The Thesis Committee for Todd Davis Carroll
Certifies that this is the approved version of the following thesis:

Opportunities and Challenges for High-Speed Rail Corridors in Texas

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

C. Michael Walton

Jolanda Prozzi

Opportunities and Challenges for High-Speed Rail Corridors in Texas

by

Todd Davis Carroll, B.S.C.E.

Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Engineering

The University of Texas at Austin

August 2011

Dedication

“Restlessness is discontent and discontent is the first necessity of progress. Show me a thoroughly satisfied man and I will show you a failure.” – Thomas Alva Edison

For future generations unknowingly burdened by current lifestyles of irresponsible consumption of bounded resources resulting in rampant social inequities and unnecessarily arduous, insurmountable challenges. There is no better time for corrective action than the present, as the cost of doing nothing is not zero.

Acknowledgments

I greatly appreciate the faculty and staff of the transportation engineering program at UT-Austin and the Center for Transportation Research with whom I've worked closely in the last two years. Special thanks to C. Michael Walton and Jolanda Prozzi for valuable advice and technical insight. Additionally, I'd like to thank Chandra Bhat for his encouragement both at the undergraduate and graduate level and Vicki Simpson for her eager personal assistance. Many thanks, of course, to my parents for selflessly accepting my pursuit of two degrees more than half a continent away, undoubtedly a challenging, yet rewarding allowance for both them and me. Finally, to the vast group of mixed Austin personalities with whom I've become familiar over the last seven years: you will continue to color my perspectives, challenge my assumptions, and make me smile long into the future.

Submitted August 12, 2011

Abstract

Opportunities and Challenges for High-Speed Rail Corridors in Texas

Todd Davis Carroll, MSE

The University of Texas at Austin, 2011

Supervisor: C. Michael Walton

Texas features a growing economy and population. The state boasts a large and well-developed network of roads, freight railroads, and air facilities, which make the state a vital link in the movement of people and goods. However, as the state continues to grow in population and economic significance, these systems are straining to meet state, national, and even global needs. It is increasingly obvious to residents and state officials that Texas should consider implementing alternative modes of transport, including development of passenger rail, for which Texas currently lags behind many of its peer states. Passenger rail provides quantifiable benefits in displacing less energy-efficient and higher pollutant-emitting air and automobile modes while generating potential positive economic impacts and enhancing consumer choice and multimodalism. Conveniently, renewed national interest in rail has invigorated research measuring the applicability of passenger rail services to many different regions of the United

States, with the possibility that future national transportation visions will include passenger rail as an essential element. This thesis seeks to clarify the potential for passenger rail specifically in Texas through comparison and contrast with other regions and nations in the midst of new national-level knowledge and the changing transportation opportunities and challenges facing the state. Some of the ideal characteristics of successful international passenger systems exist in Texas, including optimal city spacing and a well-established rail network, which have fuelled ongoing interest demonstrated by various system proposals for high-speed intercity transportation in Texas over the last four decades. Despite these characteristics, the state presents a number of barriers to rail transport rooted in low transit use coupled with generally lower density and ambivalent support from politicians and residents when officials present realities of eminent domain and land use changes. However, with revitalized national rail interest and new federal rail planning requirements, the state may yet be able to work through these challenges to exploit the opportunities the state possesses.

Table of Contents

List of Figures

Chapter 1: Introduction and Background

By most measurements, the completion of Interstate 70 through Glenwood Canyon in Colorado in 1992 finally realized the original vision for the National System of Interstate and Defense Highways (Rowe et al, 2004). This stretch of highway is likely one of the most expensive sections of the entire system, as the 12 miles of highway adorning steep cliffs alongside the winding Colorado River cost $490 million (1992 dollars, Colorado Department of Transportation, 2006). Still, the project embodies the extensive nature of the system and provides an appropriately complex capstone and punctuation to the visionary project that effectively dictated United States transportation policy for four decades. Initial estimates placed the cost of the system as low as $25 billion and the total time of construction at 12 years; $114 billion ($425 billion in 2006 dollars) and 35 years later (Minnesota Department of Transportation, 2006) one of the most tangible actions of government reached a sense of finality.

The Intermodal Surface Transportation Equity Act of 1991 (ISTEA) brought the completion of the original Interstate Highway System vision. Quickly evident in the wake of ISTEA and the finishing of the Interstate System was the lack of a new coherent national transportation policy vision. As the Interstate System dictated national transportation policy until that time and no new vision existed, improvements on the nation’s highway system expectedly continued. However, in the absence of clear national policy, most of the expenses were in the form of grants to states, which would then spend money as they saw fit. Without any national political fortitude or strong rationale for changing policies, states continued outlays toward highway widening, extension, improvement, and modification (see Figure 1, BTS, 2010). The only major difference seen between 1995 and 2006 is a notable increase in the outlays for air transportation for 2006, mostly at the federal level, likely reflecting drastic changes in airport security and airport design requirements in response to the terrorist attacks of September 11, 2001.

	1995		2000		2006	
Highway total	**90,075**	**62.9%**	**119,911**	**64.3%**	**157,613**	**61.3%**
Federal	1,685	**1.2%**	2,190	**1.2%**	2,972	**1.2%**
State and local	88,391	**61.7%**	117,720	**63.2%**	154,641	**60.1%**
Transit total	**25,460**	**17.8%**	**34,828**	**18.7%**	**44,097**	**17.1%**
Federal	1,277	**0.9%**	3,677	**2.0%**	83	**0.0%**
State and local	24,183	**16.9%**	31,150	**16.7%**	44,014	**17.1%**
Rail total	**1,049**	**0.7%**	**778**	**0.4%**	**1,548**	**0.6%**
Federal	1,023	**0.7%**	765	**0.4%**	1,528	**0.6%**
State and local	26	**0.0%**	13	**0.0%**	20	**0.0%**
Air total	**19,250**	**13.4%**	**22,525**	**12.1%**	**41,873**	**16.3%**
Federal	10,807	**7.5%**	9,285	**5.0%**	23,480	**9.1%**
State and local	8,443	**5.9%**	13,240	**7.1%**	18,393	**7.2%**
Water total	**6,623**	**4.6%**	**7,634**	**4.1%**	**10,888**	**4.2%**
Federal	4,314	**3.0%**	4,493	**2.4%**	6,603	**2.6%**
State and local	2,309	**1.6%**	3,141	**1.7%**	4,286	**1.7%**
Pipeline total	**24**	**0.0%**	**46**	**0.0%**	**91**	**0.0%**
Federal	12	**0.0%**	28	**0.0%**	66	**0.0%**
State and local	12	**0.0%**	18	**0.0%**	25	**0.0%**
General support	**775**	**0.5%**	**653**	**0.4%**	**1,117**	**0.4%**
Federal	769	**0.5%**	645	**0.3%**	1,105	**0.4%**
State and local	6	**0.0%**	8	**0.0%**	12	**0.0%**
Total, all modes	**143,256**		**186,374**		**257,226**	
Federal	19,886		21,084		35,836	
State and local	123,369		165,290		221,391	

Figure 1: Government transportation expenditures by mode (2010 dollars) for 1995, 2000, 2006 (BTS, 2010)

Despite the highway-centric emphasis for funds, highway congestion increased substantially over the last two decades (TTI's annual Urban Mobility Report most famously documents this), likely indicating that expansion of highways has not kept pace with increases in highway demand, expansion of alternative modes has not been executed in a way to significantly curb highway demand, and demand management strategies for highways specifically have made only minimal penetration into policymakers' toolboxes.

Tucked into a proverbial corner of ISTEA, the legislation also designated the first five of the nation's high-speed rail (HSR) corridors. The designation of these corridors originally began not specifically as passenger corridors, but rather as speed and safety improvement corridors, where federal money provided for elimination of at-grade crossings. TEA-21 added six additional corridors, while the DOT and Congress have brought the number of these corridors to thirteen in 2011. In the high economic times of the mid-1990s, the prospect of higher-speed trains operating in the United States brought great interest to Texas as well, where foreign interests proposed connecting major Texas cities with a European-style high-speed passenger train system. Following complications that this thesis will later address, the Texas TGV system retreated from the Texas political mindset, although it continues to survive as a dream of localized rail enthusiasts. Proposals for passenger rail would resurface in the mid-to-late 2000s with the Trans-Texas Corridor (TTC) idea, the Passenger Rail Investment and Improvement Act (PRIIA), and Federal Railroad Administration (FRA) grants available in the 2009 American Recovery and Reinvestment Act (ARRA), followed by similar grants for FY2010. As one would expect, public musing about United States potential for high-speed passenger rail soared in recent years, particularly in highly populous regions of the country. The topic received only relatively mild attention in Texas, despite the proposal for passenger rail fifteen years earlier and a large (and growing) population. Given that national leaders continue fumbling for a definitive and transformative national transportation vision that will withstand the tests of time, and that high-speed passenger rail is the only major underdeveloped intercity travel mode in the United States, it seems reasonable that intercity passenger rail will, at minimum, exist as an essential component of a future transportation vision. This thesis develops the basic concepts relating to the success of high-speed passenger rail worldwide, while analyzing those concepts with a Texas emphasis, hoping to understand what role passenger rail may have in Texas as a part of potential future transportation policy. Then, using lessons from past experiences, particularly the Texas TGV, this thesis will analyze various corridor proposals in order to provide basic cost and location data. Finally, some recommendations and ideas for future work may provide direction for passenger rail in the state. In particular, this thesis addresses several research questions:

- What experiences do other populous states/regions have in planning, promoting, and implementing passenger rail that could inform the issue in Texas?
- What factors affect the potential for high-speed rail success, and how does Texas fare when considering these factors?
- What is the current state of multi-modal connectivity in Texas and how could connectivity be improved to encourage freedom of movement and success of a potential high-speed passenger rail system?
- How do spatial and legal considerations, particularly land use, zoning, and eminent domain restrictions affect corridor development?
- What role does energy use and environmental efficiency have in a potential high-speed passenger rail system in Texas?
- Where should state policymakers prioritize corridors in order to maximize success for a potential high-speed passenger rail system?
- What is the effect of past and future statewide politics on the success for a potential high-speed passenger rail system?
- What are some innovative ideas that might aid the realization of a high-speed passenger rail system in Texas?

To build valuable conclusions on the topic of high-speed passenger rail in Texas, this thesis will first introduce a brief history of transportation development in the state, providing background information for the posed research questions. Next, this thesis will move through each of these questions, devoting a single chapter to each. A simple evaluation tool and method is developed to determine the most feasible approaches to corridor prioritization. Finally, a series of conclusions based on the work from the prior chapters as well as directions for future work will close the document. Much of the passenger rail research, especially for HSR, takes place outside the United States. Consequently, this document will use American units as often as possible given the application in Texas, however use of research and data from abroad will occasionally require use of SI units or a mixture of the two systems.

HISTORY OF STATE TRANSPORTATION FACILITIES DEVELOPMENT

The Texas transportation network is quite extensive. Stemming from a forward-thinking state highway program in the 1950s and 1960s, the state's large land area (268,000 square miles), and more recently a large population influx, the state-maintained road network is expansive, covering 192,150 lane-miles. Of this, federal and state highways comprise less than 50% and the state's farm-to-market road system covers 44% of the state's highway lane-miles, the largest segment (Texas 2030 Committee 2010). Indicative of the state's vast highway network, Interstate 10 from Anthony, TX (at the New Mexico state line) to Orange, TX (at the Louisiana state line) forms the longest segment of interstate highway within a single state at 880 miles. With Texas' largely agricultural history, roads have played a major role in the economic development of the state (hence the name "farm-to-market"), which also helps to explain the extensive system.

What initially began as trails blazed by Native Americans and Spanish explorers became Texas' first roads. Remaining largely unimproved for many years, the emergence of hard-paved roads did not occur until well into the twentieth century, when the state highway department was founded in 1917. By 1929, Texas boasted nearly 18,000 miles of roads, of which approximately half were hard-surfaced. With Great Depression efforts by the department to provide jobs, some additional 3,000 miles of roads were constructed in the next six years, with simultaneous improvements to facilities benefiting drainage, visibility, ride quality, and general safety. World War II placed notable limits on supplies, thereby curtailing expansion of the state's road system until the post-war era. However, the abrupt dismissal of these limitations following the war period ushered in the largest period of development in the Texas roadway system. As early as 1945, state transportation authorities approved additional construction for 7,500 miles of new rural highways. This legislative encouragement for development of the state rural road system continued for several years, reaching its peak in 1962 where the program expanded to include 50,000 miles of roads at a cost of at least $23 million annually (more than $170 million annually in 2011 when adjusted for inflation). Simultaneously, the nationwide system of Interstate and Defense Highways commenced in 1956, for which states completed construction and received federal reimbursement. By 1989, Texas completed nearly 42,000 centerline miles of secondary highways (the largest in the world), and more than 3,000 miles of Interstate highways, the majority of the Texas contribution to the system (Kite, 2011). As with much of the United States, the demand for roads ballooned in Texas over the last six decades as vehicles miles traveled (VMT) increased drastically at the expense of most other modes of travel (see Figure 2 below). Additionally, the state, like many others, has struggled recently to cover the maintenance costs of existing roads while also providing additional capacity to permit continued growth in VMT. It is in this context that non-road-based travel approaches are of renewed local, state, and federal interest for both passengers and freight.

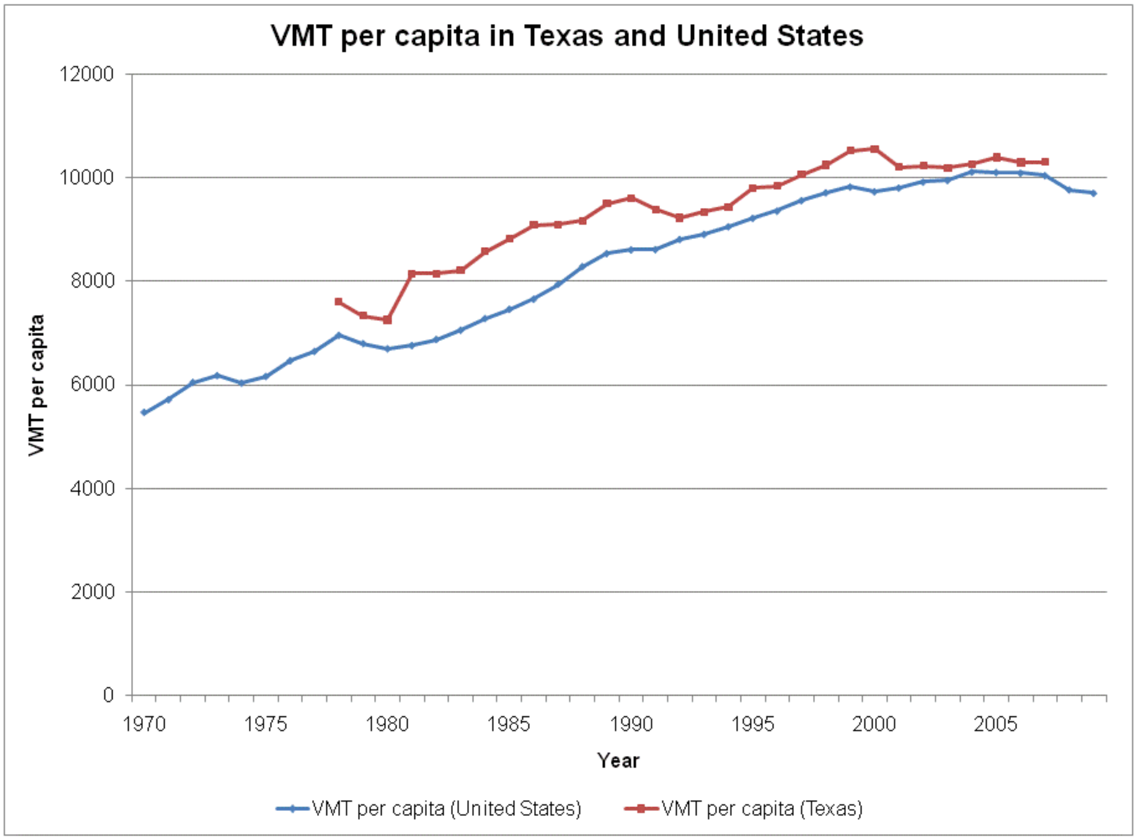


Figure 2: VMT per capita in Texas and the United States 1970-2009 (Dallas Indicators, 2011, FHWA, 2011, and Texas Department of Public Safety, 2011)

Rail has historically played a large role in Texas' transportation, primarily by providing connections to the state's agriculture areas. As with roads, Texas boasts the nation's largest network of freight rails, with 44 railroads operating nearly 15,000 miles of track, including trackage rights. Large Class I railroads operate a majority of these rails, linking major port and border cities of the state with other important freight centers of the United States. Texas leads all states in terminated rail-tons shipped. Major east-west rail movement is largely comprised of unit trains on UP tracks connecting the nation's coastal ports. BNSF dominates north-south movement, which serves the coal-rich Powder River Basin in Wyoming, providing an energy source for much of the state (TxDOT, 2010c).

Through 1850 and 1860, transportation still presented a major problem to settlers in Texas, who largely found themselves along rivers or the Texas coast. A number of attempts to develop rail lines were complicated due to lack of capital and land, but by 1861, nine companies operated 470 miles of track, much of it in and around Houston connecting different port facilities. The insufficient local capital to fund railroads and East Coast financiers wary of a frontier state required that the state, counties, and cities issue bonds to provide the necessary funding for many of the railroads. Land grant laws passed in the 1850s also encouraged railroad development. Following the Civil War, most of Texas' railroads remained functional unlike many railroads in confederate states, but suffered from years of overuse and neglect. However, with land grants, railroads began to crisscross the state by the 1870s. Texas connected to the national rail network in 1872 when the Missouri, Kansas, and Texas railroad met existing tracks in Denison. By 1890, rail had seen great increases in track with more than 6,000 miles constructed since 1880. With the conglomeration of the Gould system and monopolization of railroads in the next decades, the national rail system would reach its peak in 1916, although more than forty-five percent of Texas rail was constructed after this. The Texas Railroad Commission was created in 1891 as a regulatory body to counteract the increasing power and scandalous actions of the rail monopoly. Electric Interurban Railways made a foray into Texas rail transportation in the first three decades of the twentieth century. About 500 miles of interurban railways were eventually constructed primarily for passenger service. With increasing downward pressure on demand for rail due to the influx of personal automobiles, the Great Depression, and World War II, most of the interurban railways ceased operations by 1940. Streamlined diesel passenger service operated between Texas' major cities beginning late in the 1930s. Following several successful years of operation and increased positive economic outlook after World War II, diesel passenger rail operators purchased new equipment and entered a period of extensive passenger operation. This time would be short-lived with competition from automobiles and passenger jets rapidly siphoning demand for passenger rail. Amtrak absorbed the remaining passenger rail operations in 1970 (Rieder, 2011 and Werner, 2011). Figure 3 shows the contrast in passenger services in the twentieth century, particularly the drastic change between 1950 and 1970. Since 1970, Texas continues to operate the largest rail network of any state in the nation, although with limited passenger service. While railroads once connected the far-flung rural and agricultural regions of the state, they contribute only a minor amount to commodities moved by rail in the state at present. Coal is by far the largest commodity terminating in Texas, although stone and gravel, chemicals, food products, and intermodal freight also terminate in significant quantities. Outgoing freight has a similar makeup, with the major exception of coal. Petroleum is a major commodity exported from Texas as well (Association of American Railroads, 2011).

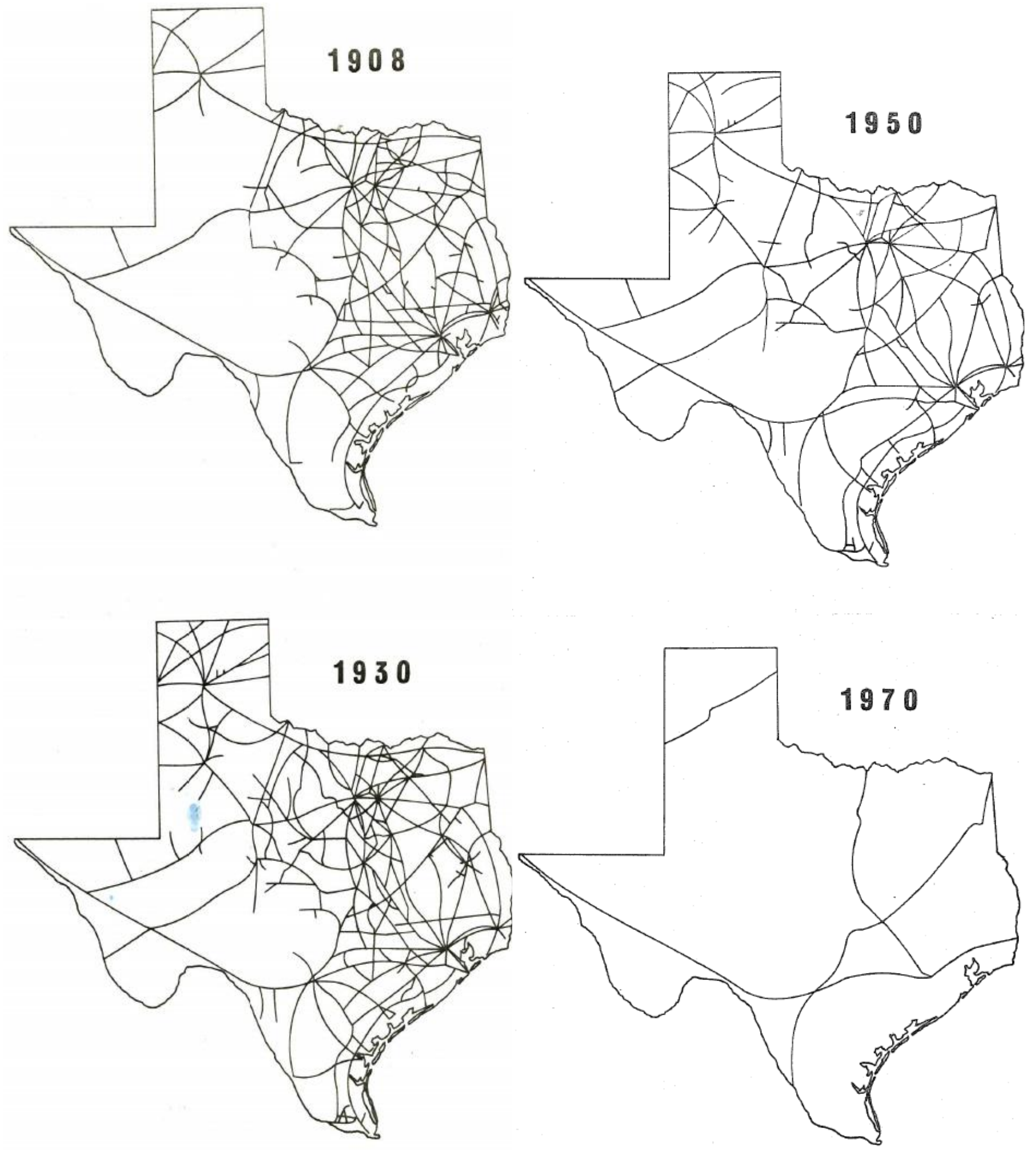


Figure 3: Passenger rail in Texas during twentieth century (Christensen, 1977)

In addition to the well-developed network of roads and freight rails, Texas also leads the nation in air facilities. Texas has more airports (292) and landing facilities (more than 1600) than any other US state, and asserts itself nationally in passenger air travel (TxDOT, 2010b). Three of the nation's largest passenger air carriers – American, Continental (United), and Southwest – are all headquartered in Texas. American and Continental/United have large hub operations at

Dallas/Ft.Worth and Houston Intercontinental airports, respectively, while Southwest provides frequent intercity service between Texas' major cities and other cities in the state and nationwide.

The history of air transportation is expectedly shorter than that of roads and rail, but it influences the trajectory of Texas transportation systems development at present. World War I first brought aircraft to Texas, where new military operations were developed and student pilots appreciated the quality flying weather and level terrain. Texans quickly became inclined to utilize flying as a means for transport in a large state with relatively large distances between cities. The 1930s and 1940s brought Texas' first commercial service from Braniff Airways operating out of Dallas Love Field. American Airlines also entered the Dallas market, providing services that linked the city with both coasts of the country. World War II saw a great influx of military pilots training at many of Texas' military bases. After the war, the demand for general aviation greatly increased as the state's increased business interests and connections to both coasts necessitate new urban airports. Houston Intercontinental airport opened in 1969, while Dallas-Fort Worth International airport saw its first flights in 1973. These facilities continue to impact state and national air travel, as they have both been adopted as major hub cities for the commercial airline operations of Continental (soon to be United) Airlines, and American Airlines, respectively. Austin Bergstrom International Airport (opened in 1997) is one of the newest airports in the nation and a successful demonstration of conversion from military operations to commercial and general aviation. The other major airports in the state have undergone recent improvements to increase capacity. Dallas Love Field and Houston Hobby will undergo renovations in the coming years, largely funded by the majority carrier, Southwest Airlines. Houston Intercontinental completed the Terminal E expansion in 2004, while Dallas-Ft. Worth International opened international Terminal D and the sleek Skylink people mover system in 2005.

POPULATION GROWTH

Texas' economic growth over the last thirty years is incredibly noteworthy. Though various cycles of economic growth and decline particularly affected Texas' peer states, Texas generally seems to have weathered these with relative ease. Since World War II, Texas decennial population growth has exceeded US growth as a whole by at least 5%, with this rate closer to 10% in more recent decades. Texas growth has continued to be higher than that of the entire country by nearly 10% (US Census Bureau, 2010a). This continued growth led Texas to pass New York in the 1990s, becoming the second most populous state in the nation. Texas cities continue to expand (see Figure 4 below), with three of the ten largest cities proper in the United States located in Texas – Dallas, Houston, and San Antonio. In terms of metropolitan population, Dallas/Ft. Worth and Houston are the central cities in the fourth and sixth largest MSAs in the United States, respectively, as of 2009 Census estimates. Together, they have grown by more than 24% since 2000 and now boast a combined population of more than thirteen million people. Other Texas metropolitan areas have seen similar growth rates since 2000. The Austin-Round Rock MSA has seen 36% growth, adding nearly 500,000 people, while the San Antonio MSA has grown by nearly 400,000, or about 21% from 2000 to 2009 (US Census Bureau, 2010b). While not confined to the eastern half of the state, growth has been slower in the other areas of the state; many of the mid-sized cities and rural counties in the western half of the state have seen stagnant population growth and/or decline over the last twenty years. The major exceptions to this include border cities in the Rio Grande Valley and El Paso, for which growth rates mirror the rest of the state. Cities in the border regions of South Texas, such as Laredo and McAllen, have experienced growth in excess of 25% since 2000, while El Paso has demonstrated a more modest, yet still significant growth rate of 10% over the same period (US Census Bureau, 2010b).

Texas population growth over the last decade presents a fascinating trend as Texas capitalizes on the overall national shift of population both south and west. Within state lines, however, this growth is heavily concentrated in the metropolitan areas, particularly those in the eastern half of the state. The Texas State Data Center estimates (0.5 scenario, which was utilized for the update of the Texas Rail Plan in 2010) that the state will add an additional 10 million people by 2040, with 92% of these new residents living in metropolitan counties of 50,000 people or more. As trends have suggested in recent years, the population of the state’s rural areas, particularly west of the I-35 corridor, will continue to lose people as migration to urban areas continues. Contrary to perhaps some stereotypes, Texas is already a highly urbanized state with about 85% of residents in metropolitan areas; Texas State Data Center estimates suggest that this number will only increase. Population increases naturally correlate with increased demand for transportation, as one intuitively expects. Urban population growth in particular results in enough demand to justify service by higher speed modes, and thus provides an impetus for considering higher speed transportation modes connecting the urban areas in Texas.

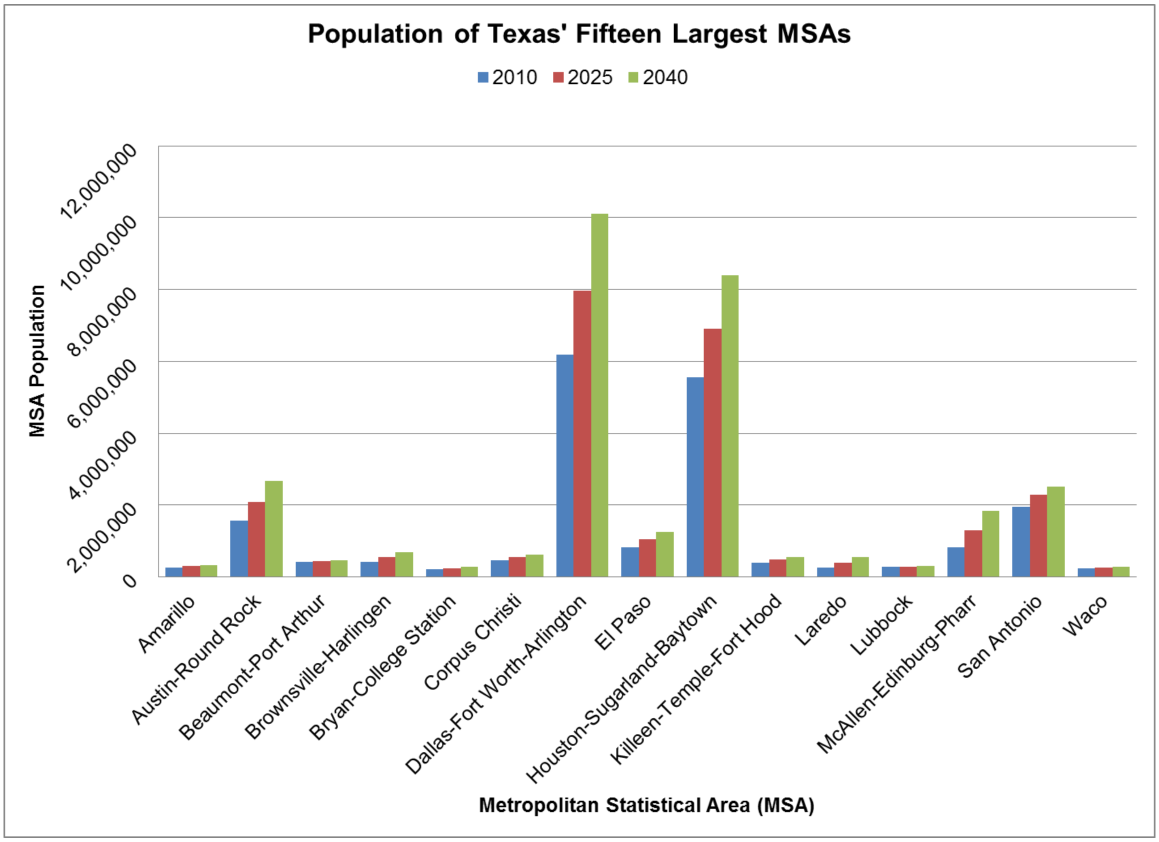
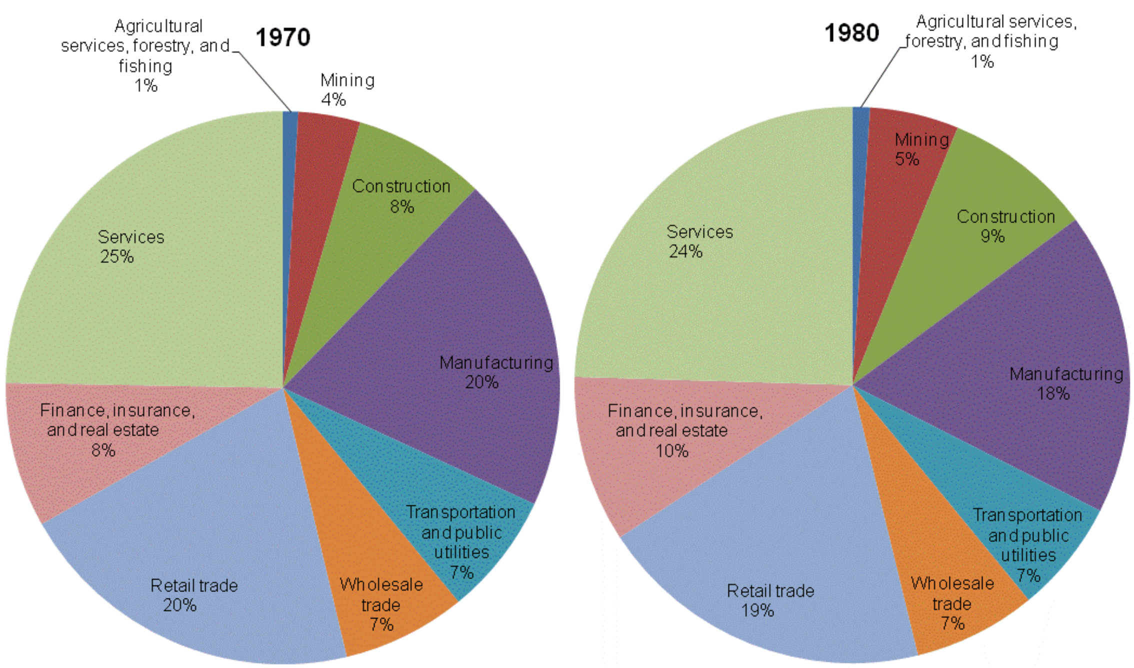


Figure 4: Population Texas' fifteen largest MSAs 2010-2040 (Texas State Data Center, 2008)

Economic Changes and Employment Growth

The Texas economy has grown in both scale and diversity. While much of the state's economy was oriented around extensive oil and gas operations well into the 1980s, Texas has since attracted a variety of different industries to its cities and suburbs, including relocations of corporate headquarters for such household names as American Airlines (AMR), JCPenney, and Kimberly-Clark to the Dallas/Ft. Worth area, for example. Houston, in addition to retaining continued affiliation with the energy sector, has developed a strong relationship with the healthcare and the aerospace industries, in part due to the proximity of the Texas Medical Center in central Houston, and the Johnson Space Center in the southeastern suburbs of the city. As of

2011, 51 Fortune 500 corporations located corporate headquarters in Texas, a leader in the United States, along with New York (57) and California (53) (Fortune, 2011). While many of these companies are still energy-related and headquartered in the Dallas and Houston metropolitan areas, San Antonio and Austin are also home to diversifying economies, especially the high-tech and biotech industries in Austin, and the communications and healthcare industries in San Antonio. For instance, Dell Computers calls Round Rock (a northern Austin suburb) home, and San Antonio houses the headquarters for media conglomerate Clear Channel Communications. The state's central geographic location has led many companies with large distribution operations to set up office in the state. Texas' extensive system of roads, airports, and freight rail make the state well-connected to the rest of the nation for goods movement. Figure 5 illustrates the economic makeup of Texas in 1970, 1980, 1990, and 2000. Worth noting is the apparent replacement of manufacturing jobs with service-oriented jobs, and the decreasing proportion of mining jobs (which include oil and gas extraction).



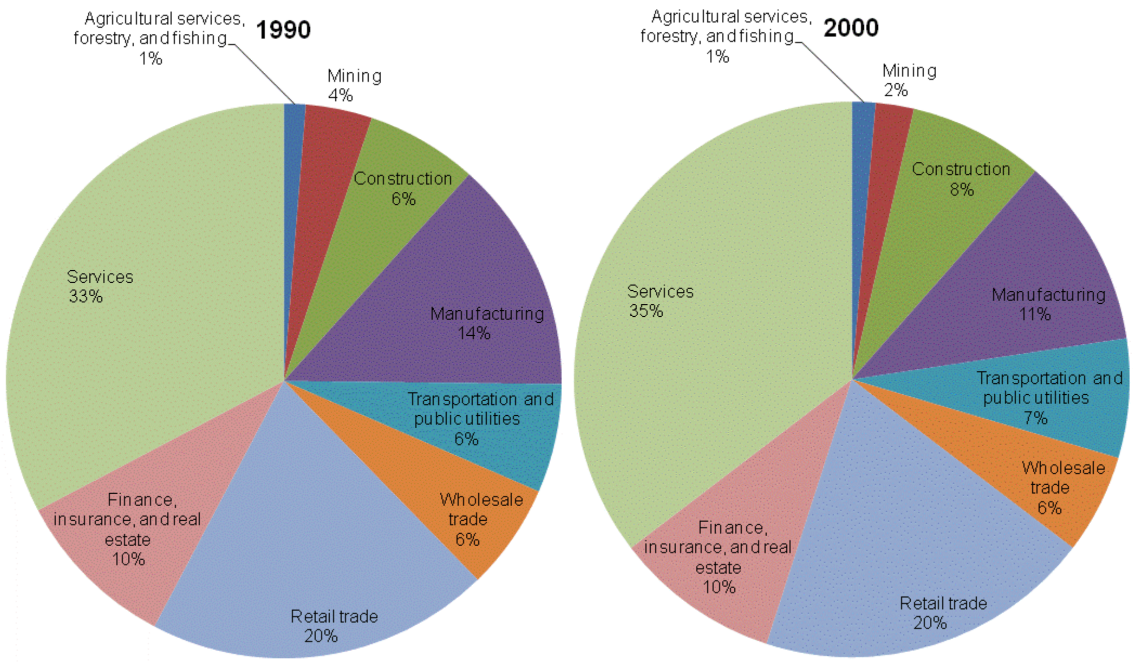


Figure 5: Texas private employment by SIC group, selected years (BEA, 2009)

As has been demonstrated in recent years, many people in Texas and the United States are accustomed to an economic system sustained only by continued growth, which fuels cyclical increases in many economic aspects (and great discomfort when prior growth rates are not sustained, as this most recent recession demonstrated). Transportation is no exception to this, as RA Smith (2003) describes whimsically:

> "Everyone has personal knowledge of the increases in mobility that have occurred in their lives. Whereas today's grandparents travelled within a relatively small compass, often only near their local town or village, to travel across the globe both for business and pleasure is now relatively commonplace."

Succinctly capturing this idea, Schafer and Victor (2000) illustrate that increases in income bring consistent increases in travel across different global populations. Texas shows this relationship between vehicle-miles traveled (VMT) per capita and gross state product (GSP) over the last 35 years (Figure 6), although slower per capita VMT growth in recent years diverges slightly from this clear trend.

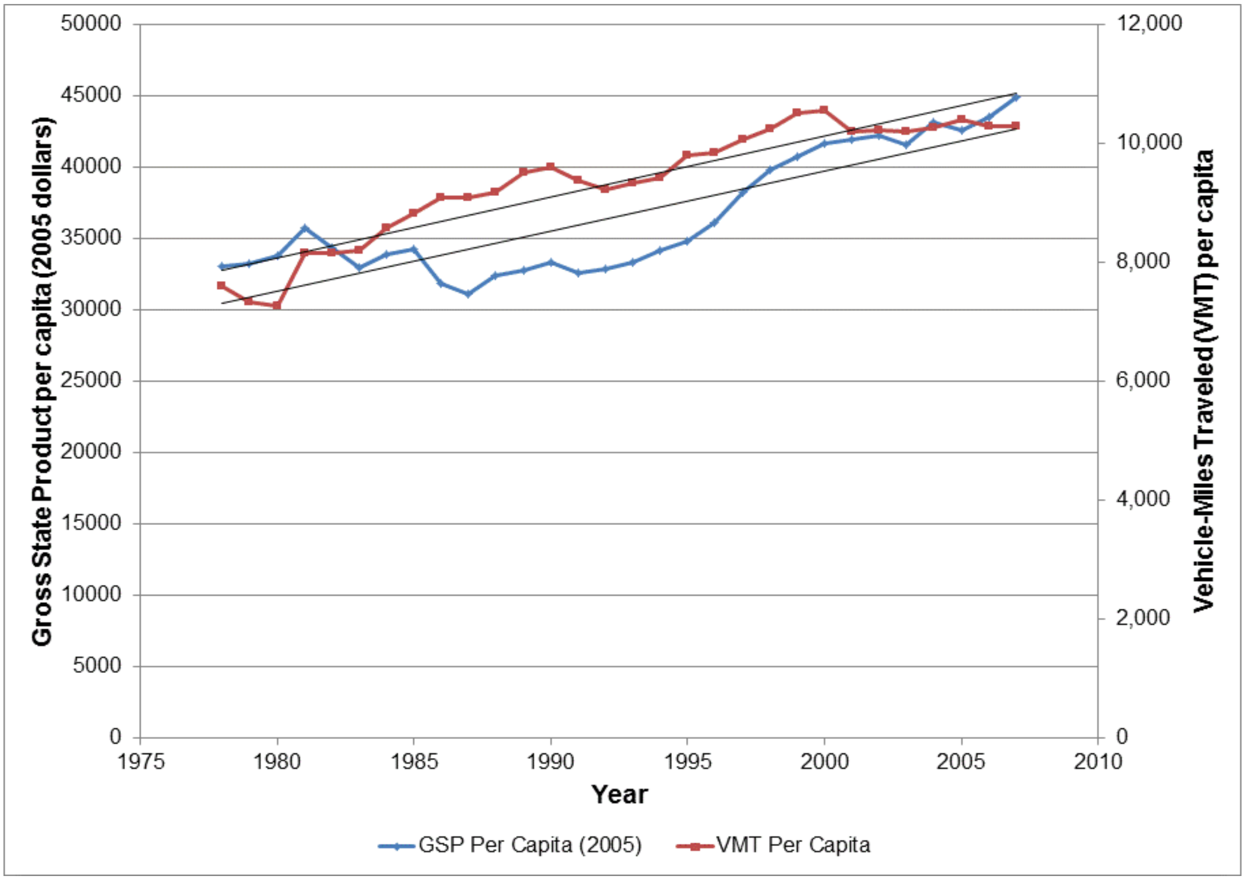


Figure 6: Gross state product (2005 dollars) per capita and vehicle-miles traveled per capita in Texas 1978-2007 (BEA, 2011, Dallas Indicators, 2011, FHWA, 2011, and Texas Department of Public Safety, 2011)

Thus, it is reasonable to conclude that continued growth in Texas will lead to continued increases in travel demand. However, the phenomenon of the relatively constant travel time budget across incomes, considered by Schafer, indicates the challenging prospect that increases in travel demand will not be met without improvements in travel speed. This implies that as people become wealthier and societies grow economically as a whole, demand for faster transportation grows. Markets where rail can offer a speed advantage over existing modes may capture a growing sector of transportation demand. Considering Texas currently has minimal passenger rail service operating at speeds capable of competing with personal automobiles, much less airplanes, the potential of passenger rail services at speeds faster or at least competitive with existing modes is high.

CONGESTION AND DEMAND CHALLENGES

Even as the strength and magnitude of the economy increases with continued population growth, Texas' transportation systems increasingly strain to meet the state's mobility needs. TTI's Urban Mobility Report (Schrank et al, 2009) indicates that a reversal of this trend is unlikely. Texas, despite being a populous majority-urban state with 85% of the state's population in urban areas, demonstrates a very strong car culture. Because of this car culture, inadequate vehicular capacity and high demand have created an exigent mobility problem. Since 1990, growth in population and VMT in the state's major urban areas has drastically outpaced growth in lane-miles of highway. This situation is not unique to Texas, but the recent surge of these in Texas is likely more exacerbated than in other states, particularly those growing more slowly. In an extreme case, VMT in El Paso have increased 72% since 1990, yet growth in lane miles has only increased 10%. While not as daunting, other large Texas cities still have seen growth in VMT at more than twice the growth in lane miles. In some areas, this may reflect the state's ambitious highway building program from previous decades. While additional lanes are just now beginning to reach capacity, auto traffic congestion is still worsening. Other cities have demonstrated ongoing mobility problems that continue to worsen. The Dallas/Ft. Worth area experienced a 43-hour average increase in traveler delay from 1982–2007, second only to the Washington DC area, according to TTI. Other major urban areas in Texas also saw above-average increases in delay, indicating that mobility issues are growing faster in Texas than in the nation as a whole.

