MAGLEV HIGH SPEED GROUND TRANSPORTATION FOR THE TEXAS TRIANGLE: A TECHNOLOGY ASSESSMENT

by

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Report

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's of Science in Community and Regional Planning

The University of Texas at Austin

May 2007

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Approved by
Supervising Committee:

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Dedication

To my family, friends, and wonderful new wife Sherry, your support has been unwavering and your patience unending.

Acknowledgements

I would like to thank Ming Zhang and Tracy McMillan for their instruction and guidance in the completion of this report. I would also like to thank Dr. Zhang for providing the opportunity to travel to China and experience the maglev firsthand. I must also express my gratitude to Austin Statesman journalist Ben Wear, TxDOT district engineer Bob Daigh, TxDOT freight planner Jack Foster, executive director of CAMPO Michael Aulick, Vice President of Parsons Brinkerhoff Robert Spillar, and HUST Professor of Urban Planning Junqing Zhou for speaking with me about issues relating to transportation planning and the maglev.

May, 2007

Abstract

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The University of Texas at Austin, 2007

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A maglev rail network connecting the Texas Triangle has the ability to unite this emerging mega-region with a highly efficient alternative to auto and air transport. This would serve to increase the economic sharing of resources and will improve the quality of life for residents with enhanced accessibility to jobs and services in all triangle cities. Many unforeseen benefits materialize from such a highly connected regional transportation infrastructure including cost reductions in highway maintenance and construction and reduced air traffic in congested skies and airports. This study examines the reasons for choosing a maglev system, regulatory barriers to implementing such a system, and the costs associated with a Maglev system built in the Texas Triangle.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

Transportation is one of the most pressing crises in many world cities today. People are spending increasingly more time on the road waiting to get to a destination and, during peak travel periods, highway traffic in large metropolitan areas is reduced to the speed of a horse and buggy. Bigger highways and airports are usually the prescribed remedy, but these have been proven to increase sprawl and pollution, segregate different areas of the city, and continue to absorb precious city land and agricultural areas as they expand. A transportation renaissance is needed that would decrease dependence on a flawed automobile system that continues to fail at providing sufficient and long-lasting capacity.

Dallas/Fort Worth, Houston, San Antonio, and Austin comprise the geographical corners of the emerging Mega-Region known as the Texas Triangle. The three sides of the triangle measure 271, 198, and 241 miles in ground distance with a total area of 57,430 square miles.[1] These four metropolitan areas each have populations of over one million people with three counted among the top ten largest U.S. cities. The close geographical proximity of these major urban centers gives each a unique role in shaping their history and dependence. The Texas Triangle cities developed as economic complements, providing unique goods to the other Triangle cities and importing goods that represented strength elsewhere. This is important because it means that the Texas Triangle is in fact a megalopolis in the sense that the pieces can be added together with very little duplication.[2] The benefits

[1] Zhang, Ming, Steiner, Fredereick, Butler, Kent. 2007. "Connecting the Texas Triangle: Economic Integration and Transportation Coordination." University of Texas at Austin.
[2] Gilmer, Bill. 2004, January. "The Simple Economics of the Texas Triangle". Federal Reserve Bank of Dallas; Houston Branch.

of a high-speed transportation system linking the relatively close complementary urban centers far outweigh the initial capital costs, especially when compared to the poorly planned and costly Trans-Texas Corridor. When cities become more interconnected they exhibit greater productivity through access to new markets and resources. This dependence does, however, present a critical need to plan at the regional and mega-regional scales. Transportation, water and air quality, and water availability are some issues that can be addressed at the larger scale.

In August of 1994, a planned high-speed rail network to connect the Texas Triangle (Dallas - Houston – San Antonio) was defeated due to a shortfall in funding and fierce opposition from regional transportation providers. This infrastructure improvement would have united the region and accelerated its eventual evolution into a mega-region providing a sustainable transportation alternative to auto and air travel. Since that time, conditions have changed. Of particular importance is that the main opponent to the 1994 proposal, Southwest Airlines, can now be a significant ally for long-range mass transit projects in Texas. They are in a new position following the repeal of the Wright ordinance this year, a federal law restricting flights from Dallas Love Field, and can be great allies in providing inter-modal transportation alternatives to Texas citizens. A revised version of the proposed high-speed rail network can be introduced using Maglev technology to provide a cleaner, quieter, faster, and more comfortable ride than high speed rail.

A high-speed Maglev train is proposed to bridge the complementary urban centers of Texas to vastly improve the time and efficiency of trade and passenger mobility in this emerging mega-region. Magnetic Levitation (maglev) is an advanced technology in which magnetic forces lift, propel, and guide a vehicle over an elevated guideway. This transportation technology is an alternative that can employ different speed systems to serve both inter-city and intra-city travel while even replacing some short-distance plain routes. "This new system bridges the technological and time gap between conventional rail and air travel and opens an era of reliable, energy-efficient, and low-maintenance high-speed ground transportation".[3] Many regional benefits become apparent from such a highly connected transportation infrastructure such as increased economic sharing of resources, cost reduction in highway maintenance and construction, and reduced air traffic in congested skies and airports. Maglev trains have the ability to travel at higher speed than wheel-based alternatives and are ideal transportation alternatives to air and auto travel. Utilizing state-of-the-art electric power and control systems, this configuration eliminates physical contact between vehicle and guideway and permits cruising speeds of up to 350 mph, somewhat higher than the speed of conventional high-speed rail service. Because of its higher speed and lower energy usage, Maglev may be able to offer competitive trip-time savings to auto and aviation modes in the 40- to 600-mile travel markets–a needed modal option for the 21st century. The system in place today is at or past capacity and, with future population growth, won't be able to handle the increased demand for trade and mobility. This research examines the potential for using Maglev technology for a high-speed train system in the Texas Triangle mega-region and also outlines regulatory opportunities and barriers and most importantly, the costs associated with such a system.

[3] Antlauf, W. 2004. Fast Track. Civil Engineering Magazine. Nov 2004. pp. 2-8.

SCOPE AND METHODOLOGY

The study methodology for this project includes three parts; desktop research, a case study, and interviews.

The first major step in this research involved studying the technology and its applications around the world. Even though the technology has been around since the 60s, it has only recently matured to the point that it can compete with other more conventional forms of travel. To learn more about past commitments to maglev by the United States documents released by the Federal Railroad Administration (FRA) were studied. To obtain information about the TIFIA program, the act as established in the Transportation Equity Act for the 21st Century, and as amended by the TEA-21 Restoration Act was reviewed. Information was obtained about past initiatives for high-speed rail in Texas and why they failed from news articles, the FRA, and transportation officials from around the Austin metro area. An independent analysis from Charles River Associates was reviewed for ridership forecasts and feasibility analyses. To identify the opportunities and major issues a maglev system could address for the Texas Triangle, attributes of the technology were compared against regional issues and their causes. Research done by Gilmer for the Reserve Bank of Dallas was used for the Location Quotient Analysis of the Triangle. FHWA, NHTS, and EPA documentation was reviewed to find congestion, VMT, and air quality figures. Much of the information on current events for the key issues was obtained by recent news briefs and articles from media outlets around Texas.

Since the basic technology of Maglev is so new to commercial use, it is helpful to study its applications in other cities around the world. The Shanghai case is of particular importance because it is the first high-speed commercial Maglev system in the world. The lessons from the last four years of operation can be illuminating when considering such a new and wholly different transit technology. To identify the status of the Shanghai project's costs, financing, ridership estimates, safety, and schedule, project documents were reviewed as well as news briefs and interviews with those associated with the project. To learn more about the perception of the project, both personal and those of residents, the author traveled to Shanghai in August of 2006 to ride it and observe the comfort level and use of the maglev by others.

While in China, the author interviewed Mr. Chen, a China International Travel Service (CITS) agent in Beijing, and Dr. Zhou, an Urban Planning Professor with Huazhong University of Science & Technology (HUST) located in Wuhan about the new Maglev and its implications for China and transportation in general. Sources from around the Austin area include interviews with Ben Wear, transportation journalist for the Austin-American Statesman and Bob Daigh, TxDOT district engineer for the Austin area, for specifics of federal funding of state highways, non-compete clauses, and the 2 year moratorium associated with the Trans-Texas Corridor. Jack Foster, transportation planner with TxDOT, discussed the fate of failed 1994 Texas high speed rail as well as the I-10 coast-to-coast corridor study on freight. Michael Aulick, executive director for CAMPO, spoke briefly with the author about regional transportation planning and transportation/land use issues.

