rail operations became competitive, air transport services found ways to cooperate, further expanding the market for both rail and air services. Cooperation in markets is a rational response to the credible threat of competition. In Europe, interviewees noted that the German rail operator, Deutsche Bahn, recently became the first rail operator to join the Star Alliance partnership of airlines. Due to this partnership, Deutsche Bahn services became available within the booking systems of the 26 airlines in the alliance, allowing the airlines and Deutsche Bahn to issue air and rail seat reservations and tickets (Preston, 2022). This is a dynamic expansion of joint services made possible by the success of Deutsche Bahn in forming a competitive alliance for services in Germany with Lufthansa, the country's national airline. In Asia and especially China, emerging studies suggest that well-designed integration results in complementary services, with rail taking in more passengers on medium haul routes and air travel benefiting from increased passengers on long-haul routes (Albalate et al., 2015; Wan et al., 2016; Xia and Zhang, 2017; Zhang et al., 2019). Altogether, this suggests that the primary benefits of air-rail integration come from a redistribution of passengers across rail stations and airport facilities in ways that facilitate door-to-door travel experiences (Albalate et al., 2015, Europe), which also promotes the use of rail to bring long-haul and international travelers to and from airports (Wan et al., 2016, Northeast Asia; Zhang et al., 2018, East Asian and Central European Region).

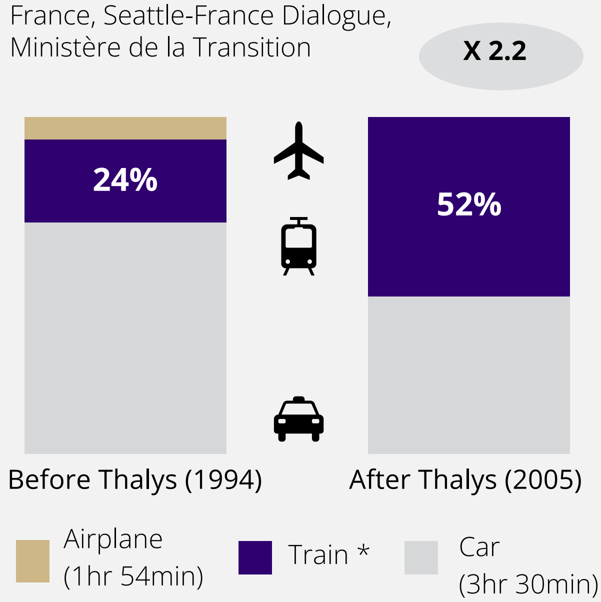
Competition with air travel supports the concept of first class or premium pricing, along with standard and discounted services. The market attracted from air to rail travel, and to integrated rail and air travel (i.e., rail travel to a hub airport), has a greater willingness to pay for first class service, thus increasing the chance that first class or premium services will be offered. Indeed, most high-speed rail services offer standard and premium options for ticketing. Compared with the standard fare, the premium options include better services, such as more comfortable seating (business class trains) and greater flexibility for cancellations and exchanges. Most high-speed rail services also include the option of bundled passes at a discounted rate, which typically cover a given number of trips (e.g., Florida's BrightLine10 one-way rides) or given number of days of travel (e.g., Japan Shinkansen 7-day pass). Pricing, however, is not the only factor that matters. Research shows and experts emphasize that travelers care about the ways in which the overall travel time—including trip time, time to rail stations and airports, transfer time, and frequency of service—provides convenience (Adler et al., 2010; Anguera and Esparrich, 2020; Albalate et al., 2015; Chen and Wang, 2019; Zhang et al., 2019). High priced fares can offset the cost of delivering standard and discounted service to the majority of travelers. These factors, however, underscore the importance of providing high-speed service in order to be able to offer, to a subset of travelers, fares that are comparable to ticket prices for air travel. The table above provides some examples of high-speed rail ticket options (Table 2.1). Although many factors influence pricing, research does suggest that costs in the US are greater than elsewhere (Eno 2021).

To succeed, however, requires central and unflagging attention to the myriad ways in which decisions can detract from the competitive operational requirements of high speed service. It is easy to lose sight of the goal of competitive high-speed service. Interviewees explained that one of the reasons why the success of high-speed service is aligned with air travel is because the operational characteristics necessary to compete ensure that the other goals of the system will also be achieved. Door-to-door competitiveness for metro-to-metro travel requires more of a high-speed rail system than any other goal. Lines that are designed and operated to compete in this market bring success in the form of positive spillover effects to less demanding competition for metro-to-metro auto, suburban commuter, and rural travel; less demanding because these services do not require high speeds in order to attract people away from auto use (Europe, China, and Japan; e.g., Figure 2.2). By providing high-speed metro-to-metro service, successful lines attract travelers from air transport and expand the attraction of travelers from autos, increasing market share and induced demand to rail lines. To succeed in this respect, however, design and operating requirements competitive with air for door-to-door travel time and frequency must be specified at the outset of planning and budgeting, central to the business plan of the service, and be maintained as the defining characteristic of all other decisions to be made. Suburban and rural access to high-speed rail does matter for the economic performance and sustainability of the system, and will be important to any high-speed rail business plan. How such access is accomplished, however, is critical to the overall success of the system because decision-makers will be tempted to serve suburban and rural markets with changes that swerve away from the most expeditious metro-to-metro route, add facilities to the system, increase construction cost, delay metro station investment, and most importantly, detract from the target speed and performance goals of express high-speed rail service. Experts were adamant and unified in their opinion that the addition of such services and facilities must not impinge on the original purpose of providing competitive high speed service from metro-to-metro centers. Design the route for express metro-to-metro service at peak speed; obtaining peak speed in route design usually requires that suburban and rural travelers come to the route to access their station, instead of bringing the route to them.

This imperative places expertise in operations and business planning for rail service at the forefront of early high-speed rail decision-making, providing critical guidance to political leadership. Experts agree that a unified political vision of the project and its services is required for any high-speed rail project to be initiated. Having established the political will for development, however, the most persistent sources of failure in high-speed rail decision-making could be traced to a lack of early and continued involvement of experts in operations and business planning. A sound business plan is essential to form a shared understanding of operational success. In the years it takes to carry out planning, design, and procurement for these megaprojects, decision-makers will be naturally drawn to questions about the effect of a variety of choices on the cost of construction and capital finance. Construction costs are important for megaprojects, but they are one-time costs, while inefficiencies in operations and

Figure 2.2: Paris to Brussels (Belgium) Market Share Before and After High Speed Rail

Source: High Speed Lines in France, Seattle-France Dialogue, Ministère de la Transition



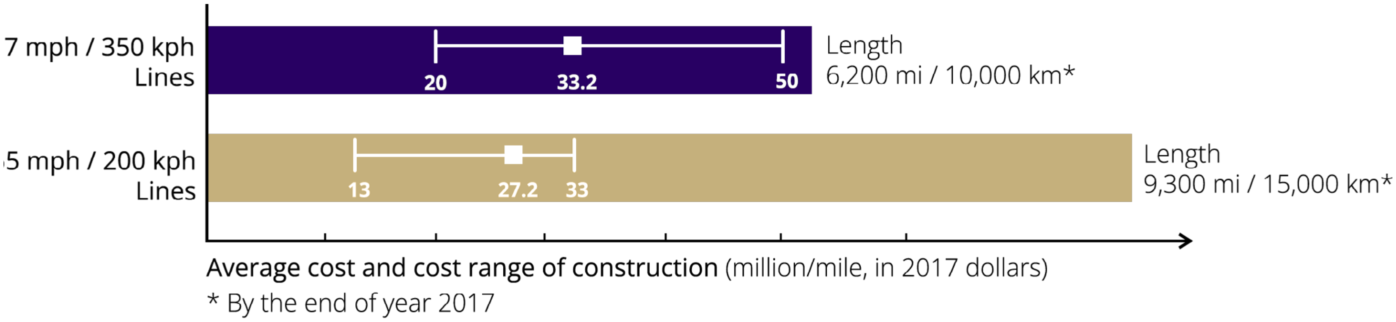
* The train travel time after Thalys is 1hr 30min.

maintenance will persist for decades. Business and operational expertise is needed to show the ways in which planning, design, and procurement decisions will change the attractiveness of the service for customers, the cost of operating the service, the frequency of operations, and the cost of maintenance. This specialized guidance is needed to avoid compromises from other influences that would reduce the performance targets of the system. Additionally, expert perspectives are useful for incorporating a more holistic view of businesses and services, a view of how features and their modifications can contribute to revenue generation without sacrificing project delivery and system goals. A competitive metro-to-metro line delivers benefits to other services and operations because of its speed; suburban and rural travelers will need to travel to the stations on the line, but having accessed the line, their travel would then be direct and swift to downtown metro areas, ticketing areas of airports, and hubs for convenient transfer onto metro commuter rail and bus systems.

Failure to compete in metro-to-metro service leaves public agencies paying for inordinately expensive rail systems that mainly serve local commuters. The infrastructure necessary to operate at high speed is significantly more expensive than local commuter rail systems (e.g., Sound Transit's Link Light Rail, Portland Metro's Tri-Met) and traditional rail systems (i.e., Amtrak). All other things being equal, the higher the peak operating speed the more expensive the line and rolling stock will be to build. One illustration of the comparative cost to develop systems with higher operating speeds comes from China, where numerous lines have been built, all subject to the same institutional rules for their development (Figure 2.3). By 2017, China had about 6,200 miles (10,000 km) of lines capable of running at 217 mph (350

Figure 2.3: China High Speed Railway System Map (Source: UIC, 2022)

Figure 2.4: Average Cost of China High Speed Railway System (Source: World Bank, 2019)



kph), and another 9,300 miles (15,000 km) of lines running at 155 mph (250 kph) (World Bank, 2019, 24). The average cost of construction for a double-track 217 mph (350 kph) line was about $33.2 million per mile, while costs from a sample of 155 mph (250 kph) lines averaged $27.2 million per mile (Figure 2.4, in 2017 dollars; World Bank, 2019). These costs are all much lower than the cost of developing rail in the U.S—average rail construction costs in the U.S. compared to other countries are 48% more for lines at grade (ground level) and 57% more when tunneled (Eno Center for Transportation, 2022, 11). What these comparative costs from China illustrate is the fact that building for higher speed costs more. Peak travel time has a significant effect on the cost of building rail systems due to different requirements for technology, design, engineering, and associated construction cost. Peak operating speed of high-speed service, commonly described within the range of 190 to 220 mph (300 to 350 kph), affects cost by setting minimum requirements for rolling stock design, route selection, turning radius, and grade separation in ways that are not comparable to commuter and traditional rail systems. For example, what could be traversed at grade with a conventional system may require an elevated track or tunnel to achieve performance targets for safe high-speed rail operations (Japan, China, Europe). High speeds are necessary to compete for metro-to-metro travel, but such speed comes at a cost much greater than commuter rail. If the service contemplated is commuter rail, or a line that provides customers with swift access to a high speed rail station, experts explained that these commuter and local systems should be complimentary metro-to-metro service, constructed as separate projects (albeit connected to the high-speed rail program), and built using technologies that do not require the exacting specifications and associated cost of high-speed rail service.

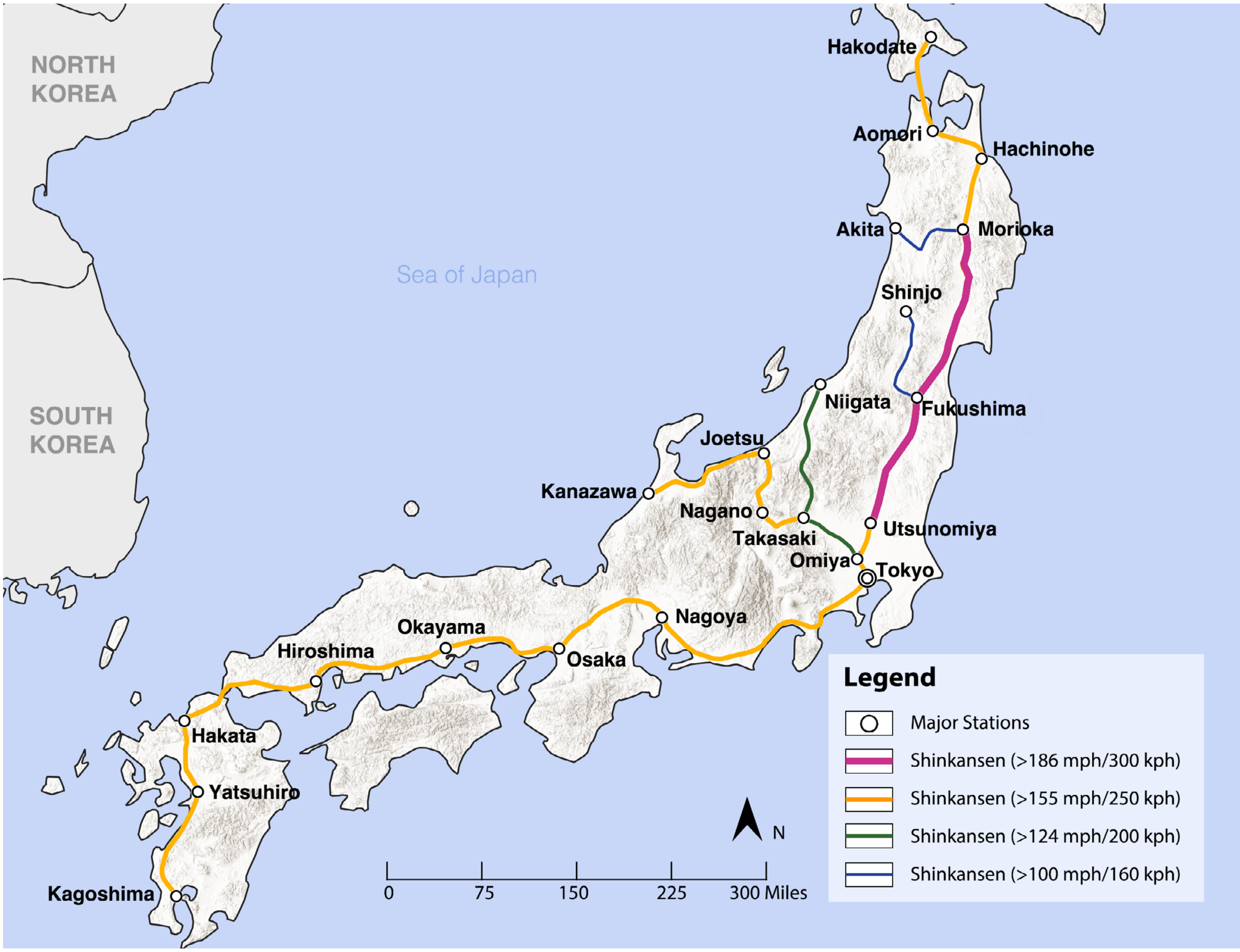
2.2 Megaproject risks magnify financial impacts

Summary. *The scale, scope, and timing of high-speed rail development are extraordinary, even by the standards of megaprojects. Nine out of ten megaprojects suffer from cost overrun, but this does not mean that overrun is inevitable. The scale and scope of a high-speed rail project creates its own market conditions. People and organizations do not usually plan activities using the 20 to 30 year timeframe of high-speed rail development. For projects in the U.S. and Canada, success will depend on avoiding the vicious cycle of underestimates, overruns, and political renegotiation. These are not highway projects; different rules apply, and different approaches are needed. Researchers caution against direct comparisons of proposed U.S. high speed lines with existing systems in other countries. Successful high-speed rail systems around the world benefit from institutional safeguards for their development.*

The scale, scope, and timing of high-speed rail development are extraordinary, even by the standards of megaprojects. Scale, scope, and timing are different but related concepts. Scale refers to the size and cost of projects. The financial impact on public budgets from minor cost increases are much greater for megaprojects. The designation of a megaproject is commonly reserved for projects with construction costs estimated at $1 billion or more. It is not unusual for a U.S. highway project to experience a 10 percent cost increase. For a project estimated at $18 billion in Taiwan (Ni et al., 2017), a 10 percent leap in cost would have amounted to $1.8 billion. Given the 2022 estimates from California's high-speed rail project, the cost of an additional 10 percent increase is approaching $10 billion (CHSRA, 2022). Scale for high speed rail also concerns the need to build one project across boundaries that divide state and national governments, which rarely occurs and creates additional sources of risk of cost overrun. Scope refers to the many components of a project, and the ways in which their interdependence raises the complexity of the development and delivery of the project and its associated services. Among its many components, high-speed rail includes features similar to those of airports, airplanes, and highways, combined and delivered together, all at once. It involves the concerted delivery of precisely constructed linear rights-of-way, urban hubs that function like airports, suburban and rural station areas that have the potential to develop into new towns, rolling stock and signaling systems as complex as jet airplanes, and the services for effective operations that span states and international boundaries, all managed in a program to be developed together. When high-speed rail systems were new to their host countries, their development into popular forms of transportation took decades. Japan, France, and Germany developed their capacity to deliver high-speed rail endogenously—within their own innovative engineering and industrial markets—before they began to export their capacity to other countries. Ridership and the market-driven build-out of suburban and rural station areas in Japan transpired over 20 years after high-speed operations began, despite the presence of favorable policies promoting the co-development of rail with high-density centers (e.g., Cervero 1998). Japan's Shinkansen lines are shown on Figure 2.5. These endogenous developments were driven by public investment.

Nine out of ten megaprojects suffer from cost overrun, but this does not mean that overrun is inevitable. Globally, megaprojects are systemically and significantly prone to cost overrun, and this evidence of poor cost performance does not favor rail projects (Flyvbjerg et al., 2003). For megaprojects, cost overruns commonly approach 50 percent; for rail, cost overruns *average* as much (Flyvbjerg, 2014). The reasons for this dismal record of performance are not inherent in the technology or the environment, they are mainly due to human behavior. It is possible to build a megaproject under budget and on time. However, the ways in which people behave in the planning, development, and delivery of megaprojects, and the choices that result, render that outcome unlikely. Engineers in local markets are drawn to the development of megaprojects; for public transportation officials and technologists in the U.S., projects like this represent a once-in-a-lifetime opportunity (Frick, 2008). Similarly, there is a fundamental tension between the need to be politically united behind such a substantial public project and the motivation of public officials to use the typical tools of their office to modify the aim, focus, and physical outlay of the project in ways that reduce viability, delay the development, and unnecessarily increase costs for the taxpayer. Referred to as the technological sublime (Frick, 2016), this term describes how the desire to promote a megaproject can too easily become a bias in favor of a project irrespective of its consequences, followed by a bias in favor of changes that appear to elevate or convey grandeur, yet are inefficient for the scope, scale, and timing of the project. In this situation, political leadership is viewed as governing the scope of the project simply by virtue of their role in continuing the allocation of public funds, and persons willing to 'speak truth to power' with alternative points of view become difficult to find (see, generally, Ginsberg and Paschall, 2022; Wildavsky, 1979). This phenomenon also describes what occurs when leadership becomes vulnerable to moral hazards. This occurs when project leadership and consulting and/or engineering firms become locked into self-affirming narratives, to avoid bad news and the risk that funding will end. Within the mechanisms of project planning

Figure 2.5: Japan High Speed Railway System Map (Source: UIC, 2022)



and development, it can lead to a lack of willingness to set up and recognize the points at which a change in direction would be beneficial.

The scale and scope of a high-speed rail project creates its own market conditions. Project development requires forecasting in order to shape estimates of cost, time to deliver, and the demand for services, all of which should then become the basis of arrangements to fund and finance the project. The scale and scope of high-speed rail projects, however, can be so large as to defy commonplace methods of forecasting. Cost estimating in the early or conceptual stages of common public transportation projects is in reference to existing, local agency experience with projects that are the same or similar in design, and the characteristics of their underlying markets for labor and materials. The first of the high-speed rail lines to be built in any country or state are so large and removed from existing experience as to have no effective local comparator, thereby injecting a new form of risk into cost estimating. This risk in high-speed rail manifests in several ways, some political and others pragmatic. Scale is a pragmatic and ever-present source of risk because the project is not complete without metro-to-metro service. Highway projects can be disaggregated into lanes and lane miles, rescaled as funds permit, with the shelved portions awaiting the next round of transportation improvement program funds. Commuter rail systems are designed across metropolitan areas as hub-and-spoke systems, where initial investments at the core of the system are given incremental additions in the form of line extensions and stations in suburban markets. If an agency faces rising costs and lacks the funds to complete the project, the outermost lines and stations are typically removed from the current scope of work, effectively shelved unless and until additional rounds of public funds are made available. On high-speed rail projects, the imperative of metro-to-metro design does not permit such adjustment. Quite the opposite, the route and station areas are publicly discussed a decade or more in advance of construction, with participants fully aware that the project will have to meet the need for metro-to-metro service. In these circumstances, markets for real estate, engineering, construction, the supply of materials such as steel and concrete, have more than adequate time to organize in their own interest, bringing new and seemingly inescapable risks of cost escalation to the project. Opposition to the project will also have time to organize (e.g., Banister and Givoni, 2017; Deakin, 2017; California and the United Kingdom). Managed poorly, high-speed rail megaprojects drain public coffers in ways that represent a transfer of wealth from public taxpayers to organized interests in engineering, construction, and real estate. Managed well—with creative use of institutions, competition, and value capture—they have inordinate capacity for economies of scale and co-benefits in urban economic growth (Landis, 2022).

People and organizations do not usually plan activities using the 20 to 30 year timeframe of high-speed rail development. The vast majority of infrastructure projects in the U.S. can rely on well-designed local and state institutional arrangements that function within set timescales. State departments of transportation in the U.S. periodically produce long-range plans with horizons of 20 years or more, emphasizing the role of the highway system in intercity travel (FTA, 2022). Occasionally, a conceptual form of regional planning for metropolitan areas is stretched over a longer timeframe to suggest a 'blueprint' or 'vision' of regional transportation improvements for the future, mainly to unify otherwise disparate political interests. Long-range plans, in the form of city comprehensive or general plans, are meant to be refreshed every ten years, often in coordination with metropolitan planning organizations for transportation improvements (e.g., MRSC, 2022). This provides a spatial framework for more near-term land use and infrastructure decision-making, and associated fiscal arrangements for public revenues and expenditures, which are commonly developed within shorter timeframes of five to seven years. Modeling of demand and supply for intercity highways is similarly fit to serve the periodicity of transportation improvement programs, at five to seven years. With few exceptions (e.g., private ownership of energy and water utilities) the private sector operates within these timeframes, on even shorter horizons of two to five years for returns on investment. What these arrangements provide is an unspoken source of certainty around the variables and margins of error that matter in estimating the cost and fiscal effects of infrastructure projects. High-speed rail, when newly conceived for a country or state, has no such guiding arrangements. These projects take at least a decade to plan and design before construction may begin, and after construction is concluded and operations begin, twenty years will pass before it is possible to realize the ridership and full associated benefits of the system (Europe, Japan). These timescales are familiar to a small set of experts (e.g., planning, demography, infrastructure system operators). Even the academic literature, in its attempt to document the fiscal benefits of high-speed rail, conducts studies too early to meaningfully discern the effects of projects, often just five to ten years after operations begin (e.g., Crozet, 2013, France; De Rus, 2011, Spain; Nash, 2015, Review). They show lower than expected returns to projects, reflected in capital cost overrun and ridership lower than forecasts. In the megaproject literature, researchers argue in favor of longer time frames and broader measures of impact, to include area real estate and economic development (e.g. Crozet, 2013, France; Deakin, 2017; Landis, 2022).

For projects in the U.S. and Canada, success will depend on avoiding the vicious cycle of underestimates, overruns, and political renegotiation. By now, people familiar with the nascent megaproject literature are aware of the fact that many forms of cognitive bias (e.g., optimism bias, uniqueness bias, overconfidence bias, strategic misrepresentation, escalation of commitment), amplified through political and organizational arrangements, threaten the efficient and effective delivery of megaprojects (Flyvbjerg, 2021; Wachs, 2013, 1990, 1989). These root causes of failure manifest at surprisingly early times in project development and persist throughout, unless addressed by a change in the structure of organizational decision-making. Early in the project there comes a time when political interests unify in favor of the project and the project as a whole is given a rough order-of-magnitude cost estimate. All too often, published estimates of cost are unrealistic and/or determined to fit within a politically expedient limit. Unrealistic estimates rely too heavily on the cost of projects outside the jurisdiction of the public agencies managing the project; unrealistic because outside projects do not share the same features, characteristics, markets, and institutional arrangements of the host country or state. Thorough local engineering and market analysis is needed to recognize the differential effects of market conditions on cost (e.g., corridor land acquisition, design of the structure, substructural conditions, unit price fluctuation) and the role that institutional conditions in international markets have played in controlling the cost of completed projects elsewhere (e.g., Europe, Japan, and China). Political determinations of cost involve reaching political agreement on a total preferred amount of fund-raising from identified sources. As discovered in the megaproject literature, the biases people have in their thinking and existing patterns of behavior point everyone in the direction of a public commitment of funds set at less than the total cost of development. Engineering and construction proceeds until funds are exhausted. The eventual need to pursue additional funding opens the project to political renegotiation. Political renegotiation moves decision-making back to the drawing board, where the project becomes vulnerable to redesign (with associated delays, inflation, and cost escalation) with elevated moral hazard (lock-in effects with existing firms and decision-makers). Political renegotiation is problematic for high-speed rail because it can change the actual stated public purpose, and therefore the scope of the project. In California, estimated costs of metro-to-metro high-speed rail published in 2008 (Proposition 1A) were at $33 billion, with funding identified as the public repayment of bonds, transfers from the federal government, and private investment (CHSRA, 2008). Published estimates of cost in 2022 (Phase 1, Anaheim to San Francisco) were in the range of $92.8 and $94.2 billion (CHSRA, 2022). Furthermore, the political goal of the project became associated with building a system that serves 85% of the population of the state. This is a laudable goal, but it suggests that the priority for the system is commuter rail service, which does not require high speed operations. The megaproject literature sends a message: this is the *typical* turn of events. It takes effort to decide to do something different.

These are not highway projects; different rules apply, and different approaches are needed. Another way of understanding the advice of the megaproject literature is to realize that the typical institutional and organizational arrangements of highway projects in the U.S. are set up to fail in the delivery of high-speed rail lines. It is possible for a highway project to rely on existing sets of rules and norms for project delivery, but the same rules pose risks for high-speed rail development (see Table 2.2 for a comparison). One can always find examples that deviate from these simplifying assumptions of the means used to effectively and efficiently manage the complex activities of highway project delivery. What matters, however, is how high-speed rail delivery deviates from these norms, and how government agencies in other countries have organized, set up rules, and fostered markets to overcome these problems.