Congested roadways do not form an entire picture of Texas' mobility issues. The nation's largest freight rail network arguably faces greater congestion issues. Texas' central location on the North American continent makes it an important intersection point for freight with many different origins and destinations. San Antonio, Fort Worth, and Houston pose some of the most egregious bottlenecks in the nation's freight rail network, and many of the major rail lines in these areas currently operate at 70-80% of capacity ("Level-of-service D") (Cambridge Systematics, 2007). More importantly, anticipated growth in freight rail operations by 2035 is expected to challenge the Texas system if no improvements are made. A majority of the Class I rail lines will experience extreme congestion and delays as they will operate near or above capacity, particularly in the eastern half of the state. TxDOT has recently funded a number of freight rail studies across the state that identify nearly $4 billion in improvements and an additional $3.6 billion in different planning cases that will benefit both the public and private railroads (TxDOT, 2010c). Outside of identification, most of the improvements have not progressed beyond paper. Developing passenger rail operations on existing congested freight facilities would be a major challenge causing additional capacity constraints and requiring additional costly improvements. Thus, locating passenger rail corridors in alignments with no freight rail operational impact is essential.

As GSP and population continue to increase, air travel is forecast to increase, requiring upgrades in terminal space and runway facilities (DFW Airport 2010) assuming no changes in mode choice. The 2010 Texas Airport System Plan (TASP) and the FAA Terminal Area Forecast (2010) estimate that Dallas-Ft. Worth International Airport (DFW) and Houston Bush Intercontinental Airport (IAH) together account for more than 70% of passenger enplanements in Texas, with respective increases of 2.5% and 3.5% annually through 2030. Statewide enplanements at commercial service airports are forecast to grow more than 50 % by 2030 to more than 100 million annually. Airport master plans detail expensive capital improvements over the next few decades. Bush Intercontinental Airport (IAH) demonstrates the boldest expansion plans, with a total inflated cost of more than $9 billion by 2025. This provides for the construction of two additional runways and 50 new aircraft gates, of which 35 are designated for regional service. Figure 7 shows other planned development at Texas commercial airports (although the list omits some airports in the state). Development of passenger rail services, particularly those that interface with Texas' larger airports, may provide a less expensive and more flexible option for regional and state travel, while simultaneously limiting additional land taking if the right-of-way is already owned.

Commercial Airport	Planned Expansion Expenditure (millions of dollars)	Planning Horizon	Source	Notes
Amarillo (AMA)				Recent Terminal Renovation
Austin (AUS)	$1,517	2020	October 2003 Master Plan Update	
Beaumont-Port Arthur (BPT)	$120	2026	Master Plan Update 2007	
College Station (CLL)	$47	2023	Master Plan February 2005	
Corpus Christi (CRP)	$77 (2006)	2026	Master Plan Update February 2007	
Dallas Love (DAL)	$147 (2001)	2020	Dallas Love Field Master Plan	Undergoing $519 million modernization program not included in plan
Dallas-Fort Worth (DFW)				Master Plan Update in Progress
El Paso (ELP)	$286	2024	Master Plan Update (2005)	
Harlingen (HRL)	$147 (2009)	2028	Master Plan 2010 Update	
Houston Hobby (HOU)	$1,400	2022	Master Plan 2003	
Houston Bush (IAH)	$9,435	2025	Master Plan December 2006	
Killeen (GRK)	$117 (2006)	2026	Airport Layout Plan Update	
Longview (GGG)	$126 (2007)	2027	East Texas Regional Airport Master Plan (2007)	
Lubbock (LBB)	$235 (2006)	2026	Master Plan Update	
McAllen (MFE)	$184	2024	Master Plan Update 2005	
San Antonio (SAT)	$1,003	2030	Vision 2050 Master Plan 2010	
Texarkana (TXK)	$133	2022	Master Plan Study 2003	
Tyler (TYR)	$183 (2006)	2025	Master Plan Update 2006	
Wichita Falls (SPS)	$55 (2010)	2029	Master Plan Update 2010	
Total	**$15,212**			

Note: Expenditures are inflated for individual project years at a given airport unless otherwise indicated

Figure 7: Planned expansion expenditures at major Texas airports

ENERGY AND ENVIRONMENTAL CONCERNS

The costs, energy effects, and environmental effect of capacity expansion affect the state at an increasing rate. Despite the many wide-open spaces in the state, environmental issues are catching up with Texas. As of 2004, Texas' two largest metropolitan areas do not meet National Ambient Air Quality Standards (NAAQS) for 8-hour ozone. The Houston area falls into "severe non-attainment" – while Dallas/Ft. Worth has remained at "moderate" for the last seven years. The Beaumont-Port Arthur area also falls into the "moderate" non-attainment for ozone (US EPA 2010). El Paso is a non-attainment area for PM10. Texas has made some progress recently in environmentally-friendly renewable energy sources, and now leads the nation in wind power generation at the state level (AWEA, 2010). However, the state's warm climate, heavy reliance on automobiles, extensive industrial operations, and less efficient building codes still contribute to very high energy use. Compared with its peer states, Texas' per-capita residential energy use was 65.2 billion BTU, higher than both California (42.4 billion BTU) and New York (59.7 billion BTU), although slightly less than Florida (69.9 billion BTU). Taking Texas industries into consideration, Texas energy consumption (across all uses) per real (2000) dollar of GDP was at 12,500 BTU per chained dollar. California, New York, and Florida were all less at 5400, 4100, and 7400 BTU per chained dollar, respectively (US DOE, 2010). A summary of various energy consumption statistics is seen in Figure 8 below, and they clearly demonstrate that Texas energy consumption is relatively high. As energy consumption is high, so is the portion of that energy consumed by transportation. While transportation amounts to 27% (which has been slowly but steadily growing since the 1970s) of the total energy use in the United States, it accounts for more than 70% of national petroleum consumption, which alone is about 180% of domestic petroleum production. Considered differently, 96% of national transportation energy consumed is petroleum-based. Nationally, highway modes consume 80.7% of transportation energy alone. As transportation contributes about 25% of total statewide energy use, it can be reasonably assumed that these values on petroleum consumption are similar in Texas as well. While Texas has accomplished great economic growth in recent decades, it has not come without costs in terms of high energy use and environmental degradation.

State	Energy consumption per capita 2008 (million BTU)	Transportation sector energy consumption per capita 2008 (million BTU)	Energy consumption per chained 2000 gross state product dollar (thousand BTU)	Transportation sector energy consumption per chained 2000 gross state product dollar (thousand BTU)
California	229.1	88.24	5.4	2.08
Florida	241.4	82.53	7.4	2.53
New York	204.9	57.47	4.1	1.15
Texas	475.3	117.87	12.5	3.1
United States	326.5	92.26	8.6	2.43

Figure 8: Summary of energy use in Texas and peer states (Davis and Diegel, 2010)

CONCLUDING REMARKS

Texas plays a crucial role in the development of transportation infrastructure. The modern influence of the state on air and rail transportation reflects decades of economic growth and transportation development bringing Texas to the mobility forefront. Though not constant over time, the Texas economic growth of recent years reflects a growing population in major cities throughout the state and a broadening in the economic base throughout multiple sectors. It is reasonable to expect that this economic growth will instigate newfound transportation demand. With this demand, the state struggles to maintain a road-focused system that meets needs. Increasing congestion on all the state's transportation facilities, particularly roadways, threatens to stymie the economic growth so lauded by the state's residents. The state struggles with energy use and environmental degradation resulting from the state's automobile reliance and fossil fuel-based energy sources. Passenger rail implementation will not solve all these issues but is nevertheless an important and overlooked transportation mode that Texas ought to consider.

Chapter 2: Texas Rail in a National Context

National Rail Policies

National passenger rail in the United States is practically synonymous with Amtrak. Even those non-federal agencies (primarily state DOTs) that enable intercity passenger rail operations commonly utilize the Amtrak branding for their service. Since the creation of the National Railroad Passenger Corporation in 1971 (operating as Amtrak), federal-level policymaking on passenger rail remains largely related to the appropriation of funds for Amtrak operations and maintenance, and occasionally capital improvements. Because Amtrak lacks a dedicated funding source in its initial creation, the Congressional song and dance on the issue of Amtrak appropriations re-appears every few years. Ideological fiscal conservatives exhibit zero tolerance for direct subsidies while Amtrak defenders and mild critics remind those vocal opponents that typically a “for profit” label, such as that established for Amtrak in its creation, allows for government-supplied capital infrastructure (as for highway and air modes) with private operators covering the cost of moving people and goods through airports and on roadways (Dunn and Perl, 1997). This argument about federal support for Amtrak isn’t new, although representatives for regions served by Amtrak have engaged in quirky political games in the appropriations process since Amtrak’s creation (Baron, 1990).

Although the 1994 congressional elections enabled perhaps the strongest round of calls for zero tolerance on Amtrak appropriations, it is possible that the rail operator emerged with some degree of reinvention and spirit for rebranding. In the coming fifteen years, Congress concocted various deals to keep Amtrak appropriations flowing and to complete the Northeast Corridor capital improvements. Some of the stipulations included self-sufficiency by 2003 (not achieved), and reduction in the dining and sleeper services which were a drain on revenues.

Until the 2000s, the Federal Railroad Administration (FRA) engaged in relatively little planning or capital improvement for passenger rail, acting primarily as a safety organization.

States pursuing passenger rail typically worked through the confines of Amtrak, with some success, while FRA remained generally uninvolved with the grant process for passenger improvements. Gradually FRA planning and grant involvement has increased, although safety still dictates much of the agency's work.

Probably the legislation most affecting Amtrak came in 2008 despite President George W. Bush's initial veto threats. PRIIA (Passenger Rail Investment and Improvement Act) addressed a number of items related to the success of passenger rail in Texas by focusing on improving operations, service, and facilities for Amtrak's long-distance intercity routes. Two of Amtrak's more maligned long-distance routes – The Sunset Limited and Texas Eagle – operate in Texas, and were subjects of performance reviews. Otherwise, this legislation marked the first major action by the FRA on planning and implementing passenger rail corridors in states, Texas included. It is unclear exactly what future role the federal government will take in developing a national rail policy that impacts Texas, although it appears that the DOT will likely take a larger role in guiding national passenger and freight rail improvements than in the past. In a departure from the present, it is possible and quite likely that Amtrak may not operate intercity passenger rail in some states and regions, yet corridors may still be eligible for federal funding through new or increased grant programs. While the President's national rail goals may be in temporary limbo given budget compromises for FY 2012, the greater national role in developing a broader passenger rail network appears likely to survive in the long term (Rutter, 2011). Because of this, Texas would be well-advised to prepare the necessary documentation and complete the essential state DOT structure updates to be eligible for future national rail funding. Even if the Texas state legislature were to suddenly embrace passenger rail for the state, such a project would likely require additional resources of federal origin, as has been demonstrated by plans in other states.

TEXAS' FREIGHT RAIL ROLE

As noted earlier, the state anticipates increases in freight traffic over its railroads in the coming years. Yet, deregulation in the 1980s contributed to reduction in excess rail capacity, as unprofitable routes were abandoned. As seen in Bhat et al (2006), more than 1200 miles of track were abandoned in Texas from 1991 to 1999, even as freight tonnage grew by approximately 40% over a similar period (1991 to 1998). The abandonment of rail infrastructure affects the capacity available for both freight and passenger rail services. With shortages of available right-of-way in metropolitan areas, shared use of freight rail by proposed passenger rail operations commonly exists as the only feasible option. However, as private for-profit enterprises, railroads will only allow the use of their track under conditions that will not undermine service quality for their customers. Specifically included in the recent Texas State Rail Plan, UP and BNSF have adopted guidelines for passenger use of freight rail corridors:

- Safety should not be compromised.
- Capacity must be provided for current and future freight operations.
- Compensation must be made to the railroads for any additional costs imposed by expanded passenger rail service, such as new infrastructure, increased maintenance costs, and any other related operational costs.
- Liability should be capped.

BNSF and UP also expressed concerns about additional capacity on their lines to prevent degradation of operations as a result of accommodating passenger rail services. Regarding shared right-of-way, UP stated that such an arrangement would only be permitted if additional right-of-way was purchased and rail lines were separated by fifty feet. Specifically considering planning for high-speed rail corridors along existing rail lines, freight railroads expressed concerns over grade separation assuming barriers would impact access to freight customers opposite any new HSR tracks (TxDOT, 2010c). In any case, implementation of passenger rail in

Texas requires collaboration with freight railroads in the state. At minimum, passenger rail operations may negotiate with freight railroads for access to tracks or right-of-way near existing intermodal stations (many of which remain in existence from a time when current railroads operated passenger services decades ago). However, future passenger rail improvements likely will require more than this. Specifically, these improvements may require acquisition of railroad, shared or acquired right-of-way, and negotiations with freight railroads for operations on their existing tracks. Passenger rail facilitators should thus engage freight railroads as primary stakeholders in any prospective passenger rail plans in Texas.

AMTRAK SERVICES

At present, the National Railroad Passenger Corporation (Amtrak) is the sole provider of intercity passenger rail service in Texas. All the major metropolitan areas in the state feature Amtrak service, although the cities themselves are not all directly connected and many of the connections are made by Amtrak Thruway bus services. Three routes serve Texas, with the shorter-distance Heartland Flyer connecting Fort Worth with Oklahoma City. The Sunset Limited connects Los Angeles and New Orleans with intermediate stops at El Paso, San Antonio, and Houston, among others. The Texas Eagle links Chicago and San Antonio via St. Louis, Little Rock, Dallas, Fort Worth, and Austin, with other stops as well. While Amtrak ridership has shown growth over the last ten years, it still comprises only a small portion of intercity travel in the state with about 320,000 passengers annually in 2009. All the major cities in Texas are served by stations in central business districts, with intermodal rail connections available in Dallas and Fort Worth, and bus connections available elsewhere.

Heartland Flyer

The Heartland Flyer operates on 72 miles of BNSF track between Fort Worth and Oklahoma City with a single daily trip in each direction. Since commencing service in 1999, the

Heartland Flyer has demonstrated increased ridership and represents one of several examples of relatively successful shorter-distance intercity service sponsored by states served (Oklahoma and Texas in this case). Ridership has increased from about 25,000 annually in 1999 to more than 60,000 annually in 2009. Currently the trip takes about 4 hours 15 minutes, or about 1 hour longer than by personal automobile. Oklahoma and Texas are evaluating improvements that could decrease route run times, thereby increasing ridership. TxDOT also requested a feasibility study for a potential station in the village of Krum, just outside Denton. Such a station would provide access to central Denton County, one of the state's fastest growing counties. The Heartland Flyer experienced volatile on-time performance over the last ten years, but recently has performed well, with an on-time performance rate of 86% in 2009.

Texas Eagle

Operating over 1300 miles of track, the Texas Eagle links San Antonio, Austin, Fort Worth, and Dallas with Little Rock, St. Louis, and Chicago, via East Texas. Within Texas, the route operates on a combination of UP and BNSF track. Three days per week, the train connects with the Sunset Limited for through service to Los Angeles. After being threatened with discontinuation in 1996, the Texas Eagle has seen increased ridership and revenues, with ridership roughly doubling between 1998 and 2009. Historically, the route suffered from dismal on-time performance, with an on-time performance rate below 30% between 2006 and 2008. Perhaps as a result of reduced freight traffic due to economic issues, on-time performance has greatly improved in recent years.

Sunset Limited

Traveling roughly east-west across the southern tier of the United States, the Sunset Limited operates for approximately 950 miles in Texas, providing nearly 50% of the trackage between the current termini of Los Angeles and New Orleans. Amtrak terminated service between New Orleans and Jacksonville following Hurricane Katrina and has not restored service, although Congressional requirements dictate a plan to restore service imminently. Ridership on the Sunset Limited remained flat or slightly declined over the last ten years, with a horrendous record for on-time performance. Not until 2009 did the train achieve any better than a 33% on-time performance rate in a given year.

LESSONS FROM TEXAS TGV

Initiated by a German-funded private consultant presentation to the Texas Legislature in 1987, a HSR venture quickly became a political hot-topic in the state. While subsequent legislation didn't incorporate the proposal itself, it did permit the Texas Turnpike Authority (TTA) to investigate for itself the feasibility of HSR. This state-funded investigation culminated in the creation of the Texas High Speed Rail Authority (THSRA), where legislation directed the authority to review franchise applications and select a franchisee if a HSR system was determined to be in the public interest. However, because the completed study already demonstrated need and acted as the required proof, the awarding of a franchisee only remained as the final hurdle. The initial TTA evaluation recommended using technology capable of 150 mph or greater based on the cost of about $8 million per mile, where other estimates by the Transportation Research Board ranged from $10 - $18 million per mile (1990 dollars). The quick-action legislation may have prevented thorough evaluation of the most cost-effective technology. Nevertheless, the study concluded that the project was economically sound although it required the use of public funds to cover initial capital costs and did not analyze the project using a benefit-cost structure.

The act creating the THSRA, Senate Bill 1190, known as the Texas High Speed Rail Act, allowed the project to move forward through a level of limited scrutiny unusual in large transportation projects, merely displaying “public convenience and necessity”, although the act also forbade the expenditure of public funds on the project. After submitting an application and the required $500,000 fee, two consortia presented possible HSR projects to the Authority. Both centered on competing European interests, the consortia offered slightly different approaches to the scope of work, technology selection, and financing. Following the earlier German involvement, the Texas FasTrac proposal included two lines linking Dallas with Houston and San Antonio estimated to cost $5.22 billion. Based on a review of German construction, the FasTrac consortium concluded that the 1989 TTA study estimates resulted in considerable error. By 2018, ridership would reach 11.7 million passengers annually and yearly revenue would exceed $500 million according to the proposal. The Texas TGV proposal (initially known as the Texas High Speed Rail Corporation) featured French technology and planned for a three-phase approach linking Dallas, Houston, and San Antonio in a triangular shape. By 2018, the system would see 22 million passengers providing about $930 million in revenue annually with an initial capital cost of $5.8 billion. The routes of these two proposals are seen in more detail in Chapter 7.

Almost immediately, issues arose with both of the rail proposals. In 1990, THSRA adopted its own administrative requirements that prescribed the selection of a team of advisors to independently review the proposals. The advising consultants concluded for both applicants that they 1) demonstrated the need for HSR, 2) exhibited capabilities of implementing a HSR project, and 3) did not demonstrate financial plans consistent with the requirements of the Texas HSR Act. Additionally, TTI reviewed ridership estimates for both proposals and determined that the FasTrac projections, while understandable, were optimistic, while the Texas TGV projections were not comprehensible and overly optimistic. Most importantly, however, the Texas HSR Act dictated that public funds shall not be utilized for the project in any way, despite the public support both consortia required. Considering the shortcomings of the applications and criticisms by the independent reviewing groups, the project should have conceivably stalled at this point. Yet, these valuable feedback tools do not explain the rationale for awarding a franchise. The likely deciding factor was a lead partner in the Texas TGV consortium making a bold declaration that the project could be built without public funds.

The THSRA awarded the franchise in May 1991, with a primary requirement of generating a commitment for equity financing of $170 million before January 1993. Nearly 40 scoping meetings took place in counties throughout the state while interagency operations sprouted. However, the looming litigation with Southwest Airlines hovered over the accomplishments of the THSRA and may have contributed to increased difficulty in attracting outside investors. Seeing this difficulty, THSRA extended by one year the deadline for equity financing. Texas TGV produced updated alignments within the year, but was unable to attract significant capital. As the extended deadline approached, Texas TGV delivered a memo to the Authority that the deadline would not be met. The months ahead (early 1994) saw Texas TGV terminate basic environmental studies and dismiss contractors while the THSRA determined its next steps. By August 1994, a settlement was reached to end the franchise agreement between THSRA and Texas TGV.

The THSRA and Texas TGV experiment obviously relate most closely to any future HSR venture in Texas. While other regions may have more recent experience, none are as directly implementable or as instructive based on similarity. Some of the primary conclusions and recommendations based on different post-mortem analyses are as follows:

- Planners must integrate rail into the planning process beyond merely promoting “intermodalism” or including additional modes in excess of prepared plans. Rail itself may be the best solution to identified issues, whether congestion, environmental impact, excess demand, or inadequate capacity, thus requiring a system-wide approach where rail has parity at minimum with other modes. Experience demonstrates that improvements in transportation require federal assistance. Federal programs reflect national priorities and provide leadership, thereby enabling and informing state-level rail proposals that integrate and function well with one another. HSR will not survive politically as a stand-alone issue; aside from the Southwest Airline litigation with the Texas TGV project, a “change in the traditional paradigms…will yield a change in the traditional alliances” (Burns, undated). Movement toward operations as “transportation companies” rather than the “airline industry” and the “automotive industry” may remove enemies.

- While planning may take place at the state level, implementation must occur at the local level. Modeling and planning tools certainly have a place in preparing for a HSR project, but cannot substitute for human contact that permits the public to buy in to the project. Merely listening, however, is inadequate; customer-based plans responding to needs allow for openness of data and information exchange, which in turn provides enhanced credibility, trustworthiness, and collaboration. Marginalized groups, including low-income households, people of color, and small communities in general tend to have inadequate control over the placement of transportation facilities. Soliciting input early with these groups may permit collaboration and/or compromise of the type that would have kept the Texas TGV project alive.
- Segmentation provides an opportunity to break a massive project, such as Texas TGV, into more manageable pieces. The total dollar amount of a smaller segment may entice and enable both public and private sector funding more easily. Generally, a segmented approach will reveal that not all project sections have the same needs; as Burns (undated) puts it, “Texas is not monolithic”, and no single solution will solve the state’s transportation issues, bringing credence to the notion that separate segmented approaches may be advantageous.
- The state should not abdicate its role in planning transportation infrastructure. As an extension of government, presumably whose goal is to protect both citizens and the

environment, particularly related to transportation, the state DOT should maintain a strong planning role. The private sector, while a valuable partner, should focus on tasks most closely related to the primary outcome of profitability. Maintaining management by the state also prevents conflicts with eminent domain benefiting a private entity.

- Employing existing rights-of-way to the fullest extent possible will limit impacts on landowners and limit costs. While technical issues affect the utilization of highway rights-of-way or rail rights-of-way, reports indicate that from a safety standpoint, it is certainly feasible (Petersen et al, 1985). Still, existing rights-of-way have their own issues and should be carefully analyzed before drawing a conclusion. Small communities may prefer existing rights-of-way without realizing such an approach may have larger impacts in developed areas and may affect a greater number of public rail crossings. Based on the unfortunate safety record of non-separated rail crossings (approximately 800 incidents in 2009, although this shows improvement over the previous ten years), grade separation is a must for any new HSR system.
- It is not wise, nor maybe even possible to build a HSR system without some public funds. However, as public funding causes significant heartburn for many constituents (ignoring the fact that public funding is essential for all transportation programs, as none are able to fully support themselves), it may be possible to limit public expense through collaboration and participation with the private sector. Certain aspects of a HSR project may lend themselves more appropriately to state expense (right-of-way, planning), while others may be easy to share between the public and private sectors (signalization, electrification, construction). Finally, some expenses are likely best borne by the future HSR operator (rolling stock). Public contributions should reflect the degree of public benefit derived from a potential HSR system by monetizing reductions in air pollution, congestion, and travel time, among others. Generally speaking, the most efficient

transportation infrastructure policy promotes projects with the largest difference between public benefit and public cost.

- Concept-state feasibility analysis by transportation planners will allow simple computer programs to assess the viability of a HSR system to meet assumed criteria. This allows transportation planners to deal primarily with transportation statistics while providing clear answers to potential planning options. Analysis of this kind on the Houston-Dallas/Fort Worth corridors indicates that the segment may be viable, warranting further investigation.
- New HSR projects may benefit from minimum standards for the expenditure of public funds such as minimum NPV, maximum required/available passenger ratio, and minimum private sector rate of return. This may prevent the waste of public funds while maintaining flexibility for viable partnerships with the private sector.
- HSR consortia may be better off with a diverse equity portfolio to guard against a single entity making unreasonable claims or promises, while the state should consider recent leadership changes within the companies associated with a franchise applicant.
- The state should prepare to analyze the feasibility of all rail projects from both the public and private sector perspective. This process should become an integral part of the feasibility study process instead of outsourcing these tasks to the private sector. The state has a vested interest in evaluating private-sector feasibility so that it does not become a facilitator of HSR projects doomed to fail from the beginning.

LESSONS FROM OTHER REGIONS AND STATES

An advantage of limited action on HSR in Texas in recent decades is the ability to glean valuable lessons from other states about the planning and implementation process (or multiple processes, in some cases). While federally-designated HSR corridors (Figure 9 below) pass through Texas, minimal action in these corridors thus far means the mistakes and challenges of rail projects in other federally-designated corridors will allow Texas to ideally bypass these errors and provide for smooth planning and implementation when such tasks are undertaken. This thesis focuses on four corridors specifically for their similar characteristics to Texas. California, Florida, the Midwest/Chicago Hub, and the Northeast corridors all exhibit similarly large population centers and large amounts of intercity travel. All the corridors feature various stutter-steps in planning and implementation of HSR, although the reasons for these issues differ from corridor to corridor, thus allowing each corridor to provide different lessons, gathered and documented in various sources.

Figure 9: FRA/US DOT designated high-speed rail corridors (FRA, undated)

California

Planned high-speed rail projects in California have neither lacked in scale or ambition, although none have yet come to fruition either. California undertook the first United States' foray into high-speed rail in 1981 offering valuable lessons for similar Texas projects. The FRA identified the San Diego-Los Angeles corridor in early 1981 as a high-potential corridor for passenger rail service. Under its own impetus, the American High Speed Rail Corporation (AHSRC) proposed to construct, operate, and maintain a privately financed passenger train service with a $3.1 billion price tag. AHSRC moved quickly, developing a plan by March 1982 for a bullet train service that would connect the two cities in an hour by traveling parallel to Interstate 5 and the populated Pacific coastline (see Figure 10 below).

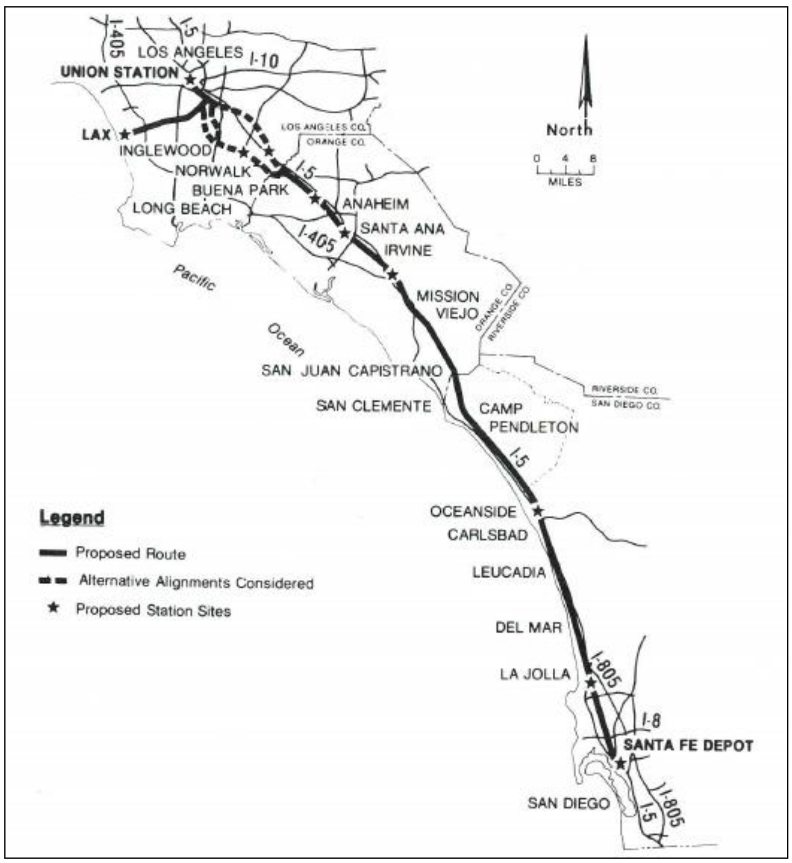


Figure 10: AHSRC proposed route for HSR in Southern California (Smith and Shirley, 1987)

Citing the following reasons (Smith and Shirley, 1987), AHSRC estimated that 36 million passengers would choose the train, representing about 12% of trips made in the study corridor:

- highway congestion would dramatically increase over the next ten years,
- gasoline prices would increase sharply,
- population and population density would both grow in the corridor,
- fares would be competitive with airline and Amtrak fares,
- the system would reinforce local and regional transit system improvements, and
- economic advantages resulting from capital expenditures, employment increases, and government revenue would materialize.

An ambitious timeline dictated service on a portion of the route by 1987, with full service by 1990. AHSRC anticipated eighteen months to complete the environmental review process (both California Environmental Quality Act – CEQA – and National Environmental Protection Act – NEPA) by 1984 and seven years of design and construction culminating in full operations by 1990. Meanwhile, legislation permitting the sale of $1.25 billion in tax-exempt revenue bonds for rapid-rail transit with speeds in excess of 120 mph also created confusion by appearing to exempt the project from CEQA, or at least disqualify typical state agencies from acting as the state environmental lead agency. Following much discussion and deliberation, Caltrans was chosen as the lead agency by August 1983 with FHWA taking the federal role in November of the same year. Subsequent scoping meetings identified stakeholders, cooperating agencies, and developed guidance for the consultant selected to complete the environmental review. Additionally, the public raised a number of environmental considerations at the public scoping meetings. Using findings from the scoping process, Caltrans adopted an optimistic timeline of twenty months for the environmental process at a planning meeting in May 1984. This meant that the submission of all technical data by AHSRC would result in commencing construction in September 1986, two years later than planned.

AHSRC asked in November 1984 for the department to cease work on the environmental process for the project, citing a suspension of plans due to a lack of short-term financing (Smith and Shirley, 1997). It is possible that potential investors saw the viability as highly dependent on optimistic and suspect travel forecasts, as criticism against AHSRC commented on the lack of an impartial ridership study. AHSRC only further fanned flames by refusing to disclose marketing and ridership studies. Public distrust seen in the development of the San Diego-Los Angeles corridor prompted high-speed rail advocates to create more credible forecasting processes (Olson and Roco, 2004). The project also generated several other valuable lessons for future high-speed rail projects:

- Political diplomacy should be executed at all levels, and leaders should avoid decisions that will prove only temporarily expedient. The financing act in this project shows that such decisions may be adverse in the long term.
- Open data processes should be maintained to permit effective discussion and debate as all parties are using the same information. Withholding of data invites skepticism, particularly from the public. Open data provides credibility and open communication; defensive actions in response to a lack of data erodes credibility.
- Open communication between public and government agencies is essential, particularly at the local level. Keeping the loop closed through continuous feedback on raised issues provides community support through widespread debate and compromise, rather than quick, backroom bargains between the elite of society.

Florida

Florida’s experience with high-speed rail follows a story of both progress and regress over the course of more than three decades. In this time, public debate addressed the many obvious issues and arguments, but also managed to uncover important ideas beyond the immediate arguments. For this reason, the history of HSR in Florida provides comprehensive guidance that should inform all future projects in the United States, especially any in Texas.

Millions of dollars were poured into investments, studies, and proposals in Florida without any resulting construction. The Florida HSR initiative began with a 1976 mandate by the Florida legislature to investigate the feasibility of a system between Daytona Beach and St. Petersburg. The study concluded that HSR would be marketable in Florida if implemented in stages, and also proposed locating tracks within the median of limited-access highways. Governor Bob Graham initially kick-started the exploration of HSR service following his experiences with the Shinkansen in Japan in the 1980s by authorizing the creation of the Florida High Speed Rail Committee. This group released a report recommending development of public-private partnerships and using publicly-owned rights-of-way to provide a HSR system that was necessary to help the state to meet mobility needs. Also that year, the state legislature created the Florida High Speed Rail Commission, authorizing it to grant a franchise to build a privately funded and operated HSR system between Miami, Orlando, and Tampa. The commission received two proposals for service with estimated costs for both at approximately $2 billion despite a large disparity in estimated ridership (5.9 million and 3.7 million annually), with each proposal using different technology. Both proposals assumed public spending and/or real estate development rights. When it became obvious that no funding would materialize, one proposal was withdrawn while the other developed a convoluted arrangement of benefit districts, impact fees, and fuel excise tax increases that led Governor Lawton Chiles to reject the proposal in 1991 (LC de Cerreño, 2006).

HSR exploration in Florida was thus effectively punted back to the Florida Department of Transportation (FDOT), which spent the next several years evaluating the feasibility of HSR corridors between the state's major cities. This was made possible by federal funding following the 1992 federal designation of the Tampa-Orlando-Miami corridor as a HSR corridor. Based on the results of these studies, FDOT affirmed a long-term commitment to HSR, establishing a dowry of $70 million annually for thirty years, making Florida's proposals far more attractive to private investors and attracting five new proposals for service in 1995. FDOT selected the Florida

Overland Express (FOX) consortium, which proposed building and operating a grade-separated new HSR system utilizing existing French TGV technology as one way to minimize risk. The capital costs not covered by FDOT or FOX equity would come from debt financing and revenue bonds. FDOT valued the project as an essential element of an integrated state transportation system that would be both environmentally and fiscally responsible in light of projected future state growth. Academic research also corroborated this inclination by the department. Just as preliminary engineering work commenced in 1998, a grass roots campaign against the bullet train arose, challenging ridership estimates, environmental issues, use of foreign technology, and use of scarce transportation dollars. Some concerns carried weight, particularly regarding lofty assumptions about relationships with airlines and diverted automobile trips. A subsequent US General Accounting Office review noted uncertainties in ridership and costs, as well as the crowding out of other projects eligible for federal TIFIA funds. Governor Jeb Bush did as prior governors had done, and terminated funding for the project with his election in 1999.

FDOT returned to the drawing board, but determined that it would not give up on the prospect of HSR in the state, as the department remained convinced that an alternative to highways was still necessary. Moving toward an incremental approach, rather than an entirely new grade-separated system, Amtrak and FDOT issued the "Florida Intercity Passenger Rail Service Vision Plan" that again focused on the Tampa-Orlando-Miami corridor (Figure 11), recognizing that operational and safety issues result in passenger and freight rail incompatibility above 80 mph. Simultaneously with the release of the Vision Plan, the legislature also crafted plans to bring the issue before voters through a constitutional amendment process. In 2000, 52.7% of the popular vote directed the legislature to develop and operate a high-speed rail system. Soon after, the legislature also created the Florida High Speed Rail Authority (FHSRA) and a consultant's report to FDOT recommended initiating service with a minimum operating segment between Orlando and Tampa using the Interstate 4 median alignment. In 2002, a series of reports completing preliminary engineering and environmental work and investment grade ridership analysis led the FHRSA to solicit proposals for the design, building, operation, maintenance, and financing of phase 1 of a high-speed ground transportation system between Tampa and Orlando.

Figure 11: Potential Florida HSR route used for preliminary planning and ridership study (HNTB Corporation, 2003).

By 2004, the FHSRA selected a proposal for a public-private partnership with Fluor-Bombardier and a number of other members. The federal government had provided $13 million for planning and crossing upgrades, while the legislature's authorization of $14 million met a veto from Governor Jeb Bush, accompanying a warning that he would not support further HSR efforts. Through the work of anti-bullet train politicians, the constitutional amendment passed in 2000 also returned to voters, who decided to repeal the amendment in a collective change of mind in November 2004. The project remained effectively shelved for the next five years, only to be revived with much pomp and circumstance in 2009 by the Obama Administration. Pundits believed the Florida line had been targeted as the best opportunity for the administration to demonstrate benefits of HSR in the short-term, as the project could be constructed quickly and would be the first grade-separated electrified HSR system in the United States. The Federal Railroad Administration (FRA) provided $2.4 billion in grants to the state, all but covering construction costs. The 2010 election of Governor Rick Scott brought uncertainty to the project, although he did not take a position on the campaign trail. However, in the midst of an anti- "big government" climate, it came as no large surprise when he chose to cancel the project in early 2011.

Following Florida's multiple instances of forward rail momentum only to be met with setbacks, several important ideas should guide future rail considerations:

- Cost and financing remain a critical dilemma for HSR. As seen in the developments in Florida, the private sector preferred the state to bear more risk, while the state preferred the private sector to take on excess risk. If HSR is to ever be built, it will require public funds; yet, in a generally anti-tax state (and nation) where skepticism regarding public benefits abounds, securing such funds remains difficult at best. A broader framing of costs and benefits with "no build" options must also take place, as this should include the cost of constructing capacity increases for other modes that will change economic results. Finally, the myth that railroads can pay for themselves must be dispelled. Not only is this untrue, it also perpetuates myths that other modes cover their own costs.

- A HSR project must define clear goals around which a consensus can be built. The argument over an incremental versus entirely new HSR system represents a larger uncertainty in Florida about the final goals for the project. Disagreement about the role for commuters and tourists with the system demonstrated lack of consensus, as well as general malaise from those advocates of a Miami connection that never seemed to be seriously considered as a part of any initial project phase.
- Individual personalities, particularly political personalities, played a large role in the project storyline. Certain governors took strong stances for the project, while others made decisions that reset the project clock; party affiliation historically has not been an indicator of support. According to LC de Cerreño (2006), "It is apparent from Florida that, given the time to develop and implement HSR, continuous leadership and support is critical. More importantly, this leadership and support needs to be more institutional in nature. Studies and plans often span several administrations and Florida clearly shows how easily such efforts can be curtailed by a single individual."

Midwest

Perhaps lacking the public profile of other HSR endeavors in the United States, the proposals related to the Midwest/Chicago Hub nevertheless provide their own set of lessons. While other planned projects have focused on trains traveling greater than 200 mph within a single state, the Midwest proposals instead use 110 mph technology and stitch together a multi-state web of Midwestern and Great Lakes cities via a central high-demand location (Chicago). The Midwest/Chicago Hub received federal corridor designation in 1991, and expanded several times since then to a current configuration of lines extending from Chicago to Minneapolis/St.

Paul (via Milwaukee and Madison), Kansas City (via St. Louis), Detroit, Louisville (via Indianapolis), and a triangular segment linking Chicago ,Cleveland (via Toledo), Columbus, and Cincinnati (see Figure 12). Together these lines bring the corridor to more than 2,000 miles in length. Various studies by state DOTS and private groups in the 1970s and 1980s assessed the technical and financial feasibility of HSR in the region, although this received a significant boost following a tour of Europe by government officials.

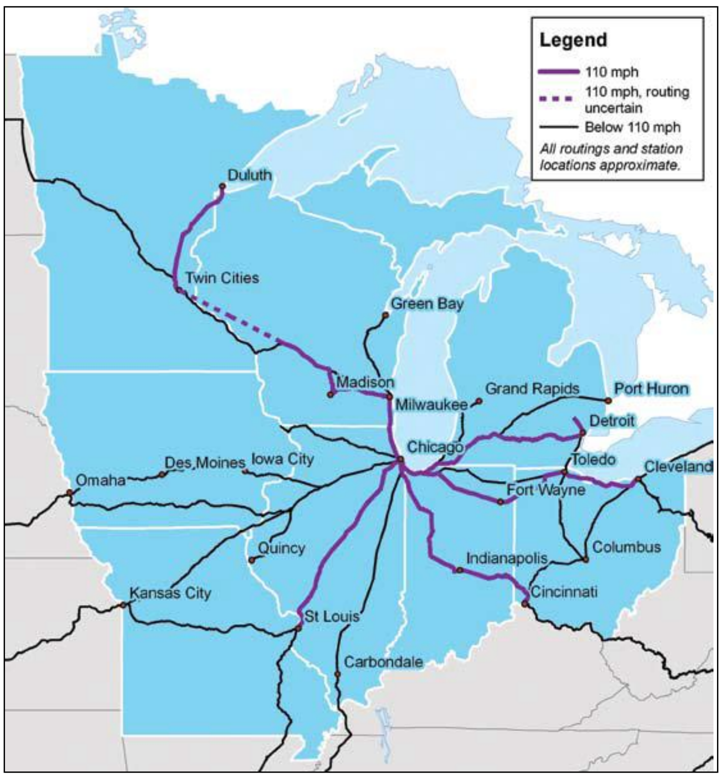


Figure 12: Midwest/Chicago Hub rail corridors (Transportation Economics and Management Systems Inc., 2004)

In 1996, pro-HSR legislators in multiple Midwest states established the Midwest Interstate Passenger Rail Commission in charge of the Midwest Regional Rail Initiative (MWRRI) while state DOT officials worked together to develop the Midwest Regional Rail System for HSR. These structural entities forged a strong relationship with FRA, Amtrak, US DOT, and states for planning and providing passenger rail service. The plan encompasses 3,000 miles of track serving 60 million people (some of these lines are not federally-designated at present) with trains of varying speeds serving populated cities throughout the region. Even with regional-level activity, the state-level activities have been uneven, although the 2009 American Recovery and Reinvestment Act (ARRA) prompted most states in the region to engage in some level of planning for passenger rail to be eligible for federal grants. In all, states in the Midwest Regional Rail System received about $2.5 billion in ARRA funds (Federal Railroad Administration, 2010). Between 1998 and 2004, the MWRRI released a series of preliminary plans that identified technology options, estimated costs, and initial demand forecasts. From here, an intermediate speed of 110 mph throughout the system, hopefully driving down costs through economies of scale, moved forward as the preferred approach and was subject to a more complete market assessment that determined expected operating and capital costs, a strategy for capital needs, and completed benefit-cost analysis. The current 2004 plan recognized the sharing of freight infrastructure, performed capacity simulation, and developed a detailed infrastructure capital plan, among other things (Transportation Economics and Management Systems Inc., 2004).

Despite the seemingly thorough approach, HSR in the Midwest still struggles to gain footing, particularly outside of Illinois. The midterm elections of 2010 may be the best evidence of this as gubernatorial candidates in two Midwest states campaigned against proposed train services that had received federal funding only months earlier. Based on the Midwest experience thus far, it is essential to keep a number of ideas in mind when considering HSR elsewhere (LC de Cerreño and Mathur, 2007):

- Roles and responsibilities within the regional corridor are unclear, as some state DOTs heavily pursue planning and funding for improvements, while others seem to be uninvolved. Some state legislators and DOT officials lend support for the project, but the region lacks strong and consistent leadership. Projects operating across state lines, like the Northeast Corridor, traditionally require federal leadership and guidance to prevent piecemeal development. Without a serious regional authority or equal commitment by involved states, implementation of HSR in the Chicago Hub will likely require a strong federal presence.