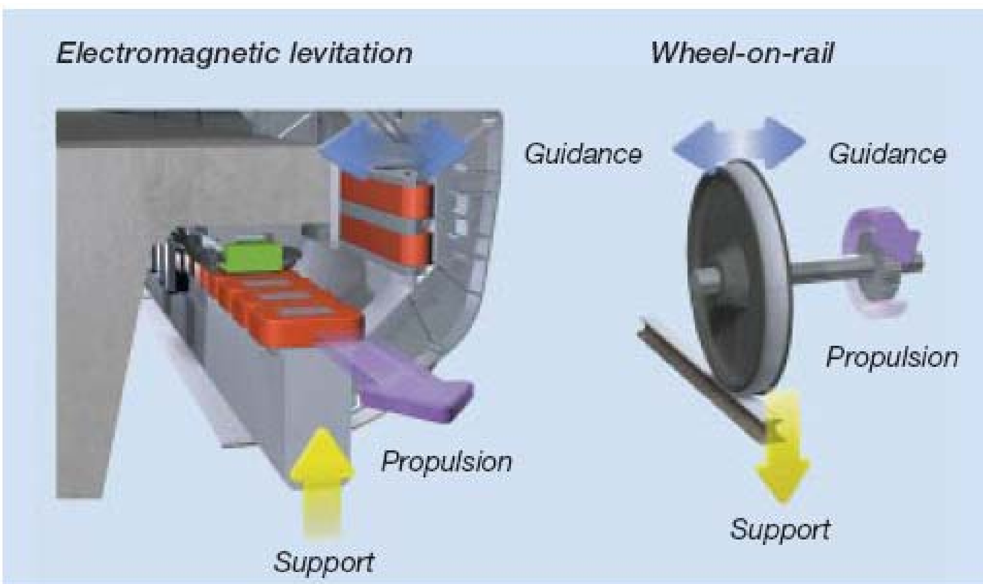
Work for this project was performed from August 2006 to May 2007.

Chapter 2: Magnetic Levitation Trains

TECHNOLOGY

To adequately assess the merits and fully realize the benefits and suitable applications of a Maglev system the technology behind it must be briefly assessed. Maglev uses the world's most advanced magnetic levitation technology to safely move people and cargo reliably and comfortably. There are two main Maglev technologies; Electro Magnetic Suspension (EMS) shown in **Figure 1**, and Electro-Dynamic Suspension (EDS).

Figure 1: Electro Magnetic Suspension (EMS) Detail



Source: www.transrapid-usa.com

With the (EMS) systems, in use by the Shanghai Maglev Train developed by Berlin-based Transrapid International, vehicles float half an inch off the guideway utilizing the attractive forces of electro-magnets, which serve to propel, brake, and provide vertical and horizontal stabilization to the train. Absence of contact with the guideway reduces frictional pressures that cause jolts and discomforts associated with conventional trains and high-speed rail. "With Maglev, the propulsion system resides in the guideway instead of the train, allowing for less weight and faster acceleration."[4] Speed is only limited by the air friction coefficient which begins to increase rapidly as speeds above 500km/h are reached.

The (EDS) system, on the other hand, is based on repulsive force and is in use by the Japanese Maglev Project. The vehicle contains superconducting magnets that induce a repulsive force in a conducting guideway as the vehicle moves along it. Superconducting electromagnets are much more powerful than ordinary electromagnets and provide a clearance of up to eight inches between the guideway and vehicle. This can reduce the need for such critical precision in construction of the guideway, and therefore, less cost. Ice and snow are also less of a problem with this system. One drawback is that the repulsive force necessary is only generated at speeds above a certain threshold and a secondary suspension system, wheels, must be used at lower speeds. Newer models of the maglev 2000 in Japan, MLX-01, can use these wheels on existing conventional rail.

APPLICATION

Maglev has many applications from high-speed intercity passenger and rail transport and medium-speed intracity travel to launching systems for spacecraft and even microchip fabrication. The first applications of maglev that are either in operation or planned are short distance routes that typically run from large airports to the city centers they serve. These are

[4] Blodget, Henry. 2005. Mine's Faster Than Yours: Riding Shanghai's Maglev, the world's fastest train. Slate. www.slate.com. posted Monday, March 21, 2005.

good first leg demonstration lines to capture travelers that are already without a car when they arrive by plane or those that don't wish to deal with the hassle of parking at the airport. These shorter routes cannot yet demonstrate long distance ridership generated from drivers and airplane passengers and induced ridership due to greater mobility between urban centers. However, some conclusions can still be drawn from highway improvement cost savings and time savings for the relatively short 30km Shanghai Maglev Train. This report focuses on its long-distance intercity transportation functions.

Maglev is a possible mode of transportation for any climate and geography in the world. It has all-weather operational capabilities, few environmental impacts, and high energy efficiency.[5] The system's high climb rate and small turning radius makes it relatively easy for it to pass over or around obstacles, thereby reducing the need to build expensive structures such as tunnels and bridges and limiting disruption to existing urban fabric and land. Automated control coupled with the elimination of any physical vehicle/guideway contact ensures a level of speed, headway control, operational effectiveness, efficiency, safety and reliability not possible in other modes.[6] Maglev can carry freight and/or people and can be built at-grade or elevated. This may be done to overlay existing right-of-way and avoid cross-traffic often allowing people or animals to pass freely underneath the guideway; a solution for areas where migratory patterns of animals should be respected or have caused traffic problems or grazing. Because the elevated guideway can be built on existing freeway and railroad right-of-ways, land consumption and related impacts are minimized. **(Figure 2)**

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[5] http://www.transrapid-usa.com/main.asp. Retrieved January 12, 2007.

[6] Eggleton, Peter L. and Zavergui, Richard M. Induced Demand: Matching the Attributes With theInformation Age Interactive Megalopolis. Telligence Group. Montreal Canada.

Additionally, Maglev operates more quietly than conventional high-speed trains, has fewer impacts on adjoining communities and operation and maintenance costs are significantly less than conventional high-speed rail.[7]

Figure 2: Transrapid Test Track Built Over Grazing Land

Source: Transrapid International

[7] Yuhong Liu & Guangsheng Sun & Rong Wei. 2004. "The Developmental Status and Future Prospects of Maglev Technology." Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing, China.

Chapter 3: The Shanghai Maglev Train

Shanghai, China teamed up with Transrapid International, a joint venture of the German companies Siemens AG and ThyssenKrupp, to plan and build the first high-speed commercial Maglev system in the world. Since Shanghai began running the world's first commercial Maglev service in May of 2003 from Pudong International Airport to Longyang Road station, it has proven reliable, cost-effective, safe, and efficient. The success of this demonstration line may be the catalyst to widespread use of this new technology for many other transit applications in China and around the world. Plans are in effect to extend the 30km long Transrapid line another 170km to Hangzhou. Economic considerations are, of course, an important factor in determining whether to go with High-Speed Rail (HSR), light-rail, or Maglev to move people between and through urban centers. Once cost-optimization occurs with industrial production and competition along with many other factors taken into account, Maglev is the clear choice for both high-speed intercity and intracity transport. The costs, benefits, and implications of Maglev trains for China and Yangtze-Delta region are considered in the following report.

COST OF SHANGHAI TRANSRAPID

Many opponents of Maglev said the initial costs were too high to justify building a track before the demonstration line in Shanghai was constructed. The energy-efficient, environmentally-friendly operation of this new technology has proven extremely valuable to Shanghai and China despite these claims. **(Figure 3)**

Current System

The Maglev project runs 30km (19m) from Shanghai's new Pudong International Airport to Longyang Lu subway station at the southeastern suburban edge of the city. With the joint efforts of the Chinese and German experts the line began offering regular daily trips to the public in April of 2004 after a rushed schedule of only 22 months for planning and construction. The 30 km flight takes only 8 minutes compared to a 45 minute taxi ride on the freeway and a one-way trip costs 6 USD. "With an acceleration force only a 10th that of gravity"[8], departure from and arrival to the station is quick and smooth as the vehicle

Figure 3: Current Shanghai Maglev Train Route

Source: Transrapid International – U.S.A., Inc.

takes 4 minutes to accelerate to a top speed of 430km/h (267mph) and starts decelerating 3 minutes before it reaches the connecting station. One of the main criticisms of the Shanghai Maglev Project is the extremely high initial cost and apparent low return. The total cost per kilometer comes to 39.759 million USD, which includes the cost of building the guideway, purchasing vehicles, substations, auxiliary equipment, and interest during the construction phase. Total cost of the project came to 1.2 billion USD.[9] This is actually much lower than many rail based high-speed systems and converts to half the per-km cost of Shanghai's metro, or subway. Critics also claim that current ridership doesn't even support daily operation costs. It is true that the train currently runs with between 25-30% of full capacity, but it was built with future ridership in mind due to city expansion.[10] One traveler, Xiao Zhanhong, states, "It'd be better if the line could be extended to downtown areas to save the trouble of changing lines, especially for those who carry a lot of luggage."[11] Longyang Lu metro station is the current terminus, somewhat removed from the heart of the city, but it will ultimately be at the intersection of 3 subway lines and there are plans that have recently been approved to extend the Maglev to central station, the 2010 expo area, and eventually, to Hangzhou. Currently the train runs daily from 8:30am to 5:30pm with an interval of 15 to 20 minutes. Shanghai Maglev Transportation Development Company (SMTDC), the systems owner, plans to extend its operations to 18 hours per day, and, "with so many international

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[8] Antlauf, W. 2004. Fast Track. Civil Engineering Magazine. Nov 2004. pp. 2-8.