Researchers caution against direct comparisons of proposed U.S. high speed lines with existing systems in other countries. There are no perfect comparators. Many reasons to be cautious in drawing conclusions from international cases of high-speed rail development have to do with the differing political, institutional, and infrastructural environments for rail development and use from country to country (Deakin, 2017). Despite their successes in high-speed rail development, some parts of the world operate with institutional arrangements that prevent reliable comparison. China's one party system of governance, for example, makes it difficult to credibly compare their project development to the U.S. and Canada. In Japan, France, and Germany, the development of high-speed

Table 2.2: Comparing Rules, Norms, and Risk

Highway Project Development Approach	Risk to High-Speed Rail Development
A highway project may be organized to rely on a contractual arrangement with an individual firm or consortium of engineering and construction firms for cost containment	A programmatic approach is needed on high-speed rail
If costs are not contained, management may resort to cuts to scope and scale	Scope and scale on high-speed rail remain metro-to-metro
Options for dispute resolution, and a willing market for project-level insurance for the agency and contractor, are commonplace	These services are difficult to find for high-speed rail, especially when such developments are new to the state and nation
Transportation agencies may be comfortable working within schedules prescribed by the National Environmental Policy Act and state-equivalent statutes to structure public debate and address NIMBY-ism on highway projects	Such confines on public engagement make it difficult if not impossible to raise adequate and consistent public agreement to fund the cost of high-speed rail
Changes in design due to problems of land acquisition would not necessarily affect the performance of a highway project	Even slight changes in routing can have severe implications for high-speed rail performance
Compensation for the taking of land may be limited to the market value of the property and related applicable damages on highway projects	The long lead times for high-speed rail allow for widespread land speculation well in advance of land acquisition
If institutional changes are made pursuant to the project, such as special purpose legislation, lobbying from the engineering and construction community may be construed as signaling the conditions that attract firms to bid on a highway project,	The relatively small numbers of experienced firms make it much more challenging to discern whether the same lobbying for high-speed rail would be motivated by a desire to pad profit margins, setting prices well above the cost of doing business
Inflation and other drivers of cost escalation during construction may be managed within the terms of the contract on a highway project	The 10 to 20 year timespan of high-speed rail development means that inflation is likely to double the construction cost of the project (and this could occur before construction begins)
Quality control in highway development is conducted with periodic surveys or sampling of work, with samples of performance assumed to reflect the conditions of the product as a whole	On high-speed rail, surprisingly small deviations from specifications can be catastrophic, giving cause to adopt different and more comprehensive approaches to quality control and quality assurance
For highways, latent defects in construction may be taken up in successive funding cycles of the transportation program	On high-speed rail, latent defects may prevent the start of operations or pose significant safety risk
On highway projects, other organizations such as utilities and to some extent local governments may be addressed through negotiations to minimize the impact on construction	On high-speed rail these organizations are partners who are needed for successful operations
The public own and operate the vehicles that traverse our highways	On high-speed rail, the rail cars (rolling stock) and their operation are a fundamental part of the project.

rail technologies and markets occurred as a result of concerted national investment over decades. Japanese high-speed lines provided timely connections between urban hubs already fitted with extensive subway and commuter rail systems (Hayashi et al., 2017; Cervero, 1998). In Japan, for example, historic markets for urban and suburban rail and real estate development grew continuously over time (Cervero 1998; Bernick and Cervero 1997). The same private real estate and streetcar developments were removed from most U.S. cities in the early 1900s; they were saved from destruction in only a few places, such as San Francisco. This means that Japan has benefitted from a Century of transit-oriented land use development, in ways that strain comparison with conditions for rail development in the U.S.. European high-speed rail lines were designed for metro-to-metro service atop existing and robust national rail networks, which served as meaningful platforms for public transportation agencies to grow and develop services (Figure 2.6, dark lines indicate high-speed service, while light lines show the extent of rail services operating at lower speeds). Another reason to be cautious in comparison is due to the incentives and disincentives that travelers have had for the competing modes of travel from country to country. In Japan and China, for example, high-speed rail development began at a time when the air travel market was not as well-developed as it is today in the U.S. Compared to the U.S., there were also greater financial disincentives to owning and operating cars in Japan, China, and Europe, which likely influenced the pace and relative success of rail travel in those parts of the world (Deakin and Pérez Henríquez, 2017; Cervero, 1998).

Successful high-speed rail systems around the world benefit from institutional safeguards for their development. Institutions are formal rules, informal norms, and their enforcement characteristics, and they are vastly influential to economic growth and development, in general, and to project development, in particular (e.g., North, 1990). As the provision of high-speed rail service expanded in Europe, so did the rules and associated organizational structures to support its development. Though more research on the topic is needed, one example stands out for its potential to alleviate several problems experienced on U.S. projects.

Figure 2.6: European Rail and High Speed Rail Service (Source: UIC, 2022)

Experts drew attention to the selection of the route (ideally, a few alternatives for the route, all capable of meeting performance targets) as an important early decision in high-speed rail development. It is important because, with this decision, a transition is made to a technical and more intensive period of public engagement. In France, the organization responsible for most of the country's high speed network (Train à Grande Vitesse, TGV) is the Société Nationale des Chemins de fer Français (SNCF), a national, state-owned railway company. The determination of a route for TGV development is informed on one level by the European Union's efforts to establish continuous networks of service across the continent. On another level, after the political decision to develop high-speed service between two metro areas, the technical determination of the route is buttressed by a legal inquiry, made by an independent agency, to determine whether the damage that will be caused by the project will be outweighed by the benefits the project will bring to society. This is a formal process to declare the use of the route for the project to be in the public interest, carried out by an agency that is not allowed to have any linkages to the rail industry or its governance. The practical effect of this institutional safeguard is to constrain political behavior to maintain the focused purpose of the project, constrain or redirect market behavior to serve the public purpose of the project, and control for the effects of real estate speculation and NIMBY-ism on the cost of land acquisition for the route and stations. There is no known equivalent to this institutional safeguard for project development in the U.S., which speaks to the fact that even with the exercise of eminent domain, negotiations for the purchase of land can be brought up through the courts over the course of years, for any number of individual parcels and/or easements along the route (e.g., Eno Center for Transportation, 2021).

2.3 Efficiency requires a competitive market for delivery of public goods

Summary. *Without competition there will be no pressure for firms to pull bid prices down toward their own actual estimates of cost. There are a limited number of knowledgeable bidders in the market for high-speed technology. Maximize the potential to reach the largest number of market participants by adopting standards with the widest number of knowledgeable firms. While many projects start with a competitive market of players at the outset, they usually end up in a game with a small number of players as project development proceeds, thereby raising the risk of increases in cost and contractual issues. Public-private partnerships have often been promoted for infrastructure megaprojects around the world, including high-speed rail, yet these arrangements can lessen competition (e.g., Dutzik and Schneider, 2011; Ho and Tsui, 2010). Though there are few examples, projects in the U.S. gravitate toward two extremes for high-speed rail development, while international arrangements represent a wide variation in ownership structures for contracting. It helps to realize that a high-speed rail line is a massive program made of many engineering, construction, manufacturing, and assembly projects, each with its own market of competitors. Consider cultivating competition in the market, as opposed to competition for the market. Continually assess the limits of your expertise, and get help.*

Without competition there will be no pressure for firms to pull bid prices down toward their own actual estimates of cost. For large scale infrastructure development, efficiency involves setting up a program of projects, each organized to attract a healthy number of responsible bidders for the work. The structuring of the program into discrete projects should assist in maximizing the benefits of competition; it is easier to attract competitive bids if the projects are structured to fit the expertise of large numbers of existing firms. The bundling of components of the larger project together can have the opposite effect, leading the market to respond by organizing interested firms and public agencies into a small number of consortia to bid on the project. A market study of Netherlands high-speed rail, for example, suggests that about 40 large contractors in the Netherlands and surrounding countries participated in the initial bidding for a project, but the number of responsible parties was actually far below 40. Some local contractors formed a cartel to divide up the work and reduce foreign competition, resulting in a final tabulated bid amount 43% higher than initially offered. The HSL-Zuid directorate had to halt the process and negotiate the price with contractors (Priemus, 2009; Netherlands). Consider, also, the case of Taiwan high-speed rail, which ultimately weighed the competing proposals from just two consortia before going forward with the project. It is difficult if not impossible to know whether a project has benefited from competition with only two responsible bids.

There are a limited number of knowledgeable bidders in the market for high-speed technology. It is common for people to discuss the prospects of high-speed rail in terms of widely publicized technical approaches, such as magnetic levitation (maglev), steel rail, and the more recent idea of hyperloop. What these characterizations miss is a window into how the selection of a technical approach will limit the number of companies that can reliably compete for the work. In other words, the selection of the technical approach limits the extent of the market of suppliers for the project. This is mainly due to the fact that a company needs experience with the technology to be able to credibly bid for the work. Of these three categories of high-speed technology, steel rail has, far and above, the greatest potential to attract and sustain competitive bidding. Magnetic levitation originated in Japan, and has also been applied to a few projects in China and South Korea. Hyperloop is a concept still undergoing trials, dramatically limiting its potential to attract bidders with experience in project development. All of the countries that currently have operating high-speed systems, however, have government agencies and corporations with experience working with steel rail technology. Experts familiar with today's high-speed rail market suggest that, depending on who you ask, there are about 12 to 17 companies (some public, some privately-owned) with the expertise to responsibly bid on high-speed rail projects, especially when considering the design of the system and technical components such as signaling, rail cars, power systems, and so on. A wider range of bidders may be possible for the construction of structures and substructures that support the track, though design for this work and its execution still benefits from high-speed rail experience.

Maximize the potential to reach the largest number of market participants by adopting standards with the widest number of knowledgeable firms. When considering the development of the first high-speed rail line for a state or region, it may seem premature to discuss standards for the development of such systems, but the standards that are chosen also determine the number of responsible bidders a project may ultimately attract. Experts point to early standard setting by the government as an important aspect of maintaining a competitive market. The standards include the development of substructure and structure of the track, rolling stock, station, signaling, electrification, and operation system. For example, Figure 2.7 shows the extent of various gauge of track in Europe's rail system. The standards ensure the interoperability within these different systems and between the new project and existing transportation and utility systems, which makes it possible to divide the project into different segments and phases that can be split into different market arrangements. The standards, along with the structuring of components of projects to increase competition, can help to prevent the consolidation of suppliers into consortia and create more opportunities for local manufacturers and small businesses to participate in the project. Currently, several countries with high-speed rail have their own standards, while the International Union of Rail is making an effort to unify standards in Europe and Asia (UIC, 2022). The California high-speed rail is following German standards. While the existing standards provide useful references, experts have noted that what ultimately determines the standards should be the principles and parameters envisioned for the service of the system, which concern the preferred maximum speed, train capacity, and requirements for clean energy.

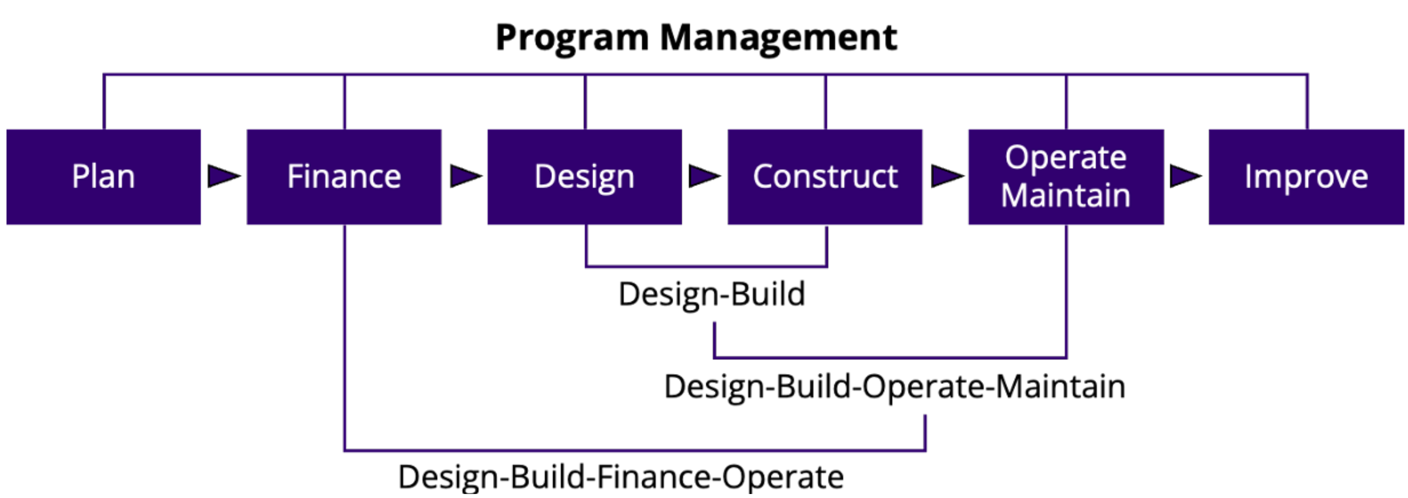
While many projects start with a competitive market of players at the outset, they usually end up in a game with a small number of players as project development proceeds, thereby raising the risk of increases in cost and contractual issues. Project delivery occurs in stages over time. The selection of consulting firms matters, even at the earliest stages of planning and engineering. In markets for large projects, consulting, planning, engineering, and construction firms have patterns of working together. Companies maintain relationships with suppliers of expertise, materials, and equipment, that will make some parameters or specifications for a project more profitable for them than others. Contracting firms who get into a project early improve their own opportunities by shaping the rules for others to participate and, in doing so, limit the possibility of competition. This is a set up for excess project costs all the way through detailed engineering, construction, operations, and maintenance. What matters is for the public agency to place themselves in a position to gain an understanding equivalent to the companies in the market, and for the agency to be diligent in accessing competitive markets through

Figure 2.7: Rail Systems and Track Gauge in Europe (Source: OpenRailMap, 2022)

the various stages of project development. Avoid lock-in by cultivating expertise with competition (i.e., working with multiple firms). This can be done in the earliest stages of consultation, through the hiring of firms as agency advocates separate from the consultants and firms working on engineering, and by maintaining a deep bench of technical expertise in a separate and paid advisory board, capable of performing audits of the work as it progresses.

Public-private partnerships have often been promoted for infrastructure megaprojects around the world, including high-speed rail, yet these arrangements can lessen competition (e.g., Dutzik and Schneider, 2011; Ho and Tsui, 2010). The term is vague, as it represents a wide variety of roles and responsibilities for the public and private sectors (Figure 2.8). Megaprojects of all kinds, including high-speed rail, need attention to how roles and responsibilities are structured in order to manage the substantial risks associated with these endeavors. The public sector has certain institutional capabilities and incentives for the public interest that are not shared by the private sector. The private sector's incentives and opportunities have benefits of their own, while raising some risks for the public sector. The question is how to structure participation in project development and operation to obtain the best of both and avoid the worst. Though it is common for academic and trade publications to promote public-private partnerships by emphasizing the idea that they may allow the allocation of risk to the party best equipped to deal with the risk, such agreements are more difficult and costly to manage than is often realized (Whittington 2012; Alexandersson and Hultén, 2022, Europe). Notions such as optimal risk sharing are promotional. They are arguments in favor of approaches that bundle stages of development together, ultimately encouraging the consolidation of bidders into small numbers of qualifying consortia. Similarly, private finance is often a key argument in favor of pursuing a public-private partnership. It is important to remember that all of this infrastructure, however it is procured, is ultimately paid for by the public (Dannin & Cokorinos, 2012). It is worth noting that the vast majority of high-speed rail systems in operation around the world today are publicly owned, either wholly by government agencies or through state-owned corporations, with at least partial government ownership of operations as well. There are prominent examples of public-private partnerships in high-speed rail that have either failed to meet performance targets for return on investment (e.g., Taiwan high-speed rail) or failed through bankruptcy of the firm (e.g., Spain to France international line and station), requiring costly government intervention and infusion of funds.

Figure 2.8: Phases of Work and Forms of Contract for Public-Private Partnerships
Adapted with permission from Pakkala (2002, p. 32)



Though there are few examples, projects in the U.S. gravitate toward two extremes for high-speed rail development, while international arrangements represent a wide variation in ownership structures for contracting. Curiously, procurement approaches to high-speed rail in the U.S. have been structured into contracts using design-build or design-bid-build procurement with the public entity as the owner (i.e., Amtrak Acela Express, and likely California's high-speed rail), or with a private sector lead as the owner and operator of the system (e.g., Brightline Florida). Internationally, projects may involve multiple players—government and private corporations as the essential players, and sometimes state-owned corporations (Dutzik and Schneider, 2011). The public agency is usually the program and/or project manager, using design-bid-build as well as design-build forms of procurement to hire firms for design and construction, or for the manufacturing of rolling stock. In Europe, state-owned corporations often assume leadership in high-speed rail development, as found in Spain, Germany, and France. State-owned corporations can be defined as those in which the government retains majority ownership and control over the corporation, even if the government does not own 100% of the stock. Sometimes these state-owned corporations branch out or service other countries, which is quite common in Europe, as is the case for SNCF from France, which also operates on the Netherlands high-speed rail track. It is important to recognize that any portion of the development and operations can be delivered through a corporation with an ownership structure shared between government agencies and private firms. For example, the operation concessionaire of HSL-Zuid, High Speed Alliance, is a joint venture with 90% from the state-owned corporation Nederlandse Spoorwegen (the Dutch national railway), and 10% from Air France-KLM (Dutzik and Schneider, 2011).

It helps to realize that a high-speed rail line is a massive program made of many engineering, construction, manufacturing, and assembly projects, each with its own market of competitors. Consider the approach to high-speed development in Spain. By the time Spain began plans for its first high-speed line, the development of high-speed systems in Japan, France, and Germany had already given rise to several public and private organizations capable of competing for the work. This meant that the government was able to contract out for the various components of the project without setting up its own manufacturing centers. High speed rail line developments were considered to be programs, consisting of several projects, each procured in a design-bid-build format, with the completion of design (subject to competitive bids by engineering firms), and approval of design by the government agency managing the program, followed by competitive bids for construction. European standards were prioritized, with consideration for the relative cost or ease with which companies could adapt to fit a shift in the standard (e.g., manufacturing longer or shorter rail cars), and the standards were used to promote modularization, further gaining benefits from economies of scale in engineering and construction (e.g., Landis 2022, 7-8). All but one project—an international connection to France—was developed using public funds. Early on, before a go/no go decision has been made for a project, people make informal use of the media to shape and influence public discourse about the project and its features. Once the decision was made to start a project, a more formal process of engagement began, with planning and then environmental review. Engineering was at 50% or more at the time of environmental review. In the European Union (as noted above for high-speed rail in France), the law supports the public administration's effort to acquire land for infrastructure to serve public interests. In Spain, after each high-speed rail line was defined to serve public interest, the government was able to move forward efficiently to acquire the land. Spain's high-speed rail system is shown in Figure 2.9. Though there are differences between general metro and high-speed rail stations, it is worth highlighting that the City of Madrid completed 39 new metro rail stations between 1995 and 1999, including 23.5 miles of expensive tunneling, at an average cost of $65 million per mile using modular designs for each station, which reduced complexity and made iterative improvements possible (Balkus, 2022).

Consider cultivating competition *in the market*, as opposed to competition *for the market*. One critical factor for enhancing competition is how the operations of the system are structured, along with the development of the track and supporting equipment. When governments bundle operations together with track development, they are issuing requests for competition for the market (i.e., the winning bidder and system will be the only organization serving the market for this line, and therefore a monopolist). This approach has been used in the British high-speed rail system, and was the arrangement for Taiwan high-speed rail's public-private partnership. In Spain and France, the preference is for competition in the market for high-speed rail, in which operators bid for the right to run services across the line/system, creating the possibility of competitive bidders for operations and the competitive differentiation of services. Competition in the market is similar to the form of competition airlines use today,

Figure 2.9: Spain High Speed Railway System Map (Source: UIC, 2022)

to determine the time slots for the origins and destinations of flights. Note, though, that competition for high-speed rail operations in Spain and France are still structured so that the government owns the rolling stock (trains). Experts have also been quick to note the need for regular government inspections to keep up the quality of service; deterioration of service quality is a threat that is present irrespective of the structure of ownership and operations.

Continually assess the limits of your expertise, and get help. The public and private sectors play different roles at each stage of high-speed rail development and service. The U.S. public sector has experience providing a limited set of megaprojects in its own region. Experts cautioned against thinking that an organization could simply proceed in the development of high-speed rail as though it were a higher-speed version of existing service, such as Amtrak, or proceed in the same way as one would for a highway development, and expect good results. High-speed rail brings new requirements for expertise and experience in creating an integrated system, which differs from those gained from civil projects (such as building bridges and highways). In contrast, the firms in these markets have concentrated experience and will become the sources of information asymmetry about design choices, cost, and profitability. This means that having international experts as in-house expertise representing the interests of the public sector is critical, especially in the beginning of the project, to provide industry context and insight.

2.4 Effective high-speed rail development requires thorough and deliberate public engagement coupled with planning and engineering

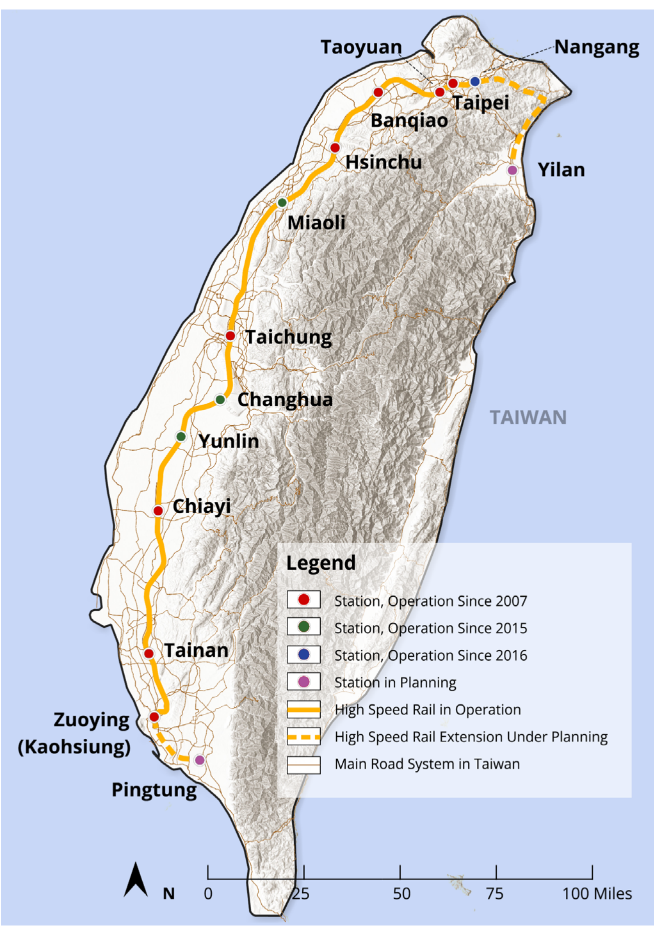
Summary. *High-speed rail lines are initiated through reaching political consensus on the vision of the project, the long-term future of service, the growth of the region, and potential efficiencies and spillover effects. Experts encourage early outreach to local leadership, with a particular view of what it means for cities, counties, and other local and regional entities to become partners in the project. Academics encourage consideration, for example, of the role of transit-oriented development in providing affordable housing choices in proximity to station areas. Let technical considerations of planning, engineering, and cost, with business performance characteristics, drive the production of options for routes. All eyes will be focused on the selection of a route and stations from point A to B. Experts describe the need to enter environmental review with 50% of engineering complete, preferably for 2 or 3 alternative routes, though they would all need to be able to meet performance expectations. Factoring in the location of electrical transmission lines on the grid during the selection of the route offers multiple cost-saving benefits, for capital cost, operating costs, and land acquisition. Don't delay the engineering and construction of urban metro and airport stations, as each is its own megaproject in need of greater than 50% engineering at the time of environmental review. In other words, "Plan slow, act fast" (Gardner and Flyvbjerg, 2023). Plan slow; bring the engineering with you in a concerted program of public outreach. Plan slow; be able to explain the costs, impacts, and operational constraints, but also the services local communities will receive. Plan slow; reach political agreement early on to put institutions in place, such as land value capture as part of the financial structure of the project. Act fast, when the time comes to advance to detailed design, land acquisition, and construction. Act fast; in the move from engineering to construction the cost per day of work rises dramatically, which means that construction techniques matter. Act fast; inflation is not on your side.*

High-speed rail lines are initiated through reaching political consensus on the vision of the project, the long-term future of service, the growth of the region, and potential efficiencies and spillover effects. If designed well and developed efficiently, high-speed rail can have a positive impact on the local and regional economy. This positive impact can galvanize political leadership to reach consensus in favor of a project and the future made possible by such a project. The main mechanism of this effect is economic agglomeration in urban settings, with positive spillover effects to suburban and rural areas (Landis, 2022). Economic agglomeration describes the advantages in large urban markets that arise from greater specialization, shared intermediate suppliers, a shared labor pool, and localized transmission of knowledge and ideas (Marshall, 1890). It refers to a dynamism that may be evident in lowering the cost of doing business, increasing the pace and breadth of innovation, and spurring economic growth in employment and associated urban development. Agglomeration effects are commonly observed in cities with high-speed rail stations (Shao et al., 2017, China; Wetwitoo and Kato, 2017, Japan). As would be expected, agglomeration effects are more likely to occur in the metro urban hubs along high-speed rail systems, with concentrations in finance, technology, and business (Shao et al. 2017; Li et al., 2020; China). Spillover effects to suburban and rural areas can take the form of increased economic growth as well, with growth in employment (Lin, 2017, China high-speed rail) and increased attractiveness for office location choice (Willigers and van Wee, 2011, Belgium, Netherlands, Germany). Spillover effects have several mechanisms, including knowledge diffusion, labor market pooling, and the effects of improved access to intermediate goods and consumer markets through enhanced accessibility (Ahlfeldt and Feddersen, 2018, Germany). In these studies, the positive impact of high-speed rail is observed when using a large geographic unit of analysis (e.g., state instead of city), and measured over a long period of time (Cheng and Chen, 2022, Meta-analysis).

Experts encourage early outreach to local leadership, with a particular view of what it means for cities, counties, and other local and regional entities to become partners in the project. Interviewees note that the time needed to engage local governments, in general and with respect to specific permits and agreements, can delay high-speed rail development during its most costly phases of engineering and construction (California). Early outreach, with candid conversations about the changes such a project would bring and advanced schedules for work to expedite permitting are recommended (e.g., Eno Center for Transportation, 2021; 2022). It is also helpful to realize that the experience of the project for local jurisdictions will spread beyond the doors of each station along the route. Academic researchers have cautioned that achieving the perceived benefits of high-speed rail requires careful land use planning strategies, for example, perhaps even more so in suburban and rural areas than in the vicinity of metro stations (Nuworsoo and Deakin, 2009, California). Access to stations along a high-speed route can induce demand, encourage more people to move to the area and raise property values. Studies have shown that access for small and medium-sized cities to high-speed rail stations raises housing prices (Chen and Haynes, 2015; Pagliara, 2019; Wang et al., 2019; China and Italy). Stations inspire new development, which should include an expansion of housing supplies. The development of Bordeaux-St-Jean train station, for example, along the Nimes-Montpellier Bypass in France, has led to the emergence of a business district with 161,000 sq. ft. (15,000 m^2) of newly developed housing units, most of which are available for a 25% social rental subsidy.

Academics encourage consideration, for example, of the role of transit-oriented development in providing affordable housing choices in proximity to station areas. A variety of housing choices will be needed to serve existing and newly attracted residents in a transit-oriented environment, with additional improvements in the form of non-automobile options to access station areas and carefully managed automobile access to stations to minimize the disruption brought on by the influx of travelers or due to the station area itself (Nuworsoo and Deakin, 2009, California). Consider, for example, the development of station areas along the route of Taiwan's high-speed rail line (Figure 2.10). For the first line and set of stations, the stations that were located within urban settings included Taipei (central metro area), Taoyuan (suburban Taipei), Hsinchu (industrial park), and Kaohsiung (urban and industrial urban hub). Some of the other stations, such as Chiayi, and Tainan, were located at some distance from urban areas. In order to connect to the high-speed rail, local transport authorities provide transfer options from the city centers to the stations through buses, conventional rail, and metros. The reasons for this have to do with the design of the route for high-speed service, which was informed by years of research and preliminary engineering from the government agencies and state-owned corporations of Japan and France in the high-speed rail industry. The more remote the station, the more the station area was provided with dedicated land for the development of supportive infrastructure and land use, including parking areas, and other transportation facilities, and development land for commercial and residential use (Feng, 2011; Taiwan Railway Bureau, 2021). Planners expect high-speed rail station areas to become centers for new communities, offering affordable housing early in the development, as access to the service will increase the property values of the area over time.