- Sub-regional goals that merely promote connectivity and reduce travel times between certain cities must be emboldened and clarified at the regional level to prevent the inclusion of corridors that will produce little ridership and balloon costs. The benefits sought by the project need clarification, which will require the inclusion of other entities in discussions, including private railroads (who own much of the right-of-way) and environmental groups. These groups will also aid in sorting out overall regional project goals.
- The Midwest regional rail plans give credence to the notion that if HSR is to succeed in the United States, it will likely take an incremental approach in many locations. Despite this, the difficulties of improvements (incremental and “true” HSR) on shared ROW with commuter and freight trains abound. Yet, given political apathy and perceived risks with HSR unproven in the United States, an incremental approach may be the most feasible approach without a stronger commitment on both the part of the federal government and the states.

Northeast

Much can be said about rail in the Northeast Corridor, and with good reason. It is the only rail corridor in the United States with any operations above 100 mph, and it connects several of the nation’s largest and most transit-oriented cities. The corridor is a major player in the intercity travel market and continues to capture the minds of researchers, rail professionals, members of the public, and politicians alike for its operational complexity, unique existence in a nation with meager passenger rail service, and perhaps yet untapped future potential. While some of the demographic and operational aspects of the corridor will be explored in Chapter 4, the corridor provides a unique experience in the planning of electrified passenger rail service in the United States. Because the history of the Northeast Corridor is rightfully complex compared to the other HSR corridors considered here, this abridged description will only highlight the major planning milestones in the corridor.

Prior to Amtrak, the Pennsylvania Railroad provided the precursor to the passenger trains seen today. With the help of federal aid for new technologies, Metroliner service debuted in 1969 operating at speeds above 100 mph between Washington and New York. Within just a few years, the deferred maintenance on the track infrastructure, which was not upgraded with the introduction of the new trainsets, took a toll on operations, resulting in late trains and reduced speeds. A similar scenario with the TurboTrain between Boston and New York took place. At first, great increases in speed caused the service to shine, but ongoing maintenance issues would eventually cause the operation to fold. Six years after the creation of Amtrak (1976), the corridor received a major federal boost with appropriations of $1.75 billion for improvements known as the Northeast Corridor Improvement Project (NECIP). With little more than political rationale, goal travel times between Washington and New York, and New York and Boston were established for achievement by 1981. Unfortunately, this amount of funding was probably only about half of what was needed to make the corridor competitive with other modes. Work progressed slowly over the next decade, eventually achieving the goal travel times in the corridor. By 1986, the FRA considered the bulk of the work accomplished and appropriations shrank (LC de Cerreño and Mathur, 2007).

A second phase of the NECIP was initiated in 1991 following a study by the Coalition of Northeastern Governors that determined improvements to the New York-Boston segment could be achieved at reasonable costs in the short-term. Led by Frank Lautenberg (D-NJ), more than

$1.5 billion in additional appropriations were directed to the Northeast Corridor (Figure 13) through 1995. By this time, major outstanding improvements that remained included the delivery of new trainsets constructed by Bombardier-Alstom and electrification of the system. Delays began almost immediately as unexpected conditions (including the Central Artery "Big Dig" Project in Boston), safety incidents, and slow production impeded progress. More than three years behind schedule, Amtrak began HSR service in 2000, with many of the identified infrastructure improvements unrealized even by 2003.

Figure 13: Primary Northeast Corridor routing (feeder routes shown in gray) (Cambridge Systematics, 2008)

At present, a number of issues affect the Northeast Corridor. First, the corridor suffers from an institutional relationship where it is tied to Amtrak, and thus the future of Amtrak. Yet, the operations differ significantly from the remainder of Amtrak's long-distance passenger rail services. Much debate exists whether the corridor should remain a part of the Amtrak network, as well whether the infrastructure and operations should be split. The overwhelming second issue revolves around operations and maintenance. Woefully under-maintained prior to Amtrak, the Northeast Corridor infrastructure currently faces a backlog of necessary improvements worth more than $5 billion (Northeast Corridor Master Plan Working Group, 2010). The corridor also faces extreme capacity issues, as no other segment of rail in the world operates such a variety of services with such a high volume (Cambridge Systematics, 2008). Yet, there is virtually no footprint available for increased capacity; additional right-of-way would need to be purchased or overhead track pursued in order to provide new capacity. Finally, the Northeast Corridor is a funding anomaly by rail standards and certainly by transportation standards. Where other modes receive funding through a combination of state DOTs, metropolitan planning organizations, or municipalities from the federal government, providing there is a state match, the Northeast Corridor receives only federal appropriations. To deliver a stronger regional tie to funding the Northeast Corridor, a greater state interest in the development of the corridor as well as a regional funding mechanism may be in order (Roth and Aggarwala, 2002). Measuring these issues against a theoretical Texas project at this juncture may not provide strong direction, but it does clarify the complications of working across state lines, something Texas would likely not face in the initial project phases, if ever. However, the capacity issues strike a similar note in Texas; even with minimal passenger rail traffic, the intense freight operations present the same general constraints, particularly at urban locations (Houston and Tower 55 immediately come to mind).

CONCLUDING REMARKS

Passenger rail in the United States traces a volatile trajectory over time particularly at the national level where Amtrak faces nearly constant scrutiny. Specific regional experiments in passenger rail also present a range of issues which are instructive for future forays in passenger rail in Texas. The Texas TGV project also demonstrates a series of structural and intellectual missteps that high-speed rail projects in Texas and nationwide should consider when analyzing feasibility of such service. These different projects show the importance of transparent planning processes that consult the public, independent analysis of project elements, and avoiding short-sighted legislation aimed at hurried action without considering longer term consequences. Additionally, the political personalities play an essential role in project development, whether positive or negative. Through consultation with these previous HSR endeavors both inside and outside of Texas, the state hopefully will benefit by avoiding many of the perils that have plagued other projects elsewhere.

Chapter 3: High-Speed Rail in a Texas Geographic Context

Initial consideration of intercity HSR in Texas spurs immediate questions about the appropriateness of such a system in the state. Analysis of these large scale and generic primary concerns, while generally non-technical, is essential to inform the population on the topic and obtain initial support. In this vein, this chapter considers some basic demographic and geographic concerns regarding the potential for HSR, including the population distribution in the state, the emergence of interwoven metropolitan areas (megaregions), city-to-city distances, urban population density, and HSR sub-regional impacts.

STATEWIDE POPULATION PROFILE

By most standards, the state of Texas is quite large. At more than 268,000 square miles in land area, the state is the second largest in the United States. It stretches nearly 800 miles along both the north-south and east-west axes, covering a wide gradient of climates incorporating vast arid plains, humid swampy coasts, rolling limestone hills, and dry mountainous desert. Placing it in a global context, Texas forms the world's twenty-seventh largest sub-national entity, and has approximately the same land area as France (including overseas possessions) (CIA 2010). One result of this size is that Texas, despite featuring the second largest population of US states at twenty-five million and growing, has a relatively low population density, falling near the middle of ranked US states with an estimated 92.9 persons/square mile (US Census Bureau 2010c). This places it behind Washington (98.4), just ahead of Alabama (91.9), and slightly above the US as a whole (86.0). Population density is a good fundamental measure of the potential for rail transportation demand as well as an indicator of urban form. It has generally been observed that population density positively correlates with high ridership of intercity passenger rail systems, based on the examples of rail in western European nations, as well as Japan, South Korea, Taiwan, and China, although the exact nature of this relationship may not be entirely understood.

This empirical evidence from rail operations in other nations suggests that intercity passenger rail has little potential in the United States and Texas given that the population density is low compared to that of France (295 persons/square mile), Germany (594), and South Korea (1261), for example (United Nations, 2009).

However, it is also important to consider the area encompassed in these density values. Much of west Texas (and the western United States) contains vast desolate stretches of land that likely would generate extremely minimal demand for rail service (or any transportation for that matter), yet still are included in these density values that are commonly used to evaluate the potential for HSR. Texas does not demonstrate a geographically balanced population profile. For example, the center of population is at Holland, Texas (about 10 miles east of Interstate 35 in Bell County), while the geographical center of the state is more than 100 miles to the west-northwest, near Brady. Specifically, the eastern half of the state (the Interstate 35 corridor and eastward) may contain more promise than the state as a whole. The eastern half of Texas is home to more than 21 million people or about 85% of the state's population and thus demonstrates a much higher density than the state as a whole. At approximately 174 persons/square mile (TxDOT 2010b), this half of Texas exhibits the density of US states such as Indiana (176) and Michigan (177) (both part of the Midwest High Speed Rail initiative), and is somewhat close to that of Spain (236), which has implemented a well-patronized HSR system in recent years (Burnett, 2009). The Texas Triangle region, with corners defined by the urban areas of Dallas/Ft. Worth, Houston, and San Antonio achieves about 305 persons/square mile. TxDOT (TxDOT, 2011a) provides population and land area information for all of the state's twenty-five transportation districts, as well as for the individual counties comprising these districts. Using this information, one can calculate the population densities for these districts. In Figure 14, the lighter blue outline shows the region of the state for which the population density is 174 persons/square mile, while the darker blue shading indicates the area for which population density is 305 persons/square mile.

From the map, it is clear that this number may not equally represent all the catchment areas for intercity travel. Because many low-density counties west of Interstate 35 are included, it is possible that a better-defined region (e.g.,, one within an hour of a potential station perhaps) may yield even higher densities. In the case of the Texas Triangle region, this is true to an even larger extent as more dense counties in East Texas are excluded while less dense counties west of Interstate 35 are included.

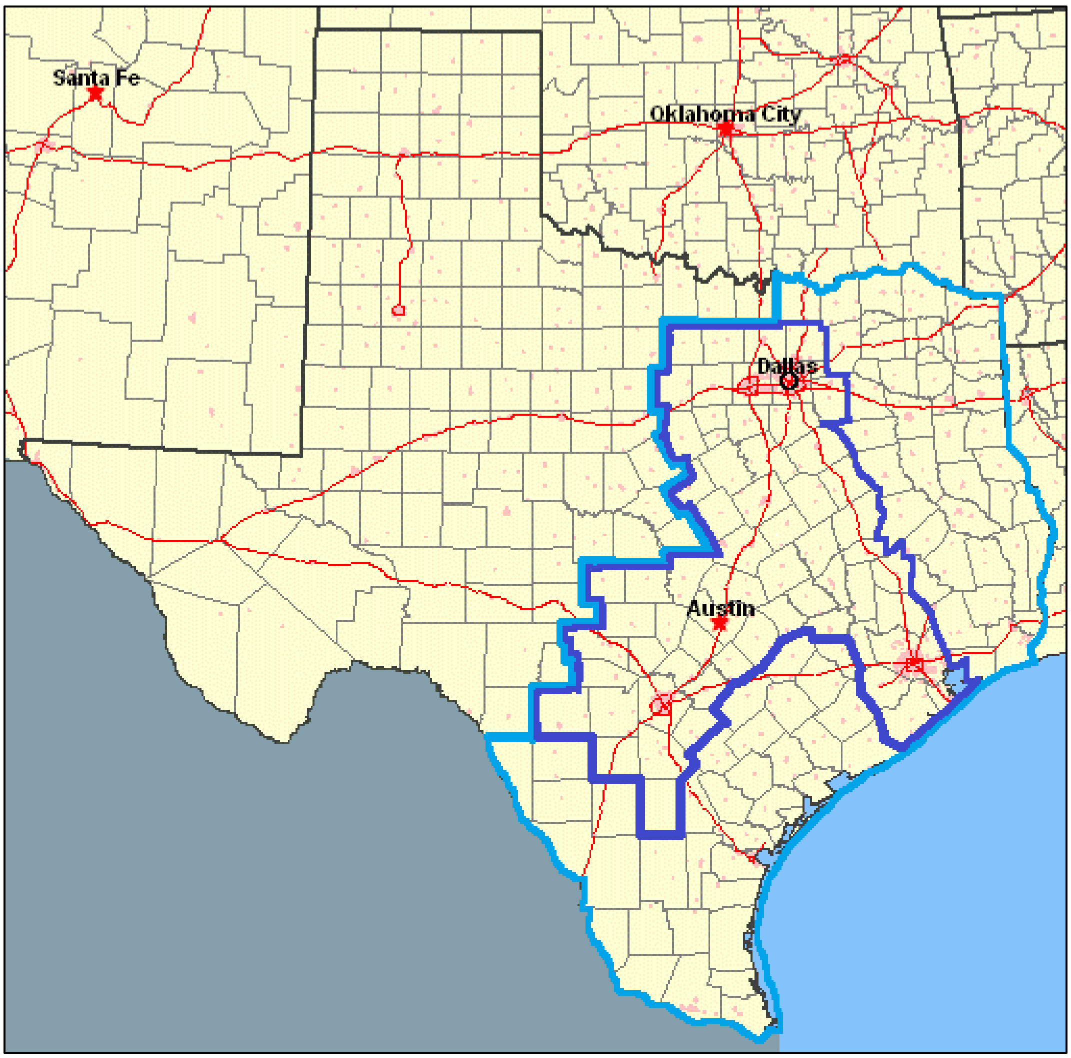


Figure 14: Areas considered for population density calculation (based on TxDOT, 2011a)

Figure 15 charts the population densities of nations currently operating, planning, or considering HSR, with different values for Texas included for comparison. Measuring national population density and immediately ascribing potential for HSR success oversimplifies the data. Two issues arise; first, just as neither Texas nor the United States demonstrates a balanced population profile, many other nations planning for HSR also fail to demonstrate this phenomenon. Thus, the densities reported are likely less than the densities in sub-national regions in which HSR exists or is in development. China may provide the best example of this, although Australia, Russia, Brazil, Argentina, and many nations in the Middle East show this as well. Second, population density, while perhaps a good measure of demand for HSR services, may more generally be an indicator of intercity transportation demand. The list in Figure 15 could easily be a list of density in nations with high intercity travel demand or high air passenger travel, with notable exceptions being populated island nations for which rail is geographically infeasible, and to some degree south Asian nations (Pakistan, India, Bangladesh) and select African nations (Nigeria, Kenya). Thus, the complexity of population density lies beyond rather arbitrary state borders.

Nation	Population density (persons per square mile), as of July 1, 2010
Monaco	61562.4
Singapore	19293.2
Republic of Korea	1254.1
Netherlands	1036.4
Belgium	909.0
Israel	867.9
Japan	867.5
Philippines	805.4
Viet Nam	686.1
United Kingdom	661.6
Germany	597.2
Liechtenstein	583.4
Italy	520.6
Luxembourg	508.4
Switzerland	481.0
Qatar	414.2
China	362.1
Thailand	349.0
Czech Republic	344.7
Denmark	333.7
Poland	306.8
Texas (Texas Triangle)	*305.0*
Portugal	300.7
France	294.9
Austria	259.3
Turkey	240.5
Spain	235.9
United Arab Emirates	232.8
Malaysia	223.1
Greece	223.0
Egypt	209.9
Croatia	201.8
Morocco	185.4
Myanmar	183.7
Bulgaria	175.1
Texas (Eastern Half)	*174.0*
Ireland	164.8
Iran	116.3
South Africa	106.4
Texas	*92.9*
United States	83.5
Laos	67.8
Brazil	59.3

Figure 15: Population densities of nations considering, planning for, or operating HSR compared with Texas (United Nations, 2009)

Sweden	54.0
Finland	41.1
Algeria	38.6
Argentina	37.7
Saudi Arabia	33.1
Norway	32.8
Russian Federation	21.7
Canada	8.8
Australia	7.5

Figure 15 (continued): Population densities of nations considering, planning for, or operating HSR compared with Texas (United Nations, 2009)

What, then, is the role of population density in the development of intercity rail? Certainly the United States and Texas should not abandon hope for intercity rail due to low large-scale population density. By that metric, the Sapsan service between Moscow and St. Petersburg should have long since failed, as Russia exhibits very low population density, yet the service operates at a profit and a high load factor (84.5%, Makarova, 2010). Instead, population density may reflect nuanced aspects of regional geography and demographics and their effects on intercity travel. In particular, a very populated city may significantly skew the population density of an otherwise unpopulated state or nation. Intercity travel demand attributed to state or national population density may in fact mostly represent the intercity travel demand for the highly populated areas. Thus, it is important to attribute the potential for intercity travel to a more disaggregated jurisdiction (city pairs, for example), rather than states or nations. Hence, the evaluation of demographics for cities to be potentially served by HSR provides a more specific and accurate perspective into rail success. Population density calculations for areas that might reasonably generate demand for intercity passenger rail show that although the state of Texas as a whole may not appear to be able to support such service, there are regions of the state, particularly the Texas Triangle, with densities comparable to successful international examples.

URBAN POPULATION DENSITY

In light of the considerations in the previous section, the urban population density of Texas metropolitan areas compared with that of other metropolitan areas provides useful instruction about the potential for HSR. Amtrak's Acela Express is the most successful example of high- (or higher-) speed rail service in the United States. It links the five large metropolitan areas of Washington DC, Baltimore, Philadelphia, New York, and Boston via stations at city centers. Comparing the examples in the Northeast with Texas' largest cities yields a wide gap on many levels, including city history, urban development pattern, and legal planning and zoning capabilities. The application of a more focused microscope reveals large disparities between Texas cities and the major cities of the Northeast. The densities of the cities proper served by the Acela Express are all at least twice the densities of Texas' five largest cities. Baltimore, the least dense of the major cities (Boston, New York, Philadelphia, and Washington DC are the others) on the Acela Express route, dwarfs Houston's density, at 7,889 and 3,872 persons/square mile, respectively. The population densities of Dallas, Austin, San Antonio, and Fort Worth are all subsequently less, with Fort Worth inhabiting 2,403 persons/square mile (US Census Bureau, 2010). Like many demographic measures, population density does not explicitly dictate the usage of intercity passenger rail, but the positive correlation between the two is clear.

Internationally, the correlation between financially stable, well-utilized HSR service becomes less clear. The density disparity between cities in wealthy nations in Europe and American cities clearly exists, although relative to the rest of the world, these cities have smaller densities. Cities in wealthy Asian nations tend to be far more dense than European or North American cities. Many of the world's densest cities exist in relatively poor, highly populated nations where vast urban slums are not uncommon. Clearly HSR does not exist in many of these places as substantial demand for high speed transportation does not exist. Alain Bertaud (2003) shows the great range of urban density in Figure 16. Thus, urban density does not solely determine the demand for HSR, although amongst cities in nations with relatively developed economies, density does appear to influence the propensity for HSR trips.

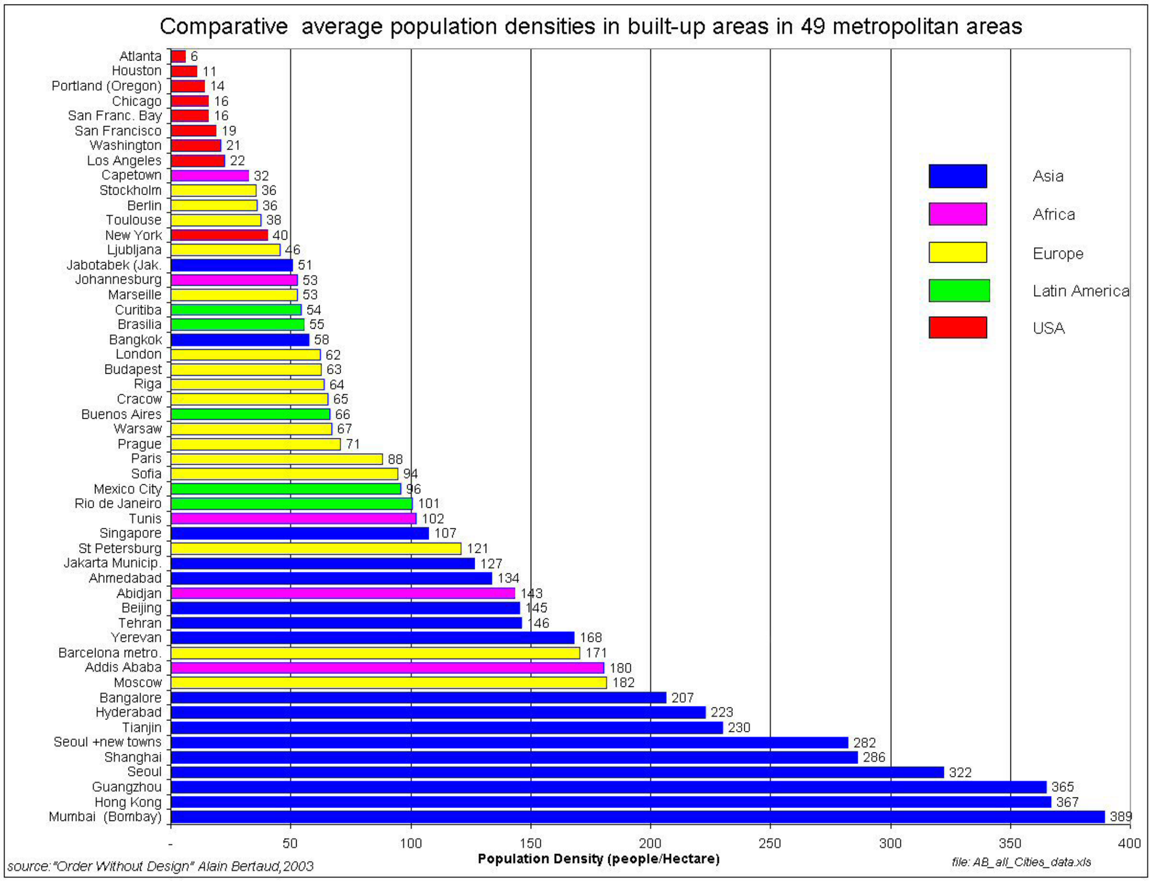


Figure 16: Population densities of selected international cities (Bertaud, 2003)

Large disparities exist between Texas cities and cities linked by HSR in other nations. In a study of the relationship between HSR and city transportation connectivity characteristics, BB&J Consult (2010, for Union Internationale de Chemins, International Union of Railways) found the population density of various major cities served by HSR (Figure 17). These cities, too, exceed population density of major cities in Texas. The differences also show that the relationship between urban density and propensity to use rail may be uncertain. The population densities within the proper administrative boundaries of Paris, Rome, and Ankara are not drastically different that those of major Texas cities. However, the differences between cities such as Seoul and Barcelona and Texas cities are stark. Thus, it appears that population density has a complex relationship with ridership potential, but nevertheless correlates positively overall. To further understand this relationship, the urban density gradient for these international and Texas cities may demonstrate a more clear connection. At present, lower population densities in Texas are probably a deterrent for HSR, although further detailed analysis for specific cities is needed.

City	Population Density (persons/km)
Barcelona	16,500
Berlin	3,848
London	4,761
Madrid	5,364
New York	10,600
Paris	1,971
Rome	2,135
Ankara	1,496
Beijing	10,154
Seoul	16,500
Taipei	9,640
Tokyo	14,254
Dallas	*1,427*
Houston	*1,505*
San Antonio	*1,313*
Austin	*1,207*
Fort Worth	*928*

Figure 17: Population density of selected international cities served by HSR and major Texas cities (BB&J Consult, 2010 and US Census Bureau, 2010d)

EMERGING MEGAREGIONS

The notion of the Texas Triangle permeates the state's intercity passenger rail discussion, particularly high-speed rail. Megaregions are defined by multiple metropolitan areas whose boundaries have begun to blur, extending for distances of 300-600 miles in some cases. The geometry lends itself well to the success of intercity passenger rail because the multiple cities in the megaregion will likely operate as an interconnected network rather than a lone city pair. Based on heavily used international examples, as well as some simple time-distance calculations, intercity passenger rail service appears to be ideal for distances 100 to 500 miles in length, and particularly so between 200 and 300 miles. Shorter distances are better suited for travel by car (or commuter rail if it exists), while air travel becomes more practical as distances approach and exceed 500 miles (Hagler and Todorovich, 2010). The barriers and inefficiencies of air travel over short distances are likely all too familiar to most Americans, who must endure long auto trips to outlying airport locations, cumbersome security procedures, early check-in times, and the effects of airport congestion and delays. However, as distances increase, the exceptional speed of airplanes gradually overtakes the relative advantage of rail. Megaregions in Europe and Asia demonstrate the greatest ridership with rail through an interconnected network of cities, although the northeastern United States also has elements of this as well.

The integrated economic nature of the Texas Triangle (see Figure 18) continues to interconnect. Where the major cities in Texas once pursued more unique strategic industries, the economic lines between the cities have begun to fade as the ability to travel, communicate, and exchange information increases.

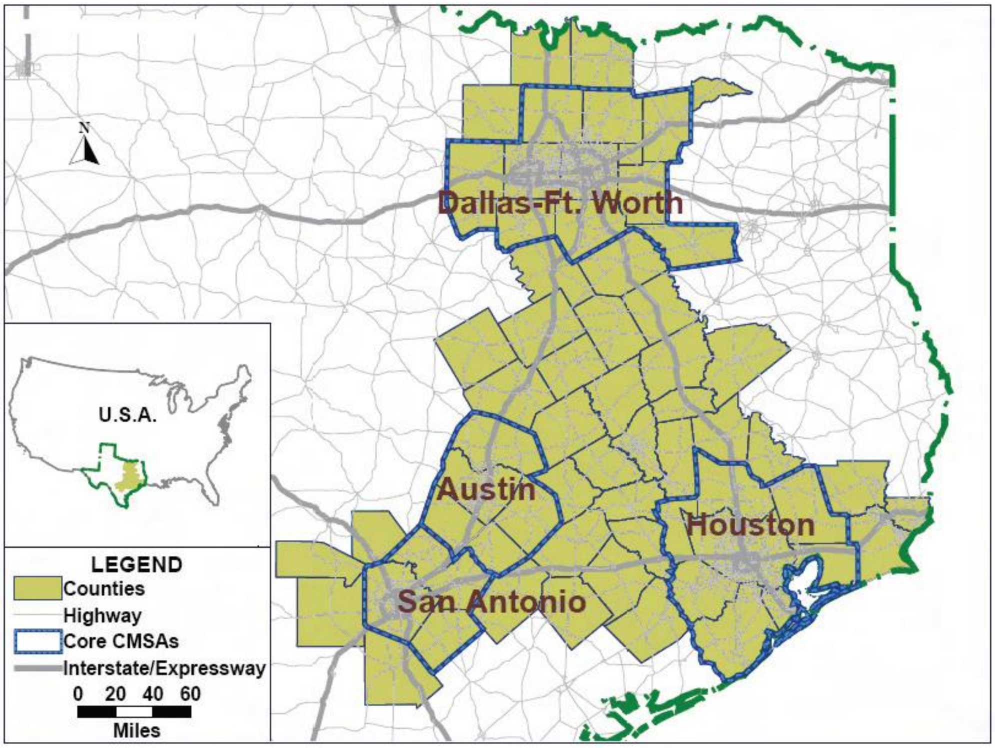


Figure 18: Approximate Texas Triangle Megaregion area (Zhang et al, 2007)

As Zhang et al (2007) reported, some industrial competition has also arisen between the different metropolitan areas, particularly in high-tech, communications, and electronics sectors. An obvious overlap between the air carriers in the region also exists. The research also indicates that the economic sectors of specialty for each metropolitan area complement each other well. Exports from the entire megaregion are few in comparison to exports from the individual cities in the Texas Triangle. As indicated earlier, these cities contribute greatly to the overall state population and economic output. Thus, as the region continues to grow, implications for changes in regional planning exist, including possibly organizations beyond MPOs (metropolitan planning organizations) that have driven transportation planning at the local level for two decades. Determining megaregions such as the Texas Triangle still amount to an inexact science as no official definitions exist. Zhang et al (2007) also suggest that changes to the definition of a metropolitan area (currently based on commuting patterns) may provide a more accurate context for transportation planning in a megaregion such as the Texas Triangle, particularly as the number of telecommuters increases. Travel time re-allocated from commuting likely contributes to increases in inter-city demand, which presents major implications for the development of high-speed travel between the major cities in Texas:

> "When the entire Triangle is within the reach of a daily commute, it then becomes an integrated megaregion meaningful to individual households and firms. To households, accessibility to jobs, housing, and services would thus expand from individual metropolitan areas to the entire Triangle. Firms would also enjoy the benefit of increased agglomeration economies at the megaregion scale."

Analysis utilizing a model by Schafer and Victor (2000) indicates that by 2050, high speed modes (air and rail) may absorb more than three quarters of the intercity mode share that includes auto, bus, and traditional rail. In order to prepare for the transportation requirements that such analysis presents, leaders must undertake substantial changes in land use planning and policy, including improved growth management legislation. This thesis addresses these challenges in more detail in Chapter 5.

CITY-TO-CITY DISTANCES

The existence of ideal intercity distances and the interconnected city networks in the Texas Triangle megaregion presents an opportunity in intercity passenger rail that is difficult to ignore. As mentioned earlier, cities within a range of about 100-500 miles, particularly 200-300 miles, seem to generate the greatest demand and highest ridership. This is a function largely of travel time, which acts as a proxy for distance, depending of course on train speed. An empirically-derived logit model approximation for mode share for rail (in a rail vs. air split) defined by Jorritsma (undated) estimates that HSR may achieve a very high modal split for trips less than 100 minutes, where it begins to drop off somewhat, although still maintaining a 50% mode split for trips of 200 minutes (3 hours 20 minutes) (see Figure 19). Here, y represents rail mode share, where x is the number of minutes of travel:

$$y = \frac{1}{(0.031)1.016^{x} + 1}$$

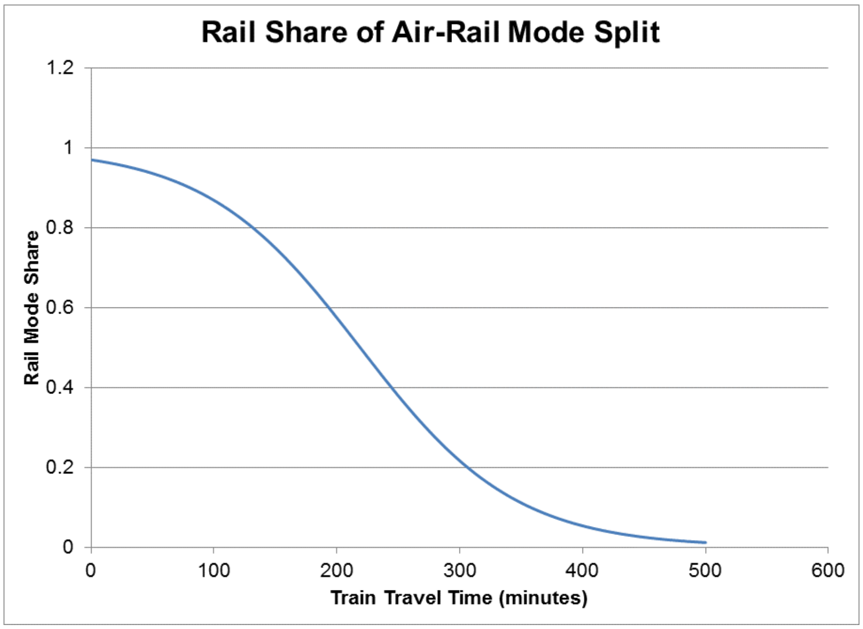


Figure 19: Graph of rail share of air-rail mode split

The overwhelming issue with the model is that air and HSR do not comprise the only intercity modes; thus, the idea that rail might occupy 100% of the mode share between two points ignores all other modes being used, which could be numerous over a short distance. Assuming a typical average speed (75-150 mph, not a *top* speed) over the distance between Texas cities demonstrates that the large and medium-sized cities in the Texas Triangle generate a large rail share by this model, and therefore lie within an ideal distance of one another. At the most distant points, the cities of San Antonio and Houston are both approximately equidistant from the Dallas/Ft. Worth metropolitan area, with about 250 miles between city centers, requiring approximately 1h40 to 3h20 of travel time. More centrally-located cities also show potential for intercity passenger rail based on distance, with Waco lying nearly 100 miles (0h40 to 1h20) from Dallas and 180 miles (1h12 to 2h24) from Houston, and Austin about 150 miles (1h00 to 2h00) from central Houston as well. This does not exhaust all corridors in the region, but does highlight the potential that geometry of Texas cities presents for intercity passenger rail (Butler et al 2009). The shortest highway distances between the fifteen largest MSAs in Texas are seen in Figure 20, where Texas Triangle segments are highlighted in blue. Other segments less than 300 miles in length linking cities outside the traditional Texas Triangle definition are highlighted in orange. These segments, most of which link Laredo, Corpus Christi, Beaumont, and the Rio Grande Valley, indicate that extensions from the Texas Triangle definition and any implemented HSR service within that Triangle should at minimum consider these metropolitan areas as well.

	Amarillo	Austin-Round Rock	Beaumont-Port Arthur	Brownsville-Harlingen	Bryan-College Station	Corpus Christi	Dallas-Fort Worth-Arlington	El Paso	Houston-Sugarland-Baytown	Killeen-Temple-Fort Hood	Laredo	Lubbock	McAllen-Edinburg-Pharr	San Antonio	Waco
Amarillo		478	637	765	503	636	361	418	596	444	609	119	728	493	423
Austin-Round Rock	478		238	325	100	192	192	573	162	67	232	368	300	79	102
Beaumont-Port Arthur	637	238		437	158	288	276	810	86	230	396	574	430	281	242
Brownsville-Harlingen	765	325	437		382	159	517	801	352	392	199	470	56	272	427
Bryan-College Station	503	100	158	382		237	165	660	95	72	318	415	364	165	85
Corpus Christi	636	192	288	159	237		377	691	207	255	141	325	152	143	287
Dallas-Fort Worth-Arlington	361	192	276	517	165	377		617	238	126	424	322	491	271	91
El Paso	418	573	810	801	660	691	617		730	595	602	344	745	548	610
Houston-Sugarland-Baytown	596	162	86	352	95	207	238	730		167	311	510	345	197	180
Killeen-Temple-Fort Hood	444	67	230	392	72	255	126	595	167		299	343	366	134	34
Laredo	609	232	396	199	318	141	424	602	311	299		498	143	154	334
Lubbock	119	368	574	470	415	325	322	344	510	343	498		618	382	345
McAllen-Edinburg-Pharr	728	300	430	56	364	152	491	745	345	366	143	618		236	401
San Antonio	493	79	281	272	165	143	271	548	197	134	154	382	236		181
Waco	423	102	242	427	85	287	91	610	180	34	334	345	401	181	

Figure 20: Highway distances between Texas' fifteen largest urban areas

In 2009, TTI (Borowiec et al) further considered a number of demographic, demand, and capacity criteria in order to determine those intercity corridors in the state that were most in need of capacity upgrades in the coming years. These criteria included, among other things, total population, percent of population 65 and older, total university enrollment, current and expected growth in AADT, current and expected growth in air travel, volume-capacity ratio on roads, and average load factor for air traffic along each of eighteen corridors. This analysis by TTI confirmed the relative importance of the Texas Triangle corridors in the state. The Dallas/Ft. Worth – San Antonio (via Austin) corridor and the Dallas/Ft. Worth – Houston corridor achieved the highest evaluation scores, far exceeding the next highest performing corridor. However, further pointing to the strength of the region statewide, four of the top six corridor scores were for corridors in the Texas Triangle, including Houston – San Antonio and Houston – Austin in addition to the top two. Other national-level analysis by the Regional Plan Association evaluated city pairs based on larger scale characteristics including congestion, economic potential, and existing transit connections in addition to density and corridor length discussed here. Amongst some 27,000 possible city pairs, Dallas/Ft. Worth – Houston scored tenth overall, with a number of other Texas city pairs, including Dallas/Ft. Worth – Austin, scoring lower (45^{th}), although still worthy of national attention. The report notes that Texas city pairs displayed a lack of transit connections which lowered the scores (Hagler and Todorovich, 2010). Despite this, even in a national comparison, Texas corridors perform well, reaffirming the idea that the naturally formed layout of Texas' major cities presents an excellent opportunity to consider intercity passenger rail service.

REGIONAL ECONOMIC IMPACTS

HSR experiences abroad indicate that when implemented appropriately, the train system may enable greater inter-regional accessibility and spur additional economic development. As Blum et al (1997) argue, HSR extends the boundaries of a "functional region" where a certain geographical area shares a common market for labor and services, and a great deal of business transactions still rely on some degree of face-to-face contact. Effectively, HSR reduces trade barriers, increases distribution of real income, reduces monopolies, increases competitive markets, and increases firm mobility and choice of inputs (labor). As the economy of Texas continues shifting from manufacturing toward services, a greater number of adults will not only work (as the number of single-earner households falls), but will work in industries requiring social mobility and knowledge dissemination, requiring greater mobility than already exists. However, “the discussion about the net economic benefit of devoting public funds to HSR investment is usually too general and imprecise” (de Rus and Nobela, 2007), indicating that rationalization of public expenditure on HSR must be vetted through more careful, enumerated analysis. This may take the form of benefit-cost analysis, or environmental life cycle analysis, for example, but has grown increasingly complex as once ambiguous social costs and environmental costs are enveloped in such analysis.

While much of the focus on HSR considers the links between large cities, the increase of HSR services also results in small- and medium-sized cities within an hour’s travel time seeing increased integration into urban transport. Guirao and Soler (2009) documented the vast changes in transport habits of both commuters and tourists between Toledo, a small city of 78,000, and Madrid. New RENFE HSR service in 2006 shortened the trip from 60 minutes by commuter rail to 30 minutes by HSR. The two cities, separated by approximately 70 km, have seen passenger traffic increase by 30%, including substantial increases in tourist traffic, despite the suburban location of the Toledo station. It is not clear if this increase is new induced travelers or merely a transfer of travelers from other modes; regardless, the reduction of less efficient modes (personal automobile and intercity bus) for either reason contributes toward achieving EU policy goals. As Facchinetti-Mannone (undated) points out, the infrastructure trade-off typically dictates the selection of city center stations versus exterior periphery stations in smaller cities. Compatibility with existing lines (and therefore somewhat slower speeds) allows service at original, historic stations, while peripheral stations utilize new rail lines, thus reducing travel time and providing other benefits. As one might expect, central stations maintain lower rates of access by personal automobile and higher integration into the regional transit network. The restoration and/or implementation of HSR service at a central station enables an opportunity to strengthen the city core and reconnect with marginalized areas, whereas the fostering of new business park growth on city exterior fringes with a new HSR station appears more difficult, particularly in areas of industrial recession. Nevertheless, the increase in marketing-related trips between Paris and the Rhône-Alps region (Lyon) following the inauguration of the TGV service in the early 1980s indicates that proximity to HSR amounts to a “bonus” for businesses. Even if those businesses do not relocate, activity appears to increase, perhaps with the opening of a branch location (Bonnafous, 1987)

Obviously it is difficult to know what the exact regional economic impacts might be for HSR in Texas. Still, evidence from other areas suggests that the state’s major metropolitan areas will benefit from increased competition in input markets, including labor, and greater ease of mobility will soften any trade barriers that currently exist within the state. Cities presently linked as leisurely weekend trips or single-day business trips likely would see a shift toward daily commuter activity, as seen in Toledo, Spain. Such a shift may result in changes in land use in addition to economic development. The California HSR system currently in planning stages anticipates significant commuter populations from Riverside to Los Angeles and/or San Diego, Palmdale and Bakersfield to Los Angeles, and various Central Valley cities to the Bay Area. While the major reasons for this include a jobs-housing imbalance and expensive home prices in the major coastal metropolitan areas (Cervero, 2003), which don’t generally afflict Texas cities so drastically, the flexibility to live in central Waco, College Station, or Austin, and commute sans automobile to Dallas, Houston, or San Antonio may have interest, particularly to those otherwise relegated to settling in suburbs under the “keep driving until it’s affordable” mentality. Station area development in a number of domestic and foreign examples indicates that large-scale transportation investment, such as HSR, linked to well-planned station area development can yield valuable results such as consolidation of economic activity, improvement in economic health, improvements to the built environment, and positive gains in public transportation use and reductions in environmental impact (Nuworsoo and Deakin, 2009). Considering the economic development and redevelopment goals of major Texas cities for their respective downtowns and CBDs, the coordination of these efforts with HSR planning could be a boon for increased density and sustainable transportation in the urban cores of Texas cities.

CONCLUDING REMARKS

The population distribution across Texas shows conflicting potential for HSR in the state. Although the state shows a low population density, more detailed analysis of the eastern half of Texas shows that population characteristics more closely reflect those of regions with well-used rail services in both the United States and abroad. The urban densities of Texas cities fall short of those in other cities abroad, but again demonstrate a need for a more nuanced analysis, as the differences in densities range greatly. Implications for the HSR in the emerging Texas megaregion demonstrate a net positive aspect for potential rail implementation, as rail will help to further stitch together the megaregion through transportation infrastructure. Partially responsible for the development of the megaregion, the city-to-city distances in Texas show that rail likely would achieve a high share of the modal split between cities. Finally, the regional economic impacts of HSR may alter city-suburb dynamics, allowing businesses to expand service areas and individuals to change commuting habits, perhaps eliminating the need for constantly growing suburban areas.

Chapter 4: Potential High-Speed Rail Intermodalism

The integration of HSR into different urban settings remains one of the largest uncertainties in both the United States and Texas. Evidence from other notable systems suggests that high urban connectivity and intermodal development correlates positively. More importantly, as shown by Givoni, Rietveld, and Brons et al (2000, 2007, 2009), the accessibility of a railway station can be a factor in determining if rail is chosen as a travel alternative. Furthermore, a high demand elasticity exists for rail travel with respect to station distance. In concert, these two findings imply that rail use may be enhanced through improved accessibility. This also supports the generic concept that intermodality promotes the integration of different transportation modes and associated services along an entire travel chain. With HSR considered competitive with air over short distances, one wonders why air travel in the United States and Texas remains so popular despite relatively poor non-automobile connections to the nation's airports. Still, all well-utilized examples of HSR exist in places with generally higher connectivity and modal variety than currently exists in Texas, indicating that at minimum, the impact of intermodal connections on HSR passenger patronage is non-negative. Exploration of Texas' potential in urban transit, intermodalism, and regional connectivity to airports yields important considerations for the future of HSR.

URBAN TRANSIT

The extent and variety of transit services plays an important role in defining a city's intermodal connectivity, and likely the demand for potential high-speed rail services. Little debate exists regarding the United States' deficiencies in urban transit use and high dependence on personal automobiles. Here too, Texas cities fall short. San Antonio currently holds the dubious claim of the most populated city in the United States without rail transit, a title formerly held by Houston. Arlington, midway between Dallas and Fort Worth, held the title for the largest American city (at about 375,000 and growing) with no public transportation of any mode until 2008 (METRO, 2008). Meanwhile, according to the 2009 American Community Survey (US Census Bureau, 2008), transit ridership in all the five major cities in the Northeast corridor connected by Acela Express is at least 15%, with all five cities falling in the top fifteen in the United States. With the top cities largely existing on the east and west coasts, with the exception of Chicago, no Texas cities are in the top 50. Houston, Dallas, and Austin citizens patronize transit at about 5%, while San Antonio and Fort Worth are lower at about 3.5% and 1.4%, respectively. These values should come as no surprise; they're perhaps slightly low by large city standards in the United States, but nevertheless close to the national average (5.0%).