[9] Chong'en, Hong. 2004. The Technology is Mature, Safe, and Reliable. Wenhui Daily.

[10] Cody, Edward. 2004. Faster than a Speeding Bullet Train: Cutting-Edge Maglev Rail Line Boost Pride in Shanghai, Ridership Lags. The Washington Post Foreign Service. Monday, May 17, 2004. p. A14.

[11] Jiang, Yaping. 2004. Maglev line Runs Smoothly in Shanghai. People's Daily Online. www.peopledaily.com. posted June 25, 2004. retrieved November 10,2005.

Figure 4: Shanghai Transrapid Exits Station

Source: Transrapid International

flights arriving after 5:30pm, it is obvious that passenger numbers will rise".[12] Furthermore, Commander Wu from the Transrapid Project Center denies reports of lost revenue stating that "even based on current ridership forecast, the operating revenue of the Shanghai Transrapid line can already cover direct operating costs."[13] Maintenance costs for the Shanghai Transrapid are a third of conventional rail with 20 vehicle maintenance staff and 10 infrastructure maintenance staff and reports have stated that if there is a future increase in ridership, there will be no need to increase the amount of staff.[14] Along with a very low

[12] Coates, Kevin C. 2005. Shanghai's Maglev Project: levitating beyond transportation theory. Engineering World. April/May 2005. pp. 26-33.

[13] Chong'en, Hong. 2004. The Technology is Mature, Safe, and Reliable. Wenhui Daily.

[14] Sharp, Andrew. 2004. Shanghai's Maglev. Air Rail Express; The newsletter of the International Air Rail Organisation-Joining railways joining airports. Vol. 7 Iss. 4. August 2004. pp. 1-3.

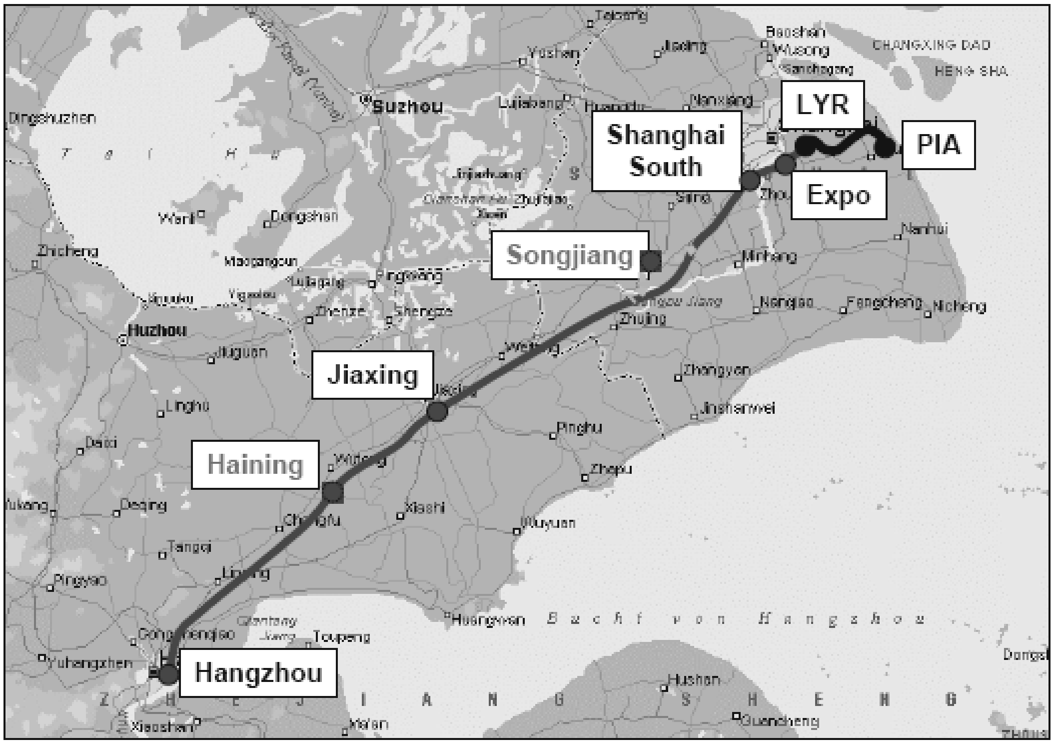
comparative energy usage, a fifth that of airplanes, the Maglev proves to be a very cost-effective transportation system. In terms of safety, reliability, availability, and functionality the Transrapid Maglev system has demonstrated the readiness of the system for future applications.

Hangzhou Extension

China's State Council has approved a high-speed magnetic levitation rail line between Shanghai and Hangzhou, the capital city of the adjacent Zhejiang Province. The National Development and Reform Commission (NDRC), the country's top planning agency, said in a statement on its official website that a feasibility study for the line had already begun.[15] The media states the total length is 175km with 450km/h design speed and proposed to be completed before 2010 with 35 billion Yuan investment. It is predicted that the per-mile costs of the extension to Hangzhou will be significantly lower than the current line. Also, with a longer route the train can spend substantially more time traveling at top speed and Maglev would shorten the travel time between the two cities to less than a fifth of its current value, from 2½ hours to 27 minutes. Gerhard Wahl, a German Maglev expert, says he "believes China will be a world leader in the construction and operation of high-speed Maglev railways, noting that China has mastered the patent technology for the manufacture of the Maglev track girder and other civil engineering aspects, which account for over half of the total cost."[16]

[15] Xinhua news agency. 2006. EBSCO. Retrieved 12/5/06.
[16] Xinhua news agency via COMTEX. 2002. EBSCO. Retrieved 12/5/06.

Figure 5: Scheme of the proposed Shanghai-Hangzhou Maglev line.



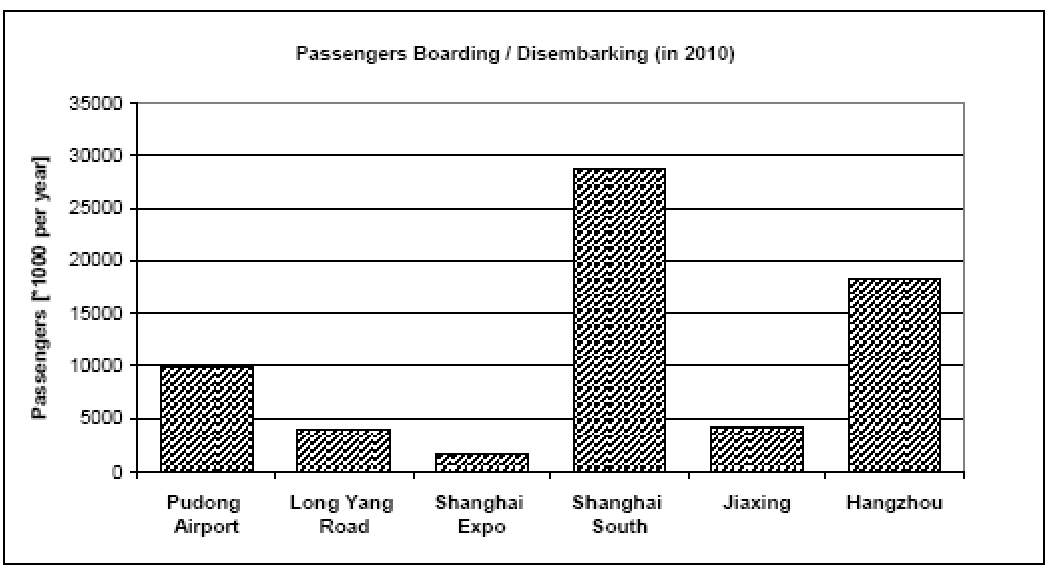
Source: Kohler

On the way, there will be three intermediate stations: 2010 World Exhibition Station, Shanghai South Station and Jiaxing Station. **(Figure** 5) The highest intercity speed will be 450 km/h with an average traveling speed of 340 km/h.[17] The first stage of the extension is planned to be finished in 2009. Firstly, a 37 kilometer extension will connect the Pudong International Airport to Hongqiao Domestic airport and pass via the World Expo 2010 site. The Maglev will also meet up with the Shanghai South Railway station, and the planned Beijing-Shanghai High Speed Railway station at the Hongqiao Airport. The second and