Figure 2.10: Taiwan High Speed Railway System Map (Source: Ministry of Digital Affairs, Taiwan, 2022)



Let technical considerations of planning, engineering, and cost, with business performance characteristics, drive the production of options for routes. Experts describe a pivot point early in high-speed rail project development that is important to observe and act on. Political consensus, including public participation, should be formed around overall principles for the service and operations, such as expected service levels and system capacity, climate targets, cost reduction goals, and system resilience, which have the effect of setting parameters for the design of the system, overall. Once political consensus is formed, with its commitment to raise public funds, the focus of the work must turn to technical considerations to generate options for routes that offer the realistic promise of high-speed performance in metro-to-metro markets. As noted above, there should be a clear and clean distinction between the formation of political consensus and the planning of the route. Many variables, such as terrain, land availability, and connection to the power grid, define the feasibility of a route. Seemingly small political choices about the route can deprive the whole high-speed rail system of its opportunity to deliver peak speed, maximize economic agglomeration and spillover effects, and achieve economies of scale in project delivery. People also may not realize how difficult it is to cost-effectively modify the system after construction to improve performance (i.e., operate at higher speed). At the outset, engineering creates the possibility of a maximum safe speed of operation; a speed that cannot be exceeded. The political and technical work continue to be closely tied, but with distinct roles. Before and during mandated environmental reviews, the technical exercises of planning and engineering are tasked with delivering, to political leadership and the public, route and station designs with increasingly accurate bottom-up estimates of the cost and time of delivery. Public funding and public engagement require this information to be able to sustain consensus among political decision-makers and broaden public awareness with realistic snapshots of design options under consideration (i.e., options that do not diminish system performance), timelines, operational characteristics, and estimated capital and operational costs, among other things.

All eyes will be focused on the selection of a route and stations from point A to B. The go/no go decision is usually tethered to forecasts of ridership between two metropolitan centers, with secondary consideration for stations along the route. In Europe and China there are many choices for connections between major metropolitan areas. The selection of metropolitan centers is used to consider whether there will be enough actual market demand for high-speed services to support their own operation and maintenance costs without significant public subsidies. Ticket pricing also matters, as ticket prices can be competitive with air travel at high speeds. For example, Figure 2.11 shows thresholds of passenger density needed for revenue to meet the cost of China's high-speed rail service (World Bank, 2019). For 124 to 155 mph (200 to 250 kph) trains, 20 million passenger miles per mile are needed each year to meet the cost of operation and maintenance. For the 186 to 217 mph (300 to 350 kph) trains, which have considerably higher ticket prices, 10 million passenger miles per mile each year to meet the cost of operation and maintenance (based on data from 2016). Note that the cost of interest (financing) can double the cost of the project, which speaks to the large capital cost of these projects and the long time frame of financing (assumes 50% of capital cost financed over a 20 year period). When considering the additional stations along the line, experts note that the factors that matter in the design of metro stations are different than those in suburban and rural areas. Metro stations are needed within city centers, operating together at the hubs of existing commuter rail and bus services, and integrated into airports. Experts strongly recommend that suburban and rural areas be served with stations that exist at the city edge, periphery, or even some distance from the city, at locations that can provide access to the system (for trains making multiple stops, for example), but do not detract from the need for express train services to travel at peak speed. Station location choice is illustrated for Spain's high-speed rail system in Figure 2.12. Such strategies reinforce the prospect of new growth and development around station areas.

Experts describe the need to enter environmental review with 50% of engineering complete, preferably for 2 or 3 alternative routes, though they would

Figure 2.11: Breakeven Passenger Density at Opening, China High Speed Rail (Source: World Bank, 2019)

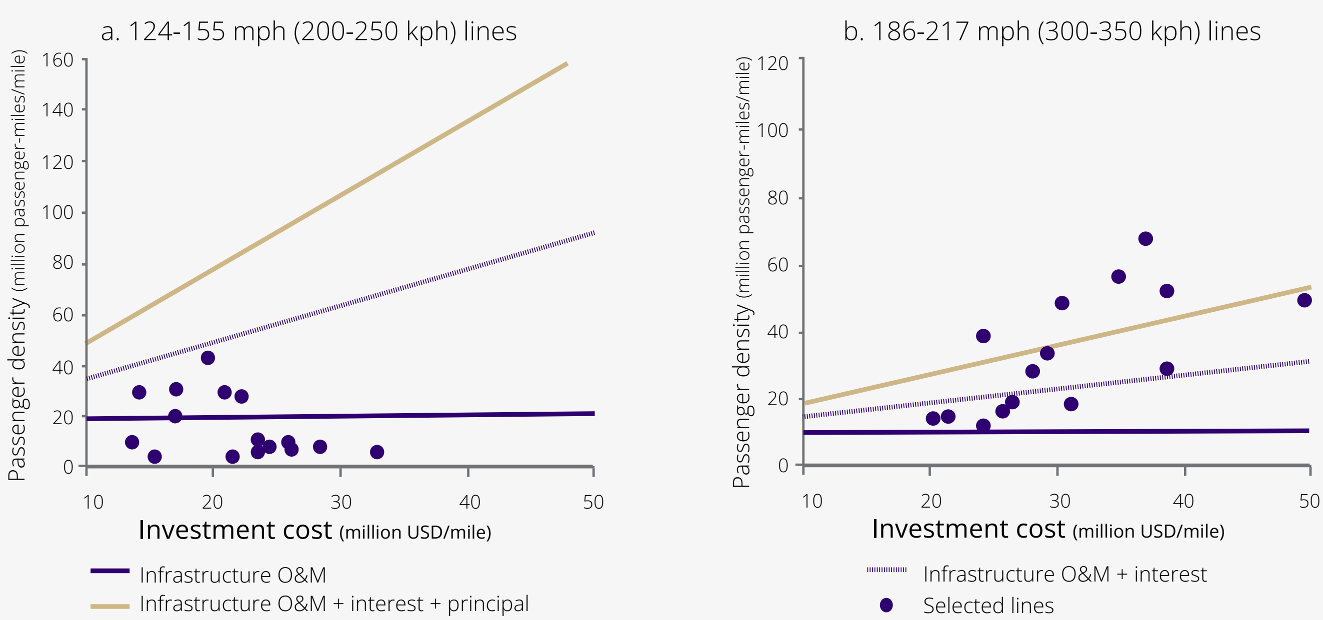
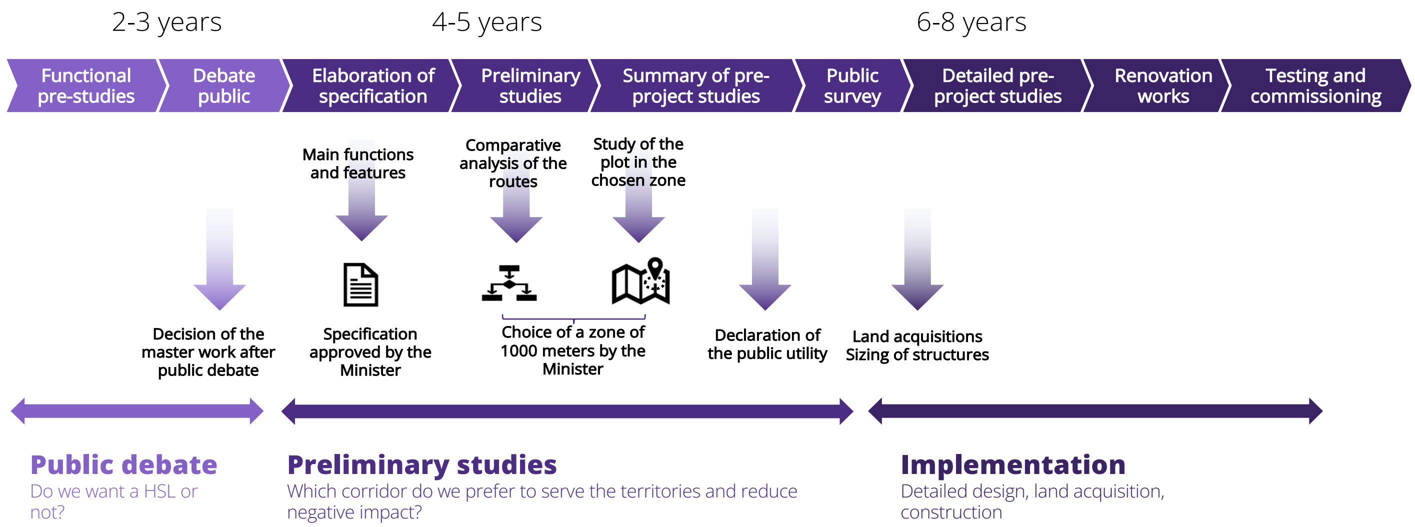


Figure 2.12: Station Location Choice in Spain High Speed Rail System

all need to be able to meet performance expectations. Internationally, experts prefer to conduct environmental review with 50% of engineering complete, for 2 or 3 alternative routes, each capable of performing peak speeds for services, ridership, and associated revenues. In the U.S., this would mean more investment in planning and engineering in advance of environmental review than is usually contemplated, and a programmatic form of environmental review, setting up programmatic permitting for all but the environmentally sensitive areas impacted by the development. Experts describe the need for a systematic approach to planning and designing the routes and associated stations, to ensure the interoperability of the various systems involved, such as the track, the rolling stock, the civil engineering and construction, the operational system, and the utility and energy systems, and to be able to take a concerted approach to forecasting what is likely to happen over the long timespan of project development and operations. How this should look in a timeline of project development, is shown in the example of high-speed rail development in France in Figure 2.13. France already benefits from well-established institutions and organizations for delivering high-speed rail, which means that this timeline reflects what could be possible if changes in institutional arrangements

Figure 2.13: French Team Presentation of Project Delivery Process
Source: High-Speed Lines in France, Seattle-France Dialogue, Ministère de la Transition



are made for such projects in the U.S. and Canada. In French high-speed rail development, projects begin with 2-3 years of public debate, resulting in a go/no go decision. This is also the pivot point of political consensus. This is followed by 4-5 years of preliminary studies, beginning with specifications for the system, comparative analysis of routes, the selection of a route, and the legal determination to show whether the public interest will be served by the project, despite the damages that will be associated with its development and operation. This is followed by 6-8 years of implementation, beginning with detailed design and land acquisition and ending with the commissioning of the project (to begin operations).

Factoring in the location of electrical transmission lines on the grid during the selection of the route offers multiple cost-saving benefits, for capital cost, operating costs, and land acquisition. High-speed rail operations require access to the high levels of energy found on the transmission lines of the electrical grid. This access has to be provided at multiple points along the route; the equivalent of building multiple electrical substations. Experts interviewed explained that the lack of familiarity with this requirement by U.S. transportation experts—whose work experience is mainly on highway development—could lead to a costly loss of opportunity during the planning of the route.

Furthermore, the electrical needs of high-speed rail operations have an unusual profile over time, tied to the need to provide each individual train with a large pulse of energy (equivalent to the needs of a small town), as the train passes by each connection to the grid. As the number of trains in service usually grow over time, so do these requirements for energy supply. This profile of energy supply is unusual for electric utilities in the U.S.. Experts familiar with the California high-speed rail project noted the challenge of obtaining agreements from existing utilities to service the electrical needs of the project, for example, in part due to questions about the likely effects of short bursts of supply on the stability of the grid, and due to the amount of capital investment that would be required of the utility to service the project. Interviewees note that the route for the California project was not selected for optimal access to the grid, though doing so could provide multiple benefits to high-speed rail. Aligning the route with the transmission lines of the electrical grid reduces the capital cost of the high-speed rail project by reducing the need for the project and/or utilities to install and service new additional transmission lines and substations. New capital investments in substations and connections to transmission lines are needed all along the route, with more provided where trains travel up a gradient; on California high-speed rail the cost of the simplest form of connection, a substation cutting into an existing transmission line, can exceed $40 million, with more transmission causing costs to rise to as much as $110 million per connection. Power is lost in transmission, mainly as heat from conductors, which means that the distance between the existing electrical grid, with its power supplies, and the high-speed rail connections to the grid, will suffer some degree of losses over time, making the utility cost of operating the project more expensive. A route aligned with the grid, if arranged in partnership or agreement with the grid owner/operator (often an electric utility), also offers the potential to alleviate land acquisition costs, at least for a portion of the project.

Don't delay the engineering and construction of urban metro and airport stations, as each is its own megaproject in need of greater than 50% engineering at the time of environmental review. Urban metro and airport stations are, in and of themselves, infrastructure megaprojects. Each may be as large and involved as the tunnel project that replaced Seattle's Alaskan Way Viaduct (Riddle and Whittington, 2022). The relative cost and difficulties included in their design will result in these stations taking longer to design than the rest of the system. It is important to know that this is normal, and to be expected: it is easier to plan and design for track, structures, and substructures through rural areas than urban centers. Experts strongly advise the early and deliberate effort to deliver these station developments on time for the launch of operations, and not to postpone their development to later periods of the project. These station developments should define the critical path for the schedule of the project as a whole—the tasks that must be completed before the project can move forward to the next stage of development (i.e., planning, the various stages of engineering, construction). Experts in high-speed rail station design describe the need to bring together a broader coalition of expertise for these projects compared to other parts of the system. Station designs concern the effect on the surrounding area, the security of the station, and the connection with local transport and other major transportation hubs, such as existing airports and multimodal transit centers. Their design requires all the relevant experts and stakeholders, including the system operators, electrical engineers, security experts, community leaders, to be involved in the early stage to have a unified and comprehensive vision. City center stations have been shown to increase surrounding property values and spur development, in ways that can be challenging to predict and are somewhat dependent on local desires for change. For example, the upgrade of London Kings Cross Station in the UK in the 2000s led to a complete transformation of the surrounding area, and attracted substantial new private investment. In many metropolitan areas, old train stations in inner cities have been upgraded to accommodate high-speed trains. Across the board, studies have found that inner-city stations raise residential property values due to increased accessibility, higher investment attractiveness, and greater access to public service infrastructure (Geng et al., 2015; Diao et al., 2017). Careful planning is needed, however, for the area and services around the station as well as the design of the station itself, as stations can bring increasing traffic congestion and crime, and train operations bring engineering challenges to address noise, vibration, and electromagnetic radiation (Geng et al., 2015). Altogether, these issues require a deeper consideration of engineering approaches than may be typically appreciated for projects at the stage of environmental review in the U.S.

In other words, "Plan slow, act fast" (Gardner and Flyvbjerg 2023). In their effort to distill research into simple principles to help megaprojects succeed, titled How Big Things Get Done (2023), Bent Flyvbjerg and Dan Gardner suggest that people "plan slow" to be able to "act fast." As they say, "Getting to the action quick feels right. But it's wrong." This message conveniently encapsulates several strands of expert advice and research reviewed for this report.

Plan slow; bring the engineering with you in a concerted program of public outreach. There is no singular day in the development of a project that is most appropriate to begin public outreach. People want to know how their communities would be impacted in both positive and negative ways from the plans for high-speed rail, in whatever stage of development those plans happen to be in. For projects with such lengthy timelines and whole system implications, outreach should begin early and give an honest depiction of the designs under consideration. Municipalities, counties, and their elected representatives may want to bargain for something that is perceived to be a better deal, asking for changes to the project design. Communities pay attention to the deliberations as they are carried out with other cities in the vicinity of the route, and adjust their expectations accordingly. Experts described this as a "knock-on effect" happening in projects in the U.S. where, having seen one suburban or rural community successfully negotiate to bring the route and station into their city center with a relatively expensive tunneled or elevated track and station—as opposed to a station on the periphery or at ground level—the next community makes the same demands (California). For planners and engineers on the project, these recommendations pose distinct challenges for public engagement as well as project design. People need a clear accounting of the ways in which each seemingly small change would add up to a shift in project design, cost, operation, and service, that would ultimately reduce the functions and financial performance of the project overall, and a responsive dialogue to find workable solutions that do not detract from project performance. Early engagement that reaches out to each community simultaneously can reduce the risk of competition for compensation from the project in the "knock-on effect".

Plan slow; be able to explain the costs, impacts, and operational constraints, but also the services local communities will receive. Experts suggest that public outreach should involve community advocates, convey the actual impacts of the project with a legally defensible environmental review, and present both the direct and indirect benefits in a tangible way. Advocates are often found in the younger generations who are more open to the idea of traveling by train and more likely to see themselves benefiting from the project. Equity should be at the forefront of community engagement to ensure people are treated fairly and benefits are equally distributed. The National Environmental Policy Act and its state-level equivalents serve unique purposes in coordinating public agencies and environmental scientists to survey and disclose to the public their assessment of the impacts that programs and projects will have on the environment, in the interest of mitigating those impacts. Interviewees explained that the investment of time and effort in environmental review matters. People, property, and natural systems are obviously affected by construction, and people rightfully care about changes in zoning and market conditions for their homes and businesses. These are real issues that need to be recognized and appreciated by everyone involved, with planning and mitigation. At the same time, people can be vulnerable to misinformation about high-speed rail projects, and engineers and operators can assist in debunking misconceptions, sometimes with the aid of online tools for visualizations and virtual experiences of how activities will be carried out, and how the system works and will function. A legally defensible, thorough, and systematic environmental review can help communicate impacts to communities and reduce risks of disputes. It is also important, however, to make the benefits and the user experience more tangible to the communities than is typically possible in an environmental assessment. On the positive side, experts suggest that people should be able to see and ideally participate in station area design, and have access to proposed interior designs of the station facilities and the conceptual designs of the seating arrangements. Service characteristics, such as the frequency, speed, and price of trips should be discussed, along with the indirect benefits, such as the job opportunities and the economic benefits to local businesses.

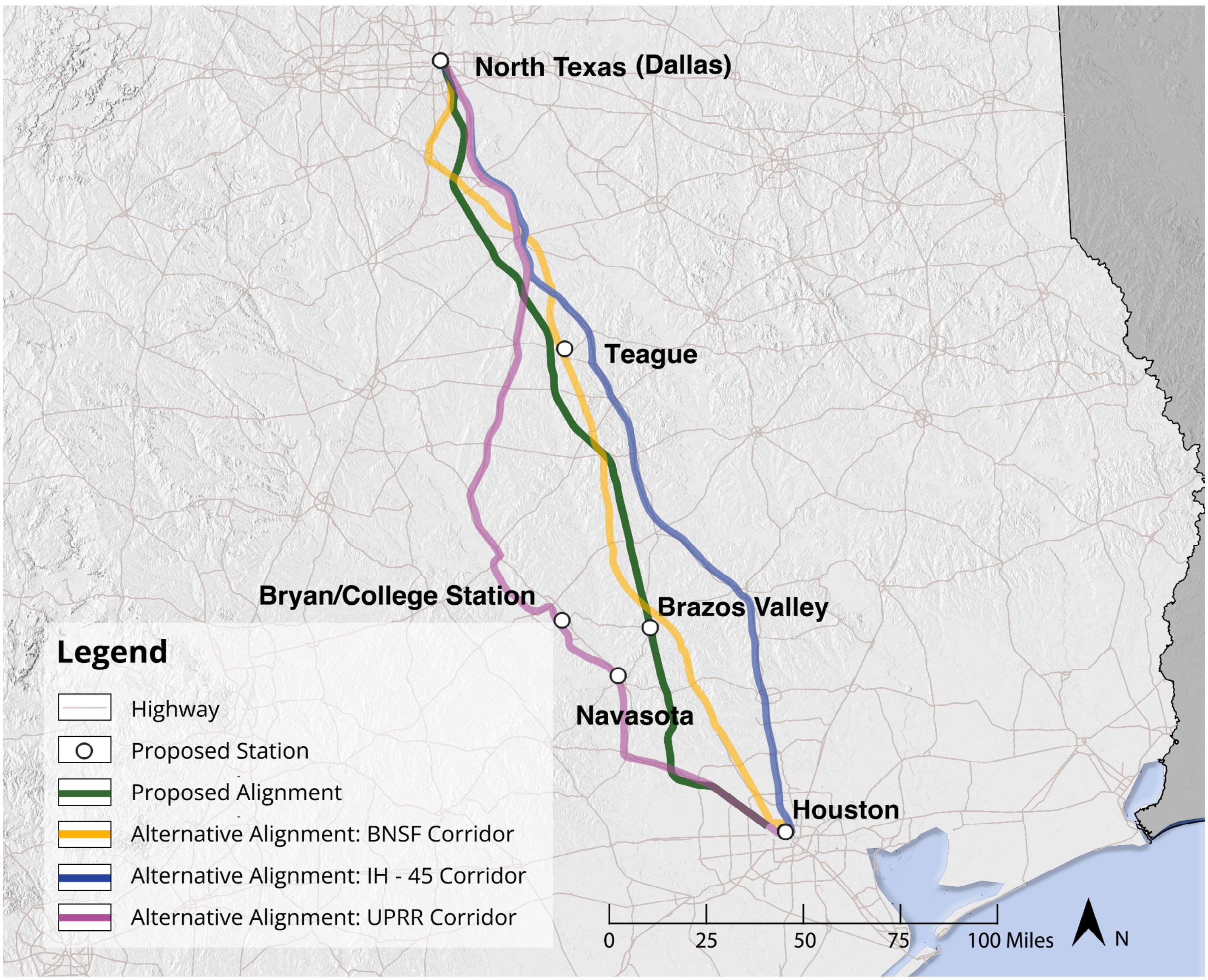
Plan slow; reach political agreement early on to put institutions in place, such as land value capture as part of the financial structure of the project. Organized interests in markets in the U.S. move quickly to attempt to either capture value from infrastructure investments through speculation in the price of land or to organize in opposition to the infrastructure development. In the U.S., early public engagement on route selection for a project, with years to go before land acquisition, can look like an invitation to dispute the value of land needed for the development of the project (e.g., Eno 2021, 2022; California, Texas, Florida). In the European context, a legal determination that a particular route and set of stations is in the public interest offers a way to avoid these problems. Such different institutional arrangements inspire two separate ways of looking at the problem for high-speed rail in the U.S.. One approach would be to arrange for a change in the institutions used to govern high-speed rail projects in the U.S. for an outcome similar to Europe. To be clear, the effect would likely be more wholesale exercise of easements and eminent domain over property on the route, limiting speculation and disputes but also limiting local compensation for takings. Another approach would be to recognize speculation as a form of benefit derived from the project and use already common systems of land value capture in the U.S., such as special assessment districts, to incorporate part of the rising property value into the revenue stream of the project. Necessity is the mother of invention. High-speed rail projects in France and Spain do not directly involve land value capture in their revenue stream, and one reason for this could be the relatively well-defined legal environment for their projects.

Act fast; when the time comes to advance to detailed design, land acquisition, and construction. There is a tension in U.S. processes for large scale infrastructure development between the desire to hire detailed engineering and construction firms as soon as possible and the need to engage in a thorough and objective process of environmental review with the participating public. There are several possible reasons for the tension, but one commonly understood reason is the daily expense of having those firms on the project. Opposition could form against a high-speed rail project for many reasons, all of which threaten to substantially delay a project during environmental review, permitting, and land acquisition, resulting in outsized payments for engineering and construction. The public may fear the large cost, or that their tax dollars would be used to subsidize a for-profit entity (Ho and Tsui, 2010). Literature suggests that the public agency should be prepared to do extensive early planning and environmental review before submitting the projects for a high-speed rail program to bid (Dutzik and Schneider, 2011; Omega Centre, 2014). In the U.S., there are organizations with vested interests against rail projects (or more generally, against the electrification of transportation), who can be expected to try to rally opposition (California). These interests should be recognized as early as possible, before environmental review ends and land acquisition begins, because such disputes can tie up a project in the court system. Interviewees explained that well-funded organizations that oppose projects have no interest in settling outside of court. The idea of planning slowly is one of using time that is relatively inexpensive—before hiring for these last stages of design and construction—to make all necessary arrangements and settle disputes. This also fits with the idea of programmatic environmental review, obtaining permits and closely examining the conditions necessary for obtaining easements and property on the route while at the programmatic level, creating standardization in permitting and land acquisition.

Act fast; in the move from engineering to construction the cost per day of work rises dramatically, which means that construction techniques matter. The idea of planning slowly and deliberately is to be prepared to act fast when the cost of each day on the job involves hundreds, if not thousands of workers. For detailed engineering and construction, concepts such as standardization and modularization are shorthand for vast changes that have been underway in the industry. Modular systems with precast components are already used in light rail construction in the U.S., and can be similarly effective in high-speed rail civil and structural work, as shown in international markets (Asia, Europe). Experts commented on the value of using such systems in terms of reducing costs and the time required for construction. Comments included the idea that precast, modular design could minimize the width of the right-of-way needed for the development of the route and improve the schedule for delivery, which suggests that the cost-effect of engineering and construction approaches can be much more widespread than the process of construction itself.

Act fast; inflation is not on your side. Time is money. By the time firms are on board for land acquisition, detailed engineering, and construction, time is very expensive. Delays to projects are a significant factor in cost overruns, observed in high-speed rail case studies in Taiwan, the Netherlands, and Texas (Alexandersson and Hultén, 2022; Dutzik and Schneider, 2011; Hodge and Greve, 2017; Koppenjan and Leijten, 2014; Roll and Verbeke, 1998). Many reasons can lead to delay, such as public opposition (the Netherlands HSL-Zuid), litigation (Texas Central), coordination issues (the Netherlands HSL-Zuid), and the renegotiation of public payments to a public-private partnership (Taiwan). In the U.S. the litigation that delays project development often arises either during environmental review or with respect to land acquisition. The Texas Central project (Figure 2.14), for example, faced a two year delay as a result of a dispute with a landowner. James Fredrick Miles challenged Texas Central's eminent domain power by claiming they were not a railroad company under the Texas Transportation Code (Supreme Court of Texas, 2022). After Miles secured a victory in the trial court, the court of appeals revised the ruling, which was later affirmed by the Supreme Court of Texas. This allowed Texas Central to use eminent domain to acquire land for the project. Brightline Florida has used existing transportation corridors to try to avoid problems with the land acquisition process. Brightline upgraded the existing Florida East Coast Railway mainline for use as a shared rail corridor from Miami to Cocoa, and used the existing Beachline Expressway between Cocoa and Orlando (High Speed Rail Alliance, 2022). This strategy can limit the peak speed of operations, depending on the configuration of the existing corridor. Published speeds for the system are close to 80 mph (129 kph), with news reports of trials scheduled to reach 110 mph (177 kph).