More striking is the relatively low use of alternative modes in the United States when compared on an international scale. As noted in Chapter 1, increases in wealth and income typically result in demand for faster transportation, which explains rapid increases in automobile ownership and use in developing economies, that is, until some saturation point is reached. Thus, large scale growth in automobile ownership decreases once a national economy reaches a relatively wealthy stage. Even amongst wealthy nations in Europe, Asia, and Oceania, the United States demonstrates that it leads by far in automobile ownership and use, and trails dramatically in transit use. The New York MSA, by far the highest in worker transit use in the United States at about 30%, pales in comparison to Stockholm (55%), Tokyo (49%), and Seoul (60%), for example (Kenworthy and Laube, 1999). From an intermodal standpoint, the percentage of workers who walk and cycle to work is even more dismal in the United States. Using recent data from Paris (not necessarily an archetype European bike haven), more than 30% of worker trips were by foot; the New York metropolitan area, again the highest in the United States, achieved a very modest 6% (INSEE Ile-de-France 2010, US Census Bureau, 2010d). Reasons for this yawning gap in use of alternative modes abound, including historic development patterns, existing density gradients, national energy and transportation policies, and merely the presence of transit facilities themselves. Even while Texas cities compare reasonably with other major United States cities in multimodal transport, addressing some or all of these limiting issues may permit Texas cities to achieve gains in multimodalism aligning them more closely with international peer cities, many of which exhibit well-integrated multimodal HSR services.

A major deterrent to transit and multimodal connectivity is the lack of a defined development pattern for many Texas cities. Houston may epitomize the land use and development conundrum, as it infamously continues to grow without any formal zoning regulations (this and other legal issues will be addressed in more detail later). The larger issue may be that outside of incorporated municipalities, counties have little formal land use zoning authority in Texas. Thus, it has historically been quite easy to partition and develop land without a large-scale plan, only to then see that land annexed by a nearby municipality that would need a highly compelling argument (and likely a war chest legal budget) to evict residents and rezone. Ergo, it makes sense why Houston, for example, has only about 70,000 residents and 140,000 jobs within a 2 mile radius of the city center, far below other very large cities. The city is known for exhibiting multiple business districts, all loosely connected via freeways. Though Texas cities may desire intercity passenger rail services, the lower densities and minimal transit usage would likely be a detriment to the service's success. The most highly demanded examples of intercity passenger rail exhibit high transit use and formally planned land development.

On the other hand, car-centric transportation in Texas may be reaching a turning point. In the last twenty years, multimodalism, particularly transit, progressed significantly in connecting the state's sprawling metropolitan areas. Since 1983, Dallas Area Rapid Transit (DART) has pursued an aggressive system of HOV lanes, bus routes, and light rail, with rail service commencing in 1996. While the agency's bus ridership is not insignificant at about 130,000 daily riders, the relatively rapid expansion of rail services may be DART's most notable achievement. DART currently operates 45 miles of rail on 3 lines serving nearly 60,000 passengers per day.

The ridership of this system has surpassed many older light rail systems, including those of Baltimore, San Jose, and St. Louis (APTA, 2010), and will operate about 90 miles of rail by 2015. DART will enhance its intermodal operations with these expansions, as the new routes encompass connections to both Dallas Love Field and Dallas/Ft. Worth International Airports, as well as a link to the Denton County Transit Authority's "A-Train" commuter rail in Carrollton. By these measures, DART may be the most rapidly expanding transit provider in the nation. Improvements to transit are not limited to the Dallas area, although the success of rail transit elsewhere in the state is limited. Houston METRO services some 230,000 daily riders, with express commuter buses utilizing regional HOV lanes, as well as a small light rail line in the central part of the city (APTA, 2010). This light rail line, although only about 7 miles in length, has the second highest ridership per mile of all light rail systems in the United States (APTA, 2010). Furthermore, METRO plans to complete five new rail segments, initiate cross-town BRT service, and upgrade or construct twelve intermodal transit centers within the next two years. San Antonio and Austin are also pursuing new transit approaches, with the opening of Capital Metro's commuter rail service in Austin, and the construction of the VIA's Fredericksburg Road BRT in San Antonio. These improvements to transit operations and facilities are amidst the adoption of alternatives by planning agencies that produce a limited increase in VMT and promote higher density and less sprawl. Unfortunately, even with these upgrades on the horizon, Texas metropolitan areas still lag behind their peer metropolitan areas in transit use and multimodalism. Despite mimicking some characteristics of successful rail operations elsewhere, Texas cities must begin to embrace fundamental changes in access, land use, density, and development patterns in order to maximize the potential for intercity passenger rail in the state.

AIRPORT AND LOCAL RAIL INTERMODALISM

The primary rationale for rail connections at airports is the need to transport passengers to and from an airport to begin and end an air travel journey. Yet, this relegates rail as an ancillary function of airlines and airports, whereas it could contribute a more integral part of the air transport network. Development of HSR services could further enhance this role (Givoni and Banister, 2006). Additionally, rail does not suffer from a significant negative public perception to the degree of other forms of transit (seen in Hine and Scott, 2000, and elsewhere). Because rail connections at Texas (and United States) airports are underdeveloped at best, this concept presents a twofold set of goals for airport intermodalism. First, the development of transit connections at airports must take a forefront role in airport planning and enhancement. As no entirely new greenfield airports are likely to be constructed in the United States any time soon (the most recent was Denver International Airport around the turn of the century, preceded by Dallas/Fort Worth International in the mid-1970s), transit connections, especially rail, must be integrated into existing airport planning regimens to promote local intermodalism. Second, airports should also consider integrated HSR connections for their potential to enhance regional connectivity and multimodalism, perhaps replacing some short-haul air traffic. The next two sections will analyze these two policy objectives.

The nation's airports, as notable origin and destination centers, provide some of the best examples of potential intermodal connection opportunities. Intermodal connections at airports would boost transit utilization, which would likely contribute to greater success of HSR in a broad sense. American airports display a wide range of intermodal connection success. Combined public mode share for rail, buses, and vans is nearly 20% for San Francisco, New York, Boston, and Washington Reagan. Only for Atlanta and Washington Reagan is the specific mode share for rail above 10% (Coogan, 2008). While this may only comprise a modest number of passengers, for many cities these numbers exceed the rate of public transportation use substantially. Still, these rates of transit use in accessing American airports continue to be lower than many peer airports abroad. Analyzed extensively by ACRP Report 4, nineteen European and Asian airports achieved 20% transit use for access. As noted in the ACRP Report, the trends in airport transit use display considerable nuances not necessarily related to airport passenger volume. Instead market research indicates that air travelers with trip ends in downtowns or transit-rich areas are far more likely to use transit at the airport. Central business districts attract business travelers, who utilize transit more than vacationers or families. Limited numbers of connections and shorter duration of connections contribute to higher transit use as well. High service frequency also contributes favorably to airport transit use. Four major types of rail links with airports appear to exist (see Figure 21 below), as defined in Givoni and Banister (2006), and will be applied specifically to Texas in the next section:

Geographic Coverage	Category according to Stubbs and Jegede (1998)	Category according to IARO (1998)	International Example	American Example
City Center	Special line	High speed dedicated links	Heathrow Express (London), Arlanda Express (Stockholm)	None
City	Heavy rail line	Heavy rail link	Piccadilly service to Heathrow	BART (San Francisco), Metrorail (Washington Reagan), CTA (Chicago O'Hare and Midway)
Region	Spur line, branch line	Accidental link	Manchester airport rail station	Newark, Baltimore, Dallas-Love (Inwood)
National/ International	Main line	Regional links, HSR Network	Frankfort to Köln, Paris (De Gaulle) to Brussels	Newark, Baltimore (Amtrak Stations)

Figure 21: Types of airport rail connections (Givoni and Banister, 2006)

Texas airports substantially lack connectivity at present. A mere 6% of passenger mode share is comprised by public modes for Dallas/Ft. Worth, for example. Neither airport is served by rail transit, although DART does have plans to construct a new light rail line that will reach

Dallas/Ft. Worth International Airport by 2015 (Leigh Fisher Associates, 2002 and DART, 2010). Dallas Love Field lies remarkably close to a new DART rail line, yet the line does not interface with the terminal, certainly a lost opportunity for DART, Dallas Love Field, and the region as a whole. Metropolitan transit providers serve some of the other commercial airports in the state, mostly by bus service (see Figure 22).

Airport	Mode	Frequency	Notes
DFW	Bus (DART)	30-60 minutes, 15 minutes	Serves Irving and parking lots, transfer to terminal bus
	Trinity Rail Express	Approx. 30-60 minutes (No Sunday), 15 minutes	Transfer to terminal bus at CentrePort station
IAH	Bus (METRO)	Approx. 20-30 minutes	Downtown to IAH
	Bus - Airport Direct (METRO)	30 minutes	Downtown to IAH Express Service
AUS	Bus (Capital Metro)	45 minutes	
SAT	Bus (Capital Metro)	30 minutes	
ELP	Bus (Sun Metro)	30-45 minutes	
DAL	Bus (DART)	20 minutes	Transfer to DART rail at Inwood/Love Field station
HOU	Bus (METRO)	Approx. 20-30 minutes	
BRO	Bus	Approx. 60 minutes	Transfer to S. Padre Island Wave Bus
CRP	Bus (RTA)	5 hours	
HRL	Bus (Valley Metro)	Approx. 60 minutes	
MFE	Bus (McAllen Transit)	60 minutes	

Figure 22: Transit connections at Texas airports

This information suggests that Texas airports must do more to prepare for intermodal connections for the future. Texas airports perform well at present, with increasing passengers and constant needs for expansion. They do not face many of the spatial constraints of other similar airports nationwide and worldwide. But, with increasing passenger frustration with air journeys and decreasing willingness to drive, as well as metropolitan air pollution issues (noted in Mahmassani et al, 2001), planning should begin soon for air-rail connections in the state, as the state's airports risk losing any competitive edge to other international gateways stateside and abroad. The IARO Best Practices Guide (1998) offers the following as reasons to consider rail links to airports:

- Resource efficiency – emissions, land take, and vehicle life all tend to be better by train
- Traffic jams unlikely on rail
- Benefits to airport neighbors with elimination of vehicles from roadways nearby
- Higher quality of customer service, reflecting both the airport and the journey
- Higher perception of airport status
- Reduced need for parking, permitting more space for development nearby (or not)

Travelers in Texas' major airports indicated through surveys seen in Mahmassani et al (2002) that willingness exists to use alternative airport access modes, particularly transit and rail. This ranged from 20% to 74% in Austin and Houston, respectively. Willingness to use rail to access airports ranged from 8% to 28% in Austin and Houston, respectively. Because this information is based on a stated preference survey, however, it must be considered with caution as respondents frequently state one action and perform another, typically showing overly optimistic predictions of personal future transit use. Encouraging intermodalism at airports may involve relatively simple, inexpensive treatments that prioritize high-occupancy modes and vehicles. As stated in ACRP Report 4 (2008), "All too frequently, the traveler who chooses more efficient, higher occupancy modes from the airport is sent to an outer curb, unprotected from weather, with little in the way of accurate information or services." Improvements could include designating interior curbs as high-occupancy drop-off and pick-up zones or covering passenger waiting areas to protect from the elements. Improved signage and information about vehicle arrivals could easily enhance intermodal services. Perhaps intuitive, making rail an attractive mode requires a fast and seamless process in traveling from train to plane (or vice-versa); the best examples co-locate air and rail terminals in the same building, but on different levels (Givoni and Banister, 2006). Enhancing airport intermodalism requires action beyond creating a station or a stop at an airport as a second thought. Effective intermodal services integrate the mode and modal information into the airport setting (seen internationally in Figure 23 below), with direct access to stations or stops and thus require some architectural prioritization. These steps may not be revolutionary, but to overlook them in the design of airport layouts will severely limit airport intermodal potential for the length of the airport's life.

Airport	Passengers (12 months ending February 2011)	Rail Connection	Distance to CBD
Atlanta (ATL)	89,497,347	Yes (Heavy Rail)	7 miles
Beijing (PEK)	74,849,249	Yes (Heavy Rail)	20 miles
Chicago O'Hare (ORD)	66,528,691	Yes (Heavy Rail)	17 miles
London Heathrow (LHR)	66,101,510	Yes (Heavy Rail)	14 miles
Tokyo Haneda (HND)	64,511,475	Yes (Heavy Rail)	9 miles
Los Angeles (LAX)	59,162,148	No	16 miles
Paris Charles De Gaulle (CDG)	58,506,082	Yes (Heavy Rail and HSR)	16 miles
Dallas/Fort Worth (DFW)	57,008,407	No (Planned Light Rail)	21 miles (Dallas), 25 miles (Fort Worth)
Frankfurt (FRA)	53,468,915	Yes (Heavy Rail and HSR)	8 miles
Denver (DEN)	52,310,145	No (Under Construction)	25 miles
Hong Kong (HKG)	50,867,241	Yes (Heavy Rail)	21 miles
Madrid (MAD)	49,902,011	Yes (Heavy Rail)	8 miles
Dubai (DXB)	47,764,900	Yes (Heavy Rail)	3 miles
New York Kennedy (JFK)	46,642,833	Yes (Heavy Rail)	12 miles
Amsterdam (AMS)	45,718,899	Yes (Heavy Rail and HSR)	6 miles
Jakarta (CGK)	44,913,287	No (Planned Heavy Rail)	12 miles
Bangkok (BKK)	43,229,242	Yes (Heavy Rail)	16 miles
Singapore (SIN)	42,723,394	Yes (Heavy Rail)	11 miles
Guangzhou (CAN)	41,541,601	Yes (Heavy Rail)	17 miles
Shanghai (PVG)	41,257,657	Yes (Heavy Rail and Maglev)	19 miles
Houston Intercontinental (IAH)	40,387,619	No	20 miles
Las Vegas (LAS)	39,614,518	No	5 miles
San Francisco (SFO)	39,447,524	Yes (Heavy Rail)	13 miles
Phoenix (PHX)	38,813,450	No (Under Construction)	3 miles

Figure 23: Texas' major airports' and peer airports' rail connections (Airports Council International, 2011)

Texas Airport Rail Connections

From a local and regional transportation network perspective, airports contribute significantly to travel demand as major activity centers. In the United States and Texas, an airport serving 45 million passengers annually may contribute as many as 5 million VMT daily. Officials charged with developing congestion management strategies or air quality improvements, for example, cannot ignore the impact of airports. Improvements to ground access also contribute to increased capacity and efficiency at airports (Coogan, 2008). Understanding successful airport connection attributes, however, shows that developing a highly successful airport rail connection is far from exact science. In addition, airport intermodal stations carry relatively high expenses; the Miami Intermodal Center is estimated to cost $1.8 billion. The range of factors identified in the previous section indicate that the degree to which each individual factor impacts success for a connection at a particular airport changes depending on the particular airport scenario. In light of this and the poor airport rail connections at present in Texas, the following will consider a number of factors in evaluating the potential plans (if any) and opportunities for rail connections at Texas' major airports (more than one million annual passengers).

Austin

Access to Austin Bergstrom International Airport via rail continues to be a discussion that began with the opening of the new airport in the 1990s. Rail right-of-way parallel to TX-71 entering the airport from the west-northwest appears in the latest version of the Airport Master Plan, with a conceptual station near the existing terminal, though likely not in the existing Barbara Jordan Terminal building. Some interest in recent months has been generated by the City of Austin Urban Rail initiative, which visualizes connecting the airport to the center of the city via Riverside Drive with 10 minute headways. The connection to the airport would likely fall into a second phase of the urban rail plan if it moves forward. Other opportunities near the airport include the two rail lines owned by Capital Metro (one is the current Red Line commuter route, while the second is the conceptual Green Line commuter route extending to Manor and Elgin), although these would require acquisition of right-of-way to extend to the airport. Finally, an old rail spur from the UP main line passing through central Austin exists roughly parallel to TX-71 and

Burleson Road extending toward the airport, and could provide another option for a rail connection. As passenger rail is proposed for the main UP line (Lone Star Rail), perhaps the spur will be useful for an airport connection to the central sections of Austin or a rail station proposed in the Seaholm district. As the airport lies east of the city, and is inconvenient for future HSR heading to the city center (except for perhaps a line from the east, such as one to Houston), the potential for HSR is limited.

Dallas Love Field

Dallas Love Field sits approximately 5 miles northwest of downtown Dallas in an urban low-rise area. DART opened a new light rail line close to the airport in late 2010, with bus service on twenty minute headways connecting the airport to the Inwood light rail station. Originally DART considered an in-terminal stop for the light rail, but this was determined to be prohibitively expensive, possibly jeopardizing federal grants for the project. As a result, the airport can neither fully capitalize on its location near the center of the city, nor its location near a light rail line. Any reconfiguration of the infant light rail line is likely to come at least several decades in the future at the earliest. With the quality of Love Field's terminal facilities declining over time, the airport recently adopted a modernization plan for which construction is underway. Coincidentally, the City of Dallas pursued a feasibility study for an automated people mover between the Burbank DART light rail station and the terminal, requiring tunneling underneath one runway. The consultant team found the connector to be feasible, with the preferred alternative including an in-terminal station, although as is typical with "last mile" connections, it is expensive, with estimates above $400 million. Love Field's opportunities for HSR are limited. First, the tight urban configuration of the air field may prohibit new rail lines for a potential HSR connection. Additionally, as the preferred model from abroad tends to connect HSR to large hub airports

(Paris, Frankfurt, Amsterdam, as seen in López-Pita and Robuste, 2004 and elsewhere), a corridor orientation with a Dallas-Fort Worth-bound trajectory would likely receive priority.

Dallas-Fort Worth International

Dallas-Fort Worth International Airport (DFW) is the busiest commercial airport in the state. After nearly four decades of existence, the airport at long last has begun actively pursuing regional rail links. Beginning at the north entrance to the airport, the former Cotton Belt rail line passes nearby creating an opportunity to link the airport with northern Dallas suburbs, northeastern Fort Worth suburbs, and central Fort Worth. Planning for the rail line between DART and the Fort Worth Transit Authority is not temporally aligned, meaning the split project will not likely be completed in unison. Additionally, the DART extension from the Green line through northern Irving and Las Colinas will enter DFW at the northern end, allowing for an excellent transfer opportunity between rail lines and the airport. Conventional wisdom would suggest integrating the facility into the terminal. Yet, a tolled parkway bifurcates the airport, acting as a barrier to adjoining rail lines approaching from opposite sides. Current plans for the Cotton Belt line indicate separate lines operating from Fort Worth and Dallas requiring a change of train at the airport. To encourage the greatest ridership possible, unifying the operations on this line would be the optimal approach. This would also limit the necessary station infrastructure to two rail lines aligned at the DFW station (the Cotton Belt and the DART Orange line), rather than three. Considering a HSR station at DFW, an essential element of any HSR plan in the state given the best practices from abroad, the potential for flight substitution (considered in depth later on), and the population of the region, the integration of rail at the airport becomes further disjointed. As all proposed HSR services in the state approach DFW effectively from the south (Fort Worth is southwest, Dallas is southeast), a highly desirable fully-integrated airport rail station with the previously mentioned services may be impracticable. Even if a future HSR station acts as a stubend, which may have potential, tracks will require tight radius curves in and/or out of the airport. If the station were oriented east-west, trains would still turn toward the CBD of either Dallas or Fort Worth. Furthermore, any non-north-south station configuration, given the north-south orientation of International Parkway, would necessitate tunneling of some type under terminals and/or runways. Given these large-scale constraints, however, the airport does not suffer from a cramped footprint. Planned with substantial expansion room, the airport owns more than 28 square miles of land area (some 20% larger than the island of Manhattan), at about 8 miles north-south and 4 miles east-west, thus allowing some freedom with development and changes in land use. With regional growth and sprawl creeping toward the airport, the airport boundary has become increasingly well-delineated by abrupt lines of buildings and carefully angled roadways, which would provide some challenge with new airport rail access. The Trinity Rail Express, operating on an old Rock Island rail line, provides the closest to existing rail access to the airport. The service operates between Dallas and Fort Worth, with a stop in an industrial area five miles south of DFW's center, conveniently known as "CentrePort". Not necessarily a strategic intermodal opportunity in itself, the station location approximately marks the midway point between the airport and central Arlington, which houses multiple professional sports facilities and theme parks, undoubtedly a large source of transportation demand, and thus may be an element in a larger scale corridor, possibly even a HSR corridor.

El Paso

Texas state boundaries insisting otherwise, El Paso historically and geographically may have more in common with New Mexico. Las Cruces, New Mexico is the only city of any size within 100 miles of El Paso, which lies at the extreme western tip of Texas along the Rio Grande. Any future rail connections to the city likely would terminate in El Paso after traveling parallel to the Rio Grande from Albuquerque. The airport lies approximately five miles east of central El

Paso just south of Fort Bliss. An abandoned rail spur to the base parallels Robert E. Lee Road and Airway Boulevard connecting with the main UP rail lines closer to the international border. This section of rail passes adjacent to the airport and may provide an opportunity for future rail linkage should the city or region pursue such a project.

Houston Hobby

Houston's Hobby Airport occupies a square piece of land approximately 10 miles southeast of downtown Houston in a mixture of residential and industrial land uses on the edge of Houston's denser core. Rail connections to Hobby, while not inevitable, have made only minimal progress since the commencement of rail transit in Houston. However, the Hobby Master Plan indicates and briefly describes the footprint for a light rail station facing the terminal entrance from across Airport Blvd. Additionally, prior to enacting phase two of the METRO Solutions plan, METRO (Harris County Metropolitan Transportation Authority) published some planning maps for rail in Houston indicated that a Hobby airport connection may exist in a future phase three. Hobby's potential for "accidental rail links" may be the highest of the major airports in Texas. As Houston is replete with rail lines and regional commuter rail planning is underway, Hobby may find an opportunity in the near future to link itself to the rest of the city via rail. Two relatively low-volume freight rail lines considered for commuter rail implementation pass within approximately two miles of the airport, generally aligned southeast-to-northwest toward central Houston, with BNSF Mykawa Subdivision rail spurs approaching the airport property from the west. Opportunities for HSR station implementation may be slim given the location of the airport. Unless routes continue past downtown Houston to Galveston, they will not travel out of the way to locate near Hobby airport to/from downtown. If trains do continue to Galveston, a stop near Hobby may be feasible if using existing rail rights-of-way. The lessons from abroad indicate that the location of HSR stations at airports tends to work best at hub airports, likely leading to a prioritization of a connection to Houston Bush Intercontinental Airport before Hobby.

Houston Bush Intercontinental

Situated on Houston's north side approximately twenty miles from the downtown area, Houston Bush Intercontinental Airport (IAH) serves the second highest number of passengers of commercial airports in the state. Much like Hobby, IAH currently does not connect to the regional transit network via rail, but the idea remains in the collective mindset of city airport planners. Unfortunately, the concept has progressed little. The latest airport Master Plan briefly mentions and budgets for light rail planning such that a rail line will eventually connect to the airport, but a conceptual alignment was not included. The same planning maps from the METRO Solutions plan mentioned for Houston Hobby airport earlier also shows a continuation to IAH of the north light rail extension currently under construction. The route, although certainly an approximation, appears to follow existing roads, likely using rights-of-way or easements. Also as with Hobby, two existing UP rail corridors pass in close proximity to the airport, each within about four miles of the airport terminal, creating a future opportunity to link the facility with rail either through shared track or parallel alignment limiting land taking. As for future HSR alignment utilizing the airport, IAH may capitalize by its geographic location in a corridor between central Houston and points north and northwest (Waco, College Station, the Woodlands, Dallas-Fort Worth, even Austin to some extent). To establish a HSR station at this busy hub airport would require little deviation, if any, from a direct corridor link with any of these cities. While IAH does not have the available land of its in-state benchmark competitor DFW, it nevertheless occupies a relatively low-density area with dispersed suburban residential splotches. A preferred in-terminal link, in concert with the Master Plan, would entail some degree of tunneling under runways and likely the terminal itself. Because two runways at IAH operate essentially perpendicular to all others and the terminal is surrounded by runways, connecting to IAH without some degree of tunneling is likely impossible. Alignment near either the southern or eastern approach to the airport (John F. Kennedy Blvd. or Clayton Pkwy) may limit this to some degree.

San Antonio

San Antonio International Airport's location alongside a rail corridor seven miles north of downtown San Antonio may enable intermodal facility development before the other larger airports in the state. Land use and physical constraints also limit the ability of the airport to expand and rail service may enhance the airport's capacity without the need for excessive land taking, freeway realignment, or earthwork that would accompany new airside and/or landside facilities. At present, no concrete plans exist to connect the airport via public transit, although the VIA Transit Smartway SA transit planning process considers a possible future light rail connection to downtown San Antonio operating north-south along San Pedro Ave. The alignment appears to be purely conceptual thus far. The existing UP line under consideration for passenger rail service between San Antonio and Austin (Lone Star Rail) likely provides the best example of a single "accidental rail connection" in the state and grants the airport its best possibility for an intermodal link. The latest airport master plan acknowledges the rail line and future passenger service, but makes no specific arrangements. The plan provides for future land acquisition near the rail line south of Interstate 410, where rental car operations currently take place. The spatial constraints for the airport may limit the otherwise optimal opportunity for air-rail intermodalism. As two freeways and the UP line essentially bound the airport on three sides such that one of the two perpendicular runways aligns parallel with the rail line, a preferred in-terminal rail station arrangement might see extreme difficulty. Truly a last-mile problem, a runway, a major freeway, a several blocks along a side street separate the terminal and the land marked for an intermodal station. While HSR experiences indicate that connections at a regional airport like San Antonio (rather than a hub like DFW or IAH) may not be ideal, the opportunity with the likely utilization of the nearby UP rail line for future passenger rail service, possibly of HSR quality, should not be left unimplemented unless dictated by extreme circumstances.

REGIONAL CONNECTIVITY: AIR-RAIL SUBSTITUTION AND INTEGRATION

Outside of measuring local connectivity at airport nodes, airport-rail integration deserves consideration in its own right at a regional level, as this holds a great opportunity for Texas. As with interactions between many other mode pairs, rail both competes with and enhances air operations. Over shorter distances, rail offers a time advantage, but as distances and travel time increase, air travel gradually overtakes this advantage. European examples (Barcelona-Madrid, Paris-Lyon, and Frankfurt-Köln, most notably) as well as Acela Express demonstrate that short haul air travel can be measurably impacted and/or eliminated by the introduction of HSR service. In addition to providing the time advantage over short flights, four major motives exist for intermodal integration at airports (Vespermann and Wald, 2010). First, related to customer needs and service quality, rail services provide increased reliability, comfort, and punctuality when compared to buses or personal cars. Second, air-rail integration enhances an airport's catchment area leading to higher passenger numbers. Third, these advantages may result in increased airside capacity for a given airport when rail acts as a feeder service for airlines by replacing short haul flights (such as many in Texas). Gates and landing slots can be reassigned to longer distance flights (commonly these utilize larger aircraft, thus increasing airport capacity). Finally, the higher occupancy of rail systems is more space efficient for accessing congested airports than roadways and parking lots, and thus promotes increased landside capacity. Texas stands to gain from air-rail integration, particularly in the second and third items, which will be the focus of this section.

The large number of regional flights operating throughout the state between the major hub airports in Dallas/Ft. Worth and Houston and the state's many small- and medium-sized cities provide an opportunity for successful air-rail integration. Degrees of both competition and complementarity exist. Competitive markets between air and HSR need not necessarily link HSR at airports at either end, as the user will select the mode providing the greatest perceived utility at the lowest generalized travel cost (Janic, 2003b). Examples of this include London-Paris, Paris-Brussels, Washington-New York, Madrid-Barcelona, and Tokyo-Osaka. Complementarity between air and HSR can be established at airports with a high number of connecting passengers, typically occurring at hub airports for major airlines. As previously mentioned, hub operations for American Airlines (DFW) and Continental/United (IAH) provide an excellent laboratory for such an experiment, as these are two of the largest air hub operations in the United States. Of three generic HSR-air complementarity schemes seen in Janic 2003b, the collection of passengers by HSR for short-distance segments then distributed to longer distance air travel at a hub airport presents the most likely scenario for Texas. While linking two hub airports via HSR may be useful, this implies two connecting operations (air-rail and rail-air, one at each hub) for a three-segment trip, which is both burdensome to passengers and generally unlikely in practice in this scenario, as DFW and IAH serve very similar sets of destinations.

Well-developed HSR may potentially divert millions of air passengers annually within the Texas Triangle region. The extensive hub operations at DFW and IAH as well as the large number of intercity flights on point-to-point carrier Southwest Airlines amount to a substantial number of passengers. Using BTS Top 100 Data (BTS, 2011a) from 2008 (which should be close to present data given the economic dip of 2009-2010), nearly eight million annual passengers enplaned and deplaned within the major airports in the Texas Triangle (see Figure 24).

Origin	Destination	Annual Passengers
Austin (AUS)	Dallas Love	284,180
	Dallas-Fort Worth	584,206
	Houston Hobby	136,627
	Houston Intercontinental	353,887
Dallas Love (DAL)	Austin	280,357
	Houston Hobby	516,331
	Houston Intercontinental	92,990
	San Antonio	322,848
Dallas-Fort Worth (DFW)	Austin	575,557
	Houston Hobby	131,630
	Houston Intercontinental	398,484
	San Antonio	596,161
Houston Hobby (HOU)	Austin	132,239
	Dallas Love	508,253
	Dallas-Fort Worth	129,688
	San Antonio	140,355
Houston Bush (IAH)	Austin	345,915
	Dallas Love	90,842
	Dallas-Fort Worth	406,270
	San Antonio	365,054
San Antonio (SAT)	Dallas Love	318,048
	Dallas-Fort Worth	593,336
	Houston Hobby	135,697
	Houston Intercontinental	374,085
	TOTAL	**7,813,040**

Figure 24: Annual commercial air passengers between major Texas Triangle airports (BTS, 2011a)

Complementarity between air and rail in Texas might take the form of HSR replacing short-distance distribution or collection flights from the major hub airports, linked to connecting flights originating or destined for other destinations at a greater distance. This would play the largest role in the smaller airports in the region, perhaps eliminating short-haul flights from cities such as Waco, Beaumont, College Station, Longview, or Laredo to larger airports with more extensive long-distance air services. Some small airports currently subsidize operations to minimize losses on connecting regional jet service (Gregg County Regional Airport, 2011);

eliminating these inefficient services makes sense both for airlines and smaller communities' budgets. According to Top 100 data from the Bureau of Transportation Statistics, an additional 600,000 passengers flew between Waco, Killeen, College Station, and Beaumont to either DFW or IAH in 2008. The short duration of these flights and the type of small aircraft utilized means these flights are best-suited for substitution by rail. The potential for rail to substitute air trips to/from cities generally thought to be just outside the Texas Triangle (including Laredo, Tyler, Longview, Corpus Christi, and Wichita Falls) would increase this number even more. Janic (2003a) describes the specific effects of air transport when substituted for rail, which will be analyzed in more detail in Chapter 6. These include:

- decreased operating costs: marginal operations costs for air are higher than for rail, although this falls with increased distance,
- decreased energy consumption,
- decreased time-to-distance cost ratio, and
- decreased air pollution: this is not constant throughout for either mode, but nevertheless over a wide range of journey distances, rail averages lower emissions of most types of pollutants.

To maximize complementarity, multimodal terminals are a necessity at hub airports, timetables of rail and air services should coordinate with one another, and through ticketing should exist across the two modes. Foreign experimentation with these ideas has occurred although it is limited. Lufthansa and Deutschebahn (DB) experimented with an air-rail arrangement, including through ticketing and baggage services, between Frankfurt Airport and the cities of Köln and Stuttgart. While the experiment did demonstrate the ability to replace air travel with rail between short distances, it also displayed the difficulties of baggage mobility between the two modes in a modern era of transportation security concerns. The newest ICE trains on the route do not feature baggage compartments and must use modified passenger compartments. Secondly, the load/unload time for baggage challenges the tight schedule of rail operations, requiring quick work during short scheduled stops. Finally, foreign baggage must clear customs, requiring customs stations at train stations. Lufthansa abandoned the baggage check concept in 2008 after passengers displayed only nominal interest in the service over the previous four years compared to the larger logistical challenges presented by the concept. Attempts at through ticketing in the United States have achieved some success, although at a limited scale. Continental Airlines (soon to be United) partners with the Amtrak and the Acela Express service to allow airline ticket booking to certain cities served by Amtrak in the Northeast for a combined ticket price using the rail station at Newark International Airport (EWR). Members of the SkyTeam airline alliance also took a similar approach to ticketing for SNCF (Société Nationale de Chemins de Fer, French National Railways) rail segments in Europe to match transatlantic flights. The service has since ceased as Air France considers operating its own HSR services competing with SNCF. The ability to purchase joint tickets removes a significant mental barrier to the intermodal process, although such arrangements require substantial planning and coordination across the two different operations. Issues that affect one may not (and perhaps should not) affect the other; weather immediately comes to mind as one area affecting air more substantially than rail. The integration of reservations systems presents a large operational challenge to the providers, and is a primary reason that more airlines do not interface with European rail services at Frankfurt, Paris, or Amsterdam. As noted in ACRP 31 (2010), “it is essential to activate the individual modes’ strengths and to combine them optimally…” although it also noted that “the complete abandonment of air service in response to the introduction of very high quality rail service is very rare” and HSR substitution for air travel in the United States will only take place as a part of a complete program. Additionally, as congestion continues to build on the state’s metropolitan area roadways, the development of alternative modes to and from airports is increasingly important. Airports are certainly not the only opportune locations for intermodal facilities, but provide an excellent proxy for measuring multimodal connectivity within a city. Furthermore, the specific air-rail interface successes seen abroad provide the best example for such connections at major airports in the United States, and Texas specifically.

CONCLUDING REMARKS

Texas cities display a notable lack of multimodal connectivity. Urban transit systems remain woefully underdeveloped compared with those in peer cities, although the systems appear to be slowly gaining ridership and growing in service area. The expansion of urban transit and multimodal connectivity benefits the potential for HSR in Texas as it provides the opportunity to choose from a greater number of modes of travel perhaps more convenient for certain trips. Interfacing HSR with airports plays a particularly important role in the urban and regional connectivity framework because airports are major trip producers and attractors. Internationally, rail connections at airports contribute to enhanced regional connectivity, whether for HSR or urban heavy rail transit. Similar connections would benefit Texas airports and a potential Texas HSR system by replacing short-haul air trips and effectively increasing airport capacity without new terminal or runway construction. Because Texas airports will likely only explore expansion and reconstruction, instead of new greenfield development, it is important to integrate planning for airport rail connections into existing airport plans.

Chapter 5: Spatial and Legal Considerations

Perhaps nothing excites and ignites the public more regarding a transportation investment than the distribution of maps with lines depicting possible alignments for a proposed project. Of course, transportation planners eventually remove all but one option from consideration through several levels of analysis as a part of federal and state environmental requirements, but the potential to change the existing landscape by constructing a new rail line, for example, particularly in rural areas, may cause the greatest contention amongst the populace. Spatial issues rarely transcend projects, causing some difficulty. Even major improvements to existing corridors occur infrequently, and the primary issues are hardly ever the same from one project to the next. Instead, the lessons from to multiple projects suggest methods for the facilitation of spatial issues and optimizing the outcome of the public outreach process. This chapter presents basic information about the spatial requirements for typical rail systems, the limitations of the rail footprint on land, and the political issues with land taking, primarily eminent domain.

EXISTING GUIDANCE FOR CORRIDOR GEOMETRY

With HSR still in infancy as a mode in the United States, guidelines for the geometric alignment of corridors continue to evolve, although some degree of federal guidance exists alongside industry standards. As for any mode of transportation, safe and comfortable operation requires facility design allowing consistent speeds and limited acceleration and deceleration. The Code for Federal Regulations (CFR), a set of standards and regulations enabling federal acts, provides fundamental guidance for horizontal track geometry in Section 213, subpart C. Here, the same standards apply to all track speeds and have been in place since 1971, thus pertaining to the six classes of track defined at that time for operations below 110 mph. The designation of track classes coincided with the development of Amtrak and a reorganization of the federal relationship with private freight railroads (see Figure 25). Emphasis on freight rail in the United States since resulted in designations only recently of track classes appropriate for successful passenger rail operations. Peterman et al (2009) note that outside the Northeast Corridor, most passenger and freight trains operate with speed limits of 79 mph because track is owned and operated by freight railroads whose trains operate most economically at slower speeds. This results in a twofold challenge for passenger operations on freight rail. While most US railroad rights-of-way have curvature and gradients that could accommodate speeds up to 125 mph with track and signal upgrades, this requires more investment than freight railroads will willingly make. In particular, FRA safety requirements for the highest speed tracks (classes 8 and 9) stipulate grade separation and practice indicates the inclusion of safety fencing (seen in subsequent diagrams), resulting in access issues for existing freight customers and faster service than is economical for freight. Meanwhile, passenger services require high speeds for success. Rail speed limits resulting in non-competitive travel times with auto or air travel severely limit the potential ridership of passenger rail service. Hence, dedicated tracks and right-of-way become essential elements for HSR service in Texas, as lower maximum speeds (e.g., 79 mph) will attract minimal ridership. The need for dedicated tracks and right-of-way for HSR means that the impacts of HSR on land take become important issues in the development of such a system.

Track Type	Speed Limit Freight	Speed Limit Passenger	Grade Crossings
Excepted	< 10 mph	Not allowed	Permitted
Class 1	10 mph	15 mph	Permitted
Class 2	25 mph	30 mph	Permitted
Class 3	40 mph	60 mph	Permitted
Class 4	60 mph	80 mph	Permitted
Class 5	80 mph	90 mph	Permitted
Class 6	110 mph		Permitted
Class 7	125 mph		Permitted with "impenetrable barrier"
Class 8	160 mph		Not permitted
Class 9	200 mph		Not permitted

Figure 25: FRA track classifications and regulations (CFR, 2011)

Additional classes of track (classes 6, 7, 8, and 9) for high speed operation (110 to 200 mph) were added in the late 1990s with subsequent subtle changes to the standards seen in subpart G. This subpart provides guidance on maximum speed in curved sections, right-of-way requirements, superelevation limits, track gauge, and track stiffness requirements, among many others. The American Railway Engineering and Maintenance of Right-of-Way Association (AREMA) represents industry standards by publishing the Manual for Railway Engineering, which has recently begun inclusion of a chapter on HSR systems. A work in progress, this AREMA chapter currently contains a number of blank sections to be completed as the guidelines develop, with current horizontal geometry guidelines addressing topics similar to those in the federal CFR added in 2005.

CURVE GEOMETRY

Engineering for curved rail segments differs little from that for curved road segments. Assuming a train maintains constant safe speeds on a track segment, passenger lateral acceleration, and therefore passenger comfort, dictates the critical design elements of a curved segment. The superelevation (also known as “cant” in Europe and elsewhere) describes the difference in elevation between the interior and exterior rails on a curve. Lateral acceleration that results on curved segments necessitates superelevation except at very low speeds. Basic static analysis shows that a vehicle traveling at velocity V in curve of radius R experiences lateral acceleration a, given small angle approximations:

$$a = \frac{V^2}{R}$$

This acceleration may have a number of negative effects, including:

- passenger discomfort,
- displacement of loads,
- risk of overturning in combination with strong lateral winds,
- risk of derailment from a wheel flange climbing the track, and
- high lateral forces on the track, causing undue track damage.

Superelevation counteracts the lateral forces that may lead to one or more of these results. The level of elevation to counteract the lateral forces, known as the equilibrium elevation, is found using the following formula, recommended by AREMA and others:

$$E = 0.0007V^2D$$

where E is the equilibrium elevation in inches, V is the velocity in mph, and D is the degree of curvature. In practice, the equilibrium elevation is reduced by up to 25% to counteract the potential discomfort that may result if a train stops on a superelevated section of track, as passengers can realistically undergo some minor discomfort without negative consequences. The maximum achievable elevation for high speed track is generally considered to be six inches, although this may be slightly higher for ballastless tracks. D, the degree of curvature, is defined as the angle subtended by a 100-foot chord. Simple arithmetic shows the following relationship between degree of curvature and radius (in feet):

$$D = 5730/R$$

Generally, for high-speed trains, the desirable curves will have a degree of curvature of one or less, indicating that curves at full speed may have radii of more than a mile (5280 feet). Underbalanced elevation (providing a "cant deficiency") results when the equilibrium elevation is greater than the actual superelevation, indicating a lateral force toward the outside of the curve. Current FRA Track Safety Standards limit the underbalanced elevation to three inches, although waivers for high speed equipment have been granted for up to five inches. Active tilt trains, such as Acela, Talgo, or the Swedish X2000, may be permitted up to nine inches of underbalanced elevation by the FRA. The California High Speed Rail Authority used the guidelines outlined above to calculate the minimum curve radii for the California HSR Project currently in its planning stages, with three scenarios: a desired scenario with larger radii and smaller superelevation (four inches), a minimum radii scenario (six inch superelevation), and an exceptional scenario (seven inch superelevation, as observed in a few instances in foreign HSR systems). Figure 26 provides the minimum radii based on superelevation limits calculated for these three scenarios:

Minimum Radii Based on Superelevation Limits			
Speed (mph)	Desirable (ft)	Minimum (ft)	Exceptional (ft)
250	45,000	28,000	25,000
220	35,000	22,000	19,500
200	30,000	18,000	16,000
186	25,000	16,600	14,000
175	22,000	14,000	11,200
150	16,000	10,000	8,200
125	10,500	7,000	5,700

Figure 26: HSR curve radii based on superelevation values (CHSRA, 2009)

RIGHT-OF-WAY AND WIDTH REQUIREMENTS

Few authoritative recommendations exist for HSR right-of-way. Currently no guidance exists from federal agencies or industry groups, although as made clear in the Texas Rail Plan

(2010), UP mandates the additional purchase of right-of-way and 50 feet separating passenger and freight rail tracks if they are to operate in parallel. While noting that a right-of-way safety plan must provide guidance to mitigate risks for a HSR corridor, the FRA provides no strict guidelines and even admits that limited information exists for shared right-of-way scenarios, such as with highway corridors (FRA, 2009b), despite the inevitability of right-of-way sharing in future HSR projects in the United States. Turning to examples from abroad, as well as California HSR 15% design specifications and the Texas TGV project, the right-of-way requirements for HSR show a need for perhaps surprisingly little space (see Figures 27-30 below). The selected cases adapted from Lindahl 2001 show very similar values to those for the system planned in California and the beleaguered Texas TGV (see below). At the narrowest – in an aerial structure – a cross-section of the California system shows about 50 feet necessary for side-by-side tracks (although a concrete column shows an above-ground footprint of about 17 feet in width). The footprint required increases slightly to 60 feet to account for drainage components when the tracks are not elevated.