[17] Xiangming, Wu. "Experience in Operation and Maintenance of the Shanghai Maglev Demonstration Line and Further Application of Maglev in China." National Maglev Transportation Engineering R&D Center, Shanghai, P.R. China.

biggest Maglev extension (104 kilometers) will connect Hangzhou to Shanghai. In total, the whole Maglev network will be approximately 200 kilometers long. The total travel time from Shanghai South Station to Hangzhou City Station will be 27.5 min. The operation should start before 2010, when the World Exhibition will open in Shanghai. Estimated capital investment to build the remaining 170 kilometers is 33% of what it cost for the Shanghai demonstration line. The Maglev extension will cost around RMB56.1 billion (USD$7.25 billion) or USD $36 million per kilometer. With recent approval, it will be the biggest national Maglev project for the next five years and creates a prototype for future long distance and intercity application. **Figure 6** shows the expected increase in ridership with the new extension to Hangzhou.

Figure 6: Station Importance



Source: Kohler

BENEFITS OF THE SHANGHAI TRANSRAPID

Many benefits of the Shanghai Maglev Project come from the choice to use the magnetic levitation, or Maglev, transportation system already outlined. Below, benefits unique to this project are explored in depth.

Economic

The procurement of Maglev technology from Transrapid International was a major benefit gained from the project allowing China to pursue plans to develop and build a national infrastructure based on it. Last year Wu Xiangming, project manager for the Shanghai Maglev Project, was chosen to lead the newly formed National Research and Development Center for Maglev Transportation Technology. This builds upon the technological know-how that was once the property of Transrapid and is "a clear sign that China intends to expand the application of this technology"[18]. Looking to future expansions, officials note that longer routes could operate at routine speeds of 500km/h so that China's vast expanse could be easily bridged. "By constructing this demonstration line, the owners would be able to accumulate and analyze data from a commercial application of this electronic transportation system".[19] Transrapid comes away from this deal with something to show as well - the first demonstration model of a safe and successfully running commercial Maglev system. This further validates the technology and takes advantage of the

[18] Coates, Kevin C. 2005. Shanghai's Maglev Project: levitating beyond transportation theory. Engineering World. April/May 2005. pp. 26-33.
[19] Antlauf, W. 2004. Fast Track. Civil Engineering Magazine. Nov 2004. pp. 2-8.

infrastructure setup to manufacture the vehicles and guideways, making it much easier to market the transportation system to other cities around the world.

Environmental

Another advantage of Maglev is that it has zero emissions causing very little environmental impact if the energy to power the track is green energy. At present, average energy consumption per capita in the United States is 11 times that of China. Limited domestic oil supply and the subsequent increase in demand for oil as China modernizes figures prominently into the deliberations to find alternative methods of transport. The high-speed Maglev line was found to require the least energy and offer the lowest life-cycle cost. In addition, the elevated guideway has a very small footprint allowing the land underneath to be used as farmland, grazing, parkland, etc. Its elevated structure means that it is more easily superimposed upon an existing urban and community form. The elevated structure eliminates the at-grade barriers and massive bridge structures of conventional railways and permits agricultural activity to continue unimpeded below it. The guideway can be used as a visual enhancement if otherwise unsightly telecommunications and electrical transmission cables are integrated with it.[20] The capacity of a Maglev system is as much as a six-lane highway, yet it doesn't present the barrier, the pollution, or the impact on the land.

Social

Construction of the first high-speed Maglev system in the world was also done to highlight Shanghai's high-tech ambitions and brand China as a leader in technology.

International cooperation between German and Chinese engineering, manufacturing, and construction firms made this possible highlighted by the inaugural run with German chancellor Gerard Schroeder and Chinese Premier Zhu Rongji on December 31st, 2002. Political considerations also played a major role in the project. Zhu Rongji, a trained electrical engineer, was intrigued enough by Maglev to send engineers to Germany to determine feasibility and setup a contract. The short construction schedule was dictated so that the inaugural run could take place before Zhu Rongji stepped down as Prime Minister in early 2003. **(Figure 7)**

Figure 7: Ceremony with Chinese Premier Rongji and German Chancellor Schroeder

Source: www.transrapid-usa.com

[20] Eggleton, Peter L. and Zavergui, Richard M. Induced Demand: Matching the Attributes With the Information Age Interactive Megalopolis. Telligence Group. Montreal Canada.

As a result, China now has the impact of successfully implementing the first high-speed commercial Maglev system in the world. One resident, Lu Cong Mei, states, "I am proud that Shanghai has this when nowhere else in the world does".[21] National pride certainly comes from such a futuristic endeavor and a 7km extension into downtown Shanghai's central rail station is planned to further showcase the achievement for the world expo in 2010.

Safety and Reliability

Exhibiting the safety and reliability of the system was another primary aim in the decision to construct the Shanghai airport demonstration line. Safety is a huge issue since this is the world's first high-speed Maglev line and it is under particularly close scrutiny worldwide. At first, there was concern that the magnetic field from normal operation would have a negative effect on people, but repeated tests show that "the magnetic field in the Transrapid vehicle is of similar strength to the Earth's natural magnetic field and a whole lot weaker than that of a household appliance, like a hairdryer".[22] Additionally, the design of the system is such that the cast aluminum support arms of the vehicles wrap around the top cantilevers of the guideway making derailment, the most common accident with steel-wheel systems, virtually impossible at any speed. Also, onboard batteries provide redundant power to maintain vehicle levitation in the event of guideway power failures. Other factors assure safety such as an elevated guideway with no at-grade crossings eliminating interference with

[21] Gluckman, Ron. 2003. It is a Bird? A Plane?. Asian Wall Street Journal: Weekend Edition. Feb. 21-23, 2003.
[22] Yi, Zhang. 2004. Contractual Acceptance for the Shanghai Transrapid project successfully completed with German Partners: an interview with Chief Commander Wu Xiangming. Jiefang Daily. May 2004.

vehicular traffic, reinforced-concrete support piers designed to withstand seismic forces of earthquakes up to 7.5 on the Richter scale, and interior doors with 30 minutes of fire resistance.[23] Wu Xiangming, the project director, states, "of all the transit systems in the world, none is safer than the Transrapid."[24] In terms of reliability, Maglev is unmatched by conventional modes of transport since it is completely automated with no on-board operator. "The system's operating reliability is now at 99.9%"[25], meaning the train is never more than a second late for arrival or departure.

IMPLICATIONS FOR CHINA AND THE YANGTZE-DELTA REGION

Shanghai Mayor Chen Liangyu referred to the new Maglev line "as a major contribution to the modernization of Shanghai." Local residents throughout the city were seething with enthusiasm on this grand occasion Tuesday.[26]

China

Shanghai is growing rapidly and the decision to put the Maglev in the financial capital of China shows foresight in anticipating and directing growth. A feasibility study was done to determine the possibility of the Maglev line handling enough passengers to decrease the need to expand the six-lane highway to the airport. At the time, this was the only route to the airport and the Maglev guideway now runs adjacent to it. The study found that "because

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[23] Sharp, Andrew. 2004. Shanghai's Maglev. Air Rail Express; The newsletter of the International Air Rail Organisation-Joining railways joining airports. Vol. 7 Iss. 4. August 2004. pp. 1-3.
[24] Chong'en, Hong. 2004. The Technology is Mature, Safe, and Reliable. Wenhui Daily.
[25] Coates, Kevin C. 2005. Shanghai's Maglev Project: levitating beyond transportation theory. Engineering World. April/May 2005. pp. 26-33.
[26] Comtex New Agency. 2002. EBSCO. Retrieved 12/5/06.

a Maglev can comprise as many as eight vehicles [currently running with five], the potential passenger capacity of the system is several times greater than that of the highway, negating any immediate need for additional highway expansion to handle the city's ever-increasing traffic."[27] "The main contribution of transportation investments to the national economy comes from lowering the transportation cost of materials, supplies and products, reducing the cost of doing business, enhancing employment opportunity, increasing business activities, and making it possible to reach new land and obtain new natural resources."[28] As an example, once the demonstration line is extended into the city center, "trips from the airport to downtown will take only 10 minutes, regardless of traffic or weather conditions - trips that routinely take over an hour by taxi."[29]

Conditions in Germany and Japan with small country acreages and a greatly developed aviation, highway, and high-speed rail system would make it difficult to develop a new Maglev system due to the intensive opposition that would ensue from these entrenched industries. China, on the other hand, has a wide territory and large population. With the rapid economic growth the standard of living in China is increasing across all segments of the population. Transportation research has found that as standard of living and wages rise, people become more mobile. The predominant transportation mode currently in use, planes and cars, is not in alignment with the conditions of the country. China has a serious lack of oil, and Chinese oil reservation per person is only 11% of average reservations in the world.