Figure 2.14: Texas High Speed Railway System Map (Source: Texas Central, 2022)



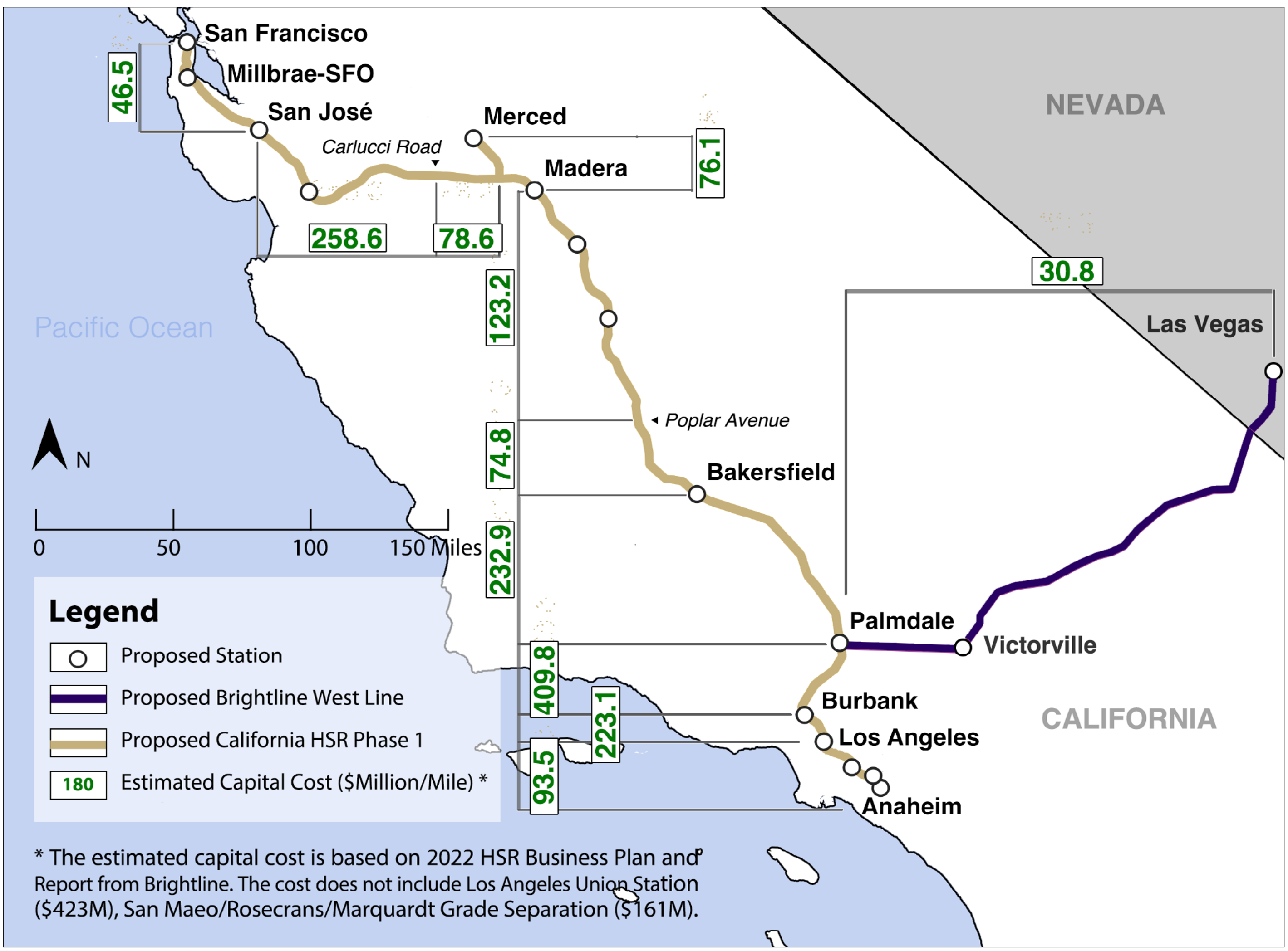
2.5 High-speed rail is increasingly discussed as a form of climate action

Summary. *As an electric system, high-speed rail has the potential to offer advantages in the effort to decarbonize transportation compared to other travel modes (i.e., auto, airline, and heavy rail train). The idea that renewable sources, such as solar energy, could power high-speed rail operations, puts rail operations in the energy business. Part of the essential story for the public about rail transportation is the comparative effect on personal emissions. Rail, like other modes of transportation are exposed and vulnerable to disruption, though the nature of those vulnerabilities differ. Designing for resilience is the only and best option, with an understanding from the beginning of the effects of climate change across the topography of the region.*

As an electric system, high-speed rail has the potential to offer advantages in the effort to decarbonize transportation compared to other travel modes (i.e., auto, airline, and heavy rail train). There are several factors to consider in the analysis of the effect of high-speed rail on greenhouse gas emissions, such as the sources and amounts of emissions that result from operations, and the sources and amounts that result from construction of the facility, in comparison with the same factors for transport by alternative means. Emissions may be measured as greenhouse gases collectively (metric tons, Mt of carbon dioxide equivalent, CO_2e) or individually (e.g., metric tons of carbon, or carbon dioxide). When compared with other transport modes, high-speed rail also has to achieve a certain level of ridership in order to outperform other modes in the reduction of emissions. These estimates can be over differing periods of time, such as one trip, one year, or the complete lifecycle of the facility. One recent study, for example, examined the full set of commercial air and high-speed rail services in China and concluded that air travel emits seven times the carbon emissions per passenger mile than high-speed rail, and that the substitution of rail travel for air travel has brought about a reduction in annual emissions of 12 million metric tons, though more would be possible if the sources of energy used to power high-speed rail were clean (Strauss et al., 2021, China). In the U.S., estimates suggest that the operation of the California high-speed rail system will reduce greenhouse gas emissions from transportation by offsetting air and auto travel. Published in 2008, the estimates were 1.15 million Mt CO2e reduced per year (CARB, 2008), and 3.08 million Mt CO2e reduced per year as of 2030 (the increase due to forecasts of increased ridership over time, CHSRA, 2008). These estimates are based on ridership forecasts for the high-speed rail compared to air and auto travel. They are also based on the effort underway to rely on renewable energy to power the operation of California's high-speed rail system. At least for operations, this commitment gives high-speed rail an emissions advantage over air and auto travel over the next 20 years, if not more, as estimates suggest that it will take decades for automobile travel to fully electrify, and non-emitting alternatives to fossil fuels for air travel have yet to enter the market. Adding the emissions that occur due to construction of the facility (and over the lifetime of operations and maintenance) provides a picture of the lifecycle of emissions for a high-speed rail project. Since the California project is committed to clean energy for its operations, lifecycle emissions for the first phase of California high-speed rail (San Francisco to Anaheim) amount to an estimated 2.4 million Mt CO_2e, due to material production (e.g., concrete and steel), material transport, and the use of fuel for equipment during construction of the facility (Chang and Kendall, 2011; California). If ridership estimates from CARB (2008) bear out, this results in the high-speed rail project reducing enough emissions (by substituting auto and air trips for rail trips) to offset the emissions from construction for the lifespan of the facility. This is also a conservative estimate, in that it does not include the emissions needed to construct highway or airport facilities.

The idea that renewable sources, such as solar energy, could power high-speed rail operations, puts rail operations in the energy business. Rail operating costs consist of labor and utility costs, plus the cost of routine annual and periodic maintenance. Of those expenses, the estimated utility cost for California high-speed rail is about $17 million a year, to service the initial 171 mi (275 km) of track. It can be helpful to break down these costs, to understand how they add up. There are different standards for electrical supply to high-speed rail, but 25 kilovolts is a common standard, leading to an estimated 8 megavolts needed per train—the amount of energy that typically serves a small town. This amount of energy suits the assumption that the train is moving between 200 and 300 kph (124 - 186 mph), carrying about 200 passengers (i.e., 7-14 cars in the train, depending on the configuration of cars and standard for rolling stock, which vary for the length of car). The higher the peak speed, the greater the utility cost of the system. Also, as everyone knows, it takes more energy to move uphill, and California high-speed rail's routes are designed with a maximum 3.5% gradient (likely 3% in most areas). To provide this energy, capital improvements are needed. Along the route and in stations, trains need utility connections (feeds from 115 or 230 kilovolt transmission lines). More stations and more locations with gradients require more such investments. The costs of these connections to the electrical grid add up; they are substations, sometimes accompanied with miles of transmission lines to reach the existing grid, and the estimated cost for each utility connection ranges from $50 million to as much as $110 million to build, and they become part of the overall capital cost of the system (Figure 2.15). The key question for high-speed rail is what to use as the source

Figure 2.15: California High Speed Rail System Estimated Cost Per Mile (Source: CHSRA 2022)



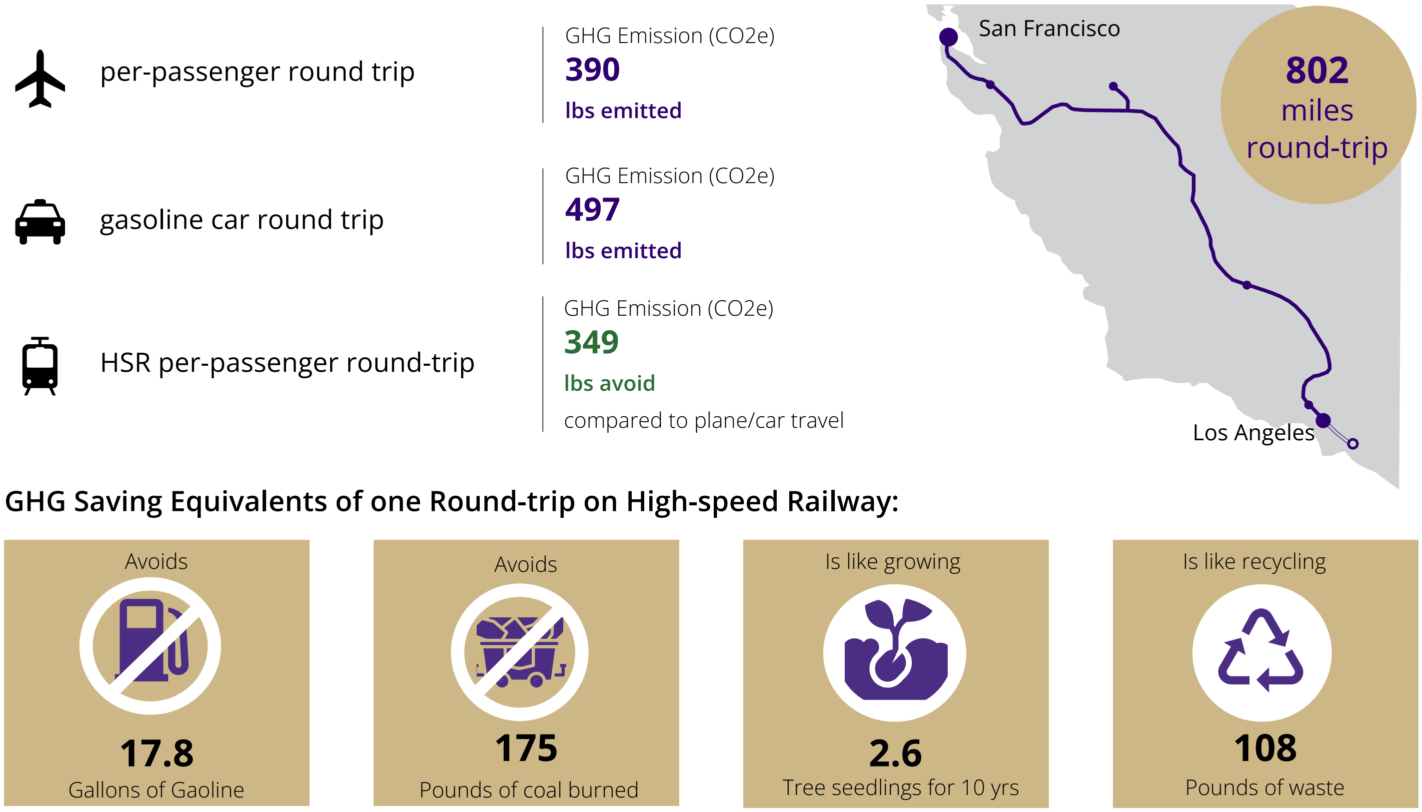
or sources of energy to operate the system. California high-speed rail is committed to using only renewable energy. If the utilities along the route do not want to be responsible for supplying the energy to operate the project, then the project has to get into the energy generation business. The connections to the grid will still be important to have, but the project will have to create its own supply of energy as well. California high-speed rail is designing solar panel and battery systems along the excess right-of-way of the route. The same utility connection along the route of the California high-speed rail, in the form of a project-owned solar panel and battery system costs an estimated $42.5 million to build. This is the cost of a system that would provide enough power to support one train per hour, per direction, for 18 hours per day, traveling at a maximum speed of 220 mph (350 kph). So designed, the initial 171 mi (275 km) section of the system could be provided with the electricity to support 2.5 million miles of train service per year. As the train system and services grow, more solar panels and batteries can be added. Solar and battery systems have useful lives greater than 20 years. By these simple estimates, if the project relied on solar for 100% of its power, California's high-speed rail could generate $17 million in utility cost savings per year, for each year in the useful life of the solar and battery systems. If solar and batteries replace the need for grid ties, then the lower capital cost of solar connections also saves money. Alternatively, grid ties allow the project to sell back excess electricity from solar to the grid. In other words, solar power generation could partially subsidize the cost of operating California high-speed rail.

Part of the essential story for the public about rail transportation is the comparative effect on personal emissions. In April 2022, the California High-Speed Rail Authority launched the Carbon Footprint Calculator. This provides the public with an opportunity to see what the greenhouse gas emissions would be for a trip between a chosen origin and destination, by high-speed rail, car, or by air (Figure 2.16, for example, shows data for San Francisco to Los Angeles). By transforming the emission savings (pounds of CO_2e) into tangible equivalents, such as gallons of gasoline, pounds of coal, number of tree seedlings (carbon sequestered), or pounds of waste recycled, the site allows users to see how their high-speed rail trips avoid greenhouse gas emissions and contribute to climate action.

Rail, like other modes of transportation are exposed and vulnerable to disruption, though the nature of those vulnerabilities differ. Only a small number of studies have examined the impact of severe weather events on the reliability of high-speed rail. One exception is a study comparing the impact of severe weather events on high-speed rail and on aviation's on-time performance in China (Chen and Wang, 2019, China). Examining 350,000 performance records from the period 2016-2017 and daily weather information from the National Climatic Data Center of the National Oceanic and Atmospheric Administration, the study found high-speed rail to be more resilient, overall, compared to aviation. The types of events considered included fog, thunder, snow, strong wind, and heavy precipitation. It also found that of the collection of extreme events studied, snow has the most impact on high-speed rail operations. That said,when considering the effects of climate change on extreme weather and on the function of systems such as high-speed rail, additional factors should be addressed. A review of the literature (Binti Sa'adin et al. 2016, Malaysia), supplemented with expert interviews, argued that extreme events can lead to asset system failure, degraded operations, and delays in services, highlighting the risks of flooding, drought, and high temperature increases on track damage and embankment deterioration. These risks will not be experienced in uniform ways across the terrain or across communities. This is a relatively new field of study, and a more broad review of the literature, on the topic of railway resilience (Bešinović, 2020, Review) identified six future directions for research, including learning from ex-post historical data, considering interdependency of critical systems, dealing with multiple simultaneous disruptions, incorporating resilience in planning, considering the impact of climate change, and integrating demand-centered and community resilience.

Designing for resilience is the only and best option, with an understanding from the beginning of the effects of climate change on the topography of the

Figure 2.16: California High Speed Rail Output for a Trip from San Francisco to Los Angeles (Source: CHSRA, 2022)



region. Climate change is already affecting the performance of infrastructure in the U.S., and these impacts can be expected to grow unless and until they are addressed through the redesign or redevelopment. All infrastructure systems—indeed, all man-made products—are designed to function within set parameters, such as exposure to heat, wind, and water. Continued greenhouse gas emissions will continue to raise global average temperatures and with that, continue to disrupt numerous natural and physical systems that engineering disciplines have taken to be stable over time. Our changing climate is thereby changing the assumptions needed for successful infrastructure design, construction, and operations, and this includes high-speed rail. The approach to design that is needed is one where the likely extremes in exposures and events due to climate change are forecasted for the lifespan of the high-speed rail system, and the design of the system accommodates the highest of those extremes, in each category of exposure and event. This approach is conservative, recommended by the World Bank and other organizations due to the cost savings associated with resilience and business continuity (World Bank, 2021, chapters 5 and 6). Research suggests that every dollar of investment in resilience for infrastructure (modified designs and locations), avoids four dollars from loss and damage (Hallegate and Li, 2022). This means that each dollar invested in the selection of a safer location for a project or a more resilient design for the project will generate savings several times over from the avoided losses and damages that would have accrued during the lifespan of the asset.

CHAPTER 3

Case Studies of High-speed Rail Development

The research for this report includes the study of a set of international and domestic cases of high-speed rail development. This small sample of lines and systems was selected for its ability to represent a wide variety of approaches to project design and development, within institutional and geographical contexts that offer some opportunity for comparison. The key facts and opinions found in Chapter 2 reflect, in part, the result of research on the historical development, services, operations, governance, and geographic context of these systems (Figure 3.1).

International

- The corridor linking Paris, France to Amsterdam in the Netherlands
- The high-speed rail systems of Spain
- Taiwan high-speed rail, linking Taipei to Kaohsiung

United States

- California, linking San Francisco and Sacramento to Los Angeles and San Diego
- Texas, from Dallas to Houston
- Florida, linking Tampa to Orlando and Miami

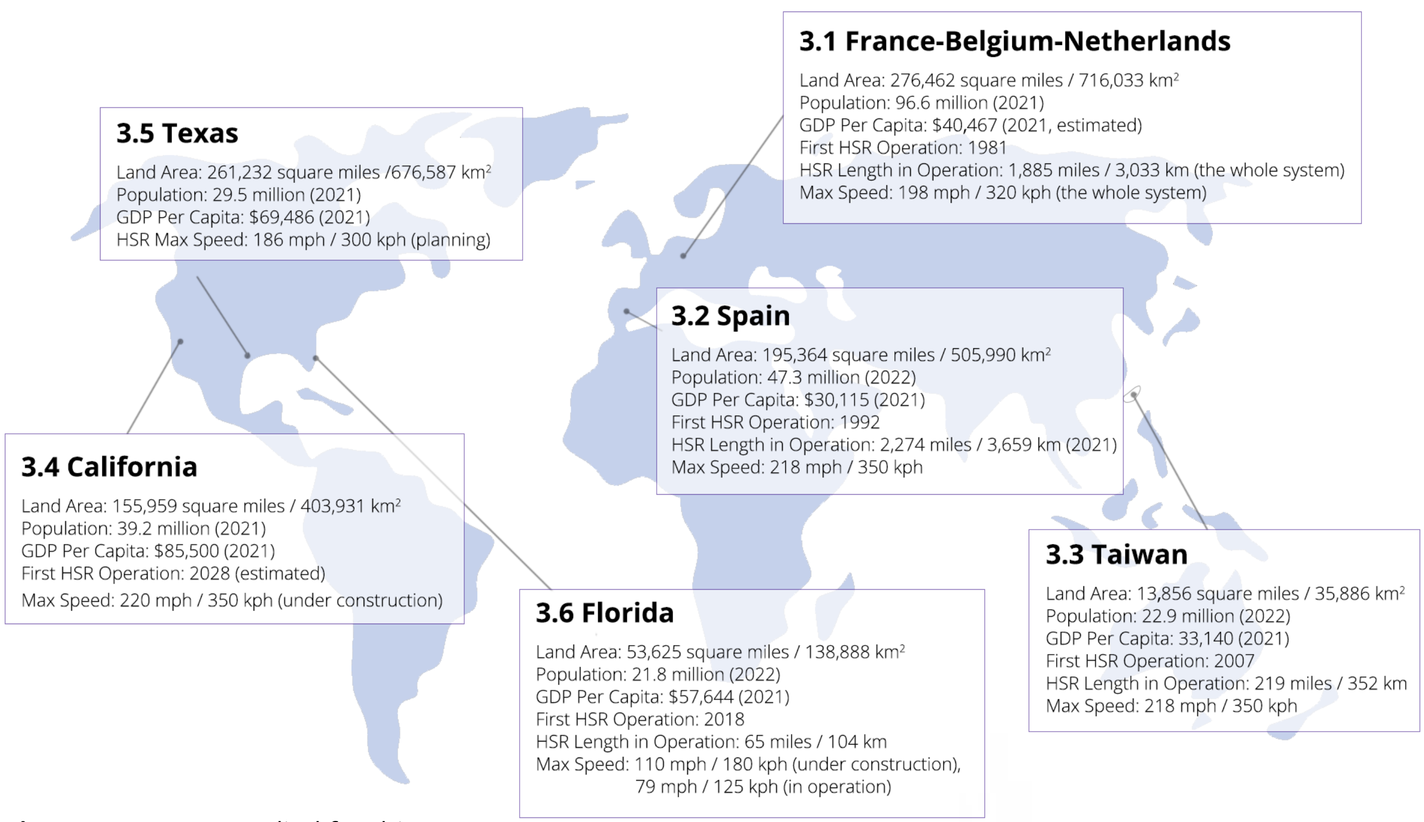


Figure 3.1: Cases Studied for this Report

The rail corridor linking France, Belgium, and the Netherlands is similar in scale and scope to the project contemplated for the Cascadia corridor in the Pacific Northwest, and includes two national border crossings. The high-speed rail systems of Spain were developed after a market of suppliers had developed endogenously within France, Germany, and Japan, allowing for methods of procurement of international expertise that more likely resemble opportunities today in the U.S. The Taiwan high-speed rail project is a public-private partnership that received bids from consortia representing firms from the U.S. as well as Japan, France, and Germany, for the partial private financing of a project that incorporates real estate development of station areas into its revenue stream.

The cases in the U.S. are separate from the more well-known Amtrak services, such as the Acela corridor, due to the need in the Pacific Northwest to consider a new route to accommodate high-speed travel. Each case is in a different stage of development. In Texas, several routes are still under consideration. The first phase of California's system is under construction. The Florida system is currently operating, though at peak speeds less than those contemplated in the Pacific Northwest. The Florida and Texas projects are private developments, inclusive of real estate development opportunities. The California system is a publicly funded project.

Around the world, there are many systems and lines that could offer further insights. Systems operating or underway in the United Kingdom, Germany, France, and other countries in continental Europe, such as Switzerland, Austria, Italy, and Portugal, offer many lessons in development. There is a new system in Morocco with interesting implications for today's markets, and a wealth of information to be gained from further study in Japan, China, and South Korea. Some of these insights are available through existing studies, focused on high-speed rail (e.g., World Bank, 2019; China) or on the broader topic of rail transportation (e.g., Eno Center for Transportation, 2022; Canada, Mexico, Chile, Norway, Germany, Italy, South Africa, South Korea, Japan, and Australia).

In the sections that follow, each case study includes an overview of the history and characteristics of the system and highlights features of the system that were influenced in the early stages of decision-making, for example, regarding routes, station selection and station area development, strategies for gaining the benefits of competition, and governance.

3.1 France–Belgium–Netherlands

3.1.1 Introduction and History

The high-speed rail corridor linking the metro areas of Paris, France, with Brussels in Belgium and Amsterdam in the Netherlands, was established on the basis of historical infrastructure networks, and is one of several successful cross-border projects in Europe. France was one of three countries in the world to initiate the development of high-speed rail technology. The corridor linking France, Belgium, and the Netherlands, was an early and prominent development in the European network. France has a population of 68 million, while Belgium has 12 million and another 17.5 million live in the Netherlands (World Bank, 2023). The economy of France is ranked 7th in the world, with a GDP of $2.8 trillion. This compares to Belgium at $597 billion, ranked 24th, and the Netherlands at just over $1 trillion, ranked 18th (IMF, 2023).

The first opening of a high-speed rail line in Europe was achieved in France in 1981. By the early 1990s, the European Union began supporting the establishment of a Trans-European transport network (TEN-T), consolidating and fortifying national efforts to develop high-speed lines. PBKAL (Paris-Brussels-Köln-Amsterdam-London) refers to a TEN-T project which links major cities and airports in France, Belgium, Germany, the Netherlands, and the United Kingdom. It was the first cross-border high-speed rail project completed.

This case study focuses on the France–Belgium–Netherlands corridor and highlights the Dutch section of the corridor (Figure 3.2). The French section of PBKAL–LGV Nord, which links Paris to the Belgium Border, opened in 1993 (Damiano Scordamaglia, 2015). Though not the subject of this study, the full LGV–Nord line stretches westward from Paris to London. The Belgian part of PBKAL North-South section is comprised of HSL1 (High-speed line 1), which links the French Border to Brussels, and HSL4, which travels between Brussels and the Dutch border. The HSL1 section began service in December 1997, and the HSL4 line in 2009 (four years later than scheduled). The Dutch section of PBKAL is called HSL–Zuid. It links Amsterdam to the Belgian border, and also began service in 2009.

The populations of major metropolitan areas along the France–Belgium–Netherlands corridor have grown since the launch of high-speed rail services. The Paris metropolitan area included nearly 11 million people as of 2019 (about 1.5 times today's Washington State population), and this grew from 9.4 million when the LGV–Nord line opened in 1993, to 9.6 million when the HSL1 line opened in 1997, and 10.4 million when HSL 4 opened in 2009 (Macrotrends, n.d.). Brussels had a total population of just over 2 million in 2019, which had grown from 1.7 million when HSL1 opened in 1997, to 1.9 million when HSL–Zuid opened in 2009. As for Amsterdam, the 2020 population was 0.87 million, up from 0.70 million in 1990, 0.73 million in 2000, and 0.76 million in 2009. All three major cities experienced slightly

Figure 3.2: France–Belgium–Netherlands High Speed Rail Line (Source: UIC, 2022)

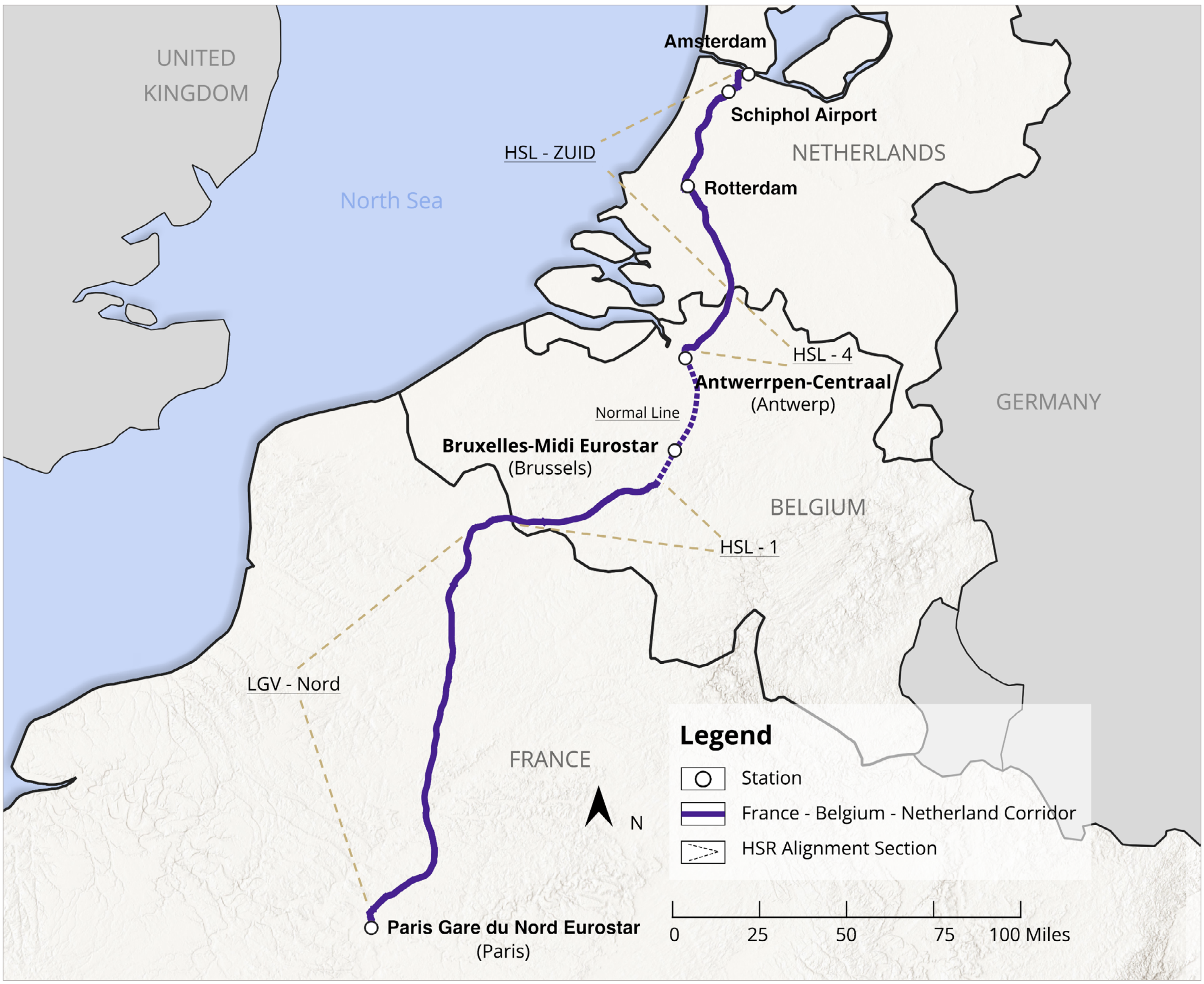


Table 3.1: Rail Route Details of France–Belgium–Netherlands High Speed Rail Line

Route and Phase	Status	Length	Speed	Cost	Ridership
LGV-Nord (connects Paris to the Belgian border and the Channel Tunnel via Lille)	Service commences between Paris and Arras in 1993	333 km (206 mi) in total. The rail links Paris to Belgium border is about 226 km (140 mi)	300 kph (186 mph)	18.5 billion FF (1992)	-
High-Speed Line 1 (connects Brussels, Belgium, with the LGV Nord at the Belgium–France border.)	Operated since 1997	88 km (55 mi) long, including 71(44 mi) km dedicated high-speed tracks, 17 km (11 mi) modernized lines	300 kph (186 mph)	€1.42 billion construction cost (2013)*	-
High speed line 4 (connect Brussels to the Dutch border where it will meet HSL-Zuid)	Opened in 2009	87 km (54 mi) long, comprising 40 km (24 mi) dedicated high-speed tracks and 47 km (29 mi) modernized lines.	300 kph (186 mph) on the new high-speed track. 160 kph (100 mph) on the upgraded existing line (with some exception)	€1.57 billion construction cost (2013)*	-
HSL-Zuid	Opened in 2009	125 km (77 mi)	300 kph (186 mph)	€7.19 billion (2013)*	24 million (forecasted) in 2010

* Source: Trabo et al., 2013.

higher population growth rates after the high-speed rail line opened, but this has not necessarily been the case for the smaller cities (Macrotrends, n.d.).