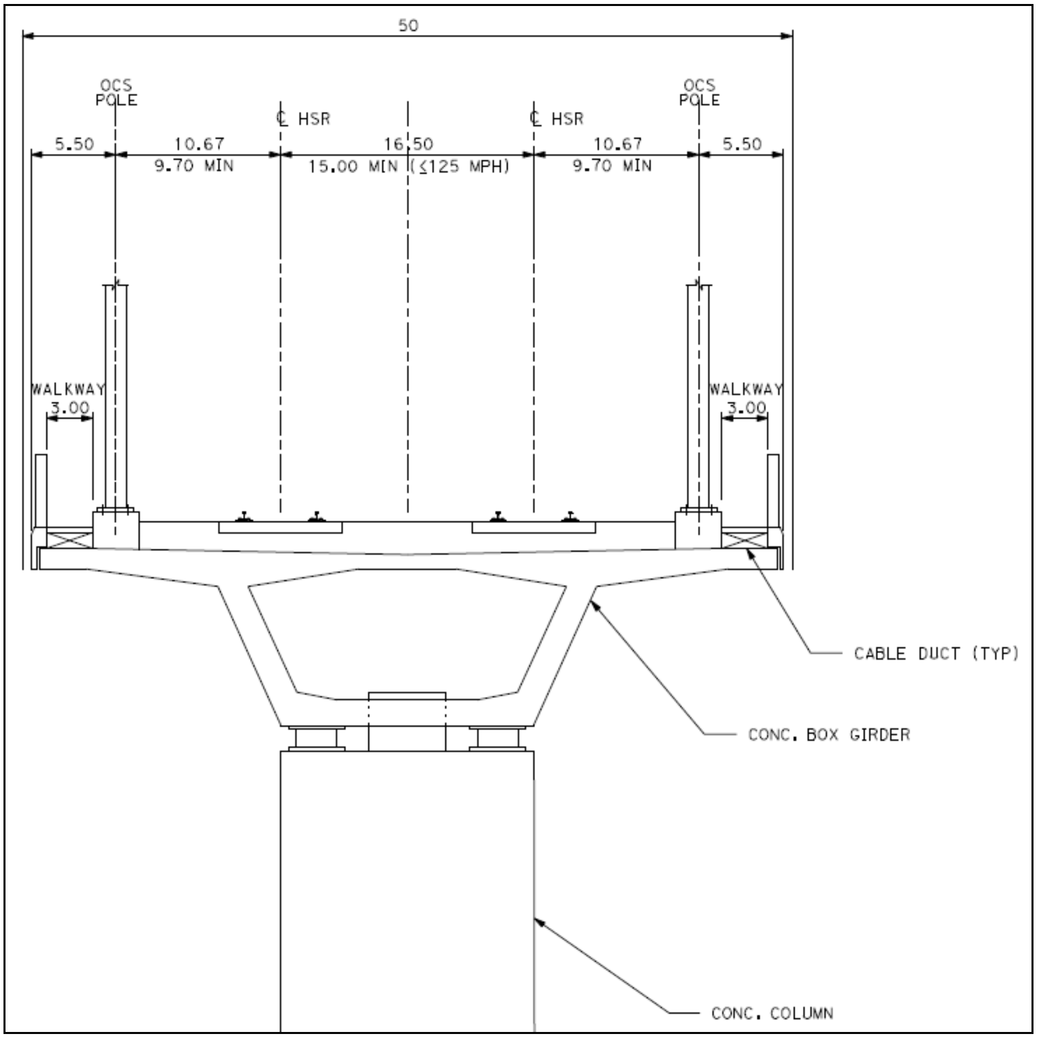


Figure 27: Aerial structure cross-section for California HSR project (Parsons Brinckerhoff, 2009)

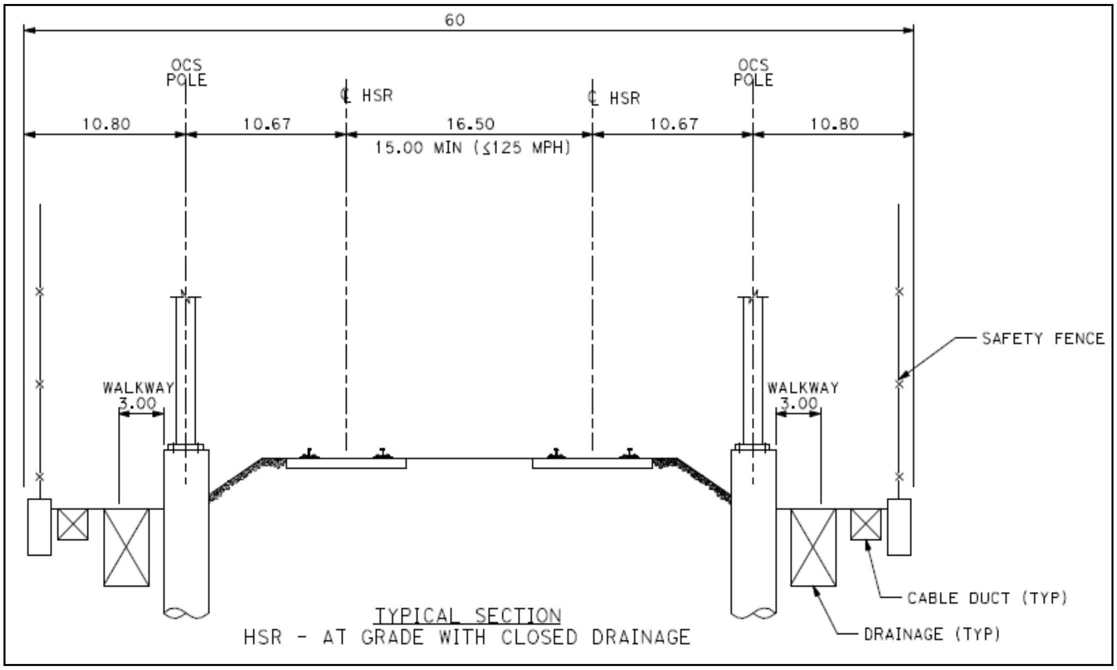


Figure 28: At grade cross-section for California HSR project (Parsons Brinckerhoff, 2009)

In the context of other HSR projects around the globe, the cross-sections for these railways appear to be very typical, if not slightly wider than typical. All are based on a standard rail gauge (4 ft 8.5 in or 1435 mm), with approximately 14-16 feet (4.6-4.9 m) between track centers for co-located tracks. Minimum curve radii are also nearly the same across the different examples, again showing their similarity. Plans from the Texas TGV proposal show similar dimensions:

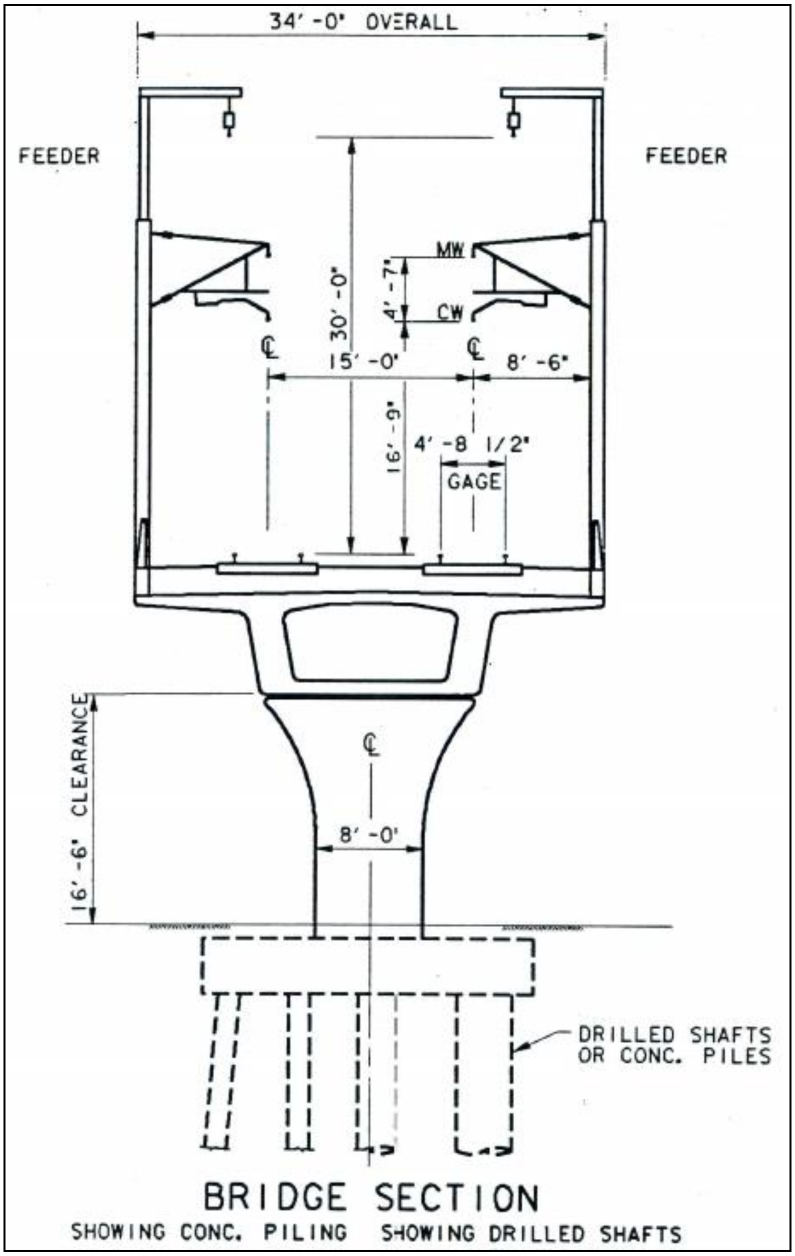


Figure 29: Aerial structure cross-section for Texas TGV project (Texas TGV Consortium, 1991)

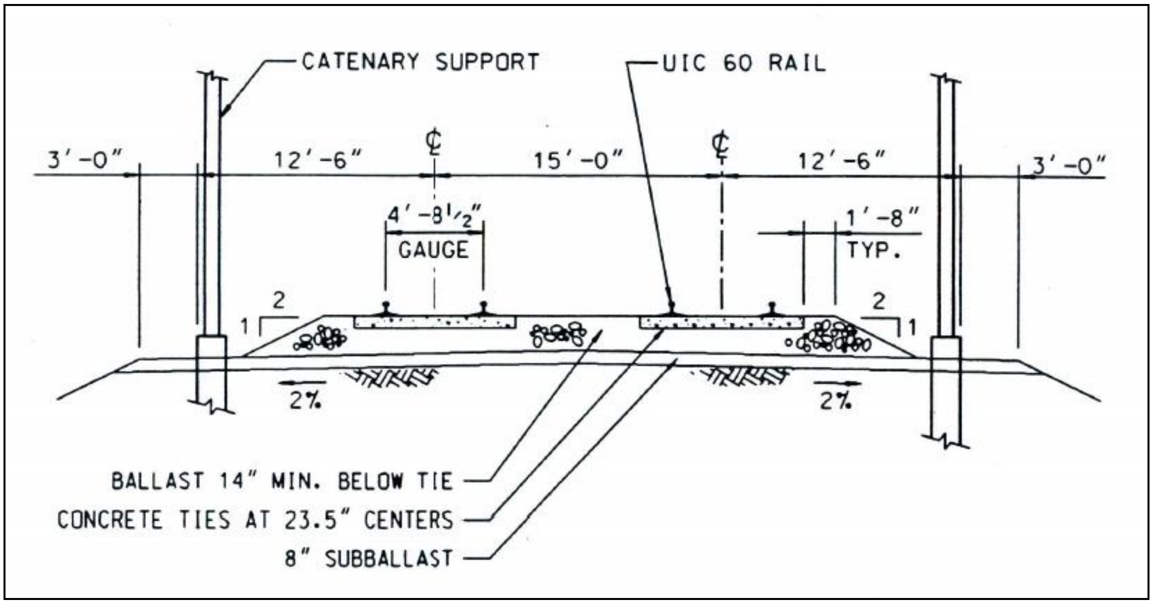


Figure 30: At grade cross-section for Texas TGV project (Texas TGV Consortium, 1991)

The elevated structure schematic for the Texas TGV project demonstrates a likely minimum width for a dual track rail segment. The cross-section omits emergency walkways and places each track approximately equidistant from the center of the platform and the outer edges of the platform. Concrete piles appear in the Texas TGV drawing, showing that the column footprint actually does not describe the entire ground level impact of HSR. In all likelihood, the width of below-surface concrete pilings closely matches the above-ground width of the structure to allow for stability, although the diagram does not explicitly show below-ground dimensions.

Implications of the right-of-way requirements for HSR thus include the potential to accommodate additional transportation growth through less land take than necessary for highway or air modes, although this tends to be site-specific.. The marginal impact of additional traffic on intercity highways and the land used by those highways, although real, is very small. This is especially true with large road traffic volumes in Texas. Marginal improvements and road expansions alleviate proportionally less traffic congestion with each subsequent improvement. Unless entirely new highways are constructed, the barrier effects on communities also likely remain unchanged, showing a very small marginal social impact. Marginal impacts of additional flights at the major airports in Texas also remain small. Because major airports already exist, air transport tends to be in a favorable position relative to HSR with respect to land take. Additionally, unlike many of the other busy airports in the United States, Texas airports generally do not face expansion restrictions due to proximate urban development or physical elements (e.g., water, mountains), which would otherwise enable a case for HSR. Janic (2003a, 2003b) reports that HSR requires approximately 2-3 ha/km of track (which, when converted, amounts to a cross-section of about 65-100 feet, which was confirmed earlier), while an airport requires about 30 ha/km of airside infrastructure such as runways and taxiways, the major land requirement for airports. Based on research from the EU, Janic further reports that the intensity of these land uses are comparable, with 3.23 and 2.86 million pass-km per year per ha of taken land for air travel and HSR, respectively. While the exact analysis method is unknown, analysis comparing typical land transportation capacities between rail and road shows that rail uses land with anywhere from six to five hundred times the efficiency of freeways. Taking data from TxDOT, approximations for freeway width based on design specifications and empirical data from Google Maps, and typical approximations for passenger volumes for both automobiles and rail, the land use efficiency for transportation carry capacity of HSR can be shown to far exceed that of freeways (see Figure 31 below).

	Width (ft)	Vehicles per day	Passengers per vehicle	Pass-km/ha-year	Space efficiency relative to 300-foot-wide freeway
Freeway	100	60000	1.89	13,608,081	3.0
	200	60000	1.89	6,804,041	1.5
	300	60000	1.89	4,536,027	1.0
Rail	35	24	400	78,994,758	17.4
	35	720	400	2,369,842,746	522.4
	50	24	400	55,296,331	12.2
	50	720	400	1,658,889,923	365.7
	75	24	400	36,864,221	8.1
	75	720	400	1,105,926,615	243.8
	100	24	400	27,648,165	6.1
	100	720	400	829,444,961	182.9

Note: 24 trains per day = 12 trains in each direction with two-hour headway, 720 trains per day = 360 trains in each direction with four minute headway, 400 pass/train represents 66% load factor for 600-seat train

Figure 31: Land space efficiency of transport carrying capacity

The efficiency values here show a wide range depending greatly on the demand for HSR service. The vehicle demand for a freeway is obtained using average annual daily traffic (AADT) data from TxDOT along a rural segment of Interstate 35 between Waco and Temple (approximately 60,000 daily vehicles). Of course, comparing a theoretical HSR system to an existing freeway system means marginal improvements to the freeway (e.g., freeway expansion alternatives) will always appear more advantageous given the incremental costs of an entirely new rail system. Still, given that the expansion of a single freeway lane in each direction (24 feet total at minimum) requires an area in which the column footprint of an aerial HSR structure would fit, the superior space efficiency of HSR must be given due consideration. Indeed, with the expense of a freeway expansion approaching the cost of HSR, failure to consider HSR as an option for corridor improvement may be a missed opportunity. TxDOT estimates it will spend $9.7 billion (in 2006 dollars) to complete planned improvements to the I-35 corridor, adding in most cases an additional lane in each direction, yet providing only 27% of the additional capacity required by 2025 (TxDOT, 2010d). The total cost of additional required capacity is estimated at more than $36 billion (in 2006 dollars) by 2025. The potential cost of rail, while unknown, is likely of this same magnitude; the estimated cost of the California HSR project is $45 billion, and as shown, HSR provides far greater transportation carrying capacity per unit of land take than freeways at a comparable capital cost.

LAND USE AND ZONING

The inextricable relationship between land use and transportation revealed through research in the last two decades shows that transportation heavily impacts community character, neighborhood quality, job density, accessibility, land values, and housing prices. Additionally, enormous implications due to unsustainable increases in automobile transportation have shifted the interaction of both policy areas. Kenworthy and Laube (1999) show that increases in motor vehicle ownership correlate with declines in population density. As Robert Cervero (2000) observes,

> "Lower densities reduce transit usage, which leads to cuts in services which in turn provoke even higher car ownership. Insidiously, sprawl and car dependency feed off one another."

As shown in Chapter 1, the increasing demand for travel, overwhelmingly by autos, recently reached a plateau in the United States. Although representing many societal trends, this plateau at least partially represents a public wearisome of increasing auto dependence and increasing auto commute times. This societal decision point marks an excellent opportunity for alternative modes to intercept the trajectory of increasing sprawl in favor of shifts toward greater urban density and reduced urban sprawl. HSR, when appropriately designed and aligned with changes in public policy, provides a once-in-a-generation opportunity for a large-scale transportation investment that will further realign the land use and transportation relationship in the United States, much as the interstate highway system did in the latter half of the twentieth century.

A section of Chapter 3 commented on the ability of HSR to spur local and regional economic development in the urban cores of Texas cities. Including Houston's unusual non-zoning land use controls (Qian, 2010), Texas municipalities possess the zoning tools to encourage development that might synergistically interact with rail stations in city centers. Texas cities have shown interest in innovative transit-oriented development (TOD), or at minimum transit-adjacent development. Urban planning instructors and transit-oriented development officials frequently point to the fairly successful Mockingbird Station along the original DART line north of downtown Dallas, if for no other reason than the obvious juxtaposition with the auto-oriented nature of the city. Unlike counties in Texas, which act as limited functional agents of the state, municipalities (cities) like Dallas may zone for various land uses, such as those guiding TOD, provided the zoning regulations follow the guidance of a comprehensive municipal plan. Section 211 of the Texas Local Government Code states that generally a municipality may regulate:

- the height, number of stories, and size of buildings;
- the percentage of a lot that may be occupied;
- the size of yards, courts, and other open spaces;
- population density;
- the location and use of buildings, other structures, and land for business, industrial, residential, or other purposes; and
- the pumping, extraction, and use of groundwater by persons other than retail public utilities.

Texas municipalities also exercise extraterritorial jurisdiction over unincorporated areas outside the city limits, with the intent of promoting the public health and welfare of those persons living adjacent to a municipality (Local Government Code Sec. 42). However, municipalities may not subject any area under extraterritorial jurisdiction to zoning regulations stated above (Local

Government Code Sec. 212). Implicitly, when municipalities annex those unincorporated areas developed with no zoning regulations under county jurisdiction, the existing land uses are “grandfathered in”. Such an arrangement means that urban areas attempting to limit sprawl must have stronger tools at the regional level to guide (or even prevent) development in unincorporated areas. Cervero (2000, 2003) highlights the successful regional planning efforts of Georgia, Florida, and Maryland, for example, to guide smart growth in those states. Regional- or county-level zoning authority in concert with city zoning encouraging density in Texas cities must accompany the development of HSR for it to transform the land use-transportation relationship. Otherwise, as observed in multiple media outlets (i.e. New York Times, the Transport Politic, Wired) HSR development will only sustain the sprawling urban reality of the present.

EMINENT DOMAIN

Among the more well-known tools used by government entities to craft transportation corridors and economic development is eminent domain. While “eminent domain” colloquially may refer to the purchase of any land for a public purpose, the actual definition specifies the seizure of land by a government entity for public use with due compensation, yet without consent from the private property owner. Thus, while land acquisition may comprise a substantial portion of a transportation project’s budget (as seen in Chapter 7), it does not imply all land purchases occurred without owner consent. Nevertheless, eminent domain remains an important aspect of transportation corridor development in Texas for HSR. Indeed, as noted in “Curve Geometry” earlier, high speed trains require massive radii to travel both fast and comfortably. Such curvature requirements, at least for the train velocity needed to succeed in Texas, do not match the curves of any other transportation infrastructure, except for perhaps certain limited access freeway segments. This implies that those rural areas where trains achieve the highest speeds will require land acquisition, possibly through eminent domain. The Texas Statutes extensively delineate land acquisition through eminent domain. Specifically, Chapter 21 of the Texas Property Code governs eminent domain legal proceedings and the required communication occurring between property owner and the particular state or local government agents. The Local Government Code and Transportation Code denote particular passenger rail-related entities and purposes that are enabled with eminent domain rights by the state:

Local Government Code

- Municipalities may "exercise the right of eminent domain for a public purpose to acquire public or private property" for various purposes including "the providing, enlarging, or improving of a…railroad terminal..." or for "any other municipal purpose the governing body considers advisable." (Chapter 251)
- County uses of eminent domain are less explicitly defined, but still state that "a county may exercise the right of eminent domain to condemn and acquire land…[for] public purpose authorized by law." (Chapter 261)
- Acquisition of property (through eminent domain if necessary) by municipalities is permitted within the county in which the municipality lies as well as the municipal limits for the purpose of a "public way", as well as for alterations to railroads. (Chapter 273)
- Elimination of slums or blight are considered "matters of state policy and concern that may be best addressed by the combined action of private enterprise, municipal regulation, and other public action through approved urban renewal plans." Improvements necessary to eliminate slum or blight conditions are "public purposes for which public money may be spent and the power of eminent domain exercised." (Chapter 374).

Transportation Code

- Railroads may "exercise the power of eminent domain for the purposes…necessary for the construction and use of its railway, stations, and other accommodations necessary to accomplish company objectives" including acquiring land for "right-of-way." (Chapter 112)
- Electric railways, corporations chartered with the purpose of constructing, acquiring, maintaining, or operating electrified lines between municipalities in the state for transportation of freight or passengers may "exercise the power of eminent domain with all the rights and power granted by law to a railroad company" provided that right-of-way does not exceed 200 feet in width. (Chapter 131)
- Intermunicipal Commuter Rail Districts, state entities linking major cities by rail, may exercise the power of eminent domain provided the acquisition of property "is a public necessity and is necessary and proper for the construction, extension, improvement, or development of commuter rail facilities and is in the public interest." However, this does not apply to land under TxDOT's or MTA's jurisdiction or a rail line owned by a common carrier or municipality. Statutes also require that districts, "to the extent possible…use existing rail or intermodal transportation corridors for the alignment of [their] system." (Chapter 173)
- Municipal grade-crossing improvements, permitted in municipalities of 100,000 people or greater, may require the acquisition of property. A municipality may "exercise the power of eminent domain to acquire…any property…necessary" for grade-crossing improvements, including "removing and relocating railroad tracks." (Chapter 317)
- Regional Mobility Authorities are authorized to study, evaluate, design, finance, acquire, construct, maintain, repair, and operate transportation projects that are included in applicable MPO plans and consistent with both the statewide transportation plan and statewide transportation improvement program (STIP). "The department [TxDOT] may

condemn property [through exercise of eminent domain] that is a part of a transportation project of an authority if the property is needed for the construction, reconstruction, or expansion of a state highway or rail facility." (Chapter 370)

- Metropolitan Rapid Transit Authorities (MRTAs) retain the ability to acquire, construct, develop, own ,operate, and maintain a transit system within the authority territory. An authority may "acquire by eminent domain any interest in real property" but may not "unduly interfere with interstate commerce or authorize the authority to run an authority vehicle on a railroad track that is used to transport property." (Chapter 451)
- Regional Transportation Authorities may, for the construction, repair, maintenance, or operation of [a] public transportation system, "acquire by eminent domain any interest in real property", provided such action takes place with the approval of the municipality or county with jurisdiction. (Chapter 452)
- Under the general powers and duties of TxDOT, the department may not "use eminent domain for a purpose…that unduly interferes with interstate commerce or establishes a right to operate a vehicle on a railroad track used to transport property." (Chapter 455)
- Coordinated County Transportation Authorities may, "as necessary or useful in the construction, repair, maintenance, or operation of a public transportation system, use a public way [and] acquire by eminent domain any interest in real property", provided it is done with the approval of the municipality or county with jurisdiction. (Chapter 460)

These statutes indicate a wide capability for the use of eminent domain for land acquisition in rail projects. The primary deficiency within these statutes is the lack of clear authority for interurban passenger rail transportation. Special districts, such as intermunicipal commuter rail districts and interurban electric railways, provide a necessary avenue for passenger rail project development and dictate integration with urban area transit systems. However, the statutes governing transit systems for small and medium-sized municipalities and counties do not address rail, and are written assuming bus-only operations. While presently accurate, such provisions do little to plan for any future rail operations and demonstrate a crucial gap in eminent domain legislation, particularly for cities such as Waco, Bryan/College Station, Temple, and San Marcos. These cities' transit providers, certain to be linked to a potential Texas passenger rail system, currently have no legislative guidance on eminent domain related to rail. Identifying future corridors for HSR in Texas will likely utilize powers granted to intermunicipal commuter rail districts and interurban electric railways, although given current gaps in rail governance, it is reasonable to expect that statutes will be clarified and enhanced. With the geometric requirements for HSR necessitating land acquisition, future implementation of HSR plans will likely induce a flurry of legislation specifically identifying the rights of the state and private property owners in rail corridors. The public has a historically critical eye for state land acquisition, even if for public benefits, probably meaning this will develop into a major issue in the future for HSR beyond recent developments (see Chapter 8).

HIGH-SPEED RAIL IN HIGH-TENSION WIRE CORRIDORS

Stemming from the spatial challenge of locating right-of-way for HSR corridors, high-tension electricity wire corridors deserve consideration. Since the transportation literature appears thin on the topic of co-locating both transportation and high-tension wire corridors, the idea deserves further research. A feasibility study by the Maryland DOT in 2002 highlights important issues and examples nationwide of such arrangements. The advantages and concerns of using such utility corridors may include:

- Reduced need for clearing forested areas. Many transmission rights-of-way have been cleared to allow for sag and/or sway of power lines. The incremental impact of constructing a transportation facility in the same right-of-way could be less than that of undisturbed land. The number of environmental permits required may be less than for an undisturbed corridor.

- Brownfield development. Many high-tension electricity corridors qualify as brownfield, and thus may qualify for particular development opportunities. Transportation facilities may make better use of the underutilized land.
- Concentrated linear land use. By utilizing high-tension wire rights-of-way, the socio-economic issues caused by the intrusion of a new transportation corridor and a utility corridor will be lessened through their combination. However, neighborhoods tend to accept utility corridors more easily than transportation corridors, meaning this advantage may be limited.
- Transportation facility geometry. High-tension wire corridors tend to be long and straight, which matches the profile of HSR geometry. Issues would come with curves. Utility corridors can abruptly change directions, whereas a high-speed train requires large radii.
- Increased costs. The co-location of the two uses may result in increased construction or maintenance costs for each out of the necessity to continue to provide both access and safety barriers
- Electrical interference. Electromagnetic interference may disturb electronic communication devices required for train operation. Interference depends on a number of climate and weather variables, but the design of “Faraday Shields” may address concerns at a high cost.

High-tension corridors may provide a feasible alternative to new land acquisition in rural areas for HSR corridors. A number of these utility corridors cross the central section of Texas and co-location of rail in the corridor would require minimal deviation from an ideally straight path between cities. These utility corridors tend to avoid urban areas. However, closer to urban areas, trains operate more slowly and must navigate more nimbly, meaning that the utility corridors may play less of a role. Certainly further investigation is needed, as such an arrangement would require a unique relationship between utilities and the rail operator, but an initial consideration seems to bear possibilities.

Concluding Remarks

As the United States delves into HSR, the importance of developing corridor design guidelines will become increasingly valuable. At present, no complete guidelines exist, although the FRA does provide recommendations based on 9 classes of track broken down by speed up to 200 mph. In addition to the implications of this on corridor curvature and alignment, the right-of-way requirements for corridors also pose challenging questions for the identification of routing. Based on estimated right-of-way requirements, rail demonstrates much higher transportation carrying capacity than roadways, although the marginal improvements needed at present sway the case for roads as only incremental improvements are possible. Land use and zoning regulations may provide the essential tools for cities to guide transportation corridor development that also promotes density and limits sprawl. Limitations on the role of counties, however, will hamper the ability to achieve such goals. Eminent domain will play an important role in the inevitable land acquisition required for transportation facilities, and thus careful analysis and improvements to eminent domain legislation will be necessary to simultaneously please the public desire for personal land ownership and adequate transportation facilities. The potential use of utility corridors provides one approach that may enable HSR to undertake long straight, rural track segments with minimal land acquisition.

Chapter 6: Emissions, Energy, Safety, and Economics

Coinciding with the effects of HSR on limited spatial resources, environmental factors also impact the success of HSR systems. Increasing concerns regarding use of fossil-based energy, climate change, and the implementation of sustainable transport practices (among other facets of human life) necessitate environmentally-conscious analysis of HSR vis-à-vis other modes already subjected to this analysis. A great many factors influence environmental measures of transport, including load factor, energy source, vehicle properties, and manufacturing. In addition to these factors, the safety implications for HSR cannot be overlooked. HSR play an important role in transport policy acting as one of several tools to achieve local, regional, or national goals for energy efficiency, environmental awareness, reduced transportation expenses, increased safety, and cost-effective transportation networks. The ability to simultaneously accomplish such goals while also achieving an increased need for higher-speed modes, discussed earlier, indicates that HSR should not be overlooked for its large first-glance price tag. However, to be clear, the implementation of HSR, all else equal, versus a do nothing scenario creates environmental burdens. But, if these burdens can be substituted for the even larger environmental burdens of existing transportation infrastructure, then the implementation of HSR produces net environmental benefits. The stream of returns HSR provides to society as a whole may indicate that it is a worthwhile investment, even if does not come cheaply in the short term.

Energy Efficiency Comparison

Energy efficiency of transport greatly affects the use of natural resources, individual transport expenditure, and the impacts of energy price fluctuations on the nation's transportation portfolio. Because of greater energy efficiency when compared to more commonly used modes, rail may provide quantifiable improvements in overall energy use at a large-scale. Implications for this range dramatically from the individual level to the global level, but generally represent an opportunity cost where decreased transport expense as a result of energy efficiency means expenses in other more preferred areas, perhaps health care or education (Woodcock et al, 2007). Rail is measurably more efficient than most other common modes in terms of energy consumption. Nevertheless, as cautioned in the Transportation Energy Data Book (Davis and Diegel, 2010):

> "Great care should be taken when comparing modal energy intensity data among modes. Because of the inherent differences among the transportation modes in the nature of services, routes, available, and many additional factors, it is not possible to obtain truly comparable national energy intensities among modes. These values are averages, and there is a great deal of variability even within a mode."

Still, despite the complexities in multimodal energy efficiency comparison, numerous sources arrive at similar results. When considering average energy use in operation, it appears that rail carries some advantage. This advantage greatly depends on several factors, including passenger load factor, trip distance, and vehicle dynamics. Yet, it can be illustrated very simply by considering a typical street with a personal automobile, a streetcar, and a bus. Space requirements aside, a personal auto with 5 passengers operates with greater energy efficiency than a streetcar or a bus carrying those same 5 passengers. Yet, depending on trip type, destination, time of day, and numerous other factors, on average the streetcar will carry a greater percentage of overall capacity. Personal autos, with an average occupancy of 1.59 persons are operating at approximately 32% (the "load factor") of capacity (for a 5-seat vehicle), whereas a 60-person-capacity bus or streetcar (that likely does not require 12 times the power of the personal vehicle) operating at 50% capacity consumes less energy per occupant than a personal car.

This presents an interesting issue regarding energy efficiency. While rail likely provides an excellent opportunity to substitute longer-distance trips from less efficient auto or air modes, it also must operate at a somewhat higher load factor in order to achieve tangible benefits. Thus, it is essential to operate rail lines that will generate significant ridership. As stated by Álvarez 2010 regarding the successful AVE service in Spain:

> "…the main advantage of the AVE is not that it consumes less energy and emits fewer greenhouse gases than the conventional train. The main advantage is that, thanks to its speed, it is capable of attracting a high percentage of travelers away from energy-inefficient modes of transportation, such as aircraft and private cars. "

It appears that operating busses may be even more efficient than operating rail in some corridors. This delves into previously addressed social stereotypes related to certain modes. Generally, it is thought that busses may never achieve ridership of comparable rail lines because of a stigma of inferiority associated with busses. Recent efforts in bus rapid transit (BRT) technology may begin to overcome the stereotypes that continue to plague urban buses.

Based on observed occupancy of the vehicles of different modes, it should be expected that a HSR system of average load factor would out-perform automobiles of average load factor on the same route. See Figure 32 for examples of energy efficiency across modes. Observed load factors on various HSR systems indicate that load factors of approximately 50%-80% are typical (Network Rail 2009). This is somewhat less than airplanes (65%-90%, average 82% in the United States for the twelve months ending February 2011, BTS, 2011a), although greater than automobiles in 100-mile-or-greater scenarios (1.89 passengers per vehicle, equivalent to about 38% load factor in a five-seat automobile, NHTS, 2009). With transport comprising the largest single end-use energy category at approximately 30% of overall energy use in the United States, of which 96% is petroleum-based (Davis and Diegel, 2010 Transportation Energy Data Book), shifts in transport energy consumption have large implications for overall energy use at a national and international level as fossil fuel resources dwindle and effects of greenhouse gases resulting from those fossil fuels become clearer.

Mode	Energy Use	Unit	Source	Notes
TGV	0.19	kWh/pass-km	Janic 2003	
ICE	0.22	kWh/pass-km	Janic 2003	
Air	0.38-0.586	kWh/pass-km	Janic 2003	100/150 person capacity, 100 occupancy (both)
Car	0.48	kWh/pass-km	AG Álvarez 2010	
Coach (Bus)	0.12	kWh/pass-km	AG Álvarez 2010	
Plane	0.54	kWh/pass-km	AG Álvarez 2010	
Conventional Train	0.26	kWh/pass-km	AG Álvarez 2010	
HSR	0.19	kWh/pass-km	AG Álvarez 2010	
Airbus A320-200	0.425-0.248	kWh/sec-km	Janic 2003	300 km/1200 km
TGV	0.106-0.141	kWh/sec-km	Janic 2003	200 km/1200 km
Car	3437	BTU/pass-mi	Transportation Energy Data Book 2010	
Personal truck	3641	BTU/pass-mi	Transportation Energy Data Book 2010	
Motorcycle	1875	BTU/pass-mi	Transportation Energy Data Book 2010	
Bus Transit	4348	BTU/pass-mi	Transportation Energy Data Book 2010	
Air	2995	BTU/pass-mi	Transportation Energy Data Book 2010	
Amtrak	2398	BTU/pass-mi	Transportation Energy Data Book 2010	
Rail Transit	2521	BTU/pass-mi	Transportation Energy Data Book 2010	
Commuter Rail	2656	BTU/pass-mi	Transportation Energy Data Book 2010	
Human (60 kg) on Bicycle	0.056	MJ/pass-km	Smith (2003)	
Human Walking	0.2	MJ/pass-km	Smith (2003)	
Intercity Train	0.59	MJ/pass-km	Smith (2003)	
Boeing 747	1.06	MJ/pass-km	Smith (2003)	
Urban Bus	1.11	MJ/pass-km	Smith (2003)	
Car	1.43	MJ/pass-km	Smith (2003)	(4 passengers, long journey)
Concorde	5.0	MJ/pass-km	Smith (2003)	
Car	5.0	MJ/pass-km	Smith (2003)	(1.15 passengers, urban commute)
Rail (electric)	0.19	MJ/pass-km	Dey Chaudhury (2010)	
Rail (diesel)	0.18	MJ/pass-km	Dey Chaudhury (2010)	

Figure 32: Estimates of energy use of various transport modes

EMISSIONS

Evaluating transportation's impact on the environment involves an increasingly complex analysis subject to some degree of subjectivity. The scope of environmental analysis regarding transportation primarily encompasses exhaust emissions, noise, water, and climate change, although also extends to include land take, health impacts, and safety implications. Because of the variety of environmental factors considered and their greatly varied effects, a common measuring stick is necessary against which to measure impacts. Yet, evaluation in terms of monetary units, by far the most common measurement, requires significant assumptions as the level of scientific knowledge and certainty exists amidst controversy (assigning monetary value to human life, for example) (Givoni, 2007). In light of the state of practice and the intent of this thesis to lean toward broad scale comprehension of rail-related issues, the environmental section merely aims to assess important environmental measures and qualitatively understand potential impacts of rail. Thus, addressing varying environmental concerns of different pollutants constitutes the focus of this section.

Nitrous Oxides (NO_x)

While not a result of electrically-propelled HSR, NO_x results from the combustion of fossil fuels and contributes to local air pollution at ground level and climate change when emitted at high altitudes (EPA, 2011). Thus, HSR substitution of air travel, a substantial contributor of tropospheric NO_x, provides an opportunity to reduce emission of this particular pollutant. With the average take-off/landing cycle (operations below the troposphere) taking less than ten minutes of flight time, the contributions to global warming become the larger concern (Givoni, 2007). Nevertheless, local NO_x accumulations affect respiratory functioning and impact local ozone development. Shown in Chester (2010), the extent of NO_x emissions over the life cycle of a HSR system greatly depends on the electricity source and the passenger load of the different modes. Relative to automobiles, HSR with the current mix of electricity sources appears to see slight advantages. This is further confirmed by acomparison of existing services between Paris and London by Givoni (2007). Currently NO_x concentrations in Texas and the United States meet existing EPA National Ambient Air Quality Standards (NAAQS). However, NO_x reacts with volatile organic compounds (VOCs) in sunlight to form ground level ozone (“bad” ozone, versus “good” ozone occurring 10-30 miles above the earth) that causes a variety of respiratory-related maladies. Ground level ozone also damages crops and ecosystems. According to the EPA, ozone reduces crop production by approximately $500 million annually. Emissions from industrial facilities, power generation facilities, vehicle exhaust, gasoline vapors, and chemical solvents contribute VOCs and NO_x to the ground level atmosphere. Currently Texas’ two largest metropolitan areas, Dallas-Fort Worth-Arlington and Houston-Galveston-Brazoria, as well as the Beaumont-Port Arthur area fall into nonattainment for NAAQS in ozone concentration, although the areas have seen modest improvements since 2000. Based on revised 2008 standards for ozone concentration, TCEQ notes that the Austin, San Antonio, Victoria, Corpus Christi, and the Longview-Tyler Northeast Texas Compact Area fall under near non-attainment, with some of these areas subject to early action to hopefully forestall seemingly impending non-attainment status (see Figure 33 below).

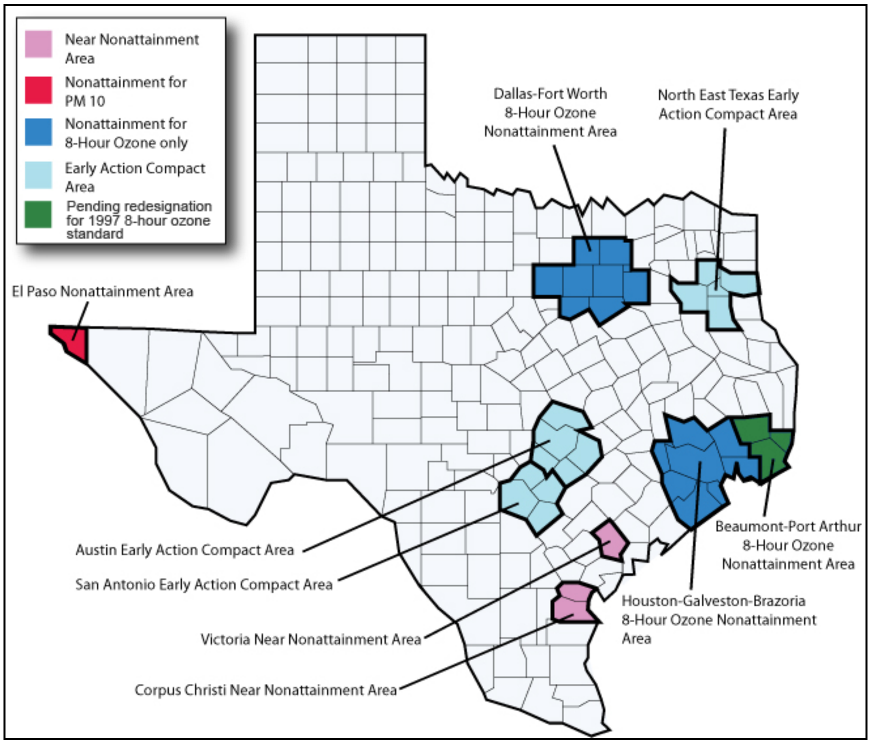


Figure 33: Air quality non-attainment status in Texas counties (TCEQ, 2010)

Sulfur Dioxide (SO_2)

SO_2 irritates respiratory function and contributes to acid deposition. Approximately 93% of SO_2 emissions in the United States result from power plants (73%) and industrial processes (20%) through the combustion of fossil fuels (EPA, 2011). Both the construction and operation phases of HSR thus create SO_2 emissions, while combustion engines in automobiles and airplanes only emit substantial quantities in vehicle construction, and small quantities in operation. Thus, as observed in Chaudhury (2003), the comparison of corridor SO_2 may be infeasible with power plants for electrically-powered HSR existing elsewhere, although larger scale emissions measurement should still occur. SO_2 presents the primary pollutant for which HSR demonstrates a substantial disadvantage. For HSR to obtain favorable levels of SO_2 emissions compared to other modes, implementation of a clean energy mix must take place. Givoni 2007 estimates 35.4 grams/seat of emitted SO_2 for a HSR journey between London and

Paris compared with only 2.9 grams/seat of emitted SO_2 for an air journey, based on the existing energy mix. Chester (2010) evaluates the life-cycle environmental impact for the 2030 operation of the proposed California HSR system using the current electricity mix in California versus a “clean energy mix” and arrives at this same general conclusion, with auto modes seeing similar values to airplanes. Analyzed in full detail later, the electricity mix in Texas, largely comparable to California, would require a substantial overhaul to achieve SO_2 emission levels that improve on current auto and airplane emissions of SO_2. Currently Texas metropolitan areas meet NAAQS for SO_2 concentration.

Particulate Matter (PM)

Particulate matter (PM) comprises a category of pollutants including both solids and liquids smaller than 10 micrometers in diameter that cause a number of ailments acting solely or when bonded with NO_x and SO_2. Potential effects encompass respiratory ailments, aggravated asthma, chronic bronchitis, irregular heartbeat, and non-fatal heart attacks when particulates lodge deeply in lungs. Fine particles (smaller than 2.5 micrometers in diameter) contribute to urban visibility issues (haze), changes in acidity in bodies of water, and affect the well-being of sensitive forests and crops. Additionally, with transport by wind and rain, deposition on stone fixtures occurs; these fixtures (many of them buildings and monuments of regional and national significance) then see degradation and damage as a result (EPA, 2011). Particulate matter results from the combustion of fossil fuels and thus concentrates in areas of industrial operations and population. As a result, electrically-powered HSR contributes minimally to this outside of electricity generation. However, because of regulations by the EPA on particulate emissions, auto and airplane emissions of particulates remain low as well. Both Chester (2010) and Givoni (2007) support the notion that HSR contributes lower particulate emissions to the environment compared with airplanes and automobiles. Currently no areas in Texas exist in non-attainment for SO_2 concentration.