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[27] Antlauf, W. 2004. Fast Track. Civil Engineering Magazine. Nov 2004. pp. 2-8.
[28] Lee, S.H. 2003. "An approach to the economic appraisal of the AVCS Maglev." Transportation Planning and Technology, June. Vol. 26, No. 3, pp. 265–287.
[29] Coates, Kevin C. 2005. Shanghai's Maglev Project: levitating beyond transportation theory. Engineering world. April/May 2005. pp. 26-33.

Furthermore, the existing railway system with an operating speed of only 100 km/h doesn't satisfy fast increasing mobility needs. According to the transportation plan, in 2050, the Chinese population will be 1.47 billion and over 75% of the people will live in cities and towns. The scale of the railway network will increase from 65K km to 120K km in which 8K km will be a high speed network for passenger transportation. Most of the primary transportation lines linking large cities in China are over 1000km. High speed Maglev systems capable of 500 km/h have obvious advantages for high-capacity long-distance passenger transport. They can provide comfortable travel of 800-1500 km within 3 hours, generating ridership from cars and planes, while reducing oil consumption.

Yangtze-delta

This could very well be the scenario by the Year 2020 for the Hangzhou - Shanghai relationship served by maglev transportation: knowledge workers could maintain their residence in Hangzhou, and enjoy its physical and cultural splendors, while having an employment base in Shanghai, and enjoy the economic vitality of this megalopolis. Regions that can best increase accessibility while at the same time manage the environmental, social and economic costs of meeting the demand for increased travel will prosper in the Information Age, while others which are less successful will suffer economically in the global competition for knowledge-based investment.[30] This project was a chance to exhibit many of these advances in a real world situation. Although much of the cost of the system is due to the technological infancy, the Shanghai Maglev Project proved very successful in many

[30] Eggleton, Peter L. and Zavergui, Richard M. Induced Demand: Matching the Attributes With the Information Age Interactive Megalopolis. Telligence Group. Montreal Canada.

other aims as well. The World Expo 2010 will support Shanghai's efforts to build the city into a world centre for economy, finance, trade and transportation, which will tremendously help propel Shanghai's modernization and internationalization.[31] The Shanghai-Hangzhou Line will effectively meet the high-speed transportation needs between these two important cities, promote the Maglev equipment industrialization process and create solid basis for future long distance and intercity application.

Other countries have similar Maglev plans in the works but it has been mainly a political barrier than a technical one that keeps them from getting built. "The technology is radically different from that of other high-speed rail systems and it will probably take time for the decision makers to learn enough about Maglev to include it in their deliberations". [32] "Maglev's U.S. supporters are hoping that the success of the Chinese route will goad officials here into action."[33] The United States currently has three projects actively being planned: a link between the San Diego region and a regional international airport; one from Baltimore to Washington, DC; and one linking Pittsburgh International Airport to the surrounding region. Peter Hall states that "a high-speed Maglev network inter-connecting the East Coast would link Boston to Atlanta in a chain of industry. We're talking about the future of a region"[34] Other countries, such as Germany and Japan, have also been waiting to determine the success of Shanghai's Maglev system before implementing their own.

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[31] Köhler, Reiner. 2006. "Transportation Market Study Yangtze Delta". Transrapid International GmbH & Co. Berlin, Germany.

[32] Coates, Kevin C. 2005. Shanghai's Maglev Project: levitating beyond transportation theory. Engineering World. April/May 2005. pp. 26-33.

[33] Hall, Peter. 2004. The Maglev train is the future of twenty-first century transit. Why we won't see it in the U.S. anytime soon?. Metropolis. January 2004. Vol. 23. n.5. pp. 94-95&123

[34] Hall, Peter. 2004. The Maglev train is the future of twenty-first century transit. Why we won't see it in the U.S. anytime soon?. Metropolis. January 2004. Vol. 23. n.5. pp. 94-95&123

Shanghai's Maglev project has provided a stage for the entire world to witness the future of transportation technology. "In spite of premature claims by some "experts" who claimed the Shanghai project was expensive, unworkable, and unproven technology, the system was built on budget, on time, is ultra-reliable, safe, and works."[35] If Germany gave birth to the technology, then it can be said that China provided the fertile soil for it to grow strong and sturdy. Many countries are looking into methods of reducing dependence on the world's dwindling oil supplies, and as the most fuel-efficient high-speed transportation system invented to date, Maglev travel can only become more attractive as oil prices rise. Shanghai has provided a stunning model of efficiency and achievement for the world to admire and to replicate.

[35] Coates, Kevin C. 2005. Shanghai's Maglev Project: levitating beyond transportation theory. Engineering World. April/May 2005. pp. 26-33.

Chapter 4: History of Federal and State Involvement in the U.S.

Large scale infrastructure has never been put in place without generous government support. The United States has been considering maglev for more than 40 years. Government history with maglev will help determine if it is a feasible alternative to other major transportation investments in the Texas Triangle.

FEDERAL INVOLVEMENT IN MAGLEV TECHNOLOGY

The concept of magnetically levitated trains was first identified at the turn of the century by two Americans, Robert Goddard and Emile Bachelet. By the 1930s, Germany's Hermann Kemper was developing a concept and demonstrating the use of magnetic fields to combine the advantages of trains and airplanes. In 1968, Americans James R. Powell and Gordon T. Danby were granted a patent on their design for a magnetic levitation train.

Serious investigation into various forms of High Speed Ground Transportation Systems (HSGT) in the United States has been underway for more than a decade. Congressional efforts, however, date back to 1965 with the passage of the High Speed Ground Transportation Act which began an R&D program into advanced technologies including Maglev. Under this Act, the FRA funded a wide range of research into all forms of HSGT through the early 1970s. In 1971, contracts were awarded to the Ford Motor Company and the Stanford Research Institute for analytical and experimental development of EMS and EDS systems. FRA-sponsored research led to the development of the linear electrical motor, the motive power used by the current Shanghai Maglev Train. Despite the promise of the technology, U.S. Maglev research stopped in 1975, not for a lack of technical progress, but because our air traffic and highway systems were deemed adequate. This conclusion may have been true then, but since congestion is now costing the U.S. an estimated 200 billion dollars a year, it is now open to question.

In the 1980s the focus on HSGT shifted to urban corridors and interest was peaked in state and local governments across the U.S. "By 1986, at least six States had formed high-speed rail entities, and ultimately Florida, Ohio, Texas, California, and Nevada awarded franchises to private-sector consortia to build and operate intercity high-speed rail or Maglev systems. For a variety of reasons, none of these proposals has yet led to construction."[36] Congressional interest surfaced once again in the late 1980s. "The Rail Safety Improvement Act of 1988 extended the statutory definition of "railroad" in the Federal Railroad Safety Act of 1920 to include "all forms of non-highway ground transportation that runs on rails or electromagnetic guideways," including "high-speed ground transportation systems that connect metropolitan areas, without regard to whether they use new technologies not associated with traditional railroads."[37] At this time, the FRA was asked to assess the potential for Maglev technology and systems in the United States. Studies were directed toward determining the role of maglev in improving intercity transportation in the United States. A preliminary Maglev report was submitted to Congress in June of 1990 and The National Maglev Institute (NMI) was subsequently launched in 1991 with an initial appropriation of $12 million.