3.1.2 System Description

All the major stations on this line are well-integrated with public transportation, and most are built in urban areas. The major stations from Paris to Amsterdam for Thalys or Eurostar include Paris Gare du Nord, Bruxelles–Midi/Brussel–Zuid (also known as Brussels South railway station), Anterwerpen–Centraal, Rotterdam–Centraal, Schiphol Airport and Amsterdam Centraal (Thalys Eurostar Group, n.d.). Five out of the six stations for this line are located in urban centers, on sites previously used for commuter or metrorail stations. All of the stations have connections to buses, and most have connections with the metrorail. Amsterdam Centraal is also served by ferries. All of the stations are connected to nearby airports via transit.

The route selection strategies differed from country to country. In France, the LGV–Nord section was designed to avoid tunneling, which made it relatively easy to operate double-deck trains (Watson, 2021). Development at grade involves greater disturbance of the environment, however, and 16% of the engineering costs of the LGV–Nord line have been attributed to measures to protect the environment (Thompson, 1994). The TGV train models that operate on the line are compatible with existing conventional railways (Watson, 2021). For the Dutch section, there were two alternatives considered for the route. One went from Schiphol Airport to Rotterdam and through the Green Heart (a sensitive green area in the Netherlands). The other involved building a new track parallel to the existing track while adding an extra stop at The Hague (the political capital of the Netherlands). Eventually, the decision was made to tunnel through the Green Heart.

The negotiation of the Netherlands–Belgium border crossing is worth noting. The Dutch government preferred the E19–A16 route that crossed a sensitive area in Belgium, while the Belgian government preferred either a route on existing track or a new route along the road Havenweg (which crossed several sensitive natural environments in the Netherlands). Eventually, the E19–A16 route was chosen for its transport benefits, and the Netherlands paid Belgium about €400 million in financial compensation (Omega Center, n.d.).

The HSL–Zuid was a public-private partnership, with 86% of the funding from the public sector and 14% from the private sector. Private funds amounted to

Table 3.2: Rail Station Details of France–Belgium–Netherlands High Speed Rail Line

Name	Location	Elevated, At Grade, or Under-ground	Existing/ new-build station	Operation Year	Multiple Mode Integration
Paris Gare Du Nord	Urban Center	Elevated	Existing	Opened in 1846. Expanded a few times. Reorganized for Eurostar in 1994. Seek refurbishment recently	Connected with several urban transport lines, including Paris Métro (underground), RER (hybrid commuter rail and rapid transit system, underground) and RATP bus network. Has direct transit to Paris Charles de Gaulle Airport
Bruxelles-Midi/ Brussel-Zuid	Urban Center	Elevated	Existing	Operated since 1869. Went through transformation in 1990s and is currently planning for new expansion	Connected with STIB (Brussels-only tram and metro network, underground), De Lijn (bus network covering Flanders and certain parts of Brussels) and TEC (bus network covering Wallonia and certain parts of Brussels). Direct Transit to the Brussel Airport
Antwerpen-Centraal	Urban Center	Under-ground	Existing	Opened in 1905. Expansion completed in 2007	There are tram, bus and premetro lines stop at Antwerpen-Centraal train station. Has transit to Antwerpen International Airport, but needs transfer.
Rotterdam-Centraal	Urban Center	Elevated	Existing	The 1957 station building was closed in 2007 and demolished in 2008. The new station was opened in 2014.	Rotterdam Centraal train station is served by metro, bus and tram lines (from GVB), as well as by RandstadRail (metro between Rotterdam and The Hague). Has direct transit to Rotterdam The Hague Airport
Schiphol Airport (Amsterdam Airport)	Suburban	Under-ground	Existing	The underground station opened in 1995.	Three Dutch public transport providers serve Schiphol Airport railway station: Connexxion (Regional buses), GVB(bus only here) and Arriva (Regional buses). underneath Amsterdam Airport.
Amsterdam Centraal	Urban Center	Elevated	Existing	Operated since 1889. Reconstruction finished in 2018	Amsterdam Centraal train station is served by metro, bus and tram lines, and ferries (from GVB). Has direct transit to Amsterdam Airport

about €940 million, while €2.6 billion were provided from the transport ministry's SVV-budget for civil engineering and €1.7 billion came from the FES fund (based on revenues from gas exports, dedicated to economic development). Private concessionaires raised funds for several components, such as signaling and track (Omega Center, n.d.; United Nations Economic Commission for Europe, 2016).

The construction of the substructure for HSL–Zuid (tunnels, concrete slab that the rail track rests on, and bridges) was divided into six contracts each worth about €400 million. The total length of the HSL–Zuid route on Dutch territory is 125 km (77 mi), of which 85 km (52 mi) is high-speed track. All these contracts were procured through design-build delivery, which means the contractors received the programmed demand but were not told exactly how to perform the tasks. The contract to provide links between the new track and old track was also administered by design-build (Omega Center, n.d.). The superstructure (track, power supply and signaling systems) contract was awarded to a consortium, Infraspeed, under a 25 year (2006-2031) design-build-finance and maintenance contract. According to the contract, Infraspeed is eligible to receive an availability charge if it meets the requirement that the track meets the terms of availability of 99%. The concession for operations was given to the High-Speed Alliance. This consortium is 90% owned by NS (the Dutch state railway) and 10% owned by Air France-KLM (Dutzik and Schneider, 2011).

3.2 Spain

3.2.1 Introduction and History

Spain is located in southwestern Europe, bordered by France to the north and Portugal to the west. Spain's land area is 505,990 km^2 (about 195,000 mi^2), which is 2.7 times the area of Washington State (World Bank, 2022). Spain, however, has a population of more than 45 million, which is 2.7 times the combined population of Washington, Oregon, and British Columbia. The GDP of Spain, at $1.4 trillion, ranks as the 14th largest economy and the GDP per capita of $30,100 per year ranks 46th (World Bank, 2022).

Alta Velocidad Española (AVE), the world's second-largest high-speed rail network, serves this nation with more than 3,700 km (approximately 2,300 mi) of high-speed rail, connecting more than 40 stations. This system began in anticipation of the Universal Exposition

Figure 3.3: Spain High Speed Railway System Map (Source: UIC, 2022)

in Seville, with a high-speed line that began operating between Madrid and Seville in 1992. It is noteworthy to consider that this pioneering investment did not connect Madrid, the capital city, with the second largest city, Barcelona, where the Olympic Games were held in the same year. Since that time, however, Spain has undertaken a rapid expansion of its high-speed network. The Ministry of Public Works Strategic Infrastructure and Transport Plan 2005-2020 (PEIT) called for all the provincial capitals to connect with Madrid via high-speed rail. This strategy was also emphasized in later national plans. By 2010, a radial network had formed, centered in Madrid, to connect major cities across the country (Seville in 1992, Valladolid in 2007, Barcelona in 2008, and Valencia in 2010).

This high-speed network is continuing to grow, with planned corridors designed to serve the growing urban population, as more than 80% of Spaniards were living in cities in 2021 (World Bank, 2022). The government plan promises that 90% of citizens will live within 30 km (18.6 mi) of a high-speed station (Administrador de Infraestructuras Ferroviarias, 2021). In keeping with this plan, most cities carry out comprehensive urban development around station areas, many of which are located at the edge or periphery of existing urban areas. For example, according to a report published in 2011, after four years of high-speed services to the city of Valladolid, the construction of housing had resulted in 2,777 (46%) of the 6,065 houses in the city being located near the station (Luis Santos y Ganges, 2011). In León, with a high-speed route still under construction, 3,254 (56%) of the 5,853 houses in the city could be found near the planned station. While impressive for its scale of investment, studies show that the urban centers of Madrid, with 6 million inhabitants, and Barcelona metropolitan area, with 5 million, provide the strongest short-term impetus for growth. Market risks and slower growth rates may accompany suburban and rural station area development, as a study published in 2017 suggested that as much as half of the station area developments in Spanish cities were vacant at that time (Miralles i Garcia, 2017).

3.2.2 System Description

High-speed rail in Spain is built and maintained by the state-owned company Administrador de Infraestructuras Ferroviarias (Adif), however, Adif may not provide any rail transport services, except those that are inherent to their own activities. This organization was formed in 2005 in response to European Union requirements to separate the natural monopoly of infrastructure management from the competitive operations of train services. Another state-owned company, Red Nacional de Los Ferrocarriles Españoles-Operadora (Renfe) was formed at the same time, and is responsible for the planning, marketing, and operation of rail passenger and freight services.

As of December, 2020, pursuant to a directive approved by the European Parliament and Council, Spain will open its system to competition for railway passenger transportation services (i.e., competition in the market). This is aligned with the concept of the 'Single European Railway Area' for rail passenger operators advocated by the European Union. Several major international suppliers supply rolling stock for Spanish high-speed

Table 3.3: Rail Route Details of Spain High Speed Rail System

Route and Phase	Status	Length	Speed	Cost	Ridership
Madrid - Sevilla*	Operated from 1992	293 mi / 472 km	Up to 186 mph / 300 kph	500 billion pesetas of 1996 (Rus and Inglada, 1997)	4.4 million in 1998, 2.1 million in 2012
Madrid- Barcelona**	Operated from 2008	386 mi / 621 km	Up to 217 mph / 350 kph	€7.54 billion (2013) ***	4.4 million in 2019

* The first high-speed rail in Spain
** The high-speed rail route connecting the two largest cities in Spain
*** Source: Beria et al., 2018. Includes Madrid-Lleida-Barcelona and Zaragoza-Huesca.

Table 3.4: Rail Station Details of Spain High Speed Railway System (from Madrid to Barcelona)

Name	Location	Elevated, At Grade, or Underground	Existing/ new-build station	Operation Year	Multiple Mode Integration
Madrid	Urban center	At Grade	Existing	1992	Connect to high-speed railway service, conventional railway service, intercity railway service, Madrid Metro, and other local transportation services
Córdoba	Urban center	At Grade	new-build station	1994	Connect to high-speed railway service, conventional railway service, and local transportation services
Sevilla	Urban center	At Grade	Existing	1992	Connect to high-speed railway service, conventional railway service, and local transportation services
Madrid	Urban center	At Grade	Existing	2008	Connect to high-speed railway service, conventional railway service, intercity railway service, Madrid Metro, and other local transportation services
Zaragoza	Suburban	At Grade	Existing	2008	Connect to high-speed railway service, conventional railway service, and local transportation services
Lleida	Urban center	At Grade	Existing	2008	Connect to high-speed railway service, conventional railway service, interurban buses, and local transportation services
Barcelona	Urban center	Underground/ At Grade	Existing	2008	Connect to high speed railway service, conventional railway service, intercity railway service, Barcelona Metro, and other local transportation services

railways, including Alstom (France), Siemens (Germany), Patentes Talgo (Spain), and CAF-Alstom (Spain, France). (Montero and Ramos Melero, 2020). In recent years, more rolling stock has also been produced by domestic manufacturers, such as CAF-Alstom and Patentes Talgo (Geography and Railway Traffic Research Group, Fundación de los Ferrocarriles Españoles (FFE), 2022).

About 15 million passengers use Spain's high-speed rail service every year (Rende, 2022), however, the Spanish HSR system has significantly lower usage intensity (4.1 thousand passengers/km per high-speed line) compared to other systems worldwide, such as France (23.5), Japan (50.1), China (38.4), and Germany (31.8) (Geography and Railway Traffic Research Group, Fundación de los Ferrocarriles Españoles (FFE), 2022). These findings raise discussions about the necessity of high-speed services. The first high-speed rail, from Madrid to Seville, was not the most congested corridor in Spain. Some scholars have claimed that the government built this line for political reasons, for the sake of economic development in less developed regions and to pursue equal development among geographic areas (Albalate and Bel, 2012; Joe Baker, 2018).

3.3 Taiwan

3.3.1 Introduction and History

Taiwan is located in East Asia, north of the Philippines, and East of mainland China. The population of Taiwan is 24 million, and its most populous city is Taipei, with about 4 million inhabitants. About 70% of the island population lives within six municipalities located along the west coast, including the metro areas of Taipei in the north to Kaohsiung in the south, which house 40% of the population (Ministry of the Interior, Taiwan, 2021; Cheng, 2010). At just over 16.5 million, this approximates the combined population of Washington, Oregon, and British Columbia.

With a GDP of $860 billion in 2021, Taiwan's economy ranks 21st among nations (IMF, 2023; Country Economy, n.d.). The main industries in the economy are export-oriented, which include electronics, oil refining and plastic, information and communication equipment, iron and steel, food processing, and consumer products (Fastener Eurasia Magazine, 2021; Trading Economics, 2022). During COVID-19 in 2020, Taiwan's Taoyuan International Airport was the world's

Figure 3.4: Taiwan High-speed Railway System Map (Source: Ministry of Digital Affairs, Taiwan, 2022)

Table 3.5: Rail Route Details of Taiwan High Speed Railway System

Route and Phase	Status	Length	Speed	Cost	Ridership
Phase 1	Operated from 2007	345 km (214 mph)	300 kph (186 mph)	NT$ 513.3 billion (1998) *	Forecasted: 240,000 passengers per day in 2008; Actual: 40,000 passengers/day in 2007; 130,000 passengers/day in 2014; 184,000 passengers/day in 2019
Phase 2	Operated from 2015 or 2016				
Phase 3a	In planning phases	17.5 km (10 mi)	N/A	NT$55.4 billion (expected)	Forecasted: 415 person/hour (weekday); 547 person/hour (weekend) in 2041
Phase 3b	In planning phases	59.3 km (36 mi)	N/A	NT$188 billion (expected)	Forecasted:19,881 person/day (in 2051)

* Source: Taiwan Railway Bureau, 2022

Table 3.6: Rail Station Details of Taiwan High Speed Railway System

Name	Location	Elevated, At Grade, or Underground	Existing/ new-build station	Operation Year	Multiple Mode Integration
Taipei	Urban center	underground	existing	2007	Connect to the West Coast Railway, Taipei Metro system (Red line and Blue line), and Taoyuan Metro system to international airport
Banqiao	Urban center	underground	existing	2007	Connect to the West Coast Railway, Taipei Metro system (Blue line and Yellow line)
Taoyuan	Suburban	elevated	new-build	2007	Connect to the Taoyuan Metro system, and shuttle bus to the airport
Hsinchu	Suburban	elevated	new-build	2007	Connect to shuttle bus and the Liujia Railway Line, which is a branch line of the Western Coat Railway
Taichung	Suburban	elevated	new-build	2007	Connect to the Taichung Railway Line, and Taichung Metro system (Green Line)
Chiayi	Rural	elevated	new-build	2007	Connect to the Chiayi BRT system and shuttle bus
Tainan	Suburban	elevated	new-build	2007	Connect to shuttle bus and the Shalun Railway Line, which is a branch line of the West Coast Railway line
Zuoying (Kaohsiung)	Suburban	elevated	new-build	2007	Connect to the West Coast Railway, and Kaohsiung Metro system (Red Line)
Miaoli	Rural	elevated	new-build	2015	Connect to the Taichung Railway and shuttle bus
Changhua	Rural	elevated	new-build	2015	Connect to the shuttle bus
Yunlin	Rural	elevated	new-build	2015	Connect to the shuttle bus
Nangang	Suburban	underground	existing	2016	Connect to West Coast Railway, Taipei Metro system (Blue line)
Pingtung	Rural	elevated	new-build	Expected in 2029	N/A
Yilan	Rural	elevated	new-build	Expected in 2030	N/A

fourth-busiest airport in terms of international freight handled and highly ranked among Asian airports (Shan, 2020; 2021).

Taiwan's high-speed rail system travels north-south from the capital city, Taipei to Kaohsiung. In 1998, when a private consortium won the 35 year concession to construct and operate the main line, the estimated cost of the project was $16.62 billion (513.3 billion NT dollars). The daily ridership was projected to grow from 180,000 to 400,000 by 2036. Organized as a public-private partnership, the government of Taiwan owns 46% of the shares in the Taiwan High Speed Rail Corporation (THSRC), which is responsible for construction, operation, and maintenance of the system (i.e., competition for the market) (Taiwan Railway Bureau, 2022). Construction began in 2000 and was completed in 2007, for a cost of $18 billion.

This system was planned over decades. The idea for a high-speed line arose in 1974, and informal planning began in 1980 (Taiwan Railway Bureau, 2022). In the 1980s and 90s, Taiwan experienced rapid population and economic growth, with associated congestion along its main north-south corridor. Supported by advisors from Japan and France, the Taiwan Ministry of Transportation completed a feasibility study for a high-speed line in 1990. The study identified high-speed rail as a viable option, with a suggested route and preliminary engineering, to meet demands for the transit volume, high-level energy savings, and reductions to air pollution, compared to other transport options (Taiwan

Railway Bureau, 2022; Taiwan High Speed Rail Organization, n.d.). The project was approved by Taiwan's Executive Yuan in 1992 and by the Legislative Yuan in 1993 (Taiwan Railway Bureau, 2022).

The route of the main line runs north-south, along the center of the island (Figure 3.4). For Taipei and Kaohsiung, the rail stations are in the urban centers. Compared to highway transportation and bus services, high-speed rail has reduced travel times between Taipei and Kaohsiung by hours. This pace similarly allows people living in the cities along the western coast to also reduce travel times to the two major urban hubs, despite the need to travel from their home city on a bus, train, or car to access the main high-speed rail line at stations such as Taichung and Chiayi.

3.3.2 System Description

The length of the system is 345 km (214 miles) in total between the two main metropolitan areas, Taipei and Kaohsiung, in the western corridor of Taiwan. The train's top speed is 300 km/h (185 mph) and travel time is as little as 94 minutes (Taiwan High Speed Rail, 2022). The system is based primarily on Japan's Shinkansen ((Jeng and Su, 2013). The high-speed railway opened in 2007 with eight stations between Taipei and Zuoying. Four stations were added in 2014 and 2015, in order to balance regional development and bridge urban-rural gaps (Taiwan Railway Bureau, 2010). In September 2019, Executive Yuan announced a new high-speed railway expansion project to Pingtung. The following year, additional extension routes from Taipei to Yilan were approved. This HSR extension will cut travel time to 24 minutes between the two cities, compared to 95 minutes travel time for conventional railways (Economic Daily News, Taiwan, 2022; Taiwan Railway Bureau, 2022, 2021, 2020).

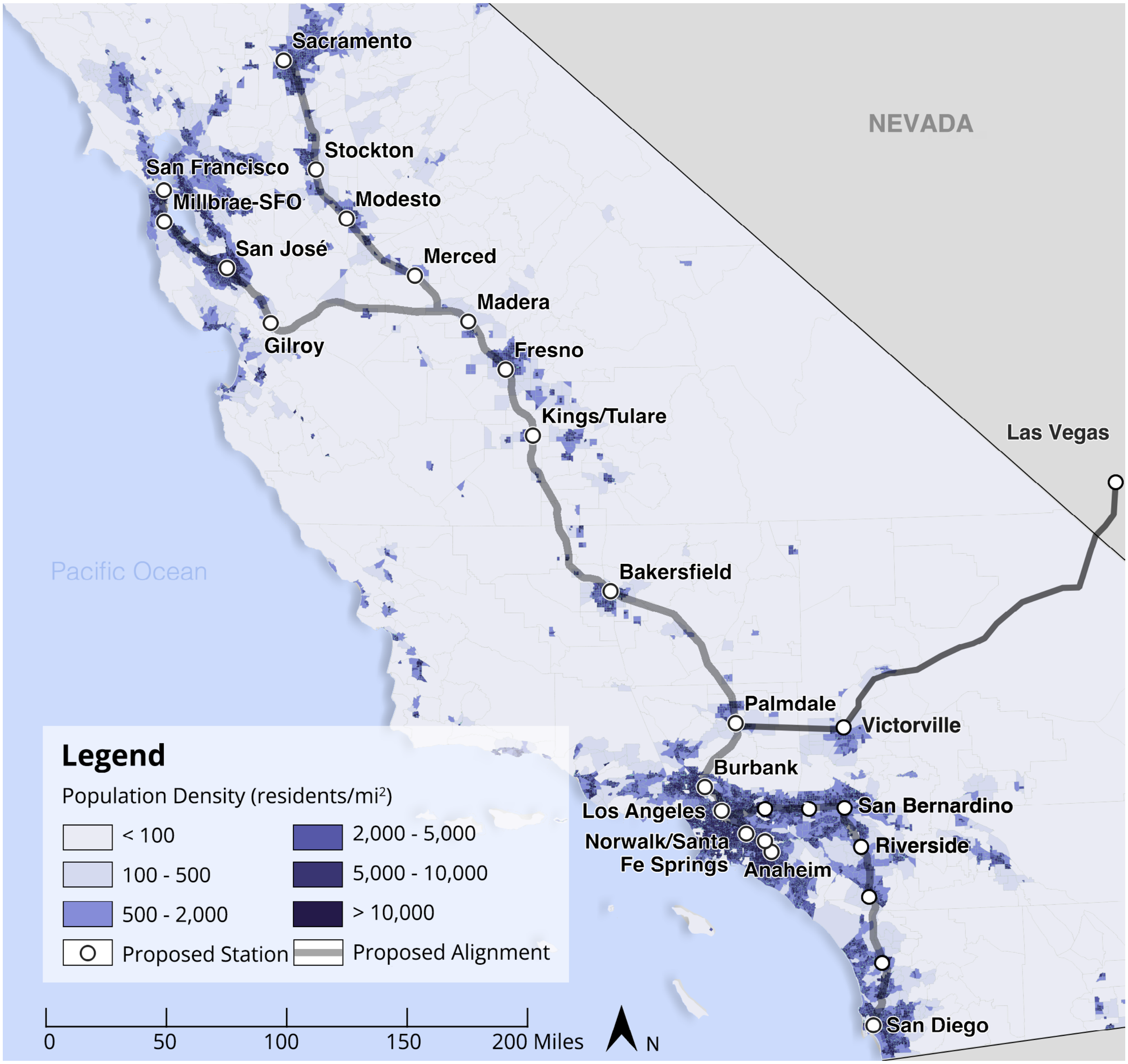
3.4 California

3.4.1 Introduction and History

California, the most populous state and largest economy in the nation, is currently embarking on one of the most ambitious high-speed railway projects in the United States, to connect the urban metropolitan centers of San Francisco Bay Area and Los Angeles, with lines extending to Sacramento and San Diego (Figure 3.5). The system, totaling about 800 mi (1280 km), is being developed in two phases. At the time of writing this report, construction is underway for phase one, with 15 stations including San Francisco and Los Angeles (Figure 3.6). Planning is underway for phase two, with 10 additional stations, three on a route between Merced and the State capital of Sacramento, and seven on a route connecting Los Angeles with San Diego. This is a public project led by the California High Speed Rail Authority. There are also plans underway from a private company (Fortress Investment Group) for a separate but connected project, to link cities on the California system with Las Vegas, Nevada (Brightline West).

Ideas for high-speed rail had surfaced since the 1970s, in the wake of Japan's achievement of the first high-speed line, and during the period of the development of the San Francisco Bay Area's Rapid Transit commuter rail system (BART). After many years of academic research on the prospects of such developments, the California High-Speed Rail Authority was formed in 1996. California voters approved Proposition 1A, with a bond to fund planning and construction in 2008, with plans to begin operations by 2022. Two years later, California received $2.25 billion of federal economic stimulus funds to support development of the high-speed rail system. In 2015, the California cap-and-trade program, one of the largest carbon markets in the United States, began operations and the distribution of proceeds to a number of projects, including the high-speed rail. The groundbreaking ceremony for construction occurred in the same year. However, by 2022, phase one of the project had only been partially constructed, and parts of the line had not completed environmental review (California High-speed Rail Authority, 2022). Despite the construction process being slow, with completion

Figure 3.5: California Population Density Map (Census Tract Level, Source: US Census, 2022)



of the first phase delayed until 2033, a recent study shows that 56% of voters favor the state continuing to build the high-speed rail project (DiCamillo, 2022).