Carbon Dioxide (CO_2)

Among the greenhouse gases, CO_2 contributes most substantially to global warming and climate change. At approximately 30% of overall emissions, the transport sector is the single largest contributor of carbon emissions, largely a result of the overwhelming use of fossil fuels described above. As such, it is essential to evaluate CO_2 emission impacts from rail. While much political debate continues in the United States regarding climate change (it appears a majority of Americans accept global warming, although support for the cause and effects show markedly less consensus), numerous other nations abroad include HSR implementation as an essential component of transport policy aiming to reduce emissions and limit climate change potential (European Commission, 2011). Simply stated, the impacts of global warming include climate change, which will likely lead to greater variability in weather patterns, rising sea levels, and other effects whose overall impacts are expected to be negative and will impose a social cost (IPCC, 2007). CO_2 forms a vast majority of greenhouse gas emissions and exhibits the greatest availability of data; analyzing the impact of HSR as a modal alternative within the realm of greenhouse gas emissions thus requires prioritization of CO_2 consideration (Givoni et al, 2009). As when comparing energy consumption of different modes, comparisons of CO_2 consumption on a modal basis requires many assumptions, and analysis changes depending on factors such as load factor, electricity source, route traversed, and vehicle type. The literature, however, appears to agree fairly uniformly that HSR use at present emits less CO_2 than other intercity modes (see Figure 34 below). Similar to many other emitted pollutants, a comprehensive life cycle analysis that considers the construction and electricity source of transport operations provides a more accurate estimate of the holistic impact of HSR implementation on the amount CO_2 emitted into the environment and can estimate breakeven points for different project alternatives. This chapter considers the impact of energy sources on HSR and its modal alternatives in more detail below.

Mode	CO_2 (g/pass-km)	Source	Notes
Air (London-Paris)	43,265	Givoni and Banister (2006)	(grams total)
Air Airbus A320	42.5-60.7	Givoni et al. (2009)	100/70 load factor, London to Paris
Airplane	34.0	Hayashi et al 2005	Operation
Airplane	171	Smith 2003	65% load factor
Domestic flight	191	Dept. for Transport, 2008	
Plane	169.1	Álvarez 2010	
Short range aircraft	117.2	Kageson 2009	
Average motorbike	106	Dept. for Transport, 2008	
Long-distance buses	19.1	Kageson 2009	
Bus/coach	69	Dept. for Transport, 2008	
Coach	32.3	Álvarez 2010	
Car	113.0	Álvarez 2010	
Car/Taxi	104	Givoni et al. (2009)	
Cars (combustion)	45.8	Kageson 2009	20% biofuels
Electric Cars	53.0	Kageson 2009	
Average car	130	Dept. for Transport, 2008	
Average diesel car	124	Dept. for Transport, 2008	
Motor Vehicle	141	Smith 2003	1.7 passengers/auto
Passenger car	31.7	Hayashi et al 2005	Operation
Electric Trains	54	Givoni et al. (2009)	
HSR	7.2-14.4	Givoni et al. (2009)	50/100 load factor, London to Paris
Diesel Trains	69	Givoni et al. (2009)	
Fast Trains (150 km/h)	14.6	Kageson 2009	
HSR (280 km/h)	20.6	Kageson 2009	
Conventional Train	37.9	Álvarez 2010	
HSR	26.7	Álvarez 2010	
HST (London-Paris)	7,194.0	Givoni and Banister (2006)	(grams total)
Light rail/tram	78	Dept. for Transport, 2008	
London Underground	65	Dept. for Transport, 2008	
National Rail	60	Dept. for Transport, 2008	
ICE	27.515	Janic (2002)	
TGV	4.011	Janic (2002)	
High Speed Trains	42	Smith 2003	50% load factor
Rail (diesel)	13.41	Dey Chaudhury (2010)	
Rail (electric)	25.57	Dey Chaudhury (2010)	Existing energy mix
Shinkansen	3.9	Hayashi et al 2005	Operation
Superconduction MAGLEV	13.0	Hayashi et al 2005	Life Cycle Analysis
Ordinary Railway	5.0	Hayashi et al 2005	Operation
Tohoku Shinkansen	16.0	Hayashi et al 2005	Life Cycle Analysis
Tokaido Shinkansen	5.4	Hayashi et al 2005	Life Cycle Analysis

Figure 34: Carbon emissions of various transport modes

IMPACT OF ENERGY SOURCES

As stated in the consideration of emitted air pollutants above, the contribution of those pollutants by HSR varies greatly on local electricity source. Highlighted earlier, though the vehicles themselves may not emit because the combustion of fuel does not take place locally, the impact of operating a train causes concentrated emissions at the energy source, a power facility or plant in this case. Thus HSR implementation without related changes of electricity source provides improvements in localized emissions perhaps along a heavily traveled auto corridor, but realizes minimal gains and possibly losses in emission reduction at a larger national, multinational, or global scale. Without delving deeply into tangential energy policy issues, this section considers different energy sources and the relationship with transport. Reported in Givoni et al (2009) and Lenzen (2008) in Figure 35, the carbon intensity of various energy sources demonstrates a clear advantage for non-fossil fuels.

g CO_2/kWh	Coal	Oil	Gas	Nuclear	Wind	Photovoltaics	Hydroelectric
Givoni et al (2009)	876	590	370	16	0	0	0
Lenzen (2008)	863	--	577	60	21	106	15

Figure 35: Carbon intensity of primary energy sources (Lenzen, 2008)

Based on this information, one can easily see the differences in carbon emissions by using different energy sources and how emissions from a HSR system rely heavily on the energy source.

Implementing a clean energy mix to minimize emissions requires a complex mixture of political momentum through support of business organizations, environmental groups, and local residents. However, government (state or federal) may enact policies encouraging lower emitting energy operations but likely cannot physically construct the necessary power facilities. Texas' action on renewable energy in some ways leads the nation despite a long history of affiliation with oil and gas industries. All multinational energy companies demonstrate a strong presence in

Texas, yet Texas currently leads the nation in wind power capacity and generation (AWEA, 2010). Texas Senate Bill 20 enacted in 2005 shows the state sees a future with renewable energy, mandating 10,000 MW by 2025 (State Energy Conservation Office, 2011), an interesting approach considering most states have mandated a proportion of overall electricity generation as renewable, rather than simply an target quantity. Substantial constraints on power delivery exist however, meaning much capacity goes unused. Texas' support of renewables could reflect a desire to avoid limiting construction of fossil fuel plants. Texas' energy portfolio shows substantial change over the last decade, although more than 80% of the state's energy still derives from fossil fuels (see Figures 36 and 37 below). The role of the state's energy policy does not merely impact transportation; transportation contributes a high amount of energy use and carbon emissions, but by no means a majority. Developing a renewable energy portfolio that enables clean electricity for all uses, including industrial, residential, commercial, and transport uses will pay dividends long in to the future by reducing volatility in price, consumption, availability, and limiting environmental impact.

	Generation (%)		Capacity (%)	
	1999	**2009**	**1999**	**2009**
Coal	39.2	35.0	26.6	19.7
Petroleum	0.5	0.4	0.4	0.2
Natural Gas	47.9	47.6	64.9	64.9
Other Gases	1.1	0.9	0.2	0.2
Nuclear	10.2	10.4	6.3	4.8
Hydroelectric	0.3	0.3	0.9	0.7
Other Renewables	0.4	5.3	0.4	9.4
Other	0.2	0.1	0.3	0.2

Figure 36: Texas energy portfolio (US DOE, 2011)

(thousand metric tons)	Sulfur Dioxide (SO_2)		Nitrogen Oxide (NO_x)		Carbon Dioxide (CO_2)	
	1999	**2009**	**1999**	**2009**	**1999**	**2009**
Coal	654	406	237	101	146,105	144,008
Petroleum	55	6	24	1	2,327	1,776
Natural Gas	--	1	237	84	106,553	97,075
Other Gases	--	--	5	5	NR	NR
Other Renewables	12	6	5	7	NR	NR
Other	--	--	3	--	--	5

(note: "—" indicates a non-zero value less than 0.5, "NR" = not reported)

Figure 37: Emissions for Texas electricity sources (US DOE, 2011)

SAFETY, NOISE, AND SECONDARY HEALTH IMPACTS

Comprehensive analyses of the effects of HSR on health and environmental topics could stand alone as thorough research activities. However, seeing as this thesis aims to provide broad scale implications of HSR within a Texas context, it will only briefly consider the impacts on safety, noise, and human health related to HSR. Safety improvements over existing modes provide one of the most tangible benefits of HSR. High-speed trains in operation worldwide exhibit exemplary safety records, especially compared to other modes of transportation. Perhaps as a result of these records, data availability in the international literature is limited. In the history of high-speed trains, several minor incidents have occurred, but only a single accident resulted in substantial loss of life. Indeed, as Levinson et al (1997) note, the existing safety rates of HSR systems mean that in practice, no risk of an accident exists. Japan Central Railway reports that no fatalities or casualties have occurred in forty-five years of commercial service, and SNCF (parent operator of TGV in France) reports a similar record, with no fatalities in high-speed service since commencing operations. SNCF trains have seen a limited number of fatalities (less than 50) at lower speeds, although these still are incredibly minimal statistically speaking, with SNCF carrying approximately two billion passengers on TGV trains alone since 1981. The slim literature on rail safety suggests that the implementation of HSR utilizing dedicated high-speed rail lines with full grade separation and security fencing makes for a mode of transportation with marked improvements in casualties over automobiles.

When compared to other popular modes of transportation, HSR (and perhaps rail in general) show an opportunity for vast gains in safety over automobiles in particular, but other modes as well. Not surprisingly, the number of fatalities in automobile crashes exceeds the number in all other modes in the United States. Remaining relatively constant over the last four decades, about 40,000 to 45,000 fatalities occurred in traffic crashes (including fatalities to automobile occupants, and exterior pedestrians and/or cyclists) in the United States, although preliminary data indicates this dropped dramatically in the last few years to about 35,000 or below. Most vehicle fatality subcategories remained constant or fell slightly over that same time period except for light trucks (which includes SUVs), which roughly doubled from 1980 to 2005 before falling slightly (BTS, 2011b). Modal fatality rates indicate similar gains to be made from rail. The National Safety Council, using data from the various modal DOT offices, reports that over ten years, the average death rate for passenger trains in the United States was 0.05 per 100 million miles traveled, less than 10% of the rate for passenger vehicles, at 0.72 per 100 million miles traveled. The rate for passenger vehicles has fallen in recent years, however, so this average value does not represent a long-term trend. Still, the rate for 2008 of 0.55 still exceeded the rail rate by tenfold (see Figure 38 below).

	Passenger automobiles		Vans, SUVs, & pickup trucks		Buses		Railroad passenger trains		Scheduled airlines	
Year	Deaths	Rate[a]	Deaths	Rate[a]	Deaths	Rate[a]	Deaths	Rate[a]	Deaths	Rate[a]
1999	20,851	0.84	11,295	0.76	40	0.07	14	0.10	24	0.005
2000	20,689	0.81	11,545	0.76	3	0.01	4	0.03	94	0.02
2001	20,310	0.78	11,736	0.76	11	0.02	3	0.02	279	0.06
2002	20,564	0.78	12,278	0.78	36	0.06	7	0.05	0	0.00
2003	19,723	0.74	12,551	0.78	30	0.05	3	0.02	24	0.005
2004	19,183	0.71	12,678	0.75	27	0.05	3	0.02	13	0.002
2005	18,509	0.68	13,043	0.76	43	0.07	16	0.10	22	0.004
2006	17,792	0.66	12,723	0.72	15	0.02	2	0.01	52	0.01
2007	16,613	0.61	12,462	0.68	18	0.03	5	0.03	0	0.00
2008	14,579	0.55	10,765	0.59	50	0.08	24	0.13	0	0.00
10-year average	**18,881**	**0.72**	**12,108**	**0.73**	**27**	**0.05**	**8**	**0.05**	**51**	**0.01**

Source: See table above.
[a]*Deaths per 100,000,000 passenger miles.*

Figure 38: Death rates in the United States by passenger travel mode 1999-2008 per 100 million passenger miles (National Safety Council, 2011)

The effect of HSR on the vehicle fatality rate is uncertain at best. The limited data and research in this area demonstrates the lack of knowledge about how HSR use might substitute for vehicle trips. However, Texas vehicle fatality rates, currently above the national average (TxDOT Tracker), indicate that further research coupled with HSR implementation may cause a drop in transportation fatalities yet unpredicted by existing automobile safety-promoting policy measures.

Noise emanating from high-speed trains also poses an incredibly tangible environmental impact. “Noise”, of course, opens a door of subjectivity, as noise might be best described as “unwanted sound”, which varies depending on the individual. Using the assumption that all transportation sounds cause discomfort to some substantial portion of the population at minimum, evaluating the extent of those transportation sounds becomes an important task. Noise generated by HSR derives from three primary sources: the wheel-rail interaction, the aerodynamic movement, and electrification equipment (FRA, 2005). Many variables affect the impact of noise, including the quality, the volume (sound intensity), and the duration to name a few. The sound intensity levels for HSR, in general, differ minimally from those for airplanes, and slightly exceed values for highways. A major difference for noise emanating from HSR is the location where such noise takes place. As noise increases with speed, trains generate minimal noise during the departure and arrival sections of a trip near stations in highly populated areas. Noise generated at cruising speed, approximately 90-100 dB(A), or roughly the same as a jackhammer or heavy truck traveling on a highway, causes substantially greater concern, particularly if trains pass through populated areas at cruising speeds. This reinforces the need to utilize existing corridors in urban areas. Not only will this limit excessive land take, but also unify transportation noise in a single corridor, rather than creating additional noise impacts that do not currently occur. As Levinson (1997) points out, noise varies based on location, and because of this location, theoretically influences land values. Research on land values near transportation corridors shows mixed results, where locations relatively near a valuable transportation connection may increase value slightly, although immediate access may decrease value because of noise, vibration, or unwanted commercial activity.

The impacts of a transportation corridor on a community addresses the growing body of research known as Environmental Justice (or “EJ”), where analysis focuses on the disproportionate impact of transportation infrastructure on communities of high ethnic and racial diversity, lower household income, and lower educational achievement. Increasingly, research indicates that the built environment influences human health, welfare, happiness, and economic output, with transportation corridor placement and design playing a major role.

Humans develop as a joint product of intrinsic characteristics and external experiences over a lifetime. Transportation infrastructure forms a substantial component of these external experiences, as the built environment contributes to social changes and shifts in human behavior. This thesis does not aim to analyze the effects of HSR on human health, as the intersection of transportation infrastructure and health is an exploding academic topic in its own right (a simple search produced more than 100 relevant papers on the topic published since 2000 alone). That said, with limited development of HSR relative to other modes, particularly in the United States, the effects of trains on societal health are far less clear than those for automobiles and roadways.

As noted by Banister et al (2007), the physical inactivity associated with car trips contributes greatly to increased obesity rates and more than 3% of deaths worldwide. Indeed, recent data indicates that more than one-third of American adults are obese (BMI ≥ 30) and more than two-thirds are overweight or obese (BMI ≥ 25) and these rates have increased dramatically over the last two decades (Centers for Disease Control and Prevention, 2011). Making short trips by foot or bicycle to those modes instead of using automobiles would enable most people to “achieve recommended levels of physical activity”. Walking or cycling segments attached to trips using trains or transit may also achieve this. Because HSR success appears to hinge on the existence of developed transit systems (noted earlier) and dense land use that allows for effective walking and cycling trips, HSR may make secondary contributions to more physically active trips, and therefore combat auto-related public health epidemics. Deakin and Nuworsoo (2009) describe the opportunities for redevelopment and infill with the California HSR project, particularly in the centers of medium-sized cities. They note that while an opportunity exists, a new focus must be created to take advantage of the opportunity including offering a variety of housing options and improving local access by foot, bike, and public transit. HSR’s existence alone will not enable the necessary changes. With Texas urban areas generally embracing pro-growth low-density suburban policies, such opportunities linked to HSR for denser, more sustainable, healthier development may be great in Texas. Plans for increased density and multimodality in city centers indicate a willingness by Texas cities to consider land use and sustainability policies as well as subsequent human health effects related to transportation.

The health impacts of the emitted substances from fossil fuel combustion also require attention of transportation and public health officials. Noted earlier in this chapter, a number of potential health impacts occur as a result of various pollutants. Although the exact number of deaths attributable to these pollutants is difficult to know primarily because of many different emission sources and the wide range of resulting diseases, more than 600,000 Americans died in

2000 from cancer, respiratory diseases, and cardiovascular diseases, which all may be partially attributed to emitted pollutants from vehicles. Litman (2003) reports that the number of deaths attributed to transportation pollutants appears to be about the same as for traffic crashes. This addresses an ethically difficult topic, as assigning value to a human life lost due to the transportation system is a challenging and evolving task. Nevertheless, the loss of human life results in large economic impacts, and the implementation of transportation infrastructure that reduces the number of lives lost due to obesity, emissions, or crashes results in benefits for society as a whole.

COMPARING ECONOMIC AND ENVIRONMENTAL IMPACTS

Microeconomics instructs that all goods have some value as a result of scarcity. This value is usually approximated in monetary terms, allowing for measurement and comparison between different trade-offs over a particular time period. For transportation, these goods include travel time, safety (value of life), and pollutant reduction, among others. These goods, or "benefits" are important goals for society. However, when analyzed against the infrastructure cost of achieving these objectives, they may become infeasible, particularly if costs exceed the value of benefits. Among multiple project alternatives, this analysis provides a method to prioritize certain best-performing alternatives. To be certain, this is not the only approach to measure the economic effectiveness of a particular project, but it may be the most comprehensive. Other methods include economic impact analysis and cost effectiveness measurements. de Rus and Nombela (2007) note that for benefit-cost analysis procedure, it is important to remember that "all transport modes produce negative environmental effects and accidents. The question is whether the overall balance favours HSR against road or air transport…the net balance depends on whether the base case is to expand existing roads or airports, or to build new infrastructure." To illustrate the procedure, the following is a typical model measuring the social profits (including environmental benefits) from rail derived from time savings and generated demand, and setting aside benefits from additional rail capacity in the long term, the subsequent reduction of road accidents, and road and airport congestion, which are more subject to local corridor conditions:

$$\int_0^T \left[B(Q) - C_q(Q)\right] e^{-(r-\theta)t} dt - \int_0^T C_t e^{-rt} dt$$

where Q is a derived transport demand; B(Q) are annual social benefits of the project variable with Q; $C_q(Q)$ is annual maintenance and operating cost variable with Q; C_t is annual fixed maintenance and operating cost; T is life of the project; r is the social discount rate; and Θ is annual growth of benefits and cost which depends on Q. If the value of the above equation is greater than the infrastructure construction costs, the project has a positive net present value (NPV) (de Rus and Nombela, 2007).

This model, as noted, makes significant assumptions that may not be valid for a particular scenario (only focused regional research will indicate whether reduction of road congestion will occur or the degree of indirect economic impact, for example). Nevertheless, it indicates the nature of evaluating the benefits and costs of implementing HSR. Certainly, the larger social benefits (e.g. travel time savings to HSR passengers, reduced congestion, increased revenues, automobile accident reduction, reduced emissions, indirect labor and housing market effects, etc.) of HSR are real, valuable, and important, for reasons previously described. However, the environmental portion of the benefits likely amount to a relatively small portion of overall benefits when economic impact values are also evaluated. A variety of cost-benefit analyses for HSR demonstrate this, but perhaps the most instructive for Texas is a proposal from French National Railways (SNCF) for HSR in Texas, submitted to the FRA in 2009 as a part of the Request for Expressions of Interest (RFEI) process. In the submission, a basic financial feasibility benefit-cost analysis estimates an overall rate of return of 9.2% over the life of the proposed project (through 2050), with a benefit/cost ratio of 1.92, seen in Figure 39:

BENEFITS	Value (millions of dollars)	Percent (benefits only)
Passenger revenue	14,493	56.2%
Benefits to HST 220 passengers	6,493	25.2%
Benefits to highway travelers		
Auto congestion reduction	3,283	12.7%
Auto accident and pollution reduction	821	3.2%
Benefits to air travelers		
Air delay reduction	465	1.8%
Air pollution reduction	257	1.0%
Total benefits	25,811	100%
COSTS		
Capital	10,755	
Operation and maintenance	2,720	
Total Costs	13,475	
Net Present Value (Benefit – Cost)	12,336	
Benefit/Cost Ratio	1.92	
Socio-economic Rate of Return	9.2%	

Figure 39: Financial feasibility benefit-cost analysis for proposed Texas HSR system (SNCF, 2009)

In this example, the environmental benefits (pollution reduction) only amount to about 3% of overall benefits. Important to note is that this analysis does not include all possible benefits, including the benefits of reduced greenhouse gases or reduced travel time, as a means to be conservative in its assumptions. Additionally, the “benefits to HST 220 passengers” are not enumerated in this chart, but include primarily reductions in travel time. Inclusion of greenhouse gas reduction monetary benefits would likely result in environmental benefits forming a larger overall portion of the total benefits, although this is difficult to calculate because the approximate value of carbon, the primary greenhouse gas, is uncertain at best. In addition, the secondary economic benefits in terms of direct and indirect wages, employment, business activity, and income are not included. Typically benefit-cost analysis does not include these benefits, but they nevertheless bolster the argument for or against project implementation because of their large impact. This financial feasibility benefit-cost analysis for SNCF takes the position of return on investment to measure the feasibility of a HSR project. When completed from a government perspective, the passenger revenues are not included, as these represent a transfer between entities.

The broad implications for HSR on energy policy, environmental impacts, and other externalities indicate that, as a mode, HSR may greatly contribute to policy goals if implemented. However, many of these areas remain in early stages of analysis, despite the relative age of rail in transportation history. As demonstrated here, the range of impacts by all transportation modes continues to grow, and no one mode serves as a panacea. Rather, Texas officials must place different modal alternatives, including HSR, within the local, regional, national, and even international context and evaluate those alternatives for a great variety of factors, including those only briefly examined in this section. While certainly not an ideal option in all scenarios, preliminary consideration of these factors appears to indicate that HSR likely improves on many currently existing scenarios and deserves serious consideration as a future transportation improvement for Texas in the face of heightened issues surrounding energy use, environmental degradation, safety, and human health.

Concluding Remarks

The impacts of transportation on the natural environment and subsequent effects of fossil fuel consumption also have a nuanced role in the implementation of HSR. Energy efficiency comparison between transportation modes represents complex analysis relying on many different variables, but based on typical load factors and energy source mixes at present, HSR demonstrates a potential for large gains in transportation energy efficiency. Of course, these gains can only be truly realized if the energy source for electric-driven trains includes those with limited emissions from fossil fuel consumption. Limiting emissions from transportation is important because those emitted pollutants cause human health defects and contribute to global warming, although the effects of that phenomenon are inexact. Additionally, the implementation of transportation modes that encourage healthy human lifestyles may aid in reduction of obesity and related health issues in the United States if implemented alongside dense development that is not necessarily automobile-centric.

Chapter 7: Corridor Evaluation

As discussed in chapter two, many different proposals to link Texas cities via high-speed passenger rail generated varying degrees of public and political interest in the state. Since the first studies issued in the 1980s, the proposed corridors evolved into many different forms, with advocacy groups selecting and promoting particular alignments. While this report covers proposals discussed in the last four decades linking the entire Texas Triangle region, and numerous additional variations certainly exist, all the studied proposals (and likely many of those not evaluated here) feature several particular elements despite their many evolved forms:

1. The Texas Triangle is the basis for service, for many of the reasons developed in Chapter 3 and 4. The population, density, and city spacing of the Triangle cities makes them the best candidates in the state for rail service. For those proposals built in multiple phases, the Dallas-Houston leg of the system acted as the primary phase.
2. All proposals envision a connection at Dallas/Fort Worth International Airport. Because of DFW's role in dispersing statewide air traffic to other states and beyond through a large number of connecting flights (discussed earlier), all proposals believed that providing a high-speed rail connection at DFW would benefit travelers and airlines alike. Not all proposals include a stop in downtown Dallas and/or Fort Worth, but all include a station at DFW.
3. Stations in the medium-sized cities of Bryan-College Station, Temple-Killeen, and Waco are included in all proposals.
4. San Antonio and Austin (and intermediate cities) are directly and linearly connected. No proposal prescribes an indirect, nonlinear route connection between the two cities.

In order to further understand the implications and costs of high-speed rail corridors, five of the primary past corridor proposals and a sixth corridor modification proposed by the author are considered and evaluated using a simple analysis on the basis of cost and distance.

PROPOSED ALIGNMENTS

Texas Triangle (Hal Cooper)

Submitted to TxDOT by Triangle Railroad Holding Company (Hal Cooper Jr, President), this proposed route (Figure 40) includes connections to the South Central and Gulf Coast corridors as seen in the National Plan for High-Speed Rail promoted by the Obama Administration. This particular corridor under consideration is the most ambitious of the proposed passenger rail corridors (as it includes several interstate commuter rail and single-tracked passenger rail corridors), with double track connecting the major cities in the Texas Triangle region. The primary route of the system follows the I-35 corridor passing through San Antonio, New Braunfels, San Marcos, Austin, Round Rock, Georgetown, Temple, Waco, Hillsboro, and Waxahachie. From here, the proposed configuration splits into two rail routes extending to downtown stations in Dallas and Fort Worth, with an additional line connecting the two cities with an intermediate station at DFW. The other major legs of the proposed route connect Houston with the Dallas-Fort Worth area and Austin. The first line heads eastward from Austin, passing through Elgin, Giddings, Brenham, and Hempstead before meeting the second rail line on an approach to downtown Houston from the northwest side of the city. The second line heads southeast from Waco toward Houston, passing Marlin, Hearne, Bryan-College Station, and Navasota before joining the Austin leg at Hempstead for the approach to Houston.

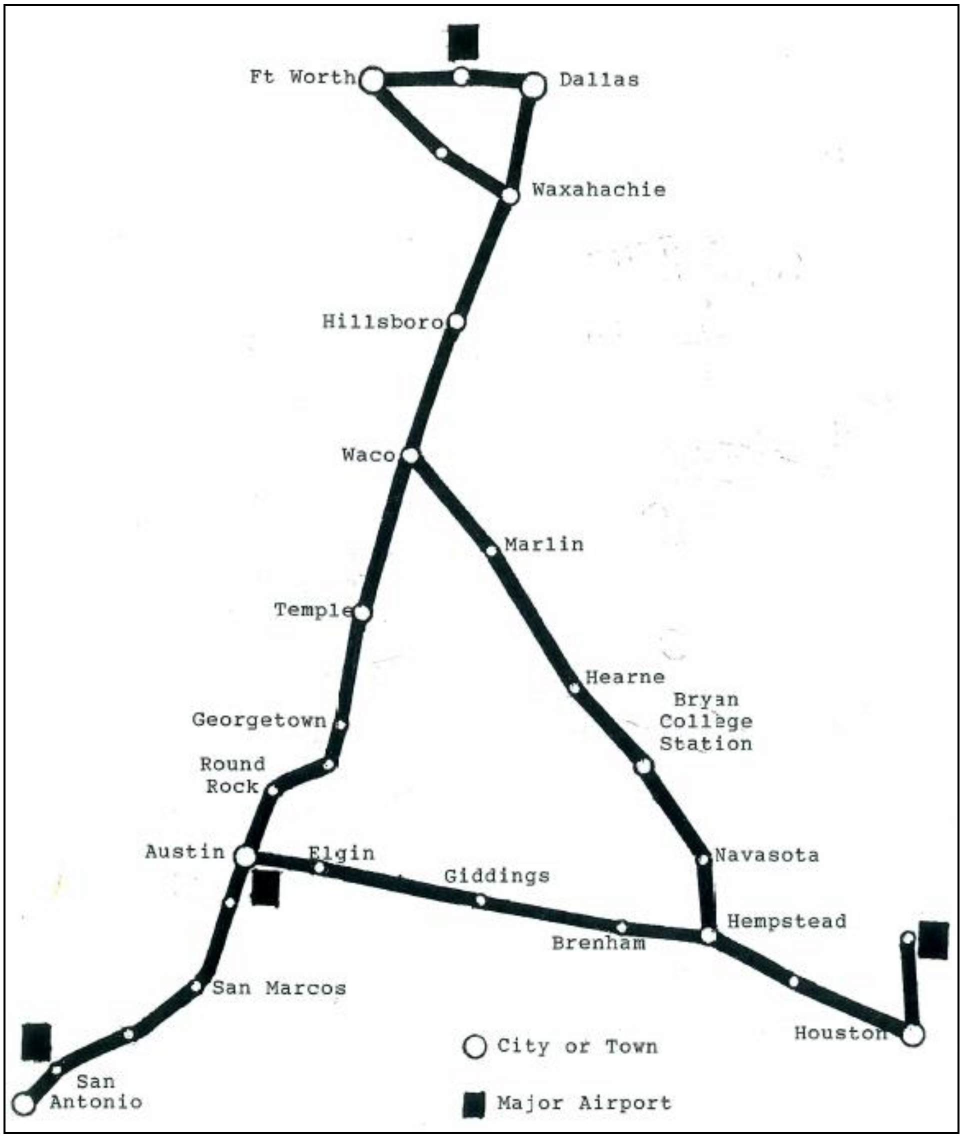


Figure 40: Texas Triangle (Hal Cooper) proposal approximate alignment (Cooper, 2009)

Texas "T-Bone"

Texas High Speed Rail and Transportation Corporation (THSRTC) primarily promotes this alignment which connects the major metropolitan areas in the Texas Triangle region with a high-speed rail corridor in a rough backward lowercase lambda (λ) shape (Figure 41). The main leg of the corridor parallels I-35 and serves the major cities between DFW and San Antonio. It is unclear if the route plans for stations in all the major cities in the corridor, but for simple sketch planning purposes of this chapter, it is assumed to be mostly the same as the Triangle Railroad Holding Company proposal. Of particular note is that the route appears to avoid downtown stations in both Dallas and Fort Worth, instead opting for an airport-only regional station at DFW. The secondary leg of the route extends southeast from Temple-Killeen to Bryan-College Station and the Houston area, again opting for a station only at IAH and no downtown Houston station. Among the corridor concepts explored here, this proposal likely requires the fewest miles of track construction, although it is comparable to the Texas TGV "New Corporation Preferred Alignment discussed below. Throughout this alignment, THSRTC envisions elevated, dual direction double track permitting trains to travel at speeds of 200 mph or greater.

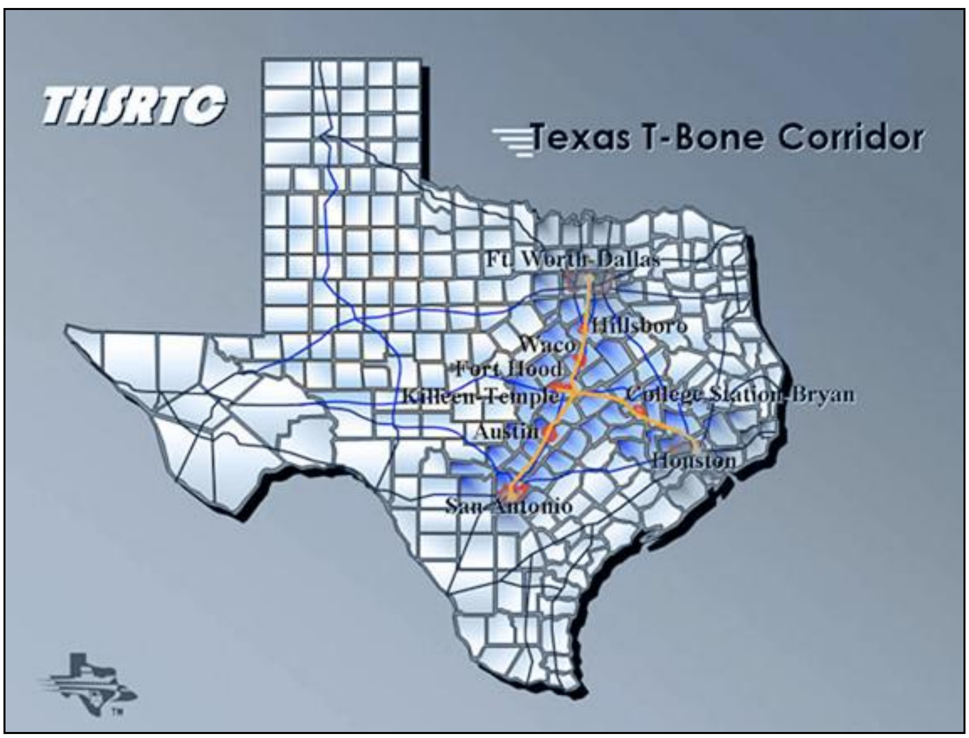


Figure 41: Texas T-Bone proposal approximate alignment (THSRTC, 2010)

Texas TGV Initial "Modified" Alignment

This alignment is one of two alignments that were initially considered by the Texas TGV Corporation in the 1990s. The first version of the alignment omitted the cities of Waco and Bryan-College Station but eventually a modified alignment included them. This modified alignment is considered here as these cities are minimal deviations from the original alignment and would likely generate significant additional ridership. Again connecting the major cities in the Texas Triangle, this proposal imagines a triangular track arrangement in the interior of the triangle formed by I-10, I-35, and I45, with vertices to the south, northwest, and northeast of Dallas-Fort Worth, Houston, and San Antonio, respectively (Figure 42). Each of these junctions is then connected by a single track corridor to the center of the nearest major city. Navarro, Hockley, and San Marcos serve as the junction points where the single track splits into the two legs of the triangular arrangement. Of note in this proposal is that the shortest route from Austin to Houston requires travelers to head southbound for a short distance before turning east toward Houston; for all other proposals here, travelers would head northeast or east for some distance before turning toward Houston. Texas TGV divided the plan into three phases, with the Houston-DFW link forming the first phase, the Navarro Junction-San Antonio segment as phase two, and the remaining section from San Marcos to Hockley Junction completing the system as phase three.

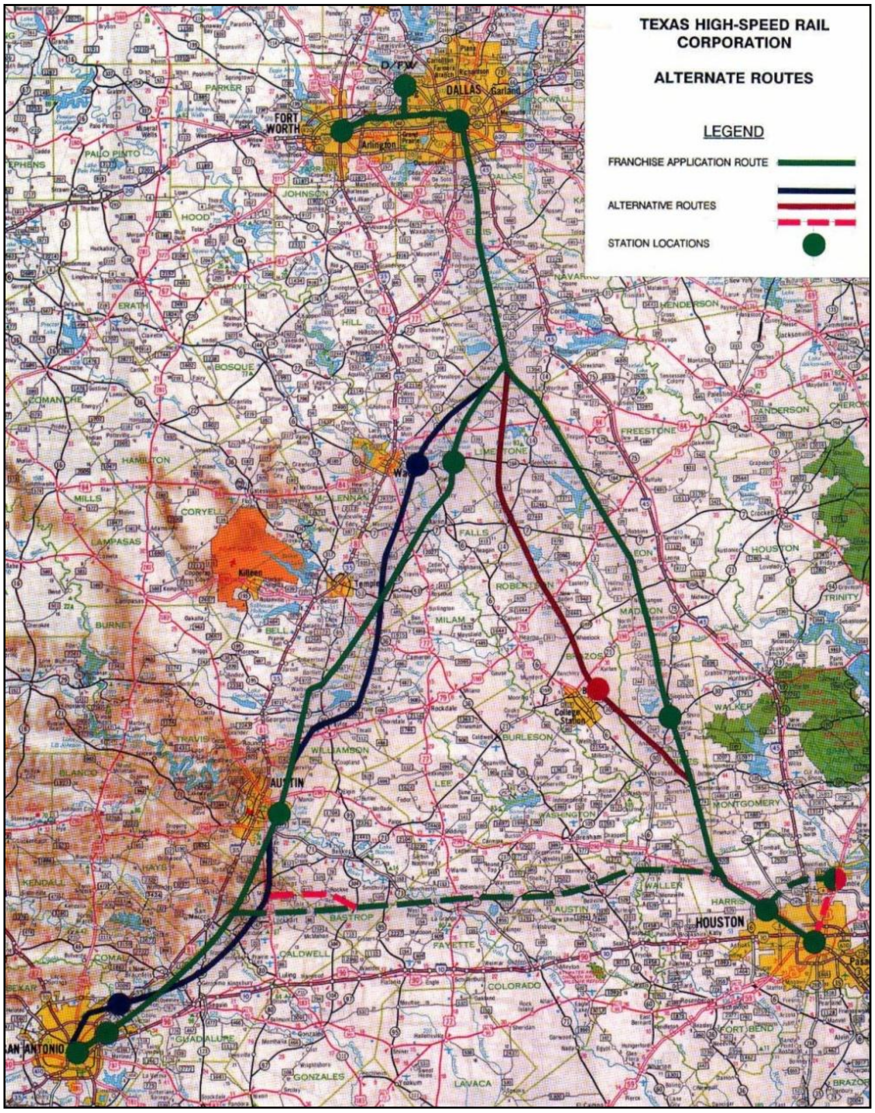


Figure 42: Texas TGV franchise application approximate alignment with alternatives (Texas TGV Consortium, 1991)

Texas TGV Corporation "New" Preferred Alignment

The Texas TGV New "Corporation Preferred Alignment" appears to be a compromise between the initial modified alignment seen in Figure 42 and the Texas FasTrac proposal, which was not carried forward when that organization was not granted a franchise. This compromise proposal features three corridors emanating from a central node situated approximately equidistant from the three cities forming the vertices of the Texas Triangle. This central node is tough to place exactly, but appears to be located in central Milam County near the town of Cameron. Each corridor extends from the central node to Dallas, Houston, or San Antonio through a secondary city (Waco, Bryan-College Station, and Austin, respectively, Figure 43). Such an arrangement means that the total trackage in the region is the least of the options evaluated in this research, but also likely leads to the longest travel times between major endpoint cities. Also of note for this alignment is the absence of a station in the Killeen-Temple area, one of the metropolitan areas along the I-35 corridor.

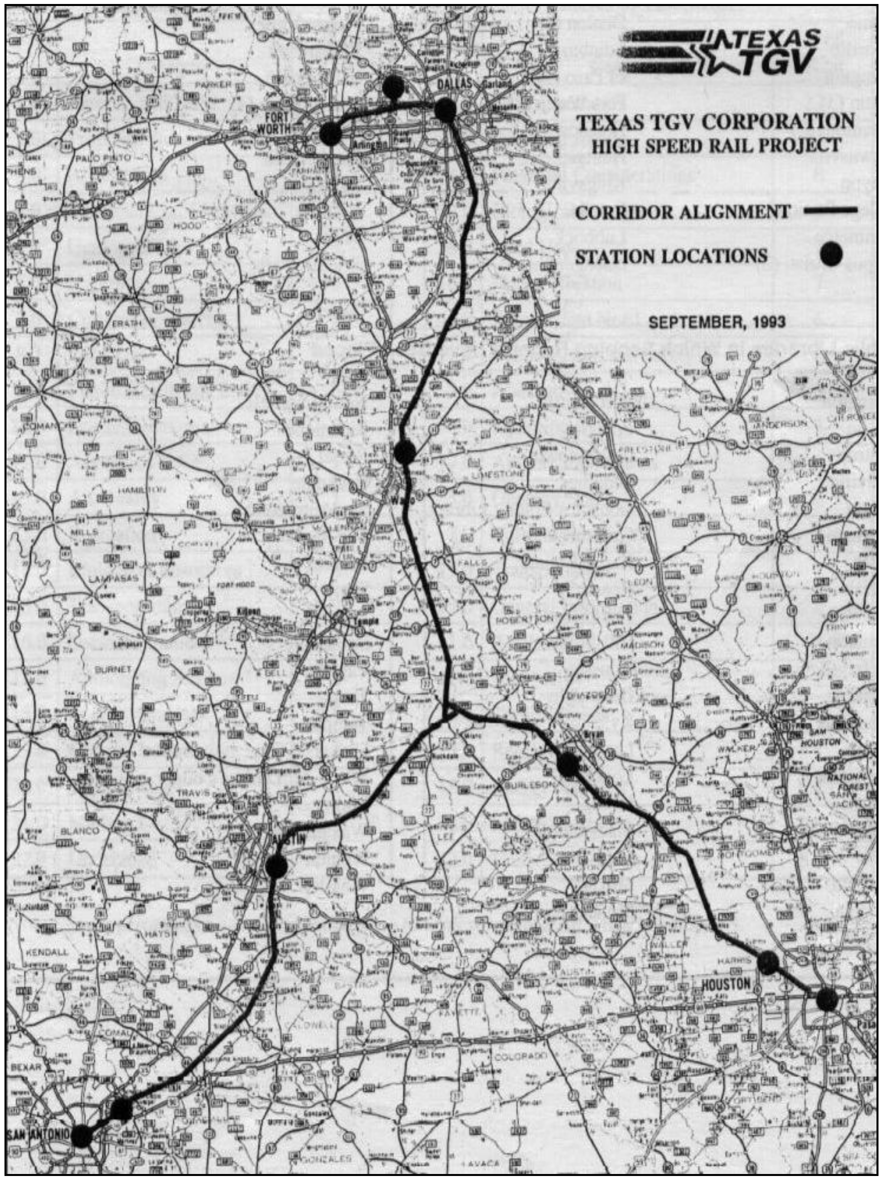


Figure 43: “New” Texas TGV franchise approximate alignment (Texas TGV Consortium, 1991)

Texas “Mini Triangle”

Gaining some attention on the Internet, this idea connects the interior Texas Triangle cites of Austin, Bryan-College Station, and Waco in a triangular form with a city at each vertex. From each of these city vertices, a track segment extends to one of the major Texas Triangle metropolitan areas (San Antonio, Houston, and Dallas-Fort Worth, respectively). This alignment attempts to maximize the interior cities served en route between the major metropolitan areas without major deviations from a straight line route. For example, by deviating slightly from the direct Dallas-Houston route, this alignment picks up potential riders at stations in Waco and Bryan-College Station (Figure 44), yet this deviation adds minimal distance compared to the straight line route. Connections in the Dallas and Houston metropolitan areas are made at downtown stations as well as the major airports. This proposal bears resemblance to the Triangle Railroad Holding Company proposal seen before, with two major differences. The Triangle Railroad Holding Company proposal provides a segment between Ft. Worth and Waxahachie not seen in this alignment, while the mini-triangle alignment creates a direct connection between Austin and Bryan-College Station en route to Houston. The Triangle Railroad Holding Company proposal plans a more direct route from Austin to Houston bypassing Bryan-College Station.