Prior to passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, Congress had appropriated $26.2 million to identify maglev system concepts for use in

[36] Federal Railroad Administration. 1997. Report on High Speed Ground Transportation for America.

the United States and to assess the technical and economic feasibility of these systems. Subsequently, an additional $9.8 million were appropriated to complete the NMI Studies. "The NMI was a cooperative effort among the Department of Transportation, the U.S. Army Corps of Engineers, and the Department of Energy, directed at system concepts for Maglev development, market analysis, and safety issues."[38] The goals of the NMI were to continue the analysis conducted earlier in evaluating Maglev's potential for improving intercity transportation in the United States and to determine the appropriate role for the Federal Government in advancing this technology.

The study compared the French TGV technology, the nearly developed German Transrapid TR-07, and a possible domestic United States Maglev (USML) program. Some key findings of these comprehensive studies completed in September of 1993 are that:

- A U.S. 300-mph maglev system is feasible.
- U.S. industry can develop an advanced U.S. Maglev (USML) system.
- A USML System is not Likely to be Developed without significant Federal Government Investment
- USML produces public benefits of reduced environmental pollution, petroleum consumption, and congestion at airports because of its ridership diversion from highways and air systems.
- A United States Maglev program would also do much to enhance the technological competitiveness of U.S. industry. (NMI)[39]

In December 1991, the (ISTEA) authorized a $725 million maglev prototype development program contingent on a favorable recommendation from this report to open the door for funding in later years. In its final recommendation the NMI concludes "that the potential benefits from a U.S. maglev system are sufficient to justify initiation of a development program."[40]

[37] Federal Railroad Administration. 1997. Report on High Speed Ground Transportation for America.

In 1992 the U.S. Department of Transportation initiated a high-speed rail corridor program under the Intermodal Surface Transportation Efficiency Act (ISTEA). This program designated corridors in California, the Pacific Northwest, the Midwest, Florida and the Southeast. In 1998, the Transportation Equity Act for the 21st Century (TEA-21) expanded the high-speed rail corridor program to include the Gulf Coast Corridor, Keystone Corridor and Empire Corridor. The Northern New England and South Central corridors were designated in October 2000. The Northeast Corridor is not officially designated as a high speed rail corridor, but the trains operate at high speeds. It gets its "high speed" status from the definition of "high speed corridor" found in the Federal 4R Act from 1976. **(Figure 8)**

In 1997, a report was submitted to the US Congress examining the economics of high-speed ground transportation (HSGT) in highly populated corridors throughout the United States. The intention of the report was "to draw nationwide-not corridor-specific-conclusions from projections of the likely investment needs, operating performance, and benefits of HSGT in a set of illustrative corridors in several regions."[41] The report noted that this study could not substitute for "the more detailed, State- and privately-sponsored analyses of specific corridors that would be prerequisite to HSGT implementation."[42] A recent study by PBS&J for the San Diego maglev connection to the new international airport gives a positive recommendation for the project in every aspect. In addition, a 1997 FRA

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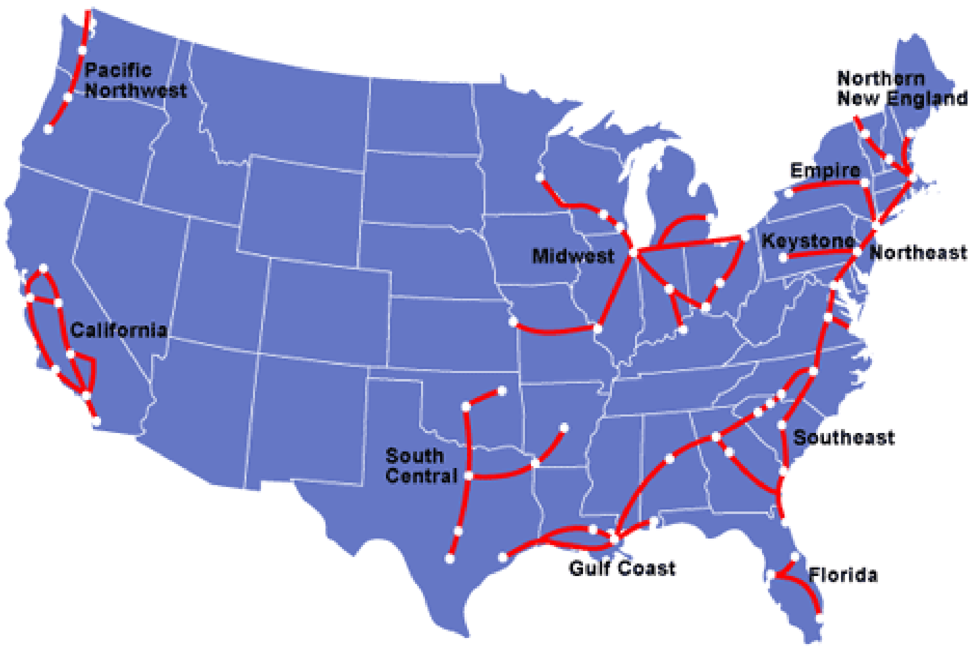
[38] Federal Railroad Administration. 1997. Report on High Speed Ground Transportation for America.
[39] Final Report on the National Maglev Initiative, DOT/FRA/NMI-93/03 , September 1993
[40] Final Report on the National Maglev Initiative, DOT/FRA/NMI-93/03 , September 1993.
[41] Federal Railroad Administration. 1997. Report on High Speed Ground Transportation for America.
[42] Federal Railroad Administration. 1997. Report on High Speed Ground Transportation for America.

report noted that estimates of new demand are controversial because little historical information exists; defining and quantifying such demand is methodologically difficult. In

Figure 8: Federally Designated High Speed Rail Corridors



Source: Federal Railroad Administration

this 1997 report, the FRA considered a range of HSGT technologies. These were a spectrum of 90- 150 mph (160-270 km/h) HSGT's termed "Accelerail", new HSR represented by ICE and TGV and Maglev for which the German Transrapid was taken as representative. The Texas Triangle (Fort Worth-Dallas-Houston-San-Antonio) was a representative corridor considered for this project and a key finding was that none of these initial corridors was commercially feasible in that it covered both its capital and operating costs but could be self sustaining once the infrastructure is in place. It is true of all major transportation projects throughout the history of the U.S. from railroad land grants to airports that major infrastructure and capital costs have been borne largely by the federal government.

In 1998 the President Clinton signed into law the Transport Equity Act for the 21st Century which had a major focus on safety but also supported two HSGT programs. One of these was the Magnetic Levitation Transportation Technology Deployment Program to fund nationally significant projects that demonstrate the feasibility and safety of transportation systems employing magnetic levitation. Under this program the Transportation Secretary was empowered to "select one or more projects to receive assistance for preconstruction planning activities. Upon completion of preconstruction planning activities for all selected projects, the Secretary will select one project to receive financial assistance for final design, engineering, and construction activities"[43] Under the former program the qualifications for consideration for Federal funding are stated to be to:

- exhibit partnership potential;
- be able to be constructed with available Federal and non-Federal funding;
- result in an operating transportation system in revenue service;
- be undertaken through a public-private partnership;
- satisfy applicable statewide and metropolitan planning requirements;
- be approved by the Secretary based on a State application;
- be carried out as a technology transfer project to the extent non-US Maglev technology is employed; and
- involve materials at least 70% of which are manufactured in the United States.

Issues of national importance such as contribution to reducing congestion, non-Federal financial support, job creation are considered relevant to the decision in determining which project to fund for final design and implementation. Two Maglev projects were selected for final evaluation: One is a 45 mile project in Pittsburgh, Pennsylvania, linking Pittsburgh

Airport to Pittsburgh and its eastern suburbs. The other is a 40 mile long project linking Camden yard in Baltimore and Baltimore-Washington International (BWI) Airport. This is envisioned as the initial stage of a high-speed Maglev system that would serve the entire northeast corridor between Boston, MA and Charlotte, NC.