3.4.2 System Description

Discussions about the California high-speed rail project often center on funding, cost, and schedule. Proposition 1A in 2008 stated, "one-third of the capital cost of 33 billion comes from bonds, one-third from the federal government, and one-third from the private sector." The estimated costs, however, have increased over time. What was estimated at $33 billion in 2008 rose to a phase one estimated cost in 2022 that ranges from $92.8 to $94.2 billion, an increase of more than 180% (CHSRA 2022). The main sources of funds ex-

Table 3.7: Rail Route Details of California High Speed Railway System (Source: CHSRA, 2022)

Route and Phase	Status	Section	Length	Speed	Cost Estimated in 2022	Ridership
Phase 1	Under Construction or Environmental Impact Assessment	North California	131 mi / 211 km	110-220 mph / 177-354 mph	$23.5 billion	35.6 million in 2033, 38.6 million in 2040
		Central Valley	199 mi / 320 km	110-220 mph / 177-354 mph	$19.7 billion	
		Southern California	164 mi / 264 km	110-220 mph / 177-354 mph	$41 billion	
Phase 2	Planning	Merced-Sacramento	280 mi / 451 km	220 mph	-	-
	Planning	Los Angeles-San Diego	280 mi / 451 km	220 mph	-	-

Figure 3.6: California High Speed Railway System Map (Source: CHSRA, 2022)

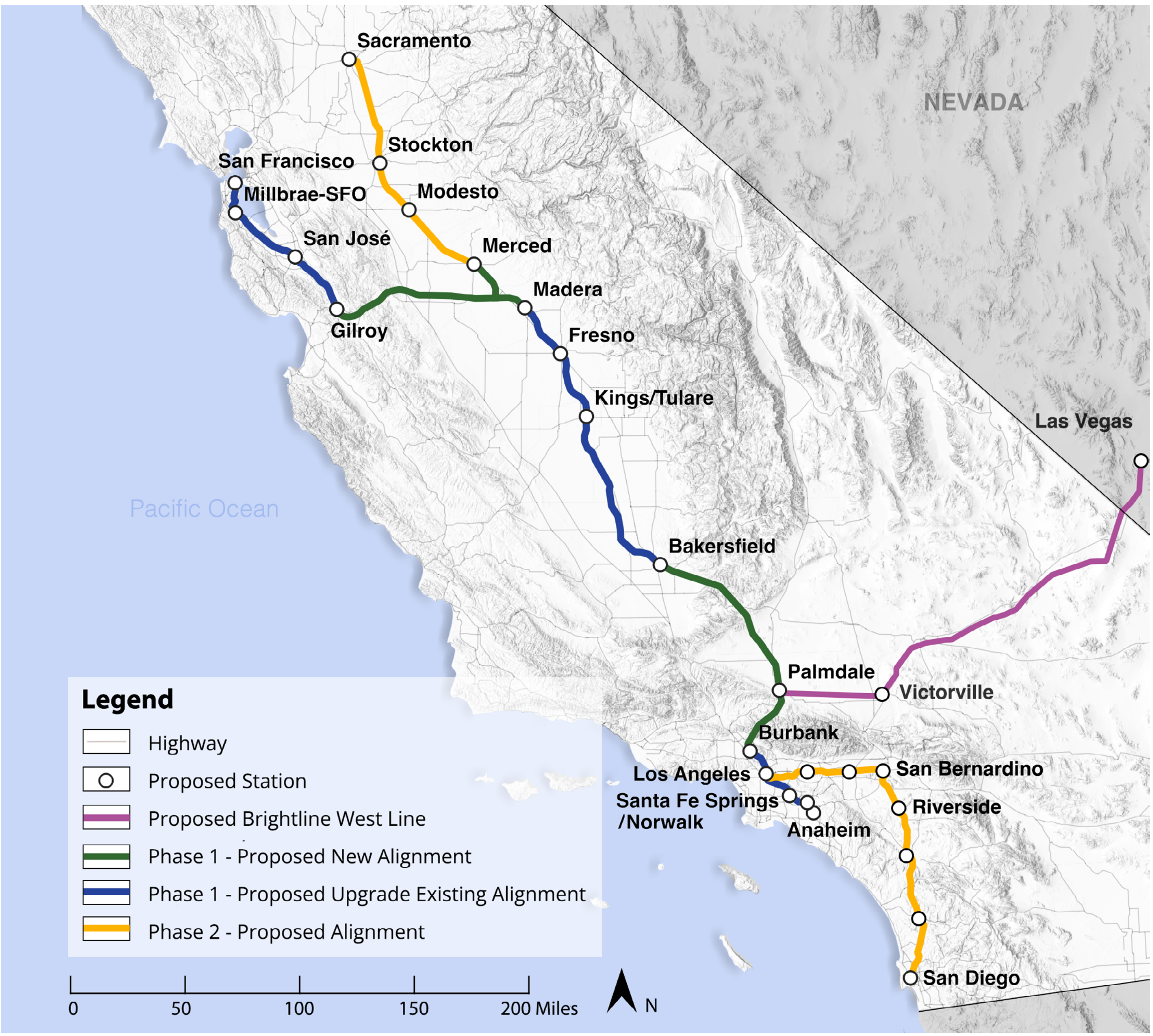


Table 3.8: Rail Station Details of California High Speed Railway System

Name	Location	Elevated, At Grade, or Underground	Existing/ new-build station	Operation Year	Multiple Mode Integration
San Francisco	Urban center	underground	new-build station	2033	Connect to Salesforce Transit Center, including 11 transit systems: AC Transit, BART, Caltrain, Golden Gate Transit, Greyhound, Muni, SamTrans, WestCAT Lynx, Amtrak, Paratransit, and future High-Speed Rail.
Millbrae-SFO	Suburban	At Grade	existing (improve)	2033	Connect to the Bay Area Rapid Transit (BART) system, Caltrain, and the San Francisco International Airport (SFO).
San José	Urban center	At Grade	existing (improve)	2033	Connect to Diridon's existing Caltrain, ACE, Capitol Corridor, Amtrak, and VTA Light Rail service, and future BART service.
Gilroy	undecided as of Oct 2022				
Merced	undecided as of Oct 2022				
Lleida	Urban center	At Grade	Existing	2008	Connect to high-speed railway service, conventional railway service, interurban buses, and local transportation services
Barcelona	Urban center	Underground/ At Grade	Existing	2008	Connect to high speed railway service, conventional railway service, intercity railway service, Barcelona Metro, and other local transportation services
Madera	Rural	Unknown	new-build station	2033	Connect to some local transit services
Fresno	Urban center	At Grade	existing (improve)	2033	Connect to local bus transit, bus rapid transit, a shuttle to Amtrak, and Yosemite Area Regional Transportation System
Kings/Tulare	Rural	Elevated	new-build station	2033	Connect to some local transit services
Bakersfield	Urban center	Unknown	new-build station	2033	Connect to some local transit services
Palmdale	Suburban	Unknown	new-build station	2033	Connect to Metrolink rail station, a local bus hub, commuter bus, Brightline West high-speed rail service
Burbank	Suburban	underground	new-build station	2033	Connect to two train stations, Hollywood Burbank Airport and multiple modes of transportation, including airport public parking, rental cars, regional buses, and bicycles.
Los Angeles	Urban center	At Grade	existing (improve)	2028	Connect to Amtrak, Metro Rail and bus services
Norwalk/ Santa Fe Springs	Urban center	At Grade	existing (improve)	2033	Connect to Amtrak, regional buses, and local transit services.
Fullerton	Urban center	At Grade	existing (improve)	2033	Connect to Amtrak, regional buses, and local transit services.
Anaheim	Urban center	Unknown	existing (improve)	2033	Connect to Metrolink, Amtrak, regional buses, and local transit services.
Sacramento	undecided as of Oct 2022				
San Diego	undecided as of Oct 2022				

Table 3.9: Estimated Capital Cost of California High Speed Rail (Phase One)

Business Plan	2008	2012	2016	2020	2022
Estimated Capital Cost Range (YOE $ Billion)	32.8-33.6	68.4	64.2	69.1 - 99.9	76.7 - 113.2

Source: California High-Speed Rail Authority, Business Plan 2008 - 2022

pended-to-date are the State's cap-and-trade system (25% of auction proceeds), the State's Proposition 1A, the federal American Recovery and Reinvestment Act, and appropriation from Congress in fiscal year 2010. The federal funds were awarded through the Federal Railroad Administration. Additional funds have been pooled from other sources, some local, for stations and linkages to existing metro systems.

The California High-Speed Rail Authority, responsible for planning, designing, building, and operating this system, and the State of California, continue to raise funds to complete construction (CHSRA 2022). Current policy states that the operation of the system will be self-sustaining, requiring no additional public subsidies, though the possibility of doing so is dependent on ridership, pricing, and other potential sources of operational funding, such as renewable energy capacity. Self-sustaining operations also become challenging if operating revenues are required to cover the interest on the debt issued to finance engineering and construction.

The California High-Speed Rail Authority is using various ways to inform and engage the public about the high-speed rail program. They provide accessible online tools such as interactive maps and visualizations for the public to understand the project, its economic impacts, and its environmental benefits. In April 2022, they launched a carbon footprint calculator to show the potential carbon emission savings from traveling by high-speed rail instead of by car or by air on five main round trips. By transforming the emission savings into tangible equivalents, such as gasoline, coal, or waste, the tool allows users to see how their future rail trips avoid greenhouse gas emissions.

3.5 Texas

3.5.1 Introduction and History

The Texas Central High Speed Rail is a planned private high-speed rail service intended to link the two metropolitan areas of Houston and Dallas with an estimated 240 mi (about 380 km) of rail (Figure 3.8). As of 2020, there are 29.1 million people in Texas. There are 2.3 million people in Houston, 2.2 million people in the Dallas–Fort Worth metro area, and 200,000 people in the Bryan-College Station area. Houston and Dallas are among the top three most populated cities in Texas, and the Bryan-College Station area has also been through major population growth in the last ten years (US Census, n.d.). Measured as GDP, Texas is the second largest economy among states, surpassed only by California.

The company of Central Texas estimated 6 million people in 2029 and 13 million people in 2050 will travel between the two cities (Webuild, n.d.). The project is advertised to reduce a four hour drive to 90 minutes or less in travel. Publications suggest that four routes have been under consideration (Figure 3.8).

3.5.2 System Description

Development entities of the Texas Central High Speed Rail include Texas Central High-Speed Railway, LLC (TCHSR), Texas Central Railroad, and its parent company, Texas Central Partners. TCHSR works with the Federal Railroad Administration on planning and coordination for the National Environmental Policy Act regulatory approval. Texas Central Partners is responsible for project development and implementation (design, construction, finance, and operation). Texas Central Railroad is the project proponent in the environmen-

Figure 3.7: Texas Population Density Map (Census Tract Level, Source: US Census, 2022)

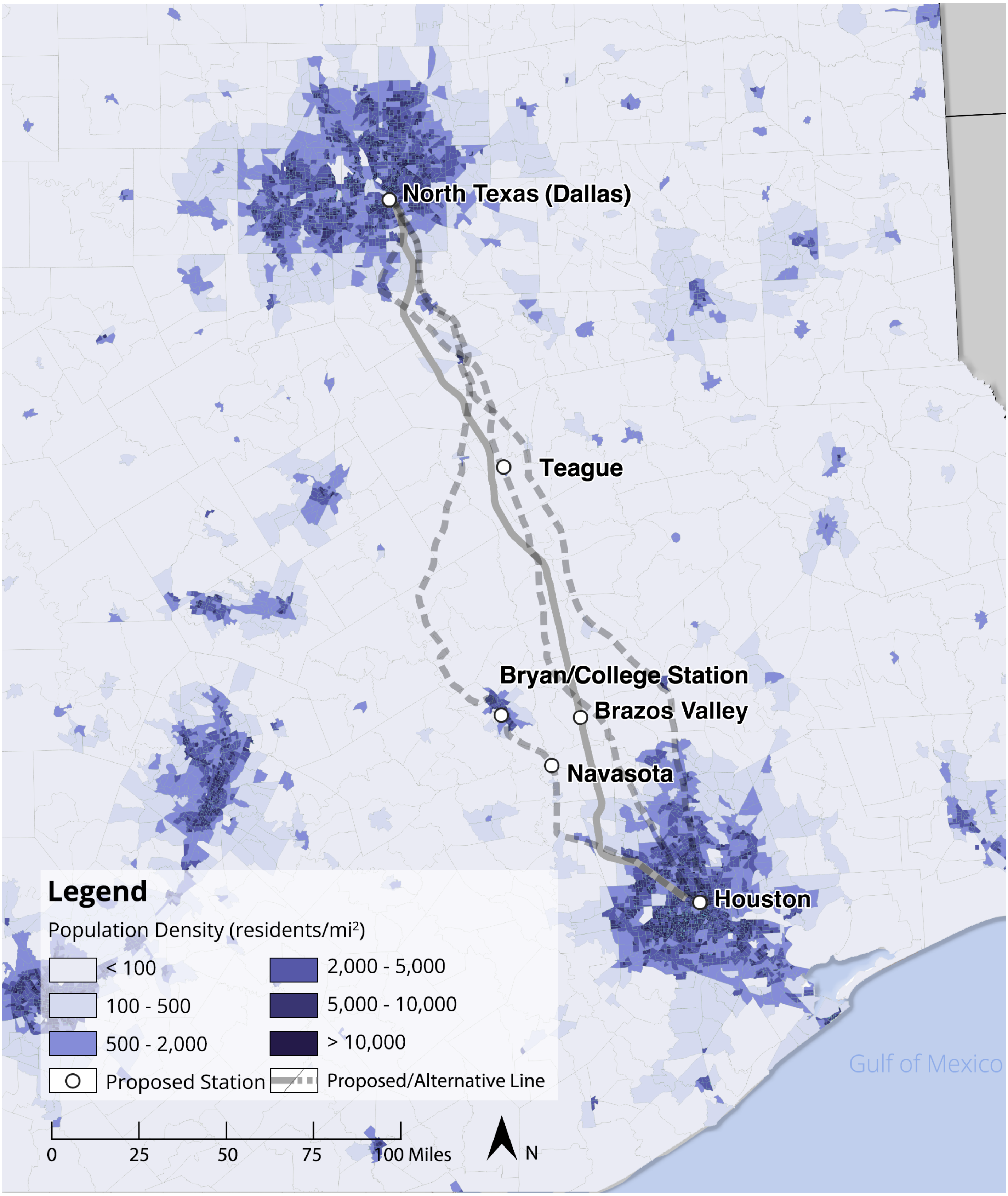
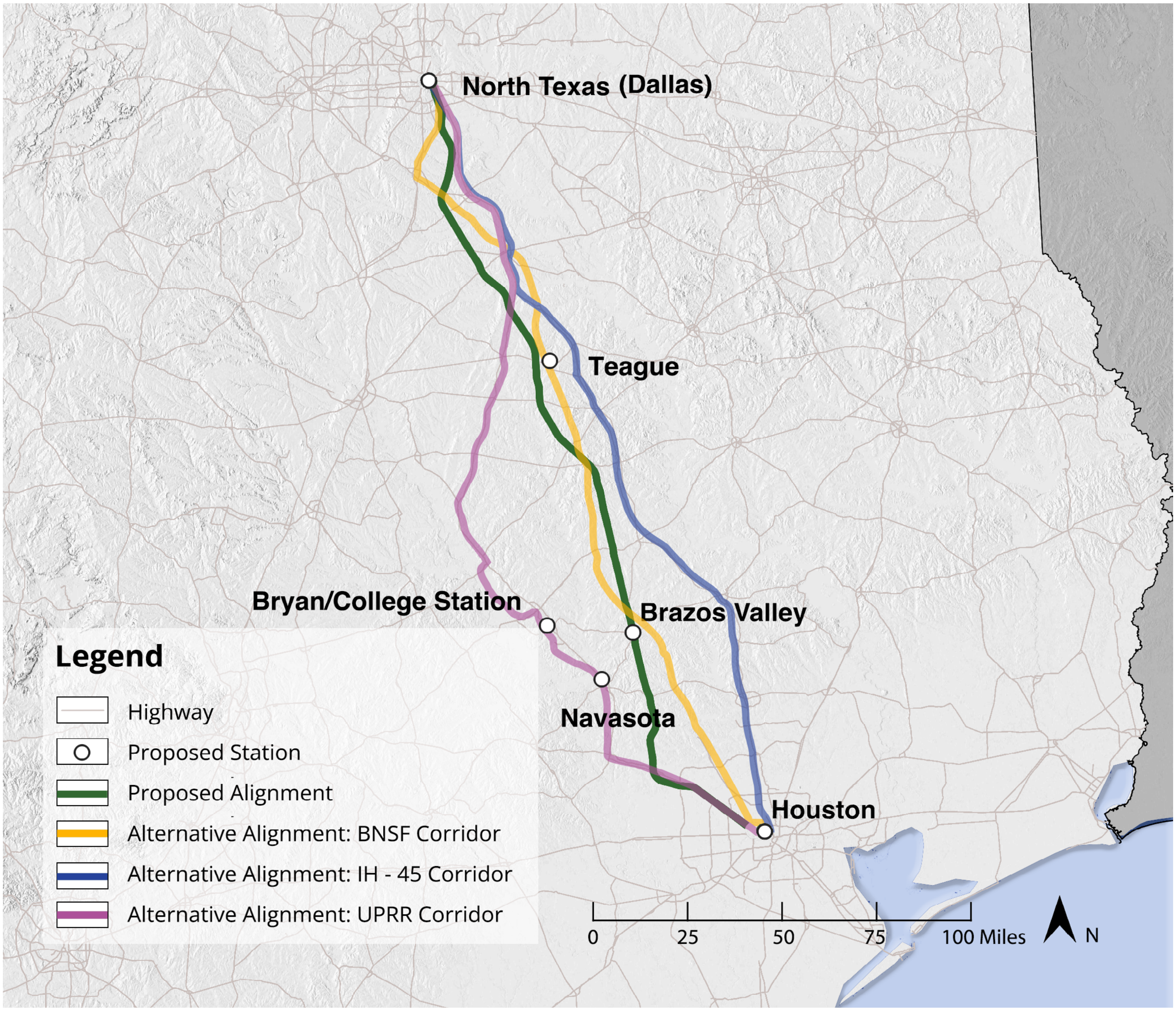


Figure 3.8: Texas High Speed Railway System Map (Source: Texas Central, 2022)



tal impact statement (FRA, n.d.). When approvals and permits are obtained from the Federal Railroad Administration and the State of Texas, the Texas High-Speed Rail Station Development Corporation—a consortium of Texas investors—intends to focus on the station development as the next step (Texas High-Speed Rail Station Development Corporation, n.d.).

The preferred alignment suggests that Texas Central High-Speed Rail will have three stations: one in Dallas, one in Houston, and one in Brazos Valley in Grimes County, which is near College Station (e.g., where Texas A&M University is located). The plans for station development have not yet been made available to the public. The Federal Railroad Administration conducted an independent evaluation of four alignment alternatives as part of the National Environmental Policy Act process, and selected the one that followed the path of transmission lines on the electrical grid for a majority of the route, known as the "Utility Corridor," as the only feasible alternative for further evaluation (FRA, 2021).

Table 3.10: Rail Route Details of Texas High Speed Railway System

Route and Phase	Status	Length	Speed	Cost	Ridership
Still pending for construction permit	Not Constructed Yet	240 mi (386 km)	186 mph (300 kph)	Official estimate $19 billion (2020) *	More than 6 million passengers expected to ride the train annually by 2029 and more than 13 million by 2050

* Source: Federal Infrastructure Projects Permitting Dashboard

Table 3.11: Rail Station Details of Texas High Speed Railway System

Name	Location	Elevated, At Grade, or Underground	Existing/ new-build station	Operation Year	Multiple Mode Integration
Houston	Urban Center	Elevated as Conceptual Design	New	-	Located at the Northwest Mall site near the interchange of US 290 and Interstate 610 in northwest Houston.
Brazos Valley	Suburban	Elevated as Conceptual Design	New	-	On Highway 30, just west of Highway 90, in the Roans Prairie area
Dallas	Urban Center	Elevated as Conceptual Design	New	-	Multimodal transportation networks in Dallas and surrounding areas.

The Federal Railroad Administration had three major screening criteria: physical characteristics, operational feasibility, and environmental constraints, that involved achieving a low impact on communities by maximizing the alignment with existing rights-of-way (FRA, 2021). For the final buildable alternatives, approximately 60% use viaducts for greater movement, and 52% of the alternatives are adjacent to existing infrastructure to reduce disturbance to surrounding areas and reduce further fragmentation of existing habitat (FRA, n.d.).

Financing has been private, but costs may be rising. The initial estimate for the construction cost was $12 billion, but the estimate listed on the Federal Railroad Administration (FRA) permitting dashboard is $19 billion. Others have suggested that the estimated cost could have risen to $30 billion by 2020 (Rodriguez, 2020). In June, 2021, Texas Central announced that they signed a $16 billion design and build contract with Webuild for the entire alignment (Lloyd, 2021). It is also worth noting that after two years of litigation, Texas Central has obtained approval to move forward with property acquisition using eminent domain (Supreme Court of Texas, 2022; Skores and Griffin, 2022).

3.6 Florida

3.6.1 Introduction and History

Florida is the third largest state and fourth largest economy in the U.S., with a population of 21.5 million (US Census, 2021; US BEA, 2021). The major metropolitan areas along the eastern coast of the state, Miami, Fort Lauderdale, and West Palm Beach, are currently being served by Brightline with passenger rail transportation. Two additional phases of development are also underway, with a line under construction to the Orlando International Airport and a further extension planned westward to Tampa Bay (Figure 3.9 and 3.10). Orlando International Airport is the busiest airport in Florida and the seventh busiest in the nation, with 40 million passengers in 2021, owing in part to the tourist economy and the proximity to attractions such as Walt Disney World and Universal Studios Orlando (GOAA and Authority, 2022).

The project and operations are privately owned. The project is being implemented by All Aboard Florida, a wholly-owned subsidiary of Florida East Coast Industries (Railway Technology, 2020), with rail operations provided by the private firm, Brightline.

Figure 3.9: Florida Population Density Map (Census Tract Level, Source: US Census, 2022)

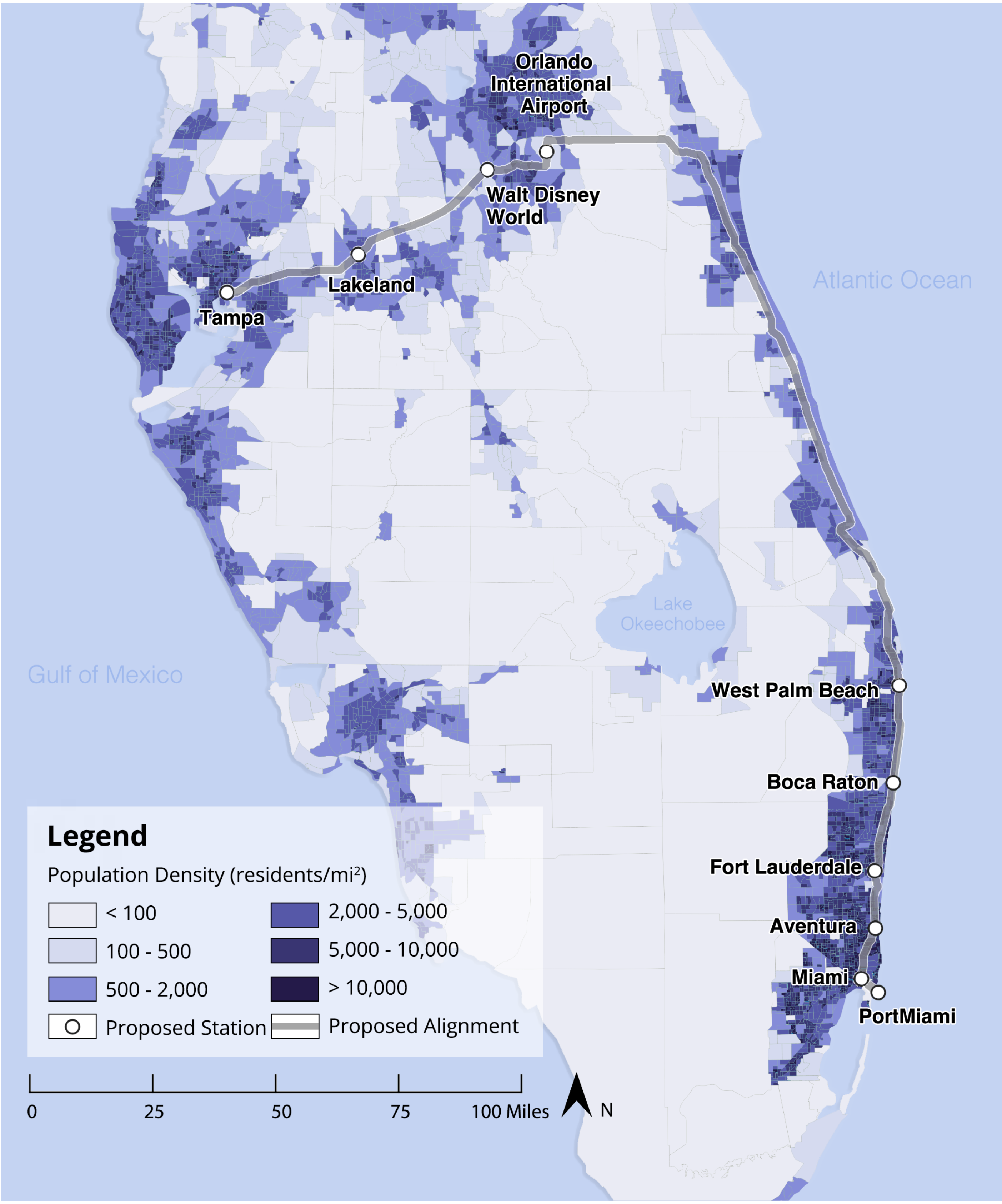
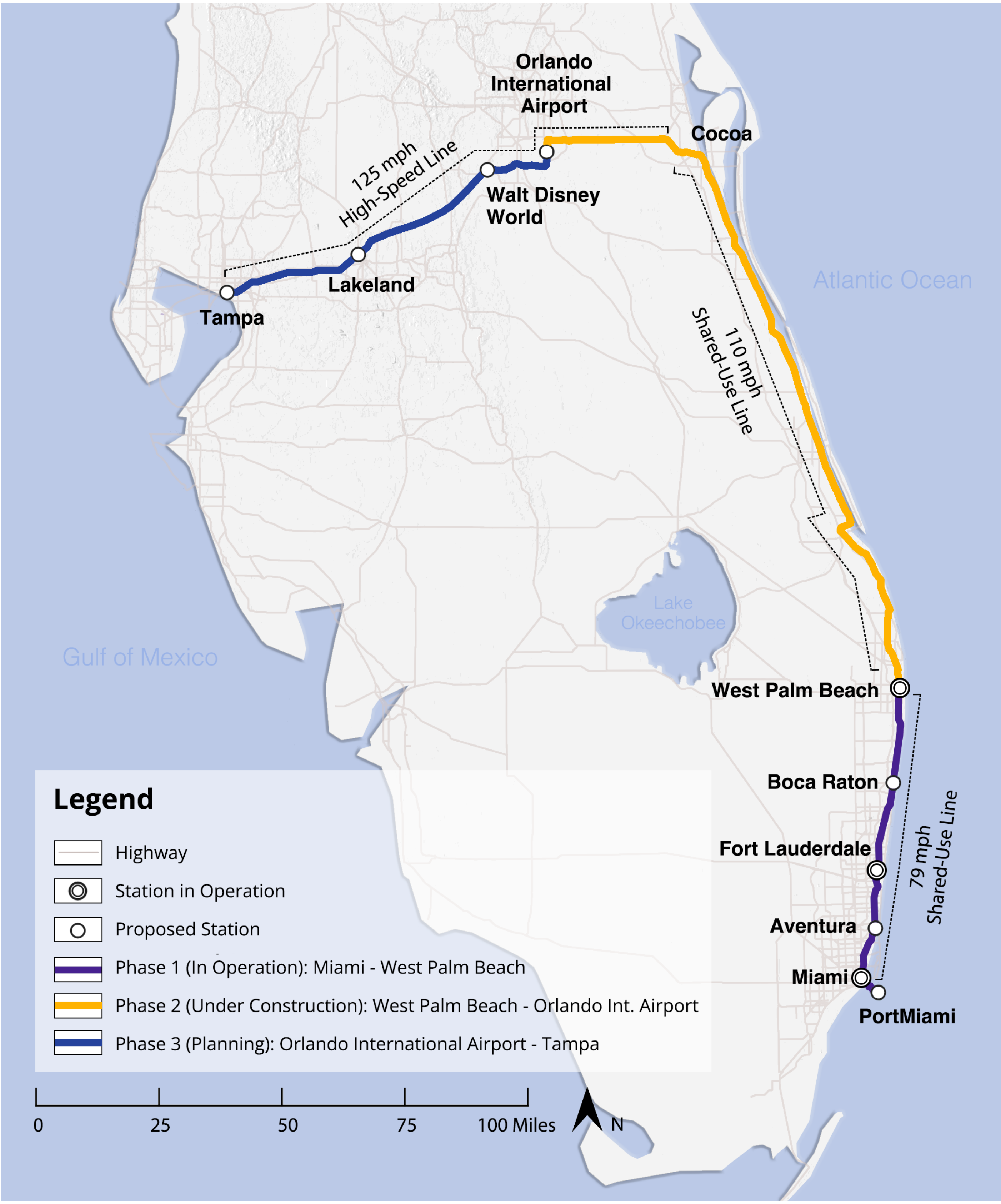


Figure 3.10: Florida High Speed Railway System Map (Source: High Speed Rail Alliance, 2022)



3.6.2 System Description

Brightline Florida's plan to offer high-speed services includes three phases for construction, Miami to West Palm Beach, West Palm Beach to Orlando International Airport, and Orlando International Airport to Tampa (Railway Technology, 2020; Brightline, 2022). The total length of the planned system is 491 km (305 mi) (High Speed Rail Alliance, 2022).