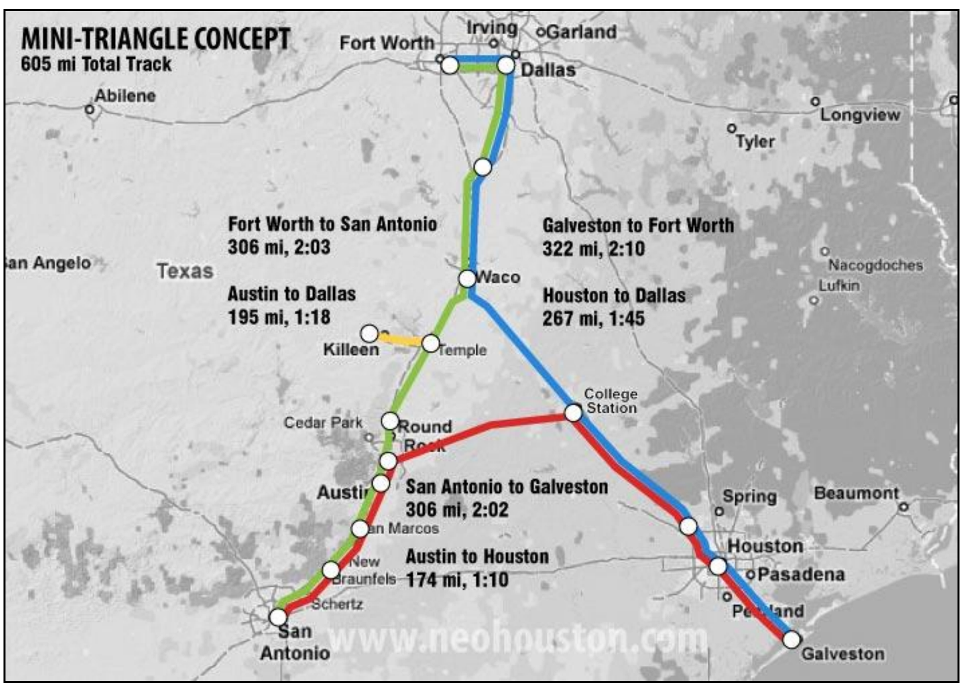


Figure 44: Texas Mini-Triangle approximate alignment (Burleson, 2009)

Alternative 6

The final alternative alignment blends the idea of the mini-triangle and the Hal Cooper proposal by creating direct links between Austin and Houston as well as Austin and College Station via the burgeoning suburbs of Round Rock and Georgetown. Conceptually, this alignment attempts to create as direct a route as possible between the larger metropolitan areas, with minor deviations from straight line routes, while facilitating direct route between the major cities and the minor cities on the interior of the Texas Triangle region. The only minor metropolitan area without direct routing with the major metropolitan areas is Killeen-Temple, which would require traveling either south to Georgetown or north to Waco in order to embark toward Bryan-College Station or Houston (Figure 45).

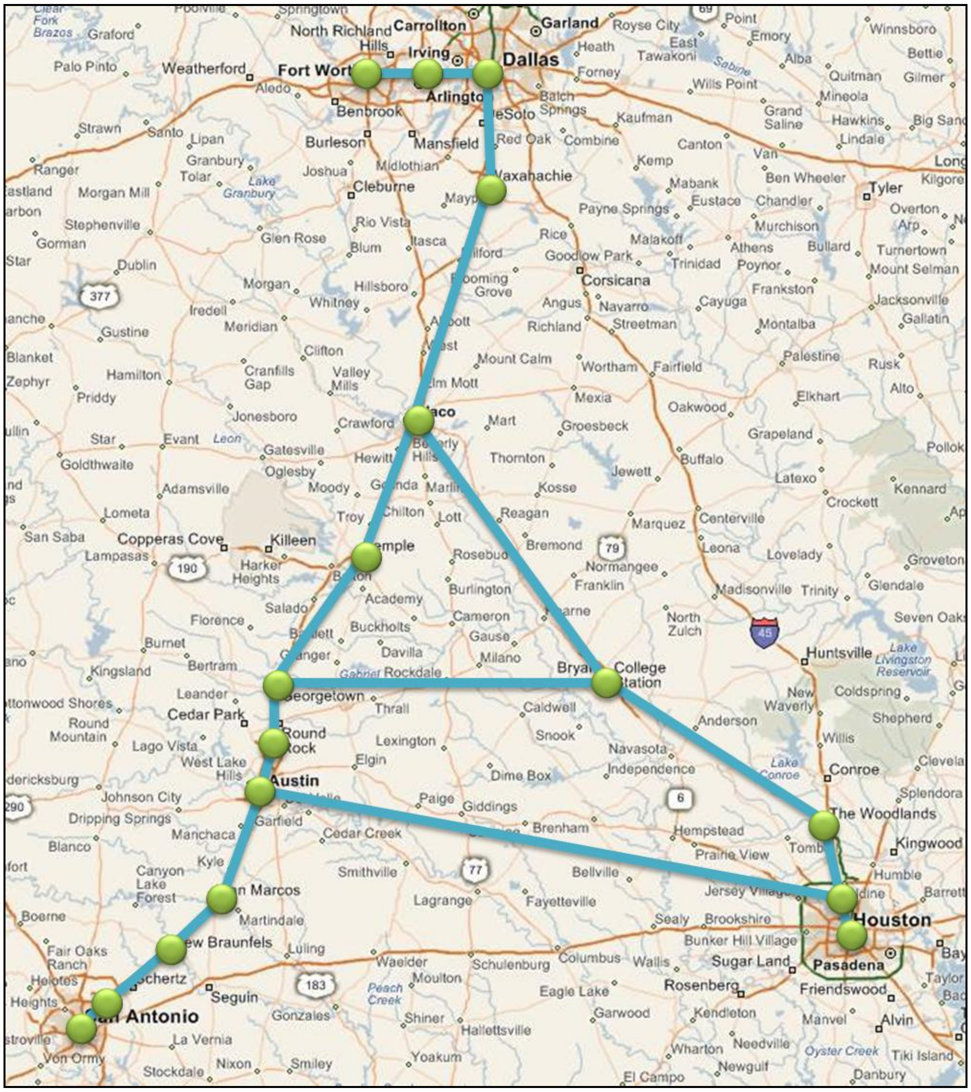


Figure 45: Alternative 6 approximate alignment

EVALUATION TOOL AND METHOD

HSR requires significant financial outlay. Because of this cost and its intense scrutiny, it is in the best interest of planners and engineers to analyze possible routes to determine the most cost-effective approach. In order to provide more information for determining the financial feasibility of these six alignments, this thesis used a simple network optimization approach to estimate the cost of the segments of each alignment. In this approach, stations in each alignment alternative acted as nodes. Between nodes, 3 possible arcs represented each of 3 routing policy options, each with slightly different costs. The costs for each routing represented a unit cost per distance multiplied by the distance along that particular node. The first routing option takes a direct geographic path between two nodes (stations), representing the extreme case of obtaining all new right-of-way (ROW) and heavy utilization of eminent domain. Such a routing also leads to the shortest overall distance by far, intuitively resulting in the shortest travel time, thereby encouraging demand for service. This routing option costs the most, as expected. The second routing option uses existing ROW for highways and roadways. Given the wide highway ROW in rural and suburban areas, the marginal land quality immediately adjacent to these facilities in rural and suburban areas, and the reduced costs due to limited use of eminent domain, such an approach deserves consideration. Nevertheless, costs exist even though the land purchase expenses are reduced. Finally, the third option follows only existing track, reflecting an arrangement either for trackage rights, or alignment immediately adjacent to track requiring either no land taking or very limited land taking. This hypothetical scenario anticipates the cheapest marginal cost of infrastructure. Many successful intercity passenger services use corridors shared with other transportation infrastructure and rail operations based on limiting the dispersion of environmental effects and this third routing option reflects such an arrangement. However, such an arrangement would probably limit the speeds of passenger service on these lines, and thus could not achieve the high speeds that may be necessary to attract substantial ridership. This approach does not seek to address ridership where benefits from passenger rail would be realized, but merely demonstrates the cost implications of different passenger rail alignments.

With each alignment alternative broken down by segment, various tools were used to calculate the distance using each of the three routing options. Direct distance measurement in Google Maps provided the distances used in the first routing option. The second routing option required the use of Mapquest's "shortest distance" option for calculating road directions between stations. Road directions are assumed to be the same as the potential shortest path of existing highway ROW. The final routing option used ArcMap in GIS to find the shortest rail route between marked stations. In the case where tracks did not pass immediately adjacent to a station, the distance along a perpendicular line between the nearest rail segment and the station was also included in the final value. Once all three values were input in a series of Excel spreadsheets, the capabilities of the Solver function provided the lowest cost option for each alignment alternative using a mixture of the different station-to-station segments.

Station Locations

Locating stations required substantial assumptions as many rail stations proposed in these alignments do not currently exist. For those cities with existing rail stations, primarily for Amtrak services, those existing stations served as the segment endpoints. For those stations not centrally located, a central point selected in the city near a rail line served as the station location. In the case of suburban stations or airport stations, a station point located near the airport centroid marked the segment endpoint, while suburban stations locations were selected primarily by visual inspection based on more detailed alignment literature, proximity of existing rail lines, and roadway alignment.

Estimated Costs

Estimated costs for HSR construction vary greatly. The costs represent variety in physical geography, extent of eminent domain utilization, labor costs, and structural complexity. As reported by Campos and de Rus (2009), of the 45 HSR projects in operation, construction costs ranged from $18 million per mile to $80 million per mile, with an average of $36 million per mile. The right of way requirements for these projects are unknown. Comparatively, the US Congressional Research Service (Peterman et al, 2008) reports that costs for incremental track improvements, as opposed to new dedicated guideway, to Midwestern rail lines range from $4.1

million per mile to $11.4 million per mile, while the cost of reducing travel time on Amtrak's Northeast Corridor by only thirty minutes between New York and Boston amounts to $31 million per mile. The Government Accountability Office (2009) also reports a similarly wide range of values ($22 million per mile to $132 million per mile), although this also includes Maglev proposals, for which data are limited as only one system (Shanghai Airport Maglev) operates at present. Perhaps the best comparison, the proposed California HSR project estimates construction costs of approximately $65 million per mile, which appear to be on the high side based on international comparison. Regardless, land acquisition, the primary variable measured in this corridor evaluation, sums to a nontrivial portion of construction expenses. According to AASHTO (2002), approximately 4% of federal funding went to land acquisition in 1999, while SNCF's EOI (2009) submitted to the FRA estimates land acquisition will comprise 6% of overall initial capital costs. Campos and de Rus (2009) verify these values by noting that planning and land costs "may be substantial in some projects…but they often represent a sunk component, between 5% and 10% of total investment." These numbers do not directly indicate the difference in marginal project costs from the different ROW options, all else equal, which is the strict intention of this corridor evaluation, but do demonstrate the need to thoroughly investigate land acquisition expenditures for a particular project.

Information on ROW acquisition costs for rail projects is exceedingly slim in the United States, as no new greenfield passenger rail projects have been constructed in decades, except for perhaps segments of the New Mexico Rail Runner operating between suburban Albuquerque and Santa Fe[1]. Thus, this evaluation relies on information from proposed projects as sources.

[1] The most pertinent examples of rail right-of-way acquisition by public agencies for passenger rail projects include sections acquired from BNSF for the New Mexico Rail Runner and Union Pacific for the Utah Transit Authority Front Runner service described in Loftus-Otway et al (2007). Additionally, this source notes the rough average figure of $1.2 million per mile commonly cited for corridor purchase. These examples, though few in number, may assist in rail corridor planning and feasibility analysis.

The California HSR project segment from Fresno to Bakersfield anticipates constructing substantial new greenfield tracks to avoid cutting through the centers of communities and cities along the existing BNSF tracks. Though alignments have changed slightly since 2009, the California HSR Authority anticipated that 10% of the segment costs between Fresno and Bakersfield would come from land acquisition (CHSRA, 2009). Put differently, land acquisition for tracks requiring new rights-of-way contributed an additional 11% of segment costs. Similarly, the SNCF proposal indicates that their routing would “wherever possible, follow existing rail transportation facilities rather than new corridors” (SNCF, 2009). As stated earlier, SNCF estimates land acquisition will amount to about 6% of overall construction costs, or an additional 6% (approximately) on top of segment construction costs using existing rights-of-way. Given the substantial error in these estimates, 10% and 6% were used in calculations. Thus, to optimize for the minimum possible cost, the use of new ROW sees a 10% cost premium (multiplier of 1.1), use of existing ROW sees a 6% cost premium (multiplier of 1.06), and use of existing tracks sees no cost premium, with a cost multiplier of 1. This is merely to state not that the use of existing tracks and/or their rights-of-way has no cost, but rather to illustrate that very similar construction undertaken in the other two right-of-way scenarios costs more. Some ambiguity exists, especially because of the comparison of service along existing tracks unlikely to permit speeds above 150 mph at most, and other alignments that might feasibly permit service as fast as 250 mph. However, the California project is instructive here as well with a great majority of the track placement for that project occurring alongside BNSF tracks, indicating that HSR above 150 mph may be able to operate within the geometry of existing tracks.

RESULTS

Based on input data for the distances utilizing three different right-of-way methods, the optimization procedure found the lowest-cost routing combination for each alignment alternative, seen in Figure 46:

Alignment Alternative	Number of Selected Direct ROW Segments	Length of Selected Direct ROW Segments (mi)	Percentage of Total Length	Number of Selected Existing Highway ROW Segments	Length of Selected Existing Highway ROW Segments (mi)	Percentage of Total Length	Number of Selected Existing Track Segments	Length of Selected Existing Track Segments (mi)	Percentage of Total Length	Total Length (mi)
Texas Triangle (Hal Cooper)	8.0	219.0	34.0	4.0	37.0	5.8	13.0	528.0	60.2	643.4
Texas T-Bone (THSRTC)	4.1	135.8	30.1	0.9	7.1	1.6	8.0	351.8	68.3	458.5
Texas TGV Old	1.9	131.6	19.8	0.1	0.4	0	10.0	533.8	80.2	665.8
Texas TGV New	3.0	106.9	23.1	2.0	86.9	18.8	4.0	269.2	58.1	463.0
Texas Mini-Triangle	2.1	215.1	37.2	1.3	30.8	5.3	11.3	333.1	57.5	579.0
Alternative 6	6.9	285.0	39.0	1.1	28.9	4.0	12.9	417.6	57.1	731.5

Figure 46: Lowest cost rail alternative routing optimization results

The results show a marked trend for utilization of existing track, with a much more reserved use of direct new ROW segments and existing highway ROW segments. This is not entirely unexpected, as these routings carry higher costs per mile. However, a great many of the rail segments are longer in mileage than their direct ROW or existing highway ROW counterparts. The relative similarity in distance covered by highway ROW to direct new ROW results in the most significant surprise. Highway ROW distances closely matched those for direct new ROW, yet cost less. Initial inclination suggested highway ROW would dominate the three categories as it is both highly direct and not the most expensive.

The portion of either direct routing or highway ROW routing never exceeds the length of routing along existing tracks. The Alternative 6 and the Texas Mini-Triangle alignment produce the greatest portion of routing not along existing tracks, at 42.9 and 42.5 %, respectively, although most of the other alignments display similar values. The only exception to this trend is the Texas TGV Old alignment, which uses 20% of routing not along existing tracks. As this alignment was originally developed based on existing rail lines, this does not come as a large surprise.. The interaction between direct ROW routing and existing highway ROW routing does not display any clear trends, although the number of segment selected for each of these routings remains low in all cases. In only the Texas TGV New alignment are more than 50% of the segments selected from non-existing track segments. In all alignments, the length of the segments selected for direct ROW exceeds the length of selected segments for existing highway ROW. The Texas Triangle (Hal Cooper) alignment uses the greatest number of segments along existing highway ROW although the Texas TGV New alignment uses the greatest segment length of existing highway ROW. All six alignments use segments from all policy options. Generally speaking, limited subdivision of segments takes place. This is somewhat surprising, although given the linear relationship between segment length and cost, based on simple multipliers, not entirely mystifying. Ten of the possible eighteen total segment selections result in subdivision with this optimization procedure. The procedure itself performed well with no major issues in processing, despite outcomes not exactly as expected.

POLICY IMPLICATIONS

This optimization procedure and the subsequent results provide basic guidance for policymakers regarding HSR in Texas. Assuming the cost premiums for direct and existing highway ROW are relatively accurate (not a trivial assumption, given the small amount of data for HSR projects, especially in the United States, and the historic potential for cost overruns for infrastructure projects), it is obvious why the pursuit of operation on existing tracks or in existing rail ROW is an cost-effective option. Indeed, as the results show, the routing for all six alternatives overwhelmingly favors existing rail lines. This is not necessarily surprising as many of the alignments, particularly the older schemes, developed based on existing rail corridor alignments. However, this analysis does not consider the institutional arrangements that must occur between railroads and passenger rail entities that tend to be quite difficult to negotiate. Additionally, this suggests that agencies should not explicitly avoid direct routing through new ROW, despite the painful public headache that tends to result from such proposals. Although utilized lightly in the optimization procedure, all six alignments nevertheless include direct ROW segments, indicating such an approach generates tangible benefits. These benefits become more explicit with more complex analysis of ridership and travel times. Similarly, agencies tending to avoid using existing highway ROW should re-evaluate such stances. This simple exercise demonstrates that use of existing highway ROW, although not necessarily a primary routing element, should play a significant role in HSR routing, even if it does not comprise the majority of an alignment. Given the widespread state and federal highway system, it should not surprise officials that these highways ought to contribute to the alignment of HSR for a minimized cost. Considering the relatively difficulty of obtaining new ROW and compromising with freight railroads, which this optimization does not evaluate, the use of highway ROW becomes an even more attractive option. However, no element of securing, planning, and implementing a HSR project of the scale needed for Texas is inconsequential and costs reflect this. Roughly estimating capital infrastructure construction cost (including land acquisition) using a value of $50 million/mile, the six alignments evaluated here require hefty investments of approximately $25-40 billion. Realizing a project of such magnitude requires a far more complex array of analysis in addition to simple alignment cost minimization, although this exercise generates conclusions for HSR alignment that officials cannot responsibly avoid.

CONCLUDING REMARKS

Texas displays many decades of interest in HSR with several different proposed alignments for rail linking the major cities in the Texas Triangle. In order to provide information about the feasibility of these alignments, minimizing the costs of these alignments using three policy options – direct routing through all new land acquisition, routing along existing highways, or use of existing rail tracks – shows that based on loose land acquisition costs from proposed projects, existing rail may be the most feasible approach. However, the different corridors also utilized a number of directly-routed segments, particularly when circuitous existing rail resulted in lengthy alignments. Although not a major component of any of the optimal routings, existing highway ROW provided a section of many corridors. More accurate cost information may provide different optimized corridor alignment selections, but likely will continue to demonstrate that all three policy options deserve consideration for implementing HSR in Texas.

Chapter 8: Political Realities

No topic instigates political squabbles quite like transportation infrastructure. The tangible, utilitarian nature of transportation infrastructure affects the general population on a daily basis, subjecting millions to the effects of both its successful design and faulty nuances. Because of this, the exchange between politicians and the public as a whole regarding transportation infrastructure represents a highly functioning democratic discourse that many other political issues fail to achieve. This highly functioning discourse results in individual politicians frequently acting as catalysts both for and against transportation development. Rail does not lack for this relationship, as seen in the earlier Chapter 2 examples of the relationships between state governors and particular rail projects. All levels of government in the United States have recently engaged in the most active political exchange regarding rail in decades. In addition to introducing the topic to the already volatile political arena, because rail is generally underdeveloped relative to other modes in the United States, a great deal of misunderstanding about rail fuels an even greater volume of discourse. With rail subject to such a volume of discourse, this chapter analyzes the impact of political exchange on the feasibility of HSR in Texas for the near future.

RECENT NATIONAL DEVELOPMENTS

As noted in Chapter 1, interest in rail is not a new phenomenon, although the amount of passenger rail action and momentum at various levels of government in the last five years marks the most action certainly since the approval of ISTEA and possibly since the formulation of Amtrak in 1971. Unfortunately spurred by a deadly train collision in Southern California, the Passenger Rail Investment and Improvement Act (PRIIA) of 2008 ushered in a period of consistent political attention to passenger rail continuing to the present. The subsequent economic recession elicited several responses from the federal government, including the American Reinvestment and Recovery Act (ARRA) in early 2009, which contained $8 billion in state grants for HSR projects among a collection of other spending on healthcare, social services, infrastructure, and fiscal relief for states, as well as approximately $300 billion in tax relief (Recovery.gov, 2011). Despite comprising less than 1% of the overall cost of the act, the HSR grant allotment arguably generated far more discussion than any other single item, particularly because it embarked on substantial funding for a theretofore very marginal aspect of transportation appropriations, as seen in the introduction. By June 2009, the FRA launched the High-Speed Intercity Passenger Rail (HSIPR) grant process with federal HSR appropriations that also took place for FY 2010-2011. Initial pre-applications for the program showed enormous interest, as 40 states and the District of Columbia requested more than $100 billion through 278 applications (Government Accountability Office (GAO), 2011). The first round of awards totaling nearly $8 billion provided another shot of adrenaline to passenger rail, with projects in California, Illinois, Wisconsin, Ohio, Florida, Washington, and North Carolina emerging with the largest grants by the end of January 2010. Rail projects planned with these funds included new service, faster service, increased service reliability, planning and environmental studies, and track rehabilitation and improvements, indicating the commencement of a wide-ranging, truly nationwide passenger rail program (FRA, 2010). As with many transportation issues, political challenges to the FRA grant program arose almost immediately. Just like with previous projects covered in Chapter 2, state governors continued to play a large role in shaping rail progress in the United States. In fact, the topic became a campaign issue for many, and a campaign centerpiece for a few (http://www.notrain.com, for example). This campaigning, combined with the FY2010 HSIPR grant announcements, the November elections, and the prompt rejection of grants by newly-elected governors of Ohio and Wisconsin resulted in a tumultuous three months for passenger rail in the United States. Dust appeared to settle following the elections. President Obama, using his 2010 State of the Union address as a platform, announced his intention to bring a $53 billion nationwide passenger rail plan to fruition. Only days later, however, this juxtaposed the announcement that Florida's newly-elected governor had decided to return Florida's approximately $2.5 billion in federal grant money marked for the Tampa-Orlando rail segment despite overwhelmingly positive economic impact analyses and opposition from within his party in the Florida legislature (Share, 2011). These returned funds provided enough for an unplanned third round of grants in May 2011. Through the three rounds of HSIPR grants, Texas amassed $21 million in grants, of which $15 million provides for a study of a Dallas-to-Houston corridor. HSIPR grants met a quick demise in the next session of Congress, meaning this third round of grants may be the final federal disbursements for the foreseeable future, despite being an "otherwise good grantmaking process" (GAO, 2011).

STATE DEVELOPMENTS AND THE TRANS-TEXAS CORRIDOR

Since the failure of the Texas TGV project in 1994, a number of smaller proposals and advocacy groups have maintained enthusiasm even as interest of leaders and the public at large has withered. Unlike substantial movement at the federal level and in select other states (e.g. California, Illinois, North Carolina, Florida, Washington, and Michigan primarily), Texas progressed slowly on passenger rail in the last five years, as evidenced by the relatively small federal grants awarded. However, within the last decade, the Trans-Texas Corridor (TTC) project, which proposed a series of multimodal corridors crisscrossing the state, brought high-speed rail back to the public light for the first time since the Texas TGV project. Texas Governor Rick Perry envisioned a broad system comprised of toll roads for trucks and passenger cars, utility lines, and both freight and passenger rail built by private interests. TxDOT officially abandoned the project concept by 2009, however, after substantial public outcry, particularly from landowners and environmentalists, in favor of more traditional piecemeal planning for individual corridors. The primary issues included massive land takings, large expense, the implementation of privately financed toll facilities, and the foreign ownership of those private financiers, many of the same groups that brought down the Texas TGV project years earlier (Rutter, 2011). Despite its unpopularity and large-scale flaws (some corridors had a planned width of more than 1200 feet), TTC set forth one of the first comprehensive new transportation visions for the state in decades (Booth and Hutto, 2004). With a more focused scope and scale, greater public input, and increased understanding regarding toll facilities, the project may have progressed beyond lines on a map. As a concept, rail appears to enjoy support from Texans, as evidenced by the many proposals seen in Chapter 7 from different advocates over the state's history. The Texas Rail Plan process also gauged support for passenger rail. Questionnaires at public meetings throughout the state and online revealed a high degree of support for implementing high-speed rail service and coordinating passenger rail service with transit. While not statistically significant, as these were not random samples, but rather self-selected responses, these results still indicate the relative priority of these particular rail program elements compared to others in the questionnaire. Support for implementation of HSR, not surprisingly, was highest in the Texas Triangle metropolitan areas. More than 50% of respondents in Dallas/Fort Worth, Houston, and San Antonio marked HSR implementation as a high priority (see Figure 47 below). Yet, despite various degrees of support scattered around the state, a number of institutional and political barriers still exist that hamper intercity passenger rail progress.

	Increase speed on existing Amtrak routes				Increase reliability, frequency of existing Amtrak routes				Expand Amtrak to new cities				Coordinating with existing transit service				Implementing high-speed rail service			
Meeting Location	NI	NEU	VI	HP	NI	NEU	VI	HP	NI	NEU	VI	HP	NI	NEU	VI	HP	NI	NEU	VI	HP
Austin	13.0	30.4	39.1	17.4	8.7	34.8	30.4	26.1	9.1	50.0	31.8	9.1	9.1	18.2	45.5	27.3	13.0	13.0	43.5	30.4
Corpus Christi	18.2	36.4	36.4	9.1	9.1	27.3	45.5	18.2	9.1	27.3	45.5	18.2	-	40.0	30.0	30.0	9.1	9.1	63.6	18.2
DFW	11.4	40.0	28.6	20.0	11.8	14.7	41.2	32.4	11.8	41.2	29.4	17.6	-	-	51.4	48.6	-	14.7	35.3	50.0
El Paso	-	28.6	42.9	28.6	-	14.3	42.9	42.9	-	-	57.1	42.9	-	14.3	42.9	42.9	14.3	14.3	57.1	14.3
Houston	13.3	43.3	30.0	13.3	3.3	36.7	40.0	20.0	6.7	33.3	43.3	16.7	-	10.0	40.0	50.0	3.2	9.7	19.4	67.7
Lubbock	16.7	66.7	16.7	-	16.7	66.7	16.7	-	16.7	33.3	16.7	33.3	16.7	33.3	50.0	-	16.7	50.0	33.3	-
Pharr	-	55.6	33.3	11.1	-	38.9	33.3	27.8	-	16.7	33.3	50.0	-	15.8	47.4	36.8	5.6	22.2	44.4	27.8
San Antonio	4.8	42.9	23.8	28.6	4.8	14.3	42.9	38.1	4.8	14.3	33.3	47.6	-	10.0	45.0	45.0	-	19.0	28.6	52.4
Tyler	-	25.0	31.3	43.8	-	18.8	31.3	50.0	6.7	26.7	46.7	20.0	-	13.3	53.3	33.3	14.3	21.4	21.4	42.9
Other	5.9	35.5	47.1	11.8	5.9	17.6	47.1	29.4	12.5	18.8	43.8	25.0	-	23.5	29.4	47.1	11.8	5.9	41.2	41.2
Online	-	25.0	58.3	16.7	-	8.3	41.6	50.0	-	33.3	50.0	16.7	-	9.1	50.0	45.4	8.3	25.0	33.3	33.3

NI=Not Important, NEU=Neutral, VI=Very Important, HP=Highest Priority
Note: Cells with more than 40% responses are highlighted in green to indicate higher support.

Figure 47: Support for passenger rail elements at Texas Rail Plan (TxDOT, 2010c) public meetings

Put simply, passenger rail has not been a transportation priority in Texas; only in 1991 was the merging of the Department of Aviation, the Motor Vehicle Commission, and the State Department of Highways and Public Transportation formally renamed the Texas Department of Transportation (TxDOT, 2011b). Despite much evidence to the contrary (see Chapters 3, 4, and 6), benefits in terms of environmental quality, energy efficiency, cost, connectivity, and economic development resulting from passenger rail received merely passing consideration from the state populace in recent years. Many citizens and politicians have accepted long-distance rail services at the national level and local commuter or transit services at the regional-urban area level, but see no need to prioritize inter-regional services linking the two systems. This is partially due to structural defects. Federally-mandated regional Metropolitan Planning Organizations (MPOs) do not necessarily create interfacing plans with other MPOs unless there are shared geographic boundaries. Limited state support for sub-state entities also challenges inter-regional transportation planning such as that required for passenger rail (Zhang et al, 2007). Counties, for example, possess extremely limited power in Texas, whereas municipalities are permitted far more control to plan and zone (see Chapter 5). From a state bureaucracy standpoint, not until 2009 did TxDOT consolidate rail offices and operations in the Division of Rail, bringing TxDOT in line with other large state DOTs. TxDOT's brief 2005 rail plan recently underwent an update that satisfied federal and state requirements, although the plan largely took the form of a statewide inventory, given no established vision for the future of rail in Texas up to that point. While the bureaucratic rearrangement takes a step in the direction of passenger rail progress, the state still lacks a prominent and visionary passenger rail champion in the legislature or elsewhere. What the Trans-Texas Corridor lacked in technical acumen and public support, it may have possessed in strictly visionary terms. The idea quickly penetrated the federal transportation discourse and gained notoriety, even if for its flaws, something that certainly cannot be specifically said about passenger rail in the state. Until a knowledgeable and willing individual steps forward in the political limelight, the state appears to continue reliance on grassroots advocacy and a biannual legislature with other priorities than to promote passenger rail.

RAIL ADVOCACY

Even with a large presence throughout the state, rail (both freight and passenger) has been largely ignored by state agencies until very recently. Several grassroots rail advocacy organizations in the state have continued to promote rail in the face of state government inactivity on the topic although they generally do not support a single vision. Of particular note is the Texas High Speed Rail and Transportation Corporation (THSRTC). Chaired by Tarrant County commissioner Gary Fickes, THSRTC advocates for a rail system that is "capable of moving Texans at speeds in excess of 200 miles per hour" (THSRTC, 2010). Involved in the organization is a wide variety of elected officials, enthusiasts, economic development representatives, and academic personnel, particularly related to the Texas A&M University system. THSRTC actively promotes the conceptual “Texas T-Bone”, the rail routing considered in the Chapter 7 corridor evaluation. Regional advocacy also exists outside the Texas Triangle region, especially in east Texas. Originally founded in 1994, the East Texas Corridor Council (ETCC) now comprises 35 different municipalities in support of rail improvements in the region. Citing future increases in freight and passenger traffic on both roads and rails, inadequate regionally-subsidized air service, and slow Amtrak train speeds, the ETCC has pursued and won federal grants to improve the existing corridor and its connections from Texarkana and Shreveport to the Dallas/Ft. Worth area, incorporating the cities of Longview, Tyler, and Marshall (ETCC, 2010). The awarding of a $740,000 federal grant to study higher speed passenger rail service in the corridor is a major accomplishment for both the organization and the region. The Texas Rail Advocates (TRA) also promote passenger rail in Texas. Established in 2000, TRA more generally encourages improvements to both passenger and freight rail in Texas. Dallas businessman Peter LeCody chairs the organization following experience working with the I-35 Corridor Advisory Committee, the Texas Rail Plan Steering Committee, and the National Association of Rail Passengers. Among the more significant achievements of the organization is the hosting of an annual Southwestern Rail Conference in Dallas. Through these efforts and others, TRA works toward its stated goal of “…accelerat[ing] Texas’ economic growth and enhanc[ing] the quality of life enjoyed by its people by advancing development of rail service to its full potential as a carrier of freight and passengers” (TRA, 2010). While not necessarily wielding substantial power in the political process, these grassroots rail advocacy organizations continue to instigate fruitful discussion about rail improvements in the state of Texas, even if these improvements are somewhat minor in the statewide context. With no clear political champion for passenger rail in Texas, these organizations attempt to fill that gap by promoting rail as best they can with their limited resources.

EMINENT DOMAIN

HSR operating above 125 mph necessitates dedicated tracks and unique right-of-way. This utilization of land for public good causes anguish for the public, as it fundamentally conflicts with a basic American tenet valuing uninhibited ownership of property, specifically land and a single-family house on that land. Even if a bit whimsical, the high value that Texans place on such land ownership illustrates the reality of such an unwritten doctrine, especially with citizens so watchful about land obtained for government purposes ("eminent domain"). Texas laws protecting landowners in cases of eminent domain, which would presumably be used by the state for new rail lines, were strengthened in November 2009 in response to the US Supreme Court decision in *Kelo v. City of New London* and on the heels of the Trans-Texas Corridor debacle. The voter referendum, overwhelmingly passing with 81% of "yes" votes, prohibited "the taking of private property for transfer to a private entity for the purpose of economic development or to increase tax revenues" (Texas Secretary of State, 2009), although critics of the measure included prominent voices claiming the protections for landowners were still too weak. The measure also limited the ability of the legislature to grant eminent domain power unless approved by two-thirds in each house. Still, some gray area certainly exists. The same statute permitted use of eminent domain for "the ownership, use, and enjoyment of the property by the State, its political subdivisions, the public at large, or by entities granted the power of eminent domain", which includes TxDOT, transit agencies, and municipalities. Increased mobility from construction of rail lines (see Chapter 6) benefits the public at large even if a private firm owns or operates the lines. Indeed, several instances in Thomas (2009) note or suggest that the law of eminent domain has "evolved from one of eminent domain being for public use to one of eminent domain being for a public purpose." Historic deference would also suggest, based on the recent allowance for constructing toll roads operated by private foreign firms in Central Texas, that a comparable HSR project with a smaller footprint would surpass comparable judicial scrutiny. The only major difference, of course, being the transportation mode. Provided the state inevitably would invoke eminent domain in HSR corridor development, the advantage of relatively cheap land somewhat limits the project construction costs compared to other populated states. According to 2008 USDA data, average Texas farm real estate values amounted to $1,550 per acre, lower than all states in the South Census Region except for Oklahoma (USDA, 2009). Compared with farm real estate values in other peer states pursuing rail projects, such as California ($6,100), Illinois ($4,530), and New York ($2,400), Texas land is quite cheap. Yet, to realize this advantage would require significant public support for passenger rail, particularly if built by or benefiting private interests, as the eminent domain limitations currently restricting new transportation corridor development represent initial public skepticism and wariness toward public land acquisition. This situation bolsters the case for using existing right-of-way and/or using marginally productive land on property edges alongside existing right-of-way where use of eminent domain is limited to only the most pressing circumstances, if for no other reason than to avoid frustrating litigation.

TEXAS LEGISLATIVE WORK

Despite fervent grassroots rail organizations, Texas rail needs fail to penetrate the federal and state legislative process, as political support is extremely limited. State Senator John Carona (R-Dallas) pursued rail work almost singlehandedly in the 81st Texas Legislative Session. With his role as the chairman of the Transportation and Homeland Security Committee, his ability to push rail legislation was enhanced. Carona's authored bills encouraged high-speed rail action through planning, tax exemption, and redirection of fuel tax receipts and registration fees. While only a single bill (SB 1382, requiring TxDOT to create a statewide passenger rail system plan) was signed in to law, Carona displayed an unmatched commitment to Texas rail issues. Carona went as far as to propose specifics for a Texas high-speed rail system, including service to the state's four largest passenger airports and connectivity to the largest military institutions in the state

(Texas Legislature, 2008). Based on regional advocacy, his interest in a statewide rail system is not unfounded, but fellow legislative support is limited. The biannual legislative arrangement in Texas means that issues addressed in each session may change drastically from one session to the next as a result of shifts in political winds. In the 2009 groundswell of rail interest, his authored bills promoting rail planning progressed in the 81st Legislature. Stark changes in political issues between the 81st and the 82nd legislative sessions and Carona's reassignment as the chairman of the Business and Commerce Committee, however, meant that both the priority and exposure of rail issues dropped dramatically in the legislative session. Situations like this could be addressed through public lobbying of state politicians on behalf of rail advocacy if a strong voice could be mustered accompanying internal agency recommendations. Unfortunately, as seen with the TTC debacle, TxDOT generally has a weak concept of public opinion on transportation needs and has, until recently, little experience outside of road project implementation. Project public meetings, envisioned by NEPA as a method for communities to address and mitigate project impacts, seem to summon only the most fervent supporters and opponents, and are a poor method to gauge overall state opinion on transportation needs, particularly untested ideas such as intercity passenger rail. Texas agencies, as well as state and federal policy makers from the state, would be smart to determine constituent support for improvements in non-roadway transportation, including intercity passenger rail. This information may allow rail to make a more significant venture into the legislative agenda beyond the support of seemingly a single politician for but a single legislative session.

FINANCE AND FUNDING

Even with greater state vision and political leadership in planning and identifying state-wide intercity passenger rail potential, straightforward action is difficult with barriers to practical implementation. This leads to perhaps the largest issue of all: a funding source. All the previous attempts at intercity passenger rail in Texas have taken a privately funded approach, which avoids some political issues. As intercity passenger rail has not seriously been tested in the United States (especially at high speeds), it faces some difficulty in finding investors willing to undergo such risk, especially with tepid state or federal government support at present. Furthermore, no successful intercity passenger rail system worldwide has been constructed without government support (Peterman et al, 2009). Even if government support for passenger rail did exist, capital costs are high, as pointed out in Chapter 7.

Transportation funding in general in Texas is in flux at the state government level, particularly with the looming $28 billion state budget deficit for 2012-2013 closed in the 82nd Legislative Session. With state fuel excise taxes providing the dedicated funding source for transportation in Texas, legislators approve the budget for transportation separately from the larger state budget based on general revenues. The budget borrows Proposition 12 bond funds for transportation expenditures. Financing for these bonds is repaid primarily from the general fund, which faced the large deficit in the latest budget cycle (Wear, 2011). With the remaining bond funds to be spent, the 30-year debt service on those bonds, amounting to $600 million every two years, has been effectively pushed beyond the 2013 fiscal year. Illustratively, the expenditures on debt will exceed available cash for highway construction for the first time (Scharrer, 2011). This fiscal circus shows that even though current finances for TxDOT may balance, they are nevertheless a major burden on the overall state budget. With declining fuel excise tax revenues as a result of greater fuel efficiency and a reduction in VMT, the state will face an urgent transportation funding issue in the near future. Finances for TxDOT will continue to tighten, requiring the agency and political leaders to consider new ideas for revenue. Proposals for regions within the state to increase taxes and/or fees by local referendum (local option taxes) and then dedicate the receipts to transportation projects reached the governor’s desk in the 80th legislative session, but met a swift veto. The state thus faces an uncertain situation for transportation finances, leaving a dim short-term outlook for a relatively massive state rail project for Texas similar to those discussed here.

Transportation improvements in Texas, such as those transit improvements mentioned in Chapter 4, appear to achieve the highest public support when local jurisdictions and/or municipalities secure funding. Local option taxes, mentioned in Chapter 8, have shown promise in Texas. Additionally, Texas enjoys creating a number of special assessment districts for a wide range of different purposes. Generally, within a special assessment district, residents approve a tax by referendum where a portion of those tax revenues provide funds for a specific purpose, perhaps school funding, water treatment facilities, transit services, or economic development (HGAC, 2011). This can be used as a tool to attract private investment for a project as well in a public-private partnership (PPP) arrangement. Even with emphasis in the United States squarely on the PPP approach, much evidence from Europe suggests that these are not without their own flaws when financing HSR projects, particularly when plagued with poor demand forecasts, unexpected project complexity, or the fundamental discord between emphasis on short-term profits in the private sector contrasted with long-term investment and social returns in the public sector (Alexandersson and Hultén, 2009). The widespread adoption of the special assessment district concept in Texas may provide an excellent approach to establish some public money marked specifically for HSR. A complex special assessment district for urban areas in the Texas Triangle with rail stops (not necessarily those locations through which track would pass without stopping) might garner political support from those urban residents who would be most likely to use such a rail system, who would then willingly tax themselves. Revenues could encourage private investment, offset maintenance costs, or cover environmental mitigation costs along the route. The transit agencies in the state (e.g. DART, METRO, Capital Metro, VIA Transit) have demonstrated relative success in generating needed funds with creation of transit districts operating through incremental increases in sales taxes voted in by referendum. A special assessment district created similarly may generate revenue that could provide substantial financial incentive for private investment, which Texans may support. But, this would require legislative guidance through to the governor's desk, meaning that legislators would first have to understand the potential for HSR in Texas and then display willingness to support it, which, as noted here, is not a priority at present.

CONCLUDING REMARKS

Present-day issues surrounding HSR nationwide and in Texas demonstrate the familiar tight intertwining of transportation and politics. The last five years have provided the most substantial action on rail in decades, however, with the enactment of PRIIA, the announcement of billions of dollars in HSR and passenger rail grants to states as a part of the 2009 economic stimulus act, and the subsequent rejection of funds by newly-elected governors in battleground states following the 2010 midterm elections. Unlike many of the more populous states in the nation, Texas received relatively little grant money for passenger rail improvement. Still, this marked the most action on passenger rail in the state since the Texas TGV project and the proposed Trans-Texas Corridor. Generally speaking, passenger rail remains a non-priority from a legislative standpoint in Texas. What little work completed in 2009 has since eroded with legislative committee reassignments and newly-elected representatives adjusting their political priorities. Additionally, the prospect of land acquisition remains a formidable hurdle for transportation planners to scale if HSR is to be implemented in Texas. Discussion on rail in Texas continues to be fueled by the many advocacy groups throughout the state. Their work, combined with a political champion and a comprehensive, original funding scheme, will be required for Texas to move forward in passenger rail planning and implementation.

Chapter 9: Conclusions and Recommendations

Quality of life for Texas residents is in flux as the state's traditional transportation solutions appear to be increasingly temporary. Based on the lack of a broad and transformational national transportation vision following the completion of the Interstate Highways System under ISTEA, Texas continues to develop an automobile-centric passenger transportation system that, with time, may not be appropriate for its needs. The sustained growth in population and economic output requires a transportation system that meets the demands to travel both farther and faster. Perhaps unique to Texas in volume or scale, most of the transportation challenges such as automobile congestion, air quality non-attainment, and increasing energy use have long plagued other areas of the nation to some degree, yet pose growing challenges for the state to overcome. Given a renewed national interest in passenger rail, trains, particularly those traveling at high speeds, have great potential as but one tool to transition the Texas transportation system into a more broad system that promotes mobility and connectivity while simultaneously achieving measurable reductions in environmental impact, energy use, safety, and land development compared to the status quo. This thesis addressed the broad range of initial issues affecting the feasibility and ridership of potential HSR in Texas through guidance from other regions of the United States and consideration of the state's demographics and geographic layout, urban connectivity, track alignment issues, social and environmental benefits, and political issues. In addition, this thesis addressed the importance of considering different right-of-way alignments of proposed corridors in Texas. Texas does not lack in issues facing the potential implementation of HSR, but despite these, HSR displays real benefits for the state that can be maximized by addressing those issues.

TEXAS RAIL IN A NATIONAL CONTEXT

Current American rail curiosity continues many decades of interest in passenger rail improvements, but little implementation. Selected regions of the country, including California, Florida, the Midwest, and the Northeast, pursued various forms of passenger rail for many years leading to the current plan iterations in those areas. Texas, conversely, for being a relatively populous state, has only minimally invested in passenger rail from the state perspective. As a result, any renewed action on passenger rail in Texas in the imminent future can rely on the prior missteps of other regional plans, as well as the guidance from the curtailed Texas TGV project in the mid-1990s. These other projects highlight, among many things, the importance of open communication between project entities, whether between agencies, between private consortia members, or integrating the private and public sector personnel. The particular personalities involved with a project play a major role, for better or worse, and thus point to the importance of incorporating individuals with keen leadership from a legislative, departmental, and private firm perspective. Though not a national leader from a passenger rail perspective, Texas nevertheless greatly benefits from actions of other regions, hopefully enabling a more efficient and focused approach than would otherwise occur.