Part of TEA-21, the Transportation Infrastructure Finance and Innovation Act of 1998 (TIFIA), established a Federal credit program for eligible transportation projects of national or regional significance under which the U.S. Department of Transportation (DOT) may provide three forms of credit assistance – secured (direct) loans, loan guarantees, and standby lines of credit.. The program's fundamental goal is to leverage Federal funds by attracting substantial private and other non-Federal co-investment in critical improvements to the nation's surface transportation system. The DOT awards credit assistance to eligible applicants, which include state departments of transportation, transit operators, special authorities, local governments, and private entities.[44] "With TIFIA funds soon to be available to support large transportation projects nationwide, proposed high-speed rail systems and other types of transportation projects in the United States will have an important source of federal financing to further their development."[45]

In August 2005, the United States Congress enacted the Safe Accountable Flexible and Efficient Transportation Equity Act – A Legacy for Users (SAFETEA-LU). Section 1307 of SAFETEA-LU, Deployment of Magnetic Levitation Transportation Projects

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[43] Transportation Equity Act for the 21st Century (TEA-21). 1998. Federal Highway Administration. Department of Transportation.
[44] Transportation Equity Act for the 21st Century (TEA-21). 1998. Federal Highway Administration. Department of Transportation.
[45] United States General Accounting Office. 1999, January. "Surface Infrastructure: High Speed Rail Projects in the United States." Report to the Chairman, Committee on the Budget, House of Representatives.

provides for the allocation of 50 percent of the funds to be made available ($90 million) for engineering and impact studies on three proposals -- $45 million for one connecting Las Vegas to California, and the rest for the Pittsburgh area project and another one between Baltimore and Washington D.C.

In summary, the USA is now very active in developing HSGT operating systems in its highly populated transport corridors. While it currently would need to import the HSGT technology components from either Japan or from Europe, the Federal Government's funding requirements are intended to lead to a domestic HSGT technology capability. "Maglev is the lynchpin of future travel in America. The convergence of excessive highway congestion, unacceptable pollution levels, and a national over-reliance on foreign oil is a compelling set of circumstances for America to finally pursue this safe, high-speed, and low maintenance mode of transportation," announces Richard Cochran, president of the United States Maglev Coalition. With the placement of High speed ground corridors and the requirement of following these corridors to receive federal assistance, the government exhibits that it is keenly interested in and aware of the need for HSGT for purposes of trade, mobility, and national security. The 1997 report on HSGT for America by the Federal Railroad Administration states that the Texas Triangle "presents a unique nonlinear configuration of heavily populated metropolitan areas."46 In June 2003, TxDOT asked FRA to designate an extension of the South Central Corridor that would extend from the Houston area through Bryan/College Station to the Killeen/Temple area, connecting the two Texas corridors. The FRA declined to designate the extension based upon the agency's

[46] Federal Railroad Administration. 1997. Report on High Speed Ground Transportation for America.

vision for the future of intercity passenger rail. The Safe, Accountable, Flexible and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) revised the language dealing with high-speed rail corridor development such that program funds will only be available for corridor development versus planning activities.[47] The challenge will be to prove that maglev is the preferred alternative to high-speed rail and that much higher benefit will be derived from an initial mega regional Texas Triangle system rather than an interstate South Central and Gulf Coast system that effectively cleaves the state in two.

HISTORY OF HIGH-SPEED RAIL IN TEXAS

Efforts toward a high speed rail system began in June of 1987 when the 70th Legislature directed the Texas Turnpike Authority (TTA) to study the feasibility of high speed rail service in the Texas Triangle – the triangle formed by drawing straight lines between DFW, San Antonio, and Houston. The study began in February 1988 and reviewed current and projected transportation needs in Texas as well as other high speed rail systems. In January of 1989, the TTA reported to the Texas legislature that under certain conditions (speeds >150mph) high speed rail would be feasible for Texas. The 71st Legislature passed legislation to implement the findings of the report and the Texas High-Speed Rail Authority (THSRA) was created that same year by Senate Bill 1190 in Regular Session.

The THSRA was charged with the responsibility to determine the best qualified applicant for award of a franchise to design, build, and operate a high-speed rail service in the State. A 50 year franchise was awarded in 1991 to the Texas TGV (train à grande vitesse,

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[47] Texas Rail System Plan. October 2005. Texas Department of Transportation.

literally, high-speed train) corporation, a consortium of businesses. Initial ridership projections for total inter-city travel between the metropolitan areas of Austin, Dallas/Fort Worth, Houston, and San Antonio (the Texas Triangle) using all modes were predicted to total 45.5 million travelers by 2010.[48] According to ridership projections generated for Texas TGV by Charles Rivers Associates, the potential share of high speed in the Texas Triangle between Houston, Austin/ San Antonio, and Dallas/ Fort Worth was 11.9 million passengers, or one-quarter of the total intercity travel market.[49] It was intended to be used by Texas TGV to refine ridership estimates using different assumptions, different line haul times, and different market response strategies. The Authority considered this report to be "one of the most complete and exhaustive examinations of the high speed ground transportation demand and revenues ever completed for any corridor in the United States."[50] The franchise agreement with TGV was rescinded in 1993 when the deadline to have $200 million sold in equity financing notes could not be met. The corporation offering a counter guarantee, Morrison Knudsen, got squeamish and withdrew its counter guarantee offer a day prior to the notes being priced and sold. Lack of federal support and lobbying against the HSR plan by Southwest Airlines were among the reasons that no other franchise applications were awarded and a high-speed rail system was not built. A lack of federal funding and heavy lobbying by groups such as Southwest Airlines prevented other firms from being awarded franchises and, subsequently, the THSRA was formally abolished in 1994. At one point the Authority was scheduled to become part of the Railroad Commission

[48] Texas Rail System Plan. October 2005. Texas Department of Transportation.
[49] Charles River Associates, Inc., "Independent Ridership and Passenger Revenue Projections for the Texas TGV Corporation Higher speed Rail System in Texas," September 1993.

at the beginning of the 1996 fiscal year. Instead, the 74th Legislation abolished the Texas High-Speed Rail Authority and repealed its legislative authorization (House Bill 2390, Regular Session). Its functions were not absorbed by any agency.

At the time there was considerable support for a high-speed rail system connecting major cities, military posts, schools, hospitals and entertainment centers in parts of North, South and East Texas. "Texas is ready to lead the nation and establish the standard by which all high-speed rail projects are judged in the United States," Lt. Gov. David Dewhurst said in a letter to the U.S. House Committee on Transportation and Infrastructure. "With increasing congestion on our state's highways, delays at our major airports, and population growth at twice the national average, it is clear that we must seek creative solutions to our transportation problems," Dewhurst said. This type of infrastructure improvement would have been a major boost to the Texas economy uniting the separate metropoli into one mega-region.

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[50] Report to the Legislature. 1994. THSRA.

Chapter 5: A Critical Need for HSGT in the Texas Triangle

EMERGING MEGA-REGION

The Texas Triangle has a total area of nearly 60,000 square miles formed by the metropolitan areas of Dallas/ Fort Worth, Austin, San Antonio, and Houston. This emerging Mega-Region is expected to grow from 13 million inhabitants in 2000 to about 25 million by 2050. At that time, 70 percent of the population of Texas will be living in the metropolitan areas that compose the Texas Triangle. Currently, "three of the nation's 10 largest cities are in the Triangle, including Houston, which has a port that handles more foreign tonnage than any other in the U.S."[51] "Combining Houston's port, Dallas' inland distribution function, San Antonio's reach into deep South Texas and northern Mexico, and even the state's political capital into one place could have produced a Third Coast megalopolis to rival New York, Los Angeles and Chicago".[52] A closer look at the economic strengths reveals that these urban areas have developed complementary industries, and a strategy of cooperative, statewide development programs makes much more sense than competition within the region.

The Triangle cities developed as economic complements as a result of their proximity and cultural cohesion. The January 2004 issue of Houston Business proposed that the Texas Triangle metro areas of Austin, Dallas/Fort Worth, Houston and San Antonio exist as distinct cities largely because of Texas geography. "With a long, navigable river

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[51] Regional Plan Association, "America 2050: A Prospectus," New York: September 2006.