The plan has been to start operations of the first phase, collecting revenue in a high-density area of the state, while planning for the other phases of development. The first phase of Brightline included three stations, Miami, Fort Lauderdale, and West Palm Beach, which started construction in 2014 and became operational in early 2018 (Railway Technology, 2020). Three additional stops, Aventura, Boca Raton, and PortMiami, are under construction to meet more local travel demands (Brightline, 2022a). It is important to note that the project includes real estate development of station areas, which can become a significant part of the project revenue stream. The station in Miami central covers 480,000 sq. ft (44,600 m^2) of property, with residential, office, and retail space, while the Fort Lauderdale station occupies 60,000 sq. ft (5,574 m^2), including a park-and-ride facility with a capacity for more than 500 vehicles, and the West Palm Beach station similarly covers another 60,000 sq. ft (5,574 m^2) (Railway Technology, 2020). Phase two extends service another 155 mi (250 km) to Orlando International Airport and is under construction, expected to begin operations in 2023. The new station in Orlando is expected to become an important transfer link for intercity rail and to airport terminals. Brightline suggests that users could easily transfer from train systems to airport terminals through pedestrian-friendly access and an elevated people mover system (Brightline, 2022b). Annual ridership is projected to be 3 million (Railway Technology, 2020). Plans include the upgrade of over 100 miles of track to increase potential operating speeds to 110 mph (177 kph). Phase three construction, an 85-mile (136.7km) line to connect Orlando International Airport to Tampa, is in the planning process.

Publicly available estimates suggest that the cost to connect Miami to Orlando is $4 billion (Railway Technology, 2020). Though the project has private investment, it has also benefited from the federal American Recovery and Reinvestment Act. The developer seeks to reduce the cost of lines by making use, where possible, of existing rights-of-way owned by the State of Florida. Of the full 491 kms, existing lines or rights-of-way are available for 298 kms, while the remaining 193

Table 3.12: Rail Route Details of Florida High Speed Railway System

Route and Phase	Section	Status	Length	Speed	Cost	Ridership
Phase 1	Miami - West Palm Beach	Operations since 2018	65-mile (104.6 km) shared use line with freight	79 mph (127 kph)	$1.5 billion US dollars (2012)	885,000 in 2019 1,290,000 in 2022
Phase 2	West Palm Beach - Cocoa	Under construction and expected operation in 2022	120-mile (193 km) upgraded shared use line	110 mph (177 kph)	$2.7 billion US dollars (2007)	Expected 3 million
	Cocoa – Orlando International Airport	In planning phases	35-mile (56 km) new dedicated high-speed line	125 mph (200 kph)		
Phase 3	Orlando International Airport - Tampa	In planning phases	85-mile (136.7 km) proposed dedicated line	125 mph (200 kph)	$2.25 billion US dollar (2005)	N/A

* Source: Universal Engineering Sciences, 2022

** Source: Federal Railroad Administration, Florida High Speed Rail Authority, 2005

Table 3.13: Rail Station Details of Florida High Speed Railway System

Name	Loca-tion	Elevated, At Grade, or Un-derground	Existing/ new-build station	Oper-ation Year	Multiple Mode Integration
Miami	Urban center	at grade	new-build	2018	The downtown Miami station connects Brightline with the Metrorail, Metromover, County bus and City of Miami trolley systems. which connect 2 Metrorail stations, 2 Metromover stations, Metrobus, and the future Tri-Rail station.
Fort Lauder-dale	Subur-ban	at grade	new-build	2018	The Fort Lauderdale station connects Brightline with Bro-ward County Transit, Sun Trolley, and Tri-Rail system.
West Palm Beach	Subur-ban	at grade	new-build	2018	The West Palm Beach station could link to the Tri-Rail, Palm Tran bus routes, Palm Trolley(Yellow Line), and Amtrak West Palm Beach station.
Cocoa	N/A	N/A	N/A	N/A	N/A
Orlando Inter-national Airport	N/A	N/A	N/A	N/A	N/A
Tampa	N/A	N/A	N/A	N/A	N/A

kms are new. Separate contracts have been let for the trains, locomotives, signaling systems, and construction management as well as construction for the stations and station areas.

Brightline aims to attract passengers from the estimated 50 million people who currently travel through Orlando and south Florida by air and by car. Brightline Florida advertises the system as a net-zero-carbon-emission travel mode, compared to air travel and other rail services (Brightline, 2022a). However, each train is pulled by diesel-electric locomotives operating at EPA Tier 4 standards, with diesel engines producing electricity to run the motors on the axles of the cars, which may draw into question the veracity of claims of carbon neutrality (Railway Technology, 2020). Florida Light and Power agree to provide a biodiesel blend of fuel under a two year contract.

The high-speed project is projected to add an estimated $3.5 billion to Florida's GDP, bringing in over $6.4 billion, and $653 million in tax revenue in total for federal, state, and local authorities in economic impact. Brightline also suggests that the current project creates 2,000 job opportunities in the south Florida region, bringing about $2.4 billion for labor income, and that the 170 mile extension to Orlando could bring as many as 10,000 jobs (Brightline, 2022a).

CHAPTER 4

Recommendations

The purpose of this report is to distill lessons of value to decision-makers in the Pacific Northwest as they consider the prospect of high-speed rail service from Vancouver, British Columbia, to Seattle, Washington and Portland, Oregon (Figure 4.1). This research targeted experienced professionals in the field and existing academic literature with questions about the decisions to be made in the earliest stages, before a go/no go decision is made for the project. The point is to find the choices that hold promise for the success of these projects—a success that, if it does arrive, will emerge over the decades to come.

To unearth pivotal decisions in early project development requires candid conversations with people who have seen how choices made in earnest have given rise, years later, to unintended consequences. If we imagine that projects face barriers and offer opportunities, the idea of this report is to describe barriers to successful high-speed lines and/or systems, so that they may be recognized and avoided or overcome. Some barriers are rather well-known, having been the subject of concerted academic research, as in the relationship between population density, transit-oriented development, and transit ridership. Others are more elusive but just as important. They are the barriers to success that, perhaps unbeknownst to participants at the time of decision-making, eventually proved consequential. This describes the slow process of learning about megaprojects through trial-and-error. It is also the source of institutional change—changes to the rules of the game for the people participating in and touched by these intendedly transformational investments—so that future projects avoid the same pitfalls. This closing chapter summarizes the contents of this report and offers a set of recommendations, but with a caveat. This brief effort to examine a global industry can only offer generalized guidance to the parties exploring high-speed rail for the Pacific Northwest. To compare the ongoing and contemplated activities in this region, and examine the possibilities for implementing these ideas in Washington, Oregon, and British Columbia, was beyond the scope of this study.

This chapter is organized into topic areas, followed by recommendations. These recommendations are not comprehensive; they do not represent a complete work plan for high-speed rail development. Many appear as requests to make use of expertise not commonly structured into transportation project decision-making, or suggestions for activities to occur outside of common time frames, or for levels and types of coordination and partnerships that would have no obvious purpose on any type of project except high-speed rail. Please note that the recommendations listed within each section are shown in chronological order of project development.

Figure 4.1: Pacific Northwest Topography, Existing Rail, and Highway Infrastructure

4.1 Focus on the service and providing value in the transportation market

High-speed rail is a service

High-speed rail is a service, defined by its competitive success in intracontinental passenger transportation, including air travel. Success is so defined by competition for metro-to-metro air travel that international experts uniformly use this factor to explain why some lines are successful and to examine why others are not. When rail operations became competitive, air transport services found ways to cooperate, further expanding the market for rail services. Competition with air travel supports the concept of first class or premium pricing, along with standard and discounted services.

Recommendations

1. Develop sound population density and demographic forecasts for the next 20 to 50 years to form the basis for the ridership demand and pricing discussions essential to a go/no go decision
2. Organize political and technical stakeholders around the idea of providing competitively fast and convenient transport services between major metropolitan centers
3. Let competition with air transport be the driving force behind principles to guide performance in terms of the speed, frequency, reliability, safety, comfort, and service quality of the system
4. Coordinate with airlines on the mutually positive benefits of integrating rail and air travel, the role of airport rail stations as hubs for long-haul travel, and the mutual benefits of alliances for ticketing and fare integration

A vision of competitive metro-to-metro service should guide decision-making

To succeed, however, requires central and unflagging attention to the myriad ways in which decisions can detract from the competitive operational requirements of high-speed service. This imperative places expertise in operations and business planning for rail service at the forefront of early high-speed rail decision-making, providing critical guidance to political leadership. Failure to compete in metro-to-metro service leaves public agencies paying for inordinately expensive rail systems that mainly serve local commuters.

Recommendations

5. From the beginning, bring experts from successful international high-speed rail services and operations in-house, to guide both political and technical decision-making
6. In preparation for a go/no go decision, the early planning of the project should have a vision beyond the construction of the infrastructure and a way to account for each part of the system (hardware, such as track and rolling stock, but also soft systems, such as personnel and protocols for train and station operations), looking ahead five or more years into operations
7. Use such a systems approach to consider the stakeholders and experts to be involved in developing a unified and comprehensive vision; begin public engagement with the vision (e.g., hearings and workshops as opposed to lobbying)
8. Stakeholders may want to bargain; all choices have cost consequences that must be known, weighed, and communicated, with the awareness that small choices can place the success of the entire project at risk if those choices detract from the performance of the system necessary for competitive metro-to-metro travel
9. A go/no go decision should be based on a realistic business plan, for a known customer base, with a well-grounded sense of what is plausible for high-speed operations, adequate funds secured for planning, and the identification of known as well as likely adequate sources of funding for capital costs and their financing
10. Start with political consensus for a go/no go decision

A program of this magnitude calls for a new institutional approach

Megaproject risks magnify financial impacts. The scale, scope, and timing of high-speed rail development are extraordinary, even by the standards of megaprojects. Nine out of ten megaprojects suffer from cost overrun, but this does not mean that overrun is inevitable. The scale and scope of a high-speed rail project creates its own market conditions. People and organizations do not usually plan activities using the 20 to 30 year timeframe of high-speed rail development. For projects in the U.S. and Canada, success will depend on avoiding the vicious cycle of underestimates, overruns, and political renegotiation. These are not highway projects; different rules apply, and different approaches are needed. Researchers caution against direct comparisons of proposed U.S. high speed lines with existing systems in other countries. Successful high-speed rail systems around the world benefit from institutional safeguards for their development

Recommendations

11. If the decision is to 'go' on the project, form a new entity with political endorsement, cross-jurisdictional representation from technical and institutional experts, international expertise, and a technical advisory board (e.g., high-speed rail, border crossings, program management)

12. Recognize the institutional gap (difference in rules and governance structures) between the U.S. and the countries that have successful high-speed rail systems

13. Conduct research to identify legislative and regulatory changes possible now, for the state/region to overcome the most significant hurdles to cost-effective project and service delivery (e.g., state-local and international agreements, partnerships with utilities and airlines, pathways for programmatic environmental review and permitting, provide land value capture)

14. Obtain a technically-supported cost estimate for the project and its major components, with reference class forecasting --- using data that includes cost overrun from completed projects to adjust cost estimates ---, to use as a basis for fundraising (with support from program and bottom-up planning; conceptual but with schematic engineering basis where possible)

15. Organize for systematic and sustained public engagement, democratic participation, and project fundraising

4.2 Effective and productive private sector relationships

Successful implementation depends on the capacity of the public agency

Efficiency requires a competitive market for the delivery of public goods. Without competition there will be no pressure for firms to pull bid prices down toward their own actual estimates of cost. There are a limited number of knowledgeable bidders in the market for high-speed technology. Maximize the potential to reach the largest number of market participants by adopting standards with the widest number of knowledgeable firms. While many projects start with a competitive market of players at the outset, they usually end up in a game with a small number of players as project development proceeds, thereby raising the risk of increases in cost and contractual issues.

Recommendations

16. The simple arrangement of a public agency working with a consortium should be changed to provide the public agency with a more robust capacity to understand the markets it wishes to engage, and how to engage them for a cost-effective outcome; bring international experts in-house and as public agency advocates

17. The public agency should adopt widespread international standards for the system, known to a wide array of responsible corporations in the industry (note that many are government-owned corporations) and establishing interoperability; conduct a study to understand, in advance of contracting, the extent of the market (suppliers) in the industries and sub-industries of high-speed rail, with the idea of tailoring requests for proposals that meet a well-represented market

This is program management for projects and services

Public-private partnerships have often been promoted for infrastructure megaprojects around the world, including high-speed rail, yet these arrangements can lessen competition (e.g., Dutzik and Schneider, 2011; Ho and Tsui, 2010). Though there are few examples, projects in the U.S. gravitate toward two extremes for high-speed rail development, while international arrangements represent a wide variation in ownership structures for contracting. It helps to realize that a high-speed rail line is a massive program made of many engineering, construction, manufacturing, and assembly projects, each with its own market of competitors. Consider cultivating competition in the market, as opposed to competition for the market. Continually assess the limits of your expertise, and get help.

Recommendations

18. Recognize that public ownership is the norm for high-speed rail in the countries that have pioneered high-speed rail development

19. Develop a deep bench of advice on program management, to guide the division of the program into sub areas and projects, with procurement practices that avoid unnecessary bundling to maximize the benefits of competition while attending to economies of scale and scope, and to monitor effects of the program on key markets, and effects of key markets on the program

20. Begin early to investigate cost- and time-saving approaches in the market, such as modularization in engineering, permitting, pre-fabrication, and construction

21. Organize for competition in the market: retain public ownership of the infrastructure such as stations, tracks, station areas, with a starting set of rolling stock, which have a long timespan, and invite private operators to compete for the operation and maintenance of the system and service

22. Have contingency plans and rainy-day funds for those times when private partners fail to deliver the project or service and the public agency needs to regroup and issue new proposals

4.3 Coordinated public engagement

Deliberate, systematic, and sustained public engagement is key

Effective high-speed rail development requires thorough and deliberate public engagement coupled with planning and engineering. High-speed rail lines are initiated through reaching political consensus on the vision of the project, the long-term future of service, the growth of the region, and potential efficiencies and spillover effects. Experts encourage early outreach to local leadership, with a particular view of what it means for cities, counties, and other local and regional entities to become partners in the project. Academics encourage consideration, for example, of the role of transit-oriented development in providing affordable housing choices in proximity to station areas. Let technical considerations of planning, engineering, and cost, with business performance characteristics, drive the production of options for routes.

Recommendations

23. Have early, systematic, and sustained community engagement, approaching communities to understand their needs instead of selling the idea of high-speed rail

24. Identify and involve local advocates (especially the younger generation who are more open to the idea of traveling by rail) in the outreach

25. Be honest about negative impacts, and present conceptual designs, visualizations, and accessible facts and data to demystify false beliefs and make the direct and indirect benefits more tangible

26. Let routes be determined by the technical requirements of delivering a high-speed metro-to-metro service, but also organize with communities to plan for the integration of stations along the route with existing commuter rail and local transport systems, to expand the service area of high-speed rail (bringing people to the rail) instead of diverting the route of the rail through the centers of towns along the route
27. Identify, with communities and local stakeholders, the preferred locations for stations along the high-speed route, station area development land uses and densities, and station-to-community local transport options to align the benefits of high-speed rail with the needs of communities, including direct benefit from the service and indirect benefits such as job creation, housing, and economic growth

4.4 Making the most of dollars and sense

All eyes will be focused on the selection of routes, which is a technical decision

All eyes will be focused on the selection of a route and stations from point A to B. Experts describe the need to enter environmental review with 50% of engineering complete, preferably for 2 or 3 alternative routes, though they would all need to be able to meet performance expectations. Factoring in the location of electrical transmission lines on the grid during the selection of the route offers multiple cost-saving benefits, for capital cost, operating costs, and land acquisition. Don't delay the engineering and construction of urban metro and airport stations, as each is its own megaproject in need of greater than 50% engineering at the time of environmental review.

Recommendations

28. Manage the program to advance engineering in concert with public engagement, before and during environmental review
29. Make sure that all proposed routes meet the performance specifications set for competitive metro-to-metro service
30. Work early in partnership with utilities and grid operators to understand the role of transmission and on-site renewable energy generation and storage on project capital and operating costs, and to design the route accordingly
31. Recognize the urban metro hub and airport stations for the infrastructure megaprojects that they are, on the critical path for the program, with many local stakeholders
32. Take a programmatic approach to environmental review; organize environmental surveys/studies at a programmatic level for economies of scale, establish programmatic permitting for areas that meet the no-significant-impact criteria and systematic review at project level for sites with significant impacts, and prepare easements and public purchases where possible to ease land acquisition

"Plan slow, act fast" (Gardner and Flyvbjerg 2023)

Plan slow; bring the engineering with you in a concerted program of public outreach. Plan slow; be able to explain the costs, impacts, and operational constraints, but also the services local communities will receive. Plan slow; reach political agreement early on to put institutions in place, such as land value capture as part of the financial structure of the project. Act fast, when the time comes to advance to detailed design, land acquisition, and construction. Act fast; in the move from engineering to construction the cost per day of work rises dramatically, which means that construction techniques matter. Act fast; inflation is not on your side.

Recommendations

33. For the planning, public engagement, public agreements, engineering, permitting, and environmental review, getting it right is more important than going fast
34. Don't hire design-build or construction contractors until you are actually ready to finalize detailed de-

sign and begin construction, likely after project-level records of decision from environmental review

The impact of the project on climate, and climate on the project, is game-changing

High-speed rail is increasingly discussed as a form of climate action. As an electric system, high-speed rail has the potential to offer advantages in the effort to decarbonize transportation compared to other travel modes (i.e., auto, airline, and heavy rail train). The idea that renewable sources, such as solar energy, could power high-speed rail operations, puts rail operations in the energy business. Part of the essential story for the public about rail transportation is the comparative effect on personal emissions. Rail, like other modes of transportation are exposed and vulnerable to disruption, though the nature of those vulnerabilities differ. Designing for resilience is the only and best option, with an understanding from the beginning of the effects of climate change across the topography of the region.

Recommendations

35. The potential for high-speed rail to decarbonize transportation is significant and yet an easily squandered opportunity; research to account for greenhouse gas emissions in the design, construction, and operational choices for the program and its projects should proceed with the guidance and participation of experts in this emerging field of study, alongside and embedded in the organizations delivering the project

36. People at the top of the organizational structures for this project need to recognize that funding (e.g., Washington's cap-and-invest) and preferred financial terms (e.g., ESG finance) are at stake, and make decarbonization a primary objective of the program

37. Highly specialized expertise in modeling for extreme events exacerbated by climate change (e.g., heat, flooding, wildfire, landslide) and costly, even if separate from climate change (e.g., earthquakes) is needed from the beginning, to understand the exposure of the area under consideration for routes and stations, and how that exposure will grow during the full designed life of the asset

38. This expertise in climate and infrastructure will need to be able to guide and work with the technical team during route and station area selection, to move toward designs that are robust from an all-hazards approach; designs made to avoid loss and damage

39. Organizations that claim to reduce greenhouse gas emissions through their activities, and avoid the impacts of natural hazards should document these claims with evidence-based forecasts, and monitoring and verification systems; this should be the case for high-speed rail

40. The scale of the project and its uses of electricity are conducive to cost-saving investments in solar and battery systems along the route, to support the cost of operations and to shave off the substantial and expensive spikes in electrical demand placed on the grid from train operations; study the effects this could have and the enabling environment for its execution

References

ACP Rail. 2022. "AVE Train." 2022. https://www.acprail.com/train-tickets/renfe/ave-trains/.

Adler, Nicole, Eric Pels, and Chris Nash. 2010. "High-Speed Rail and Air Transport Competition: Game Engineering as Tool for Cost-Benefit Analysis." Transportation Research Part B: Methodological 44 (7): 812–33.

Administrador de Infraestructuras Ferroviarias. 2021. "2022 Network Statement." https://www.adif.es/en/sobre-adif/conoce-adif/declaracion-sobre-la-red.

Ahlfeldt, Gabriel M, and Arne Feddersen. 2018. "From Periphery to Core: Measuring Agglomeration Effects Using High-Speed Rail." Journal of Economic Geography 18 (2): 355–90. https://doi.org/10.1093/jeg/lbx005.

Albalate, Daniel, and Germà Bel. 2012. "High-Speed Rail: Lessons for Policy Makers from Experiences Abroad." Public Administration Review 72 (3): 336–49. https://doi.org/10.1111/j.1540-6210.2011.02492.x.

Albalate, Daniel, Germà Bel, and Xavier Fageda. 2015. "Competition and Cooperation between High-Speed Rail and Air Transportation Services in Europe." Journal of Transport Geography 42 (January): 166–74. https://doi.org/10.1016/j.jtrangeo.2014.07.003.

Alexandersson, Gunnar, and Staffan Hultén. 2022. "Using Public-Private Partnerships to Create High-Speed Railway Networks in Europe - Prospects and Pitfalls," September.

Anguera, Ricard, and Xavier Esparrich. 2020. "Air vs. Rail: Can Rivals Become Partners?" ALG: Shaping Future. November 19, 2020. https://algnewsletter.com/land-transportation/air-vs-rail-can-rivals-become-partners/.

Balkus, Brian. 2022. "Why America Can't Build." Palladium: Governance Futurism (blog). June 9, 2022. https://www.palladiummag.com/2022/06/09/why-america-cant-build/.

Banister, David, and Moshe Givoni. 2017. "Realising the Potential of HSR: The United Kingdom Experience." In High-Speed Rail and Sustainability: Decision-Making and the Political Economy of Investment, edited by Blas Luis Pérez Henríquez and Elizabeth Deakin, Chapter 2. Routledge. https://doi.org/10.4324/9781315709406.

Bernick, Michael. 1997. Transit Villages in the 21st Century. New York: McGraw-Hill.

Bešinović, Nikola. 2020. "Resilience in Railway Transport Systems: A Literature Review and Research Agenda." Transport Reviews 40 (4): 457–78. https://doi.org/10.1080/01441647.2020.1728419.

Binti Sa'adin, Sazrul Leena, Sakdirat Kaewunruen, and David Jaroszweski. 2016. "Risks of Climate Change with Respect to the Singapore-Malaysia High Speed Rail System." Climate 4 (4): 65.

Brightline. 2022a. "Brightline Florida." 2022. https://www.gobrightline.com/brightline-florida.

———. 2022b. "Brightline: High-Speed Rail Tickets, Schedules, and Deals." Brightline. 2022. https://www.gobrightline.com/.

———. 2022c. "The Train Station of Your Dreams." 2022. https://www.gobrightline.com/station-experience.

Bureau of Economic Analysis(BEA). 2022a. "GDP by State | U.S. Bureau of Economic Analysis (BEA)." 2022. https://www.bea.gov/data/gdp/gdp-state.

———. 2022b. "Gross Domestic Product by State and Personal Income by State, 2nd Quarter 2022." Bureau of Economic Analysis(BEA). https://www.bea.gov/sites/default/files/2022-09/stgdppi2q22-a2021.pdf.

California High-speed Rail Authority(CHSRA). 2022. "California High-Speed Railway Business Plan 2022." https://hsr.ca.gov/wp-content/uploads/2022/05/2022-Business-Plan-FINAL-A11Y.pdf.

CARB(California Air Resources Board). 2008. "Climate Change Scoping Plan, Appendices. Analysis and Documentation, Vol. II. A Framework for Change as Approved December 2008 Pursuant to AB 32, the California Global Warming Solutions Act of 2006, Sacramento."

Cascadia Innovation Corridor. 2020. "Cascadia Vision 2050: How the Cascadia Innovation Corridor Can Serve as a Global Model for Sustainable Growth." https://connect-cascadia.com/wp-content/uploads/2020/09/Cascadia-Vision-2050_Published.pdf.

Cervero, Robert. 1998. "The Transit Metropolis: A Global Inquiry." Washington, D.C: Island Press.

Chang, Brenda, and Alissa Kendall. 2011. "Life Cycle Greenhouse Gas Assessment of Infrastructure Construction for California's High-Speed Rail System." Transportation Research Part D: Transport and Environment 16 (6): 429–34. https://doi.org/10.1016/j.trd.2011.04.004.

Chen, Zhenhua, and Kingsley E. Haynes. 2015. "Impact of High-Speed Rail on International Tourism Demand in China." Applied Economics Letters 22 (1): 57–60. https://doi.org/10.1080/13504851.2014.925043.

Chen, Zhenhua, and Yuxuan Wang. 2019. "Impacts of Severe Weather Events on High-Speed Rail and Aviation Delays." Transportation Research Part D: Transport and Environment 69 (April): 168–83. https://doi.org/10.1016/j.trd.2019.01.030.

Cheng, Hsi-Kai. 2010. "Lessons Learned from BOT Infrastructure Development in Taiwan: A Case Study of the Taiwan High Speed Railway (THSR) Project." 2010. https://spaef.org/article/1159/Lessons-Learned-from-BOT-Infrastructure-Development-in-Taiwan:-A-Case-Study-of-the-Taiwan-High-Speed-Railway-(THSR)-Project.

Cheng, Junmei, and Zhenhua Chen. 2022. "Socioeconomic Impact Assessments of High-Speed Rail: A Meta-Analysis." Transport Reviews 42 (4): 467–502. https://doi.org/10.1080/01441647.2021.1979689.

Cheng, Yung-Hsiang. 2010. "High-Speed Rail in Taiwan: New Experience and Issues for Future Development." Transport Policy 17 (2): 51–63. https://doi.org/10.1016/j.tranpol.2009.10.009.

CHSRA(California High-Speed Rail Agency)). 2022. "California High-Speed Rail 2022 Business Plan." https://hsr.ca.gov/wp-content/uploads/2022/05/2022-Business-Plan-FINAL-A11Y.pdf.

CHSRA(California High-Speed Rail Authority). 2008a. "Addendum/Errata to Final Program EIR/EIS for the Bay Area to Central Valley Portion of the California HST System, Sacramento."

———. 2008b. "California High-Speed Rail 2008 Business Plan." https://hsr.ca.gov/about/high-speed-rail-business-plans/2008-business-plan/.

———. 2022. "Key Topic: Carbon Footprint Calculator." California High Speed Rail. 2022. https://hsr.ca.gov/.

Country Economy. n.d. "Taiwan GDP - Gross Domestic Product 2021." Countryeconomy.Com. Accessed September 21, 2022. https://countryeconomy.com/gdp/taiwan.

Crozet, Yves. 2013. "High-Speed Rail Performance in France: From Appraisal Methodologies to Ex-Post Evaluation."

Damiano Scordamaglia. 2015. "High Speed Rail in EU Briefing 2015." European Parliamentary Research Service.

Dannin, Ellen, and Lee Cokorinos. 2012. "Infrastructure Privatization in The New Millennium." In The Oxford Handbook of State and Local Government Finance, edited by Robert D. Ebel and John E. Petersen. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199765362.013.0026.

De Rus, Ginés. 2011. "The BCA of HSR: Should the Government Invest in High Speed Rail Infrastructure?" Journal of Benefit-Cost Analysis 2 (1): 1–28. https://doi.org/10.2202/2152-2812.1058.