HIGH-SPEED RAIL IN A TEXAS GEOGRAPHIC CONTEXT

From a geometric and demographic standpoint, Texas fits the profile of well-patronized intercity passenger rail service very well. Despite the state's large size, the population is primarily focused in the eastern one-third of the state. The major urban areas in the state most likely to generate demand for rail service conveniently form a triangle. This triangle has two properties that strongly enable the popularity of future passenger rail service in the region. First, the region forms a prominent megaregion, the Texas Triangle, where the economies of the different urban areas are increasingly interwoven and co-dependent, spurring intercity transportation demand between those urban areas more pronounced than between urban areas without this economic cohesion. Second, the primary urban areas (Dallas/Fort Worth, Houston, Austin, and San Antonio) all lie within a nearly ideal distance of one another for passenger rail services, based on experience from Europe and Asia. Trains averaging typical speeds (75-150 mph) over the distance between many of these cities and the smaller urban areas could be expected to easily capture half the air-rail mode split. The high potential for passenger rail use based on the intrinsic geometric layout of the major urban areas in the state cannot be understated.

POTENTIAL HIGH-SPEED RAIL INTERMODALISM

However, within many of the urban areas in Texas, the essential transportation connections most conducive to passenger rail require attention. Urban connectivity and intermodal travel develop concurrently, with rail station accessibility a determining factor in the selection of the mode. Current transit services in Texas leave much to be desired, with a low modal share in all Texas urban areas and limited service areas. Their use differs substantially from the cities connected to passenger rail in foreign countries, indicating that for passenger rail to succeed, some degree of urban transit improvement is probably necessary. The integration of air and rail transportation provides an excellent opportunity to promote intermodalism. High development of air travel in Texas due to hub operations at both Dallas/Fort Worth International and Houston Intercontinental Airports includes frequent short intra-Texas flights between cities in the Texas Triangle. Passenger rail operations with airport connections present a fourfold opportunity to improve mobility by promoting reliability and punctuality compared to personal automobiles, enhancing both landside and airside airport capacity, and connecting moderately-sized cities by eliminating relatively inefficient short-haul flights. Codeshare ticketing with airlines, successfully demonstrated in the United States, may make airport intermodal connections with passenger rail more intuitive. Despite relatively poor transit connections when compared with other major metropolitan areas worldwide, Texas cities nevertheless demonstrate an unharnessed opportunity for passenger rail to interface with a well-developed air transport system.

Spatial and Legal Considerations

The guidelines for the geometric arrangement of HSR still face much future development in the United States. Additionally, the spatial concerns regarding right-of-way requirements and zoning to encourage appropriate land use for HSR present new issues local governments must address because HSR itself does not necessarily encourage efficient development. As seen with airports, high speed modes can generate high ridership when connected to only automobiles. Nevertheless, a once-in-a-generation opportunity to re-define land development guidelines to increase sustainable transportation practices lies with HSR. This will require new capabilities for cities, urban areas, and even inter-urban regions to plan and zone for particular land uses, lest the uninhibited sprawl that defines American land development continue. For HSR to comfortably operate at high speeds, curve radii must be quite large – multiple miles at top speeds – which do not conform to existing rail lines, or other transportation infrastructure. Because of this, the implementation of new HSR services will require land acquisition, introducing a host of issues related to the use of eminent domain. Multiple public agencies in Texas may exercise the right of eminent domain if necessary, although the vague nature of doing so for a "public purpose" remains to be tested in the realm of passenger rail. Only the future will determine the interaction between HSR and private property rights.

Emissions, Energy, Safety, and Economics

Society stands to gain real environmental benefits from the careful implementation of HSR. While many factors influence the energy efficiency of transportation modes, including the overall capacity, the load factor, the length of the trip, and the electricity source, at typical load factors, HSR outperforms air and automobiles in energy efficiency. Because transportation purposes comprise about 30% of energy use in the United States, of which 96% is petroleum-based, improvements in energy efficiency in transport mean substantial improvements in nationwide energy efficiency and petroleum use. Rail cannot solely create these improvements, but can contribute to substantial improvements in intercity travel. Limiting petroleum use will limit the emission of greenhouse gases and pollutants that cause respiratory harm. While trains may increase energy efficiency, essential reduction in fossil fuel use must occur at the electricity source. Currently fossil fuels provide a majority of electricity in Texas, meaning changes in the energy source portfolio must occur to realize significant gains in energy efficiency and fossil fuel use reduction along with HSR implementation. Other benefits of rail in Texas include increased safety, with rail improving on the safety record of the automobile, and the encouragement of land development that promotes positive human health. A thorough cost-benefit analysis based on the estimated values of these positive and negative externalities provides the basis for selecting transportation projects with positive returns exceeding a certain threshold. Such analysis shows that, in many cases, the benefits of HSR exceed the costs.

CORRIDOR EVALUATION

Many different HSR proposals for Texas over time demonstrate a variety of thought about the future of passenger rail in Texas. In order to provide guidance for the implementation of passenger rail, six corridors representing various approaches were analyzed using three policy options: using entirely new right-of-way, using existing highway right-of-way, or using existing tracks. Minimizing the costs of a particular corridor using an optimization procedure based on different estimated costs for the three policy options showed the importance of using existing rail lines for service. While only a simple exercise, this shows that despite being cheaper than a direct routing with new right-of-way, existing right-of-way along highways may not necessarily provide the expected cost savings compared to using existing rail lines. However, this simple analysis does not consider the other side of cost-benefit analysis. Train velocity obviously affects travel time, and therefore ridership. If existing lines do not permit the speeds necessary to achieve substantial ridership, the benefits may not exceed the costs, even if the costs are low. Thus, more comprehensive analysis and ridership estimates based on different routing may show another optimal routing for a given alignment.

POLITICAL REALITIES

Finally, despite a great wealth of information about the factors affecting HSR potential in Texas, political issues play a very important and unpredictable role in transportation. Politicians act as critical catalysts for many transportation projects. This reflects the necessity of grassroots advocacy and public education so that political leadership can be made aware of the value the public places on a particular project. National developments and leadership for HSR have taken a tumultuous path in the last three years as a result of economic frustration, changes in political leadership, and modifications of federal priorities. This volatility reached the state level, where rail became a major campaign issue for some. As Texas has historically limited its planning and implementation of passenger rail, these events did not affect the state as drastically as others. This also reflected the prioritization of other political issues at the Texas state level. The 2009 legislative session marked a high point for rail legislation in the state, led by State Sen. John Carona of Dallas, although the visionary yet flawed Trans-Texas Corridor of some years earlier also spurred some political action. Among the more important issues specific to Texas that will affect any HSR progress in the future are the challenging eminent domain issues related to transportation and the lack of a visible, visionary political champion for passenger rail in the state.

RECOMMENDATIONS

Development of transportation in Texas including a future with HSR will require new and innovative direction from many different angles. The implementation of a system such as those described herein prompts many new directions that various entities in the state ought to explore. The critical areas for future action include arrangements for financing and alignment, as the state struggles with a public wary of government-financed rail and corridors that involve land acquisition. Recommended in Chapter 5, the use of utility corridors may provide one solution to locating rails in rural areas, as these corridors are already somewhat marginal in public minds because of the utilities that have already been implemented. The impact of rail in such corridors may be less than that of entirely new greenfield corridor development, and should be analyzed for feasibility in Texas. From a finance standpoint, the success of special assessment districts for various purposes in the state shows that many public improvements with a focused purpose may receive support from those who see potential benefits at a local level. The creation of a complex special assessment district that would be locally financed by those most likely to use HSR could provide a financial dowry that might entice private capital and/or cover environmental mitigation costs, operating costs, or maintenance costs. There appears to be no lack of alignment suggestions for the state, but an independently-authored ridership analysis for the state would provide some much-needed up-to-date data about the costs and benefits of a HSR system in Texas. However, by creating such an analysis, the state must be prepared to interface with the public to simultaneously educate them on the issues, communicate important facts and figures, and mitigate potential impacts. In the short-term, this will require the state to develop a comprehensive approach to use various media sources (print and electronic), undertake a focused campaign to align itself with local chambers of commerce, and provide state legislators with comprehensive information that limits the spread of politically-enhanced misinformation about rail. Maybe the most difficult and essential item that the state cannot control, a political champion for HSR in the state must emerge to promote the untapped passenger rail opportunity that exists. Just as Texas wants to be an economic leader, it too wants to be a transportation leader. Yet, it insists on using increasingly inefficient and ineffective capacity improvements to roadways as solutions. To continue its economic and transportation leadership, the state should implement the necessary foundation for passenger rail implementation that will allow it to capitalize on natural geometric advantages, and then proceed forward with an innovative one-state push, just as it did in the 1950s with limited-access freeways.

References

Airports Council International. (2011). “Year-to-data Passenger Traffic” Accessed online at http://www.airports.org/cda/aci_common/display/main/aci_content07_c.jsp?zn=aci&cp=1-5-212-218-222_666_2__ on June 20, 2011.

Alexandersson, Gunnar and Staffan Hultén. (2009). “Prospects and Pitfalls of Public-Private Partnerships in the Transportation Sector: Theoretical Issues and Empirical Experience” Thredbo 10 International Conference Series on Competition and Ownership in Land Passenger Transport. Accessed online at http://www.thredbo-conference-series.org/downloads/thredbo10-papers/thredbo10-themeC-Alexandersson-Hulten.pdf on August 1, 2011.

Álvarez, Alberto García. (2010). “Energy Consumption and Emission of High-Speed Trains” Transportation Research Record 2159: 27-35.

American Association of State Highway and Transportation Officials (AASHTO). (2002). “The Bottom Line” Accessed online at http://bottomline.transportation.org on July 1, 2011.

American Public Transportation Association (APTA). (2010). “Public Transportation Ridership Report: First Quarter 2010” Accessed online at http://www.apta.com/resources/statistics/Documents/Ridership/2010_q1_ridership_APTA.pdf in July 2010.

American Railway Engineering and Maintenance-of-Way Association. (2009). “Chapter 17: High Speed Rail Systems” Manual for Railway Engineering.

American Wind Energy Association (AWEA). (2010). “AWEA US Wind Industry Annual Market Report”. Accessed online at http://www.awea.org/reports/annual_market_report_press_release_teaser.pdf in July 2010.

Association of American Railroads. (2011) “Freight Railroads in Texas” Accessed online at http://www.aar.org/Railroads-States/Texas-2009.pdf on May 1, 2011.

Baron, David P. (1990) “Distributive Politics and the Persistence of Amtrak” Journal of Politics, 52 (3): 883-913.

BB&J Consult SA. (2010). “High Speed and the City” Union Internationale de Chemins. Accessed online at http://www.uic.org/etf/publication/publication-detail.php?code_pub=518 on July 15, 2011.

Bertaud, Alain. (2003). “Order Without Design” Accessed online at http://alain-bertaud.com/images/Average%20Density%20graph.pdf on July 15, 2011.

Bhat, Chandra et al. (2006) “Public Support of Passenger Rail Sharing Freight Infrastructure” Report 0-5022-1, Center for Transportation Research, The University of Texas at Austin.

Black, R. C. (2005). “The Acela Express”. Japan Railway & Transport Review 40. Accessed online at http://jrtr.net/jrtr40/pdf/f18_bla.pdf in July 2010.

Blum, U. et al. (1997). “The Regional and Urban Effects of High-Speed Trains” The Annals of Regional Science 31 (1): 1-20.

Bonnafous, A. (1987). “The Regional Impact of the TGV” Transportation 14: 127-137 (translated from French).

Booth, Cathy and Thomas Hutto. (2004). "The Next Wave in Superhighways, or A Big, Fat Texas Boondoggle?" TIME. Accessed online at http://www.time.com/time/magazine/article/0,9171,832224-1,00.html on August 1, 2011.

Borowiec, J.D. et al. (2010). Potential Development of an Intercity Passenger Transit System in Texas. Texas Transportation Institute. http://tti.tamu.edu/documents/0-5930-2.pdf. Accessed June 30, 2010.

Brons, Martijn et al. (2009). "Access to Railway Stations and its Potential in Increasing Rail Use" Transportation Research Part A 43: 136-149.

Bureau of Economic Analysis (BEA). (2009). "Texas Employment by SIC Group". Department of Commerce. Accessed online at http://www.bea.gov/regional/remdmap/REMDMap.aspx on May 25, 2011.

Bureau of Economic Analysis. (BEA). (2011). "Per Capita Real GDP by State (Texas)" and "Per Capita GDP" Accessed online at http://www.bea.gov/iTable/ on April 10, 2011.

Bureau of Transportation Statistics (BTS). (2010). "National Transportation Statistics: Tables 3-29a and 3-30a". Research and Innovative Technology Administration, Department of Transportation. Accessed online at http://www.bts.gov/publications/national_transportation_statistics/ in January 2011.

Bureau of Transportation Statistics (BTS). (2011)a. Selected Statistics from "Top 100 Domestic Segments (US Carriers)". Research and Innovative Technology Association, Department of Transportation. Accessed online at http://www.transtats.bts.gov/Fields.asp?Table_ID=259 in January 2011.

Bureau of Transportation Statistics (BTS). (2011)b. "Occupant Fatalities by Vehicle Type and Nonoccupant Fatalities". Research and Innovative Technology Administration. Department of Transportation. Accessed online at http://www.bts.gov/publications/national_transportation_statistics/html/table_02_19.html on July 3, 2011.

Burleson, Andrew. (2009). "The Routes". neoHouston Blog. Accessed online at http://www.neohouston.com/2009/09/texas-high-speed-rail-introduction/ on June 20, 2011.

Burnett, V. (2009). "Spain's High-Speed Rail Offers Guideposts for U.S.". New York Times. Accessed online at http://www.nytimes.com/2009/05/30/business/energy-environment/30trains.html?_r=2 in January 2011.

Burns, Marc H. (undated) "High-Speed Rail in the Rear-View Mirror: A Final Report of the Texas High-Speed Rail Authority"

Butler, Kent et al. (2009). "Reinventing the Texas Triangle: Solutions for Growing Challenges" Center for Sustainable Development, University of Texas School of Architecture. Accessed online at http://soa.utexas.edu/files/csd/ReinventingTexasTriangle.pdf in June 2010.

California High Speed Rail Authority (2009). "Report to the Legislature December 2009" Accessed online at http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx on July 22, 2011.

California High Speed Rail Authority. (2008). "California High Speed Train Business Plan" Accessed online at http://www.cahighspeedrail.ca.gov/Business_Plan_reports.aspx in January 2011.

Cambridge Systematics. (2007). “National Rail Freight Infrastructure Capacity and Investment Study”. Accessed online at http://www.camsys.com/pubs/AAR_RRCapacityStudy.pdf. pp. 4-1 through 4-12 in June 2010.

Cambridge Systematics. (2008). “High Speed Rail: A National Perspective” Accessed online at http://www.camsys.com/pubs/Amtrak_Amtrak-High_Speed_Rail-A_National_Perspective.pdf on May 3, 2011.

Campos, Javier and Ginés de Rus. (2009). “Some Stylized Facts About High-Speed Rail: a Review of HSR Experiences Around the World” Transport Policy 16: 19-28.

Centers for Disease Control and Prevention. (2011). “Obesity and Overweight for Professionals: Data and Statistics: US Obesity Trends” Accessed online at http://www.cdc.gov/obesity/data/trends.html on June 12, 2011.

Central Intelligence Agency (CIA). (2010). “CIA – The World Fact Book: France”. Accessed online at https://www.cia.gov/library/publications/the-world-factbook/geos/fr.html in July 2010.

Cervero, Robert. (2000). “Growing Smart By Linking Transportation and Urban Development” Virginia Environmental Law Review 19 (357): 357-374.

Cervero, Robert. (2003). “Growing Smart by Linking Transportation and Land Use: Perspectives from California” Built Environment 29 (1): 66-78.

Chester, Mikhail and Arpad Horvath. (2010). “Life-cycle Assessment of High-Speed Rail: the Case of California” Environmental Research Letters 5: 1-8.

Christiansen, Dennis. (1976) “The History of Rail Passenger Service in Texas 1820-1970” 1976. Accessed in “Texas Rail Plan 2010” October 2010 Texas Department of Transportation.

Code for Federal Regulation Section 213 Subpart C and Subpart G. Accessed online at http://www.access.gpo.gov/nara/cfr/waisidx_03/49cfr213_03.html on July 15, 2011.

Colorado Department of Transportation. (2006) “Glenwood Canyon I-70 Final Link” http://www.coloradodot.info/about/50th-anniversary/interstate-70/glenwood-canyon, accessed April 22, 2011

Coogan, Matthew A. (2008). “Ground Access to Major Airports by Public Transportation” ACRP Report 4, Transportation Research Board.

Cooper, Hal B. H. Jr. (2009). “Preliminary Implementation Plan for the High-Speed Rail Passenger Project in the Texas Triangle and Southwest Corridor”. Triangle Railroad Holding Company.

Dallas Area Rapid Transit. (2010). “DART.org - Orange Line Expansion Information”. Accessed online at http://www.dart.org/about/expansion/orangeline.asp in July 2010.

Dallas Indicators. (2011). “Texas’ Annual Vehicle Miles Traveled 1999-2003” Accessed online at http://www.dallasindicators.org/Default.aspx?tabid=1305 on April 10, 2011.

Dallas/Ft. Worth International Airport. (2010). “Building a Future Together: DFW International Airport Strategic Plan”. Accessed online at http://www.dfwairport.com/about/pdf/publications/14816_DFWAIR_STRATEGIC_PLAN_012508_resizepdf in July 2010.

Davis, Stacy C. and Susan W. Diegel. (2010). “Transportation Energy Data Book Edition 29” Oak Ridge National Laboratories for the United States Department of Energy. Accessed online at http://cta.ornl.gov/data/download29.shtml on May 15, 2011.

de Rus, Ginés and Gustavo Nombela. (2007). “Is Investment in High Speed Rail Socially Profitable?” Journal of Transport Economics and Policy 41 (1) 3-23.

Demerjian, D. (2008). “On One Key Route, Amtrak is Up, Airlines Down”. Autopia: Wired Magazine. Accessed online at http://www.wired.com/autopia/2008/03/would-people-av/ in July 2010.

Dey Chaudhury, Prosenjit. (2003). “Rail and Road in Intercity Transport: Energy and Environmental Impact” Economic and Political Weekly 38 (42): 4423-4425.

Dunn, James A. Jr., and Anthony Perl. (1997) “Reinventing Amtrak: The Politics of Survival” Journal of Policy Analysis and Management, 16 (4): 598-614.

East Texas Corridor Council (ETCC). (2010). “East Texas Corridor Council – Goals”. Accessed online at http://www.eastxcc.com/goals in July 2010.

Engle, J. (2010). “Interview: Amtrak president on what’s next for rail in the west”. LA Times Travel. Accessed online at http://travel.latimes.com/daily-deal-blog/index.php/interview-amtrak-pre-7153 in July 2010.

Environmental Protection Agency (EPA). (2011). “Six Common Air Pollutants”. Accessed online at http://www.epa.gov/airquality/urbanair/ on June 20, 2011.

European Commission. (2011). “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system” Accessed online at: http://ec.europa.eu/transport/strategies/2011_white_paper_en.htm on June 20, 2011.

Facchinetti-Mannone, V. (undated). “Location of High Speed Rail Stations in French Medium-Size City and Their Mobility and Territorial Implications” Laboratory THEMA, University of Burgundy.

Federal Highway Administration (FHWA). (2011). “Travel Monitoring – Traffic Volume Trends” Accessed online at http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm on April 10, 2011.

Federal Railroad Administration (FRA). (2005). “High Speed Ground Transportation Noise and Vibration Impact Assessment” United States Department of Transportation. Accessed online at http://www.fra.dot.gov/Pages/253.shtml on June 30, 2011.

Federal Railroad Administration (FRA). (2009)a “Overview, Highlights, and Summary of the Passenger Rail Investment and Improvement Act of 2008 (PRIIA)” Accessed online at http://www.fra.dot.gov/downloads/PRIIA%20Overview%20031009.pdf on May 1, 2011.

Federal Railroad Administration (FRA). (2009)b. “High Speed Passenger Rail Safety Strategy” Office of Railroad Safety, Federal Railroad Administration. Accessed online at http://www.fra.dot.gov/downloads/safety/HSRSafetyStrategy110609.pdf on June 15, 2011.

Federal Railroad Administration (FRA). (2010) “HSIPR Project Funding” Federal Railroad Administration. Accessed online at http://www.fra.dot.gov/rpd/HSIPR/ProjectFunding.aspx on May 20, 2011.

Federal Railroad Administration (FRA). (2011). “High-Speed Grade Crossings” Federal Railroad Administration. Accessed online at http://www.fra.dot.gov/Pages/217.shtml on June 20, 2011.

Federal Railroad Administration (FRA). (undated) “Chronology of High-Speed Rail Corridors” Accessed online at http://www.fra.dot.gov/rpd/passenger/618.shtml on May 1, 2011.

FORTUNE on CNNMoney.com. (2011). “Fortune 2011: Near You”. Accessed online at http://money.cnn.com/magazines/fortune/fortune500/2011 in June 2010.

Freemark, Yonah. (2010). “The Sprawling Effects of High-Speed Rail”. The Transport Politic. Accessed online at http://www.thetransportpolitic.com/2010/03/18/the-sprawling-effects-of-high-speed-rail/ on July 15, 2011.

Givoni, Moshe and David Banister. (2006). “Airline and Railway Integration” Transport Policy 13: 386-397.

Givoni, Moshe and David Banister. (2007). “Role of the Railways in the Future of Air Transport” Transportation Planning and Technology 30 (1): 95-112.

Givoni, Moshe and Piet Rietveld. (2007). “The Access Journey to the Railway Station and its Role in Passengers’ Satisfaction with Rail Travel” Transport Policy 14: 357-365.

Givoni, Moshe et al. (2009). “Are Railways ‘Climate Friendly’?” Built Environment 35 (1) 70-86.

Givoni, Moshe. (2007). “Environmental Benefits from Mode Substitution: Comparisons of the Environmental Impact from Aircraft and High-Speed Train Operations” International Journal of Sustainable Transportation 1: 209-230.

Glaeser, Edward L. (2009). “What Would High-Speed Rail Do to Suburban Sprawl?”. The New York Time Economix Blog. Accessed online at http://economix.blogs.nytimes.com/2009/08/18/what-would-high-speed-rail-do-to-suburban-sprawl/ on July 15, 2011.

Government Accountability Office. (GAO). (2008). “Transmission Lines Along Transportation Rights-of-Way” Report GAO-08-347R Accessed online at http://www.gao.gov/products/GAO-08-347R on June 12, 2011.

Government Accountability Office. (GAO). (2011). “Recording Clearer Reasons for Awards Decisions Would Improve Otherwise Good Grantmaking Process” Report GAO-11-283 Accessed online at http://www.gao.gov/products/GAO-11-283 on July 1, 2011.

Gregg County Regional Airport. (2011). Personal communication via e-mail.

Guirao, Begoña and Francisco Soler. (2009). “Regional High Speed Rail Lines and Small Cities Mobility: Toledo, a Spanish Experience” Transportation Research Board 2009 Annual Meeting.

Hagler, Yoav. and Petra Todorovich. (2010). “America 2050: Where HSR Works Best”. Regional Plan Association. Accessed online at http://www.america2050.org/pdf/Where-HSR-Works-Best.pdf in July 2010.

Hagler, Yoav. and Petra Todorovich. (2011). “High Speed Rail In America”. Regional Plan Association. Accessed online at http://www.america2050.org/pdf/HSR-in-America-Complete.pdf in January 2011.

Harris County Metropolitan Transportation Authority (METRO), (2009). “Metro Solutions: Scope of Program”. Accessed online at http://www.metrosolutions.org/go/doc/1068/261828. in July 2010.

Hayashi, Yoshitsugu et al. (2005). “A Life Cycle Assessment for Evaluating Environmental Impacts of Inter-Regional High-Speed Mass Transit Projects” Journal of the Eastern Asia Society for Transportation Studies 6: 3211-3224.

Hine, J. and J. Scott. (2000). “Seamless, Accessible Travel: Users’ Views of the Public Transport Journey and Interchange” Transport Policy 7: 217-226.

HNTB Corporation and HDR Inc. (2007). “Section 1: Estimate for I-35 Planned Improvements” Accessed online at http://www.txdot.gov/public_involvement/state_issues/i35_expansion/default.htm on June 20, 2011.

HNTB Corporation. (2003). “Orlando-Miami Planning Study” Florida High Speed Rail Authority.

Houston-Galveston Area Council (HGAC). (2011). “Best Practices Planning and Implementation Toolbox” Accessed online at http://subregional.h-gac.com/toolbox/Implementation_Resources/Special_Assessment_Districts_Final.html on August 1, 2011.

INSEE Ile-de-France. (2010). “Les Franciliens consacrent 1h20 par jour à leurs déplacements” A la page 331. (In French)

Intergovernmental Panel on Climate Change (IPCC). (2007). “Climate Change 2007 Synthesis Report”. Accessed online at http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm on June 20, 2011.

Intermodal Surface Transportation Equity Act (ISTEA). (1991). Section 1010 HR 2950 Accessed online at http://thomas.loc.gov/cgi-bin/query/F?c102:5:./temp/~c102RRBq83:e27514: on April 20, 2011.

International Air Rail Organisation. (1998). “Air Rail Links: Guide to Best Practice” Accessed online at http://www.toolulee.es/LinkClick.aspx?fileticket=p3dTYsKu5f4%3D&tabid=72&mid=421 on May 10, 2011.

Janic, Milan. (2003)a. “High-speed Rail and Air Passenger Transport: a Comparison of the Operational Environmental Performance” Proceedings of the Institute of Mechanical Engineers, 217 Part F: Journal of Rail and Rapid Transit: 259-269.

Janic, Milan. (2003)b. “The Potential for Modal Substitution” In Upham, Paul et al. (Eds.) Towards Sustainable Aviation: 132-148. London: Earthscan.

Jorritsma, Peter. (undated) “Substitution Opportunities of High Speed Rail for Air Transport” Transport Business Journal Issue 43. Accessed online at http://www.aerlines.nl/index.php/2009/substitution-opportunities-of-high-speed-train-for-air-transport/ on May 5, 2011.

Kageson, Per. (2009). “Environmental Aspects of Inter-City Passenger Transport” International Transport Forum 2009.

Kambitsis, Jason. (2010). “High-Speed Rail As a Conduit of Sprawl”. Wired Autopia Blog. Accessed online at http://www.wired.com/autopia/2010/03/high-speed-rail-and-sprawl/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+wiredautopia+%28Blog+-+Autopia%29&utm_content=Google+Reader on July 15, 2011.

Kenworthy, Jeffrey R. and Felix B. Laube. (1999). “Patterns of Automobile Dependence in Cities: An International Overview of Key Physical and Economic Dimensions with Some Implications for Urban Policy” Transportation Research Part A 33: 691-723.

Kimley-Horn and Associates, Inc. (2008). “Regional Commuter Rail Feasibility Study”. Accessed online at http://www.hgaccommuterrail.com/docsmaps.htm on May 15, 2011.

Kite, Kirk. (2011) "Highway Development" Handbook of Texas Online, Texas State Historical Association. Accessed online at http://www.tshaonline.org/handbook/online/articles/erh02 on March 30, 2011.

L.C. de Cerreño, Allison and Shishir Mathur. (2007). “High Speed Rail in the United States: Can the Dream Be Realized?” Transportation Research Board 2007 Annual Meeting.

L.C. de Cerreño, Allison. (2006). “High Speed Rail in Florida: Lessons and Themes for Consideration of Other High Speed Efforts” Transportation Research Board 2006 Annual Meeting.

Lea and Elliott Transportation Consultants. (2008). “Dallas Love Field People Mover Connector Feasibility Study” Accessed online at http://www.dallas-lovefield.com/pdf/LoveField_FeasibilityStudy.pdf on May 15, 2011.

Leigh Fisher Associates. (2002). “Strategies for Improving Public Transportation Access to Large Airports”. TCRP 83: 20-27. Transportation Research Board.

Lenzen, M. (2008) “Life Cycle Energy and Greenhouse Gas Emissions of Nuclear Energy: A review” Energy Conversion and Management 49: 2178-2199.

Levinson, David et al. (1997). “The Full Cost of High-Speed Rail: An Engineering Approach” The Annals of Regional Science 31: 189-215.

Litman, Todd. (2003). “Integrating Public Health Objectives in Transportation Decision Making” American Journal of Health Promotion 18 (1): 103-108.

Loftus-Otway, Lisa et al. (2007). “Protecting and Preserving Rail Corridors Against Encroachment of Incompatible Use” Report 0-5546-1 Center for Transportation Research, The University of Texas at Austin.

López-Pita, Andrés and Francesc Robusté. (2004). “High-Speed Line Airport Connections in Europe: State-of-the-Art Study” Transportation Research Record 1863: 9-18.

Mahmassani, Hani S. et al. (2001). “Domestic and International Best Practice Case Studies” Report 0-1849-2 Center for Transportation Research, The University of Texas at Austin.

Mahmassani, Hani S. et al. (2002). “Assessment of Intermodal Strategies for Airport Access” Report 0-1849-3 Center for Transportation Research, The University of Texas at Austin.

Makarova, Avrora Yana et al. (2010). “Sapsan train races ahead in profitability for Russian Railways.” RIA Novosti. Accessed online at http://en.rian.ru/business/20101026/161088304.html on May 5, 2011.

Maryland Aviation Administration. (2010). “Ground Transportation BWI Airport”. Accessed online at http://www.bwiairport.com/en/travel/ground-transportation in July 2010.

Maryland Department of Transportation. (2002). “High Voltage Transmission Line Right-of-Way Usage for Transportation Facilities” Accessed online at http://www.mdot.maryland.gov/Planning/Plans_Programs_Reports/Historical_Documents/High_Voltage_TL.pdf on June 10, 2011.

Minnesota Department of Transportation. (2006) “Mn/DOT joins Interstate Highway System’s 50th Anniversary Celebration” http://classic-web.archive.org/web/20071204072603/http://www.dot.state.mn.us/interstate50/50facts.html accessed April 22, 2011

National Cooperative Highway Research Program (2006) “The Interstate and National Highway System – A Brief History and Lessons Learned” Accessed online at http://classic-web.archive.org/web/20070919233931/interstate50th.org/docs/techmemo1.pdf on April 22, 2011.

National Household Travel Survey (NHTS). (2009). “Total Travel by Selected Trip Characteristics”. Accessed online at http://nhts.ornl.gov/det/Extraction3.aspx on June 20, 2011.

National Safety Council (2011). “Injury Facts 2011 Edition” Home and Community, Transportation Mode Comparisons. Accessed online at http://static.mgnetwork.com/rtd/pdfs/20110610_deathrates11.pdf on June 10, 2011.

Network Rail. (2009). “Comparing Environmental Impact of Conventional and High Speed Rail” Accessed online at http://www.networkrail.co.uk/documents/About%20us/New%20Lines%20Programme/5878_Comparing%20environmental%20impact%20of%20conventional%20and%20high%20speed%20rail.pdf on June 20, 2011.

North Texas Turnpike Authority (NTTA). (2010). “NTTA: About NTTA”. Accessed online at http://www.ntta.org/AboutUs/Who/History.htm in June 2010.

Northeast Corridor Master Plan Working Group. (2010). “The Northeast Corridor Infrastructure Master Plan” Accessed online at http://www.amtrak.com/servlet/ContentServer?c=Page&pagename=am%2FLayout&cid=1241245669222 on May 3, 2011.

Nuworsoo, Cornelius and Elizabeth Deakin. (2009). “Transforming High-Speed Rail Stations to Major Activity Hubs: Lessons for California” Transportation Research Board 2009 Annual Meeting.

Olson, Leslie E. and Craig E. Roco (2004). “Policy and Financial Analysis of High-Speed Rail Ventures in the State of Texas” Report 167150, Texas Transportation Institute, Texas A&M University.

Parsons Brinckerhoff (2009). “Technical Memorandum: Alignment Design Standards for High-Speed Train Operation”. California High Speed Rail Authority. Accessed online at http://www.calhsr.com/wp-content/uploads/2011/01/TM-2.1.2-Alignment-Design-Standards-R0-090326.pdf on June 1, 2011.

Parsons Brinckerhoff (2009). “Technical Memorandum: Typical Cross-Sections for 15% Design”. California High Speed Rail Authority. Accessed online at http://www.calhsr.com/wp-content/uploads/2011/01/TM-1.1.21-Typical-Cross-Section-15Percent-R0-090404.pdf on June 10, 2011.

Peterman, David Randall et al. (2009). “High Speed Rail (HSR) in the United States” Congressional Research Service.

Petersen, Harry C. et al (1985). “Comparison of Freeway and Railroad Rights-of-Way for High-Speed Trains in the Texas Triangle” Transportation Research Record 1023: 24-30.

Qian, Zhu. (2009). “Without Zoning: Urban Development and Land Use Controls in Houston” Cities 27: 31-41.

Recovery.gov. (2011). “Breakdown of Funding” Accessed online at http://www.recovery.gov/Transparency/fundingoverview/Pages/fundingbreakdown.aspx on July 10, 2011.

Resource Systems Group, Inc. (2010). “Innovative Approaches to Addressing Aviation Capacity Issues in Coastal Mega-regions” ACRP Report 31, Transportation Research Board.

Rieder, Robert. (2011) "Electric Interurban Railways" Handbook of Texas Online, Texas State Historical Association. Accessed online at http://www.tshaonline.org/handbook/online/articles/eqe12 on March 28, 2011.

Rietveld, Piet. (2000). “The Accessibility of Railway Stations: the Role of the Bicycle in the Netherlands” Transportation Research Part D 5: 71-75.

Roth, Daniel L. and Rohit T. Aggarwala. (2002). “Whose Railroad Is This, Anyway?” Transportation Research Record 1785: 1-9.

Rowe, Karen Stufflebeam et al. (2004). “Glenwood Canyon 12 Years Later”. Public Roads 67 (5).

Rutter, Allan. (2011). Personal communication via e-mail and telephone. May and June 2011.

Schafer, Andreas and David Victor. (2000) “The Future Mobility of the World Population” Transportation Research Part A, 34: 171-205.

Scharrer, Gary. (2011). “Texas on Road to Highway Crisis” San Antonio Express News. Accessed online at http://www.mysanantonio.com/news/politics/texas_legislature/article/Texas-on-roadto-highway-crisis-984511.php on July 5, 2011.

Schrank, David et al. (2009). “Urban Mobility Report 2009”. Texas Transportation Institute. Accessed online at http://tti.tamu.edu/documents/mobility_report_2009_wappx.pdf. in June 2010.

Share, Adrian. (2011). Personal communication via e-mail and telephone. July 2011.

Smith, George C. and Earl Shirley. (1987). “High-Speed Rail in California: Avoidable Controversy” TR News 130: 2-7.

Smith, RA. (2003) “Railways: How They May Contribute to a Sustainable Future” Proceedings of the Institute of Mechanical Engineers, 217 Part F: Journal of Rail and Rapid Transit: 243-248.

Société Nationale de Chemins de Fer (SNCF, French National Railways). (2009). Untitled Response to Federal Request for Expression of Interest (RFEI).

State Energy Conservation Office. (2011). “Texas Renewable Energy Portfolio Standard” Accessed online at http://www.seco.cpa.state.tx.us/re_rps-portfolio.htm on June 25, 2011.

Texas 2030 Committee. (2010). “2030 Committee Texas Transportation Needs Report”. Accessed online at http://texas2030committee.tamu.edu/documents/final_022609_report.pdf on June 28, 2010.

Texas Commission on Environmental Quality (TCEQ). (2010). “Air Quality Successes: Update of Air Quality in Texas”. Accessed online at http://www.tceq.texas.gov/agency/air_main.html on July 10, 2011.

Texas Department of Public Safety. (2011). “Historical Data – Fatalities, Miles Traveled, and Death Rates 1978 – 1998” Accessed online at http://www.txdps.state.tx.us/director_staff/Public_information/final98.htm on April 10, 2011.

Texas Department of Transportation (TxDOT). (2005). “2005 Texas Rail System Plan”. Accessed online at ftp://ftp.dot.state.tx.us/pub/txdotinfo/library/reports/gov/tpp/finalrail.pdf in June 2010.

Texas Department of Transportation (TxDOT). (2010)a. “TxDOT History: 1970 to 1951”. Accessed online at http://www.txdot.gov/about_us/1970_1951.htm in June 2010.

Texas Department of Transportation (TxDOT). (2010)b. “2010 Texas Airport System Plan”. Accessed online at ftp://ftp.dot.state.tx.us/pub/txdotinfo/avn/tasp_2010.pdf in June 2010.

Texas Department of Transportation (TxDOT). (2010)c. “Texas Rail Plan”. Accessed online at http://www.txdot.gov/public_involvement/rail_plan/trp.htm in July 2010.

Texas Department of Transportation (TxDOT). (2011)b. “TxDOT History: 2000 to 1971” Accessed online at http://www.txdot.gov/about_us/2000_1971.htm on August 1, 2011.

Texas Department of Transportation (TxDOT). (2011)b.”TxDOT Performance Measures: Fatalities”. Accessed online at http://apps.dot.state.tx.us/txdot_tracker/enhance_safety/fatalities.asp on July 10, 2011.

Texas Department of Transportation. (TxDOT). (2010)d. “I-35 Expansion Options”. Accessed online at http://www.txdot.gov/public_involvement/state_issues/i35_expansion/default.htm on July 15, 2011.

Texas Department of Transportation. (TxDOT). (2011)a. “Local Information”. Accessed online at http://www.txdot.gov/local_information/ on May 5, 2011.

Texas High Speed Rail and Transportation Corporation (THSRTC). (2010). “HOME”. Accessed online at http://www.thsrtc.com/home_page.html in July 2010.

Texas Local Government Code. (2011). Chapters 42, 211, 217, 251, 261, 273, 374. Accessed online at http://www.statutes.legis.state.tx.us/Index.aspx on June 25, 2011.

Texas Property Code. (2011). Chapter 21. Accessed online at http://www.statutes.legis.state.tx.us/Index.aspx on June 25, 2011.

Texas Rail Advocates (TRA). (2010). “Texas Rail Advocates – About Us”. Accessed online at a http://www.texasrailadvocates.org/index.html in July 2010.

Texas Railroad Commission. (undated). “An Informal History Compiled for Its Centennial – Creation of the Railroad Commission of Texas”. Accessed online at http://www.rrc.state.tx.us/about/history/centennial/centennial02.php in June 2010.

Texas Secretary of State. (2009). “Explanatory Statements for the November 3, 2009 Constitutional Amendment Election”. Accessed online at http://www.sos.state.tx.us/elections/voter/2009novballotexp.shtml in July 2010.

Texas State Data Center. (2008). “2008 Population Projections – Texas Metropolitan Statistical Areas” Institute for Demographic and Socioeconomic Research. The University of Texas at San Antonio. Accessed online at http://txsdc.utsa.edu/tpepp/2008projections/2008_txpopprj_msatotnum.php on April 10, 2011.

Texas State Legislature. (2008). “SB 1570. 81st Texas Legislative Session”. Accessed online at http://www.legis.state.tx.us/tlodocs/81R/billtext/pdf/SB01570I.pdf in July 2010.

Texas TGV Consortium. (1991). “Franchise Application to Construct, Operate, Maintain, and Finance a High-Speed Rail Facility”. Submitted to Texas High-Speed Rail Authority.

Texas Transportation Code. (2011). Chapters 112, 131, 173, 317, 370, 451, 452, 455, 460. Accessed online at http://www.statutes.legis.state.tx.us/Index.aspx on June 25, 2011.

Thomas, Larry W. (2009). “Selected Studies in Transportation Law: Volume 2 Eminent Domain” National Cooperative Highway Research Program, Transportation Research Board. CD-ROM.

Transportation Economics and Management Systems, Inc. (2004) “Midwest Regional Rail System Executive Report” Accessed online at http://www.dot.wisconsin.gov/projects/state/docs/railmidwest.pdf on May 2, 2011.

UK Department for Transport (2008). “Carbon Pathways Analysis: Informing Development of a Carbon Reduction Strategy for the Transport Sector” Accessed online at http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/sustainable/analysis.pdf on June 24, 2011.

United Nations, (2009). “World Population Prospects: The 2008 Revision Population Database”. Population Division. Accessed online at http://esa.un.org/unpd/wpp2008/tab-sorting_population.htm in July 2010.

US Census Bureau. (2008). “Selected Economic Characteristics 2006-2008. American Community Survey 2006-2008 3 Year Estimates”. Accessed online at http://www.census.gov/acs/www/index.html in July 2010.

US Census Bureau. (2010)a. “Historic Census Statistics by Population Totals: United States and Texas”. Accessed online at http://www.census.gov/population/www/documentation/twps0056/twps0056.html in June 2010.

US Census Bureau. (2010)b. “Cumulative Estimates of Population Change for Metropolitan Statistical Areas and Rankings”. Accessed online at http://www.census.gov/popest/metro/CBSA-est2009-pop-chg.html in June 2010.

US Census Bureau. (2010)c. “State Population - Rank, Percent Change, and Population Density”. Accessed online at http://2010.census.gov/2010census/data/apportionment-dens-text.php in July 2010.

US Census Bureau. (2010)d. “Selected data from American Fact Finder”. Accessed online at http://factfinder.census.gov/home/saff/main.html?_lang=en in July 2010.

US Department of Agriculture. (2009). “Land Values: Farm Real Estate Value by State 2009”. National Agriculture Statistics Service. Accessed online at http://www.nass.usda.gov/Charts_and_Maps/Land_Values_and_Cash_Rents/farm_value_map.asp in July 2010.

US Department of Energy (US DOE). (2011). “State Energy Profiles. Energy Information Administration”. Accessed online at http://www.eia.gov/cneaf/electricity/st_profiles/texas.html in July 2010.

US Environmental Protection Agency (US EPA). (2010). “Nonattainment Status for Each County by Year for Texas”. Accessed online at http://www.epa.gov/airquality/greenbk/anay_tx.html in July 2010.

Vespermann, Jan and Andreas Wald. (2010). “Long-term Perspective of Intermodal Integration at Airports” Airport Management 4 (3): 252-264.

Wear, Ben. (2011). “Budget Woes Mostly Miss Transportation” Austin American Statesman. Accessed online at http://www.statesman.com/news/texas-politics/budget-woes-mostly-miss-transportation-1457367.html on July 5, 2011.

Werner, George. (2011) "Railroads" Handbook of Texas Online, Texas State Historical Association. Accessed online at http://www.tshaonline.org/handbook/online/articles/eqr01, on March 29, 2011.

Woodcock, James et al. (2007). “Energy and Transport” Lancet 370: 1078-1088.

Zhang, Ming et al. (2007). "Connecting the Texas Triangle: Economic Integration and Transportation Coordination" The Healdsburg Research Seminar on Megaregions.

Vita

Todd Carroll was born in 1986 in Carbondale, Illinois, USA. After moving to rural Northern California at a very young age, he graduated from Union Mine High School in El Dorado, California in May 2004. Following high school, Todd enrolled at The University of Texas at Austin as an undeclared undergraduate business student before eventually changing majors and completing a B.S. degree in Civil Engineering in May 2009. Upon completion of his degree, Todd immediately enrolled as a transportation engineering graduate student at UT-Austin. In his seven years at UT-Austin, Todd was active in university athletic bands, university service organizations, transportation research, international opportunities, cycling, and running.

Permanent e-mail: todd.d.carroll@gmail.com

This thesis was typed by the author.