Deakin, Elizabeth. 2017. "Background on High-Speed Rail in California." In High-Speed Rail and Sustainability: Decision-Making and the Political Economy of Investment, edited by Blas Luis Pérez Henríquez and Elizabeth Deakin, Chapter 12. Routledge. https://doi.org/10.4324/9781315709406.

Deakin, Elizabeth, and Blas Luis Pérez Henríquez. 2017. "Conclusions: High-Speed Rail and Sustainability." In High-Speed Rail and Sustainability: Decision-Making and the Political Economy of Investment, edited by Blas Luis Pérez Henríquez and Elizabeth Deakin, 1st ed. Routledge. https://doi.org/10.4324/9781315709406.

DeFazio, Peter A. 2021. "H.R.3684 - 117th Congress (2021-2022): Infrastructure Investment and Jobs Act." Legislation. 2021/2022. November 15, 2021. http://www.congress.gov/.

Diao, Mi, Yi Zhu, and Jiren Zhu. 2017. "Intra-City Access to Inter-City Transport Nodes: The Implications of High-Speed-Rail Station Locations for the Urban Development of Chinese Cities." Urban Studies 54 (10): 2249–67. https://doi.org/10.1177/0042098016646686.

DiCamillo, Mark. 2022. "Release #2022-08: Voters Offer a Wide Range of Issues They'd Like the State to Address," April. https://escholarship.org/uc/item/7sn293xs.

Dutzik, Tony, and Jordan Schneider. 2011. "High-Speed Rail: Public, Private or Both? Assessing the Prospects, Promise and Pitfalls of Public-Private Partnerships," 45.

———. n.d. "A Track Record of Success: High-Speed Rail Around the World and Its Promise for America," 53.

Economic Daily News, Taiwan. 2022. "Spending 188 billion NTD to complete in 2030, the high-speed rail extension to Yilan is now finalized to enter the second-stage environmental assessment." August 24, 2022. https://money.udn.com/money/story/5648/6561305?-from=edn_related_storybottom.

Eno Center for Transportation. 2021. "Saving Time and Making Cents: A Bluepoints for Building Transit Better." Washington, DC: Eno Center for Transportation. https://projectdelivery.enotrans.org/wp-content/uploads/2021/07/Saving-Time-and-Making-Cents-A-Blueprint-for-Building-Transit-Better.pdf.

———. 2022. "On the Right Track: Rail Transit Project Delivery Around the World." Washington, DC: Eno Center for Transportation. https://projectdelivery.enotrans.org/wp-content/uploads/2022/09/On-the-Right-Track.pdf.

Eurail. 2022. "TGV High-Speed Train, France." Eurail. 2022. https://www.eurail.com/en/get-inspired/trains-europe/high-speed-trains/tgv.

European Commission. 2012. "TEN-T Trans-European Transport Network- Implementation of the Priority Project." https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/brochures_images/PP_report_low_FINAL.pdf.

Fastener Eurasia Magazine. 2021. "Analysis of Taiwan." Https://Fastenereurasia.Com. 2021. https://fastenereurasia.com?h1680/analysis-of-taiwan.

Federal Infrastructure Project. 2020. "Dallas to Houston High Speed Rail." 2020. https://www.permits.performance.gov/permitting-projects/dallas-houston-high-speed-rail.

Federal Railroad Administration, Florida High Speed Rail Authority. 2005. "Florida High-Speed Rail Corridor: Tampa-Orlando Final Environmental Impact Statement (EIS)." Federal Railroad Administration, Florida High Speed Rail Authority. https://railroads.dot.gov/elibrary/florida-high-speed-rail-corridor-tampa-orlando-final-environmental-impact-statement-eis.

Feng, Cheng-Min. 2011. "Lessons Learnt from Taiwan's High Speed Rail." Proceedings of the Eastern Asia Society for Transportation Studies, 9.

Flyvbjerg, Bent. 2014. "What You Should Know About Megaprojects and Why: An Overview." Project Management Journal 45 (2): 6–19. https://doi.org/10.1002/pmj.21409.

———. 2021. "Top Ten Behavioral Biases in Project Management: An Overview." Project Management Journal 52 (6): 527–623. https://doi.org/10.1177/87569728211049046.

Flyvbjerg, Bent, Nils Bruzelius, and Werner Rothengatter. 2003. Megaprojects and Risk: An Anatomy of Ambition. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781107050891.

FRA. 2021. "Dallas to Houston High-Speed Rail – Passenger Service from Houston to Dallas." 2021. https://railroads.dot.gov/environmental-reviews/dallas-houston-high-speed-rail/dallas-houston-high-speed-rail-passenger.

———. n.d. "Dallas to Houston High-Speed Rail Draft Environmental Impact Statement (DEIS) MAIN TEXT I." Accessed September 5, 2022a. https://railroads.dot.gov/elibrary/dallas-houston-high-speed-rail-draft-environmental-impact-statement-deis-main-text-i.

———. n.d. "Dallas to Houston High-Speed Rail Draft Environmental Impact Statement (DEIS)_MAIN TEXT III." Accessed September 5, 2022b. https://railroads.dot.gov/elibrary/dallas-houston-high-speed-rail-draft-environmental-impact-statement-deismain-text-iii.

———. n.d. "Dallas-Houston HSR Final EIS Main Text II." Accessed September 5, 2022c. https://railroads.dot.gov/elibrary/dallas-houston-hsr-final-eis-main-text-ii.

Frick, Karen Trapenberg. 2016. Remaking the San Francisco–Oakland Bay Bridge: A Case of Shadowboxing with Nature. New York, NY: Routledge. https://www.routledge.com/Remaking-the-San-FranciscoOakland-Bay-Bridge-A-Case-of-Shadowboxing/Frick/p/book/9781138209329.

Frick, Karen Trapenburg. 2008. "The Cost of the Technological Sublime: Daring Ingenuity and the New San Francisco-Oakland Bay Bridge." In Decision-Making on Mega-Projects: Cost–Benefit Analysis, Planning, and Innovation, edited by Hugo Priemus, Bent Flyvbjerg, and Bert Van Wee, 239–62. Northampton, MA: Edward Elgar.

FTA. 2022. "Long-Range Statewide Transportation Plan." November 21, 2022. https://www.transit.dot.gov/regulations-and-guidance/transportation-planning/long-range-statewide-transportation-plan.

Fu, Jinyang, Ningning Zhao, Yong Qu, Junsheng Yang, and Shuying Wang. 2022. "Effects of Twin Tunnel Undercrossing Excavation on the Operational High Speed Railway Tunnel with Ballastless Track." Tunnelling and Underground Space Technology 124 (June): 104470. https://doi.org/10.1016/j.tust.2022.104470.

Gardner, Dan, and Bent Flyvbjerg. 2023. "How Big Things Get Done: The Surprising Factors That Determine the Fate of Every Project, from Home Renovations to Space Exploration and Everything In Between." Penguin Random House Canada. 2023. https://www.penguinrandomhouse.ca/books/672118/how-big-things-get-done-by-dan-gardner-and-bent-flyvbjerg/9780771098437.

Geng, Bin, Haijun Bao, and Ying Liang. 2015. "A Study of the Effect of a High-Speed Rail Station on Spatial Variations in Housing Price Based on the Hedonic Model." Habitat International 49 (October): 333–39. https://doi.org/10.1016/j.habitatint.2015.06.005.

Geography and Railway Traffic Research Group, Fundación de los Ferrocarriles Españoles (FFE). 2022. "High-Speed Rail Atlas 2022." https://uic.org/IMG/pdf/uic-atlas-high-speed-2022.pdf.

Ginsberg, Benjamin, and Collin Paschall. 2022. Speaking Truth to Power: Expertise, Politics and Governance. Speaking Truth to Power. Cheltenham, UK: Edward Elgar Publishing. http://www.elgaronline.com/display/book/9781803927633/9781803927633.xml.

Givoni, Moshe. 2006. "Development and Impact of the Modern High-speed Train: A Review." Transport Reviews 26 (5): 593–611. https://doi.org/10.1080/01441640600589319.

Givoni, Moshe, and Anthony Perl. 2020. "Rethinking Transport Infrastructure Planning to Extend Its Value over Time." Journal of Planning Education and Research 40 (1): 82–91. https://doi.org/10.1177/0739456X17741196.

GOAA, and Greater Orlando Aviation Authority. 2022. "Orlando International Remains Busiest Airport In Florida For 2021 & Becomes 7th Busiest In USA." Orlando International Airport (MCO). 2022. https://orlandoairports.net/press/2022/02/14/orlando-international-remains-busiest-airport-in-florida-for-2021-becomes-7th-busiest-in-usa/.

Hallegatte, Stéphane, and Jia Li. 2022. "Investing in Resilience and Making Investments Resilient." PLOS Climate 1 (10): 1–3. https://doi.org/10.1371/journal.pclm.0000077.

Hayashi, Yoshitsugu, Aoto Mimuro, Ji Han, and Hirokazu Kato. 2017. "The Shinkansen and Its Impacts." In High-Speed Rail and Sustainability: Decision-Making and the Political Economy of Investment, edited by Blas Luis Pérez Henríquez and Elizabeth Deakin, Chapter 3. Routledge. https://doi.org/10.4324/9781315709406.

High Speed Rail Alliance. 2022. "Brightline Florida: A Model for Fast, Successful Trains." High Speed Rail Alliance. June 10, 2022. https://www.hsrail.org/brightline%20florida.

Ho, S. Ping, and Chun-Wei Tsui. 2010. "When Are Public-Private Partnerships Not an Appropriate Governance Structure? Case Study Evidence." In Construction Research Congress 2010, 817–26. Banff, Alberta, Canada: American Society of Civil Engineers. https://doi.org/10.1061/41109(373)82.

Hodge, Graeme A., and Carsten Greve. 2017. "On Public–Private Partnership Performance: A Contemporary Review." Public Works Management & Policy 22 (1): 55–78. https://doi.org/10.1177/1087724X16657830.

International Monetary Fund(IMF). 2023. "World Economic Outlook: GDP, Current Prices." International Monetary Fund. 2023. https://www.imf.org/external/datamapper/NGDPD@WEO.

JapanRailPass. 2023. "Shinkansen Tickets: How to Buy and Use." Japan Rail Pass Travel Blog | JRailPass (blog). January 3, 2023. https://www.jrailpass.com/blog/shinkansen-tickets.

Jeng, Chi-Ruey, and Chao-Hsu Su. 2013. "The Predicament of Domestic Airline Service after the Introduction of Taiwan High-Speed Rail." Transportation Journal 52 (1): 134–43. https://doi.org/10.5325/transportationj.52.1.0134.

Joe Baker. 2018. "Is Spain's High-Speed Railway a Case of 'Too Much, Too Soon'?" Railway Technology (blog). October 25, 2018. https://www.railway-technology.com/analysis/spain-high-speed-railway/.

Koppenjan, Joop, and Martijn Leijten. 2014. "Privatising Railroads: The Problematic Involvement of the Private Sector in Two Dutch Railway Projects." Asia Pacific Journal of Public Administration 27 (January): 181–99. https://doi.org/10.1080/23276665.2005.10779307.

Landis, John D., ed. 2022. Megaprojects for Megacities: A Comparative Casebook. 1st ed. Edward Elgar Publishing. https://www.e-elgar.com/shop/usd/megaprojects-for-megacities-9781803920627.html.

Li, Feng, Yang Su, Jiaping Xie, Weijun Zhu, and Yahua Wang. 2020. "The Impact of High-Speed Rail Opening on City Economics along the Silk Road Economic Belt." Sustainability 12 (8): 3176. https://doi.org/10.3390/su12083176.

Lin, Yatang. 2017. "Travel Costs and Urban Specialization Patterns: Evidence from China's High Speed Railway System." Journal of Urban Economics 98 (March): 98–123. https://doi.org/10.1016/j.jue.2016.11.002.

Lloyd, Danica. 2021. "Texas Central Signs $16B Construction Contract for High-Speed Rail Project." Impact. June 15, 2021. https://communityimpact.com/houston/cy-fair/transportation/2021/06/15/texas-central-signs-16b-construction-contract-for-high-speed-rail-project/.

Macrotrends. n.d. "Amsterdam, Netherlands Metro Area Population 1950-2022." Accessed October 21, 2022a. https://www.macrotrends.net/cities/21930/amsterdam/population.

———. n.d. "Bruxelles-Brussel, Belgium Metro Area Population 1950-2022." Accessed October 21, 2022b. https://www.macrotrends.net/cities/20144/bruxelles-brussel/population.

Marshall, Alfred. 1890. "Principles of Economics Macmillan." London (8th Ed. Published in 1920).

Ministry of Digital Affairs, Taiwan. 2022. "Taiwan High-Speed Rail Stations." Data.Gov.Tw. 2022. https://data.gov.tw/dataset/73225.

Ministry of the Interior, Taiwan. 2021. "Household Registration Statistics,Taiwan." 2021. https://www.ris.gov.tw/app/en/3910.

Miralles i Garcia, J.L. 2017. "Integration of High-Speed Train Stations in Cities: The Case of Spain and Valencia City." International Journal of Transport Development and Integration 1 (4): 677–94. https://doi.org/10.2495/TDI-V1-N4-677-694.

MRSC(Municipal Research and Services Center of Washington). 2022. "Comprehensive Plan Update Process." MRSC. November 7, 2022. https://mrsc.org/explore-topics/planning/general-planning-and-growth-management/comprehensive-plan-updates.

Nash, Chris. 2015. "When to Invest in High Speed Rail." Journal of Rail Transport Planning & Management 5 (1): 12–22. https://doi.org/10.1016/j.jrtpm.2015.02.001.

Ni, Jason, Jason Chang, and T.C. Kao. 2017. "Taiwan's HSR and the Financial Crises of the Taiwan High Speed

Rail Corporation." In High-Speed Rail and Sustainability, edited by Blas Luis Pérez Henríquez and Elizabeth Deakin, Chapter 8. Routledge. https://doi.org/10.4324/9781315709406.

North, Douglass C. 1990. Institutions, Institutional Change and Economic Performance. New York: Cambridge University Press. https://doi.org/10.1017/CBO9780511808678.

Nuworsoo, Cornelius, and Elizabeth Deakin. 2009. "Transforming High-Speed Rail Stations to Major Activity Hubs: Lessons for California."

Omega Center. 2014. "Netherlands HSL-Zuid Profile." Omega Centre: Centre for Mega Projects in Transport and Development. http://www.omegacentre.bartlett.ucl.ac.uk/wp-content/uploads/2014/12/NETHERLANDS_HSL_ZUID_PROFILE.pdf.

———. n.d. "OMEGA Case Studies – Project Profiles of 30 Mega Urban Transport Projects (MUTPs) Case Studies." Accessed October 21, 2022. http://www.omegacentre.bartlett.ucl.ac.uk/publications/omega-case-studies/.

OpenRailwayMap. 2023. "OpenRailwayMap." 2023. https://www.openrailwaymap.org/.

Pagliara, Francesca. 2019. "High Speed Rail, Megalopolis and House Prices: What Is the Link?" International Journel of Real Estate and Land Planning 2: 125–36. https://ejournals.lib.auth.gr/reland.

Pakkala, Pekka. 2002. "Innovative Project Delivery Methods for Infrastructure: An International Perspective." Helsinki: Finnish Road Enterprise. https://www.tieh.fi/julkaisut/pdf/pakkalae5.pdf.

Preston, Robert. 2022. "DB Joins Star Alliance as First Rail Partner." International Railway Journal (blog). July 18, 2022. https://www.railjournal.com/passenger/main-line/db-joins-star-alliance-as-first-rail-partner/.

Priemus, Hugo. 2009. "Do Design & Construct Contracts for Infrastructure Projects Stimulate Innovation? The Case of the Dutch High Speed Railway." Transportation Planning and Technology 32 (4): 335–53. https://doi.org/10.1080/03081060903119592.

Railway Technology. 2020. "Brightline High-Speed Rail Project, Florida." Railway Technology (blog). 2020. https://www.railway-technology.com/projects/brightline-high-speed-rail-project-florida/.

Rende. 2022. "Alta Velocidad (High Speed) – a Success Story." 2022. https://www.renfe.com/es/en/renfe-group/corporations/renfe-passengers/passengers-get-to-know-us/high-speed.

Riddle, Molly, and Jan Whittington. 2022. "A Tunnel beneath Seattle: The Megaproject to Replace the Alaskan Way Viaduct." In Megaprojects for Megacities: A Comparative Casebook, 275–305. Cheltenham, UK: Edward Elgar. https://www.elgaronline.com/edcollchap/book/9781803920634/book-part-9781803920634-14.xml.

Rodriguez, Gilbert. 2020. "Rep. Toth Urges TxDOT to Cease Relationship with High-Speed Rail, Citing Tripled Costs & Investor Concerns." Texasinsider. 2020. http://texasinsider.org/articles/citing-tripled-costs-and-investor-concerns-rep-toth-urges-txdot-to-cease-relationship-with-high-speed-rail.

Roll, Martin, and Alain Verbeke. 1998. "Financing of the Trans-European High-Speed Rail Networks:: New Forms of Public–Private Partnerships." European Management Journal 16 (6): 706–13. https://doi.org/10.1016/S0263-2373(98)00047-4.

Román, Concepción, Raquel Espino, and Juan Carlos Martin. 2007. "Competition of High-Speed Train with Air Transport: The Case of Madrid–Barcelona." Journal of Air Transport Management 13 (5): 277–84.

Shan, Shelley. 2020. "Taoyuan Airport Drops in World Rankings- Taipei Times." Taipei Times. May 13, 2020. https://www.taipeitimes.com/News/taiwan/archives/2020/05/13/2003736314.

———. 2021. "Taoyuan Fourth on Airport Freight List- Taipei Times." April 26, 2021. https://www.taipeitimes.com/News/taiwan/archives/2021/04/26/2003756370.

Shao, Shuai, Zhihua Tian, and Lili Yang. 2017. "High Speed Rail and Urban Service Industry Agglomeration: Evidence from China's Yangtze River Delta Region." Journal of Transport Geography 64 (October): 174–83. https://doi.org/10.1016/j.jtrangeo.2017.08.019.

Skores, Alexandra, and Matthew Griffin. 2022. "Texas Supreme Court Says Company Can Use Eminent Domain for Dallas-Houston Bullet Train." June 24, 2022. https://www.dallasnews.com/business/local-companies/2022/06/24/texas-supreme-court-rules-30-billion-dallas-to-houston-bullet-train-can-go-forward/.

Strauss, Jack, Hongchang Li, and Jinli Cui. 2021. "High-Speed Rail's Impact on Airline Demand and Air Carbon Emissions in China." Transport Policy 109 (August): 85–97. https://doi.org/10.1016/j.tranpol.2021.05.019.

Supreme Court of Texas. 2022. "On Petition for Review from the Court of Appeals for the Thirteenth District of Texas." http://docs.texasappellate.com/scotx/op/20-0393/2022-06-24.lehrmann.pdf.

Taiwan High Speed Rail. 2022. "Taiwan High Speed Rail- Ticket and Fare." 2022. https://en.thsrc.com.tw/.

Taiwan Railway Bureau. 2010. "Taiwan High-Speed Railway follow-up construction projects."

———. 2020. "Feasibility Study Report on the New Line of High Speed Rail Extension in Pingtung (Approved Version)." https://www.ey.gov.tw/File/95146772F14C7711.

———. 2021a. "Development Plan for Land Acquisition in Specific Areas of High-speed Railway Stations." Text/html. Taiwan Railway Bureau. Taiwan Railway Bureau. March 30, 2021. https://www.rb.gov.tw/showpage.

php?lmenuid=3&smenuid=69&tmenuid=98&pagetype=0.

———. 2021b. "Taiwan High Speed Rail Extension Yilan Project: Yilan End Station Site Scheme Local Explanation Session." September.

———. 2022a. "Project Introduction- High Speed Rail Construction- Taiwan High Speed Rail." Text/html. Taiwan Railway Bureau. Taiwan Railway Bureau. March 11, 2022. https://www.rb.gov.tw/showpage.php?lmenuid=3&smenuid=68&tmenuid=93&pagetype=0.

———. 2022b. "Project Introduction- Prospective Construction- High Speed Rail Extension Pingtung Planning Operation." Text/html. September 8, 2022. https://www.rb.gov.tw/showpage-print.php?lmenuid=3&smenuid=166&tmenuid=139&pagetype=0.

Texas Central. 2022. "The Project, Texas Central." Texas Central. 2022. https://www.texascentral.com/project/.

———. 2023. "Learn The Facts: Texas Central." Texas Central. 2023. https://www.texascentral.com/facts/.

Texas High-Speed Rail Station Development Corporation. n.d. "Texas High-Speed Rail Investors Form Station Development Company." Accessed September 5, 2022. https://www.prnewswire.com/news-releases/texas-high-speed-rail-investors-form-station-development-company-301398930.html.

Thalys Eurostar Group. n.d. "Discover All the Thalys Trains Destinations." Accessed September 3, 2022. https://www.thalys.com/de/en/all-our-destinations.

the State of Washington. 2022. "Engrossed Substitute Senate BillNG 5689-Supplemental Transportation Budget." https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Session%20Laws/Senate/5689-S.SL.pdf.

Thompson, Ian. 1994. "The French TGV System — Progress and Projects." Geography 79 (2): 164–68. https://www.jstor.org/stable/40572412.

Trabo, I., A. Landex, J. E. Schneider-Tilli, and O. A. Nielsen. 2013. "The New Line Copenhagen-Ringsted: The Benefits from EU Railway Benchmarking." Computers in Railways XIII: Computer System Design and Operation in the Railway and Other Transit Systems 127: 369. https://doi.org/10.2495/CR120311.

Trading Economics. 2022. "Taiwan Exports." 2022. https://tradingeconomics.com/taiwan/exports.

UIC. 2023. "Intercity and High-Speed." UIC - International Union of Railways. January 8, 2023. https://uic.org/passenger/highspeed/.

UIC, International union of railways. 2022a. "Atlas High-Speed Rail 2022." Paris, France: UIC, International union of railways. https://uic.org/IMG/pdf/uic-atlas-high-speed-2022.pdf.

———. 2022b. "UIC Activity Report 2020-2021." Paris, France: UIC - International union of railways. https://uic.org/IMG/pdf/uic_activity_report_2020-2021.pdf.

United Nations Economic Commission for Europe. 2016. "Review of the PPP Work since the Eighth and Final Session of the Team of Specialists on PPPs on 20-21 October 2016." https://unece.org/fileadmin/DAM/ceci/documents/2017/PPP/WP/Presentations/UNECE-WP_PPP_2017-Review_work_since_2016-Standards_and_Guidelines.pdf.

Universal Engineering Sciences. 2022. "Brightline High-Speed Rail (Formally All Aboard Florida)." 2022. https://teamues.com/project/all-aboard-florida/.

US Census. 2022. "American Community Survey (ACS)." Census.Gov. 2022. https://www.census.gov/programs-surveys/acs.

———. n.d. "U.S. Census Bureau QuickFacts: Texas; Bryan City, Texas; College Station City, Texas; Dallas City, Texas; Houston City, Texas." Accessed September 5, 2022. https://www.census.gov/quickfacts/fact/table/TX,bryancitytexas,collegestationcitytexas,dallascitytexas,houstoncitytexas/PST045221.

US Census, US Census. 2021. "Florida Was Third-Largest State in 2020 With Population of 21.5 Million." Census.Gov. 2021. https://www.census.gov/library/stories/state-by-state/florida-population-change-between-census-decade.html.

U.S. Department of Transportation, Federal Railroad Administration. 2020. "Florida High-Speed Rail Corridor: Tampa-Orlando | FRA." 2020. https://railroads.dot.gov/environment/environmental-reviews/florida-high-speed-rail-corridor-tampa-orlando.

Wachs, Martin. 1989. "When Planners Lie with Numbers." Journal of the American Planning Association 55 (4): 476–79.

———. 1990. "Ethics and Advocacy in Forecasting for Public Policy." Business & Professional Ethics Journal 9 (1/2): 141–57. https://doi.org/10.5840/bpej199091/215.

———. 2013. "The Past, Present, and Future of Professional Ethics in Planning." In Policy, Planning, and People, edited by Susan S Fainstein, Naomi Carmon, Susan S. Fainstein, and Naomi Carmon, 101–20. Philadelphia: University of Pennsylvania Press. https://doi.org/10.9783/9780812207965.101.

Wan, Yulai, Hun-Koo Ha, Yuichiro Yoshida, and Anming Zhang. 2016. "Airlines' Reaction to High-Speed Rail Entries: Empirical Study of the Northeast Asian Market." Transportation Research Part A: Policy and Practice 94 (December): 532–57. https://doi.org/10.1016/j.tra.2016.10.014.

Wang, Rong, Li Ye, and Liwen Chen. 2019. "The Impact of High-Speed Rail on Housing Prices: Evidence from China's Prefecture-Level Cities." Sustainability 11 (13): 3681.

Watson, Inara. 2021. "High-Speed Railway." Encyclopedia

1 (3): 665–88. https://doi.org/10.3390/encyclopedia1030053.

Webuild. n.d. “Texas High Speed Rail - Webuild.” Accessed September 5, 2022. https://texashighspeedrail.webuildgroup.com/en.

Wetwitoo, Jetpan, and Hironori Kato. 2017. “High-Speed Rail and Regional Economic Productivity through Agglomeration and Network Externality: A Case Study of Inter-Regional Transportation in Japan.” Case Studies on Transport Policy 5 (4): 549–59. https://doi.org/10.1016/j.cstp.2017.10.008.

Whittington, Jan. 2012. “When to Partner for Public Infrastructure?” Journal of the American Planning Association 78 (3): 269–85. https://doi.org/10.1080/01944363.2012.715510.

Wildavsky, Aaron B. 1979. Speaking Truth to Power: The Art and Craft of Policy Analysis. Boston: Little, Brown.

Willigers, Jasper, and Bert van Wee. 2011. “High-Speed Rail and Office Location Choices. A Stated Choice Experiment for the Netherlands.” Journal of Transport Geography 19 (4): 745–54. https://doi.org/10.1016/j.jtrangeo.2010.09.002.

World Bank. 2019. China’s High-Speed Rail Development. Washington, DC: World Bank Group. https://doi.org/10.1596/978-1-4648-1425-9.

———. 2021. “The State of Cities Climate Finance PART 2: The Enabling Conditions for Mobilizing Urban Climate Finance.” Washington, DC: World Bank. https://citiesclimatefinance.org/wp-content/uploads/2021/06/2021-State-of-Cities-Finance-Part-2.pdf.

———. 2022a. “Land Area - Spain, World Bank Data.” 2022. https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=ES.

———. 2022b. “Urban Population- Spain, World Bank Data.” 2022. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=ES.

———. 2023. “France: Place Explorer.” Data Commons. 2023. https://datacommons.org/place/country/FRA.

Xia, Wenyi, and Anming Zhang. 2017. “Air and High-Speed Rail Transport Integration on Profits and Welfare: Effects of Air-Rail Connecting Time.” Journal of Air Transport Management 65 (October): 181–90. https://doi.org/10.1016/j.jairtraman.2017.06.008.

Zhang, Anming, Yulai Wan, and Hangjun Yang. 2019. “Impacts of High-Speed Rail on Airlines, Airports and Regional Economies: A Survey of Recent Research.” Transport Policy 81 (September): A1–19. https://doi.org/10.1016/j.tranpol.2019.06.010.

Zhang, Fangni, Daniel J. Graham, and Mark Siu Chun Wong. 2018. “Quantifying the Substitutability and Complementarity between High-Speed Rail and Air Transport.” Transportation Research Part A: Policy and Practice 118: 191–215.

URBAN INFRASTRUCTURE LAB
UNIVERSITY of WASHINGTON

CHALLENGE SEATTLE

MOBILITY INNOVATION CENTER
UNIVERSITY of WASHINGTON