[52] Gilmer, Bill. 2004, January. "The Simple Economics of the Texas Triangle". Federal Reserve Bank of Dallas; Houston Branch.

reaching the heart of the state or a deep saltwater bay or other inlet making Waco or Temple a seaport, many of the roles played by the Triangle cities could have been combined at a single location."[53] Below is an economic snapshot of each of the Triangle cities:

> "**Houston**. The state's major deepwater port—the second largest in the United States based on tonnage—Houston is home to Texas' international business community. However, the city's bread and butter are oil and natural gas, with oil producers, oil services and machinery companies, refineries and petrochemicals directly or indirectly accounting for half the jobs. The Texas Medical Center and Johnson Space Center, along with companies such as Continental Airlines, American General Insurance Co. and HP/ Compaq, help define the non-oil part of Houston's economy.
>
> **Dallas/Fort Worth**. The metroplex still plays its original role as a major inland transportation hub and distribution and service center for the surrounding area, but now the area it serves stretches over several states. It is home to D/FW Airport, the fifth busiest in the world. Following the oil bust, Dallas has clearly emerged as the state's banking and financial center. Dallas and Fort Worth also have a significant presence in oil-related activity, notable on any standard except that set by Houston. High-technology industries, especially telecommunications, became a major center of growth in the 1990s, partly a legacy of the region's history in aviation and defense electronics.
>
> **Austin**. As the state capital and home to the University of Texas' main campus, Austin's major strength has historically been a robust government sector. Beginning in the late 1960s, Austin began developing a significant presence in high technology— IBM Corp. in 1967, Texas Instruments in 1969 and Motorola in 1974. The arrival of chipmaker-consortium International Sematech in 1988 provided the momentum for the 1990s. Today, about 120,000 employees— 25 to 30 percent of the local workforce—are tied to technology industries, and Dell has emerged as the city's most important technology employer. Austin is also renowned for its music industry. Billed as the "Live Music Capital of the World," it sponsors a number of music-related festivals and conventions.
>
> **San Antonio**. The Alamo City's historic role has been as the distribution point for South Texas and northern Mexico. This role has grown with the rapid expansion of the maquiladora industry and the implementation of NAFTA. Tourism is a major industry, with Fiesta Texas and SeaWorld located there, as well as the River Walk, El Mercado and other attractions. Lackland and Randolph Air Force bases and Fort Sam Houston represent a major military presence."[54]

The mature industrial structure of these cities is such that where one is strong the others are weak so there is little overlap or competition among economic roles. To get a picture of the

[53]Gilmer, Bill. 2004, January. "The Simple Economics of the Texas Triangle". Federal Reserve Bank of Dallas; Houston Branch.

[54] Gilmer, Bill. 2004, January. "The Simple Economics of the Texas Triangle". Federal Reserve Bank of Dallas; Houston Branch.

industrial structure of the Texas Triangle region we turn to the location quotient (*LQij*), as defined:

$$LQij = \frac{\text{\% share of income earned in industry i in city j}}{\text{\% share of income earned in industry i in the United States}}$$

Location quotients can answer whether the Texas Triangle cities have developed as rivals or if they complement each other in production. If the exports from one industry match the imports in other cities then the cities of Houston, DFW, Austin, and San Antonio complement each other. In other words, where one city has a location quotient greater than 1, the others have a *LQ* value of less than 1. If the Texas Triangle cities are combined by simply adding them together, the variance of the computed *LQ*s for the combination should be smaller than an average of the variance of the individual cities. Calculations of the location quotients and their respective variances was done by Bill Gilmer in the Houston Business branch of the Federal Reserve Bank of Dallas. **Table 1** shows the average LQ for each city and its variance.

The average LQ is 1.07 whether a weighted average is computed for the individual Triangle cities or computed once they are combined. However, once combined, the variance falls from 1.67 to 0.92. The F test can then be used to measure whether the variance of the LQs for the combined cities is less than the variance of the cities taken individually. The computed ratio for the two variances is (1.67/.92) = 1.82. It is a one-tailed test and ratio of

Table 1: Variance Change among Location Quotients in the Texas Triangle

	Average LQ	Variance	Share
Austin	0.79	0.45	0.09
San Antonio	0.99	0.55	0.1
Dallas/Fort Worth	0.98	0.48	0.43
Houston	1.26	3.59	0.38
Weighted Average	1.07	1.67	
Triangle combined	1.07	0.92	

Source: Gilmer 2004

the variances of the cities taken individually and the cities taken together as a mega-region falls almost exactly on the 1 percent critical value from the table of the F distribution. This means that we can be 99 percent sure that the variance has declined significantly, and the roles played by the four cities are highly complementary to each other. [55]

[55] Gilmer, Bill. 2004, January. "The Simple Economics of the Texas Triangle". Federal Reserve Bank of Dallas;Houston Branch.

Table 2: Export Sectors for Texas Triangle as Indicated by Location Quotients

Export Sectors	Locatin Quotient
Oil and gas extraction	7.49
transportation services	2.52
petroleum and coal products	2.22
electric, gas, and sanitary services	2.15
heavy construction	1.73
transportation by air	1.71
electronic and other electric equipment	1.54
holding and other investment companies	1.54
communications	1.41
water transportation	1.32
wholesale trade	1.31
real estate	1.31
chemicals and allied products	1.21
engineering and management services	1.20
miscellaneous repair	1.19
business services	1.17

Source: Gilmer 2004

Table 2 lists the export sectors for the Texas Triangle if all of the individual cities were aggregated to one large metropolis. What is most apparent is that there are only 16 export industries compared to the 54 export industries for the individual cities. The collapse in the number of export industries is a result of those industries only serving the Triangle region. After combining the cities into a single metro area, the export industries that remain can be seen as true national industries. "This fall in the number of industries is one more indication of the deep-seated economic interdependence among the four metro areas."[56] If the cities of the Texas Triangle do constitute a megalopolis divided into four by Texas geography and history, then their aggregate industrial structure should compare to other top U.S. metro areas.

[56] Gilmer, Bill. 2004, January. "The Simple Economics of the Texas Triangle". Federal Reserve Bank of Dallas;Houston Branch.

Table 3: Economic Characteristics of Texas Triangle and Major U.S. Metro Areas, 2001

Major U.S. Metro Area	Population Millions	Rank	Personal income Billions of dollars	Rank	Per capita income (dollars)	Cost of living (U.S. = 100)
New York	21.3	1	872.7	1	40,949	n/a
Los Angeles	16.7	2	508.2	2	30,360	140.9
Texas Triangle	**13.2**	**3**	**433.4**	**3**	**32,897**	**96.7**
Chicago	9.3	4	331.3	4	35,751	n/a
Washington	7.8	5	302.7	6	38,915	112.3
San Francisco	7.1	6	326.8	5	45,778	183.0
Philadelphia	6.2	7	216.2	7	34,750	121.1

NOTE: All metro area population and income figures are based on the consolidated metro area definition. This includes the Texas Triangle definition, except for Austin and San Antonio,for which an MSA definition is used. The cost-of-living figures use the best possible fit, using primary metro area data, for example, for Los Angeles and Philadelphia.
SOURCES: Bureau of Economic Analysis; American Chamber of Commerce Research Association

Source: Gilmer

A combined Texas Triangle provides a wide-ranging complement of sophisticated urban exports on a national basis. The number and composition of Texas Triangle exports compare favorably with those of the nation's largest metro areas, even after regional exports are canceled out. **(Table 3)** This evidence suggests that an efficient long-distance transportation system quickly taking goods and people between major urban areas in the Texas Triangle would have many positive externalities. Effective planning for megaregions will be one of the great challenges of the 21st century. The choice in transportation technology (highway, rail, water, and air) along with the location and alignment of infrastructure will have profound impacts on demand for land, water, energy, and other natural resources.[57] At the very least, the major players need to coordinate major investments in infrastructure to plan for anticipated future growth and transportation needs.

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[57] Zhang, Ming. 2006. "Simulating Land Use Impacts of Highway Development in the Texas Triangle". SWUTC Research Project.

Just as the Interstate Highway System enabled the growth of metropolitan regions during the second half of the 20th century, emerging megaregions will require new transportation modes that work for places 200-500 miles across. The key new links in this mobility system are likely to be High-Speed Rail (HSR) lines, which are uniquely suited to trips of this length.[58]

HIGHWAY AND AIRPORT RELIEF

The United States transportation system has been much admired around the world for the high quality of life it affords for many Americans. The extensive network of Interstate highways and sophisticated air system has facilitated business and leisure travel for much of the last century. Traffic congestion, however, is much worse today than it was for the last generation with costs to the nation that exceed $200 billion annually. Interstate Highway routes have become subject to development trends and travel patterns in metropolitan areas causing delays that are local in origin, especially during peak travel hours. Also, airports are continually expanding into the surrounding urban fabric at great cost with modest increase to capacity. A Maglev system is needed to relieve the increasing intercity travel congestion that is constricting economic growth and development within the region.

The National Household Travel Survey, most recently completed in 2002, defines long distance trips as more than 50 miles from home to the furthest destination. Some findings are that:

- "90 percent of long-distance trips are made by personal vehicle.

[58] Regional Plan Association, "America 2050: A Prospectus," New York: September 2006.

- Personal vehicles are used for almost all trips less than 300 roundtrip miles
- 62 percent of long distance trips are to destinations within the traveler's home state (intrastate travel)"[59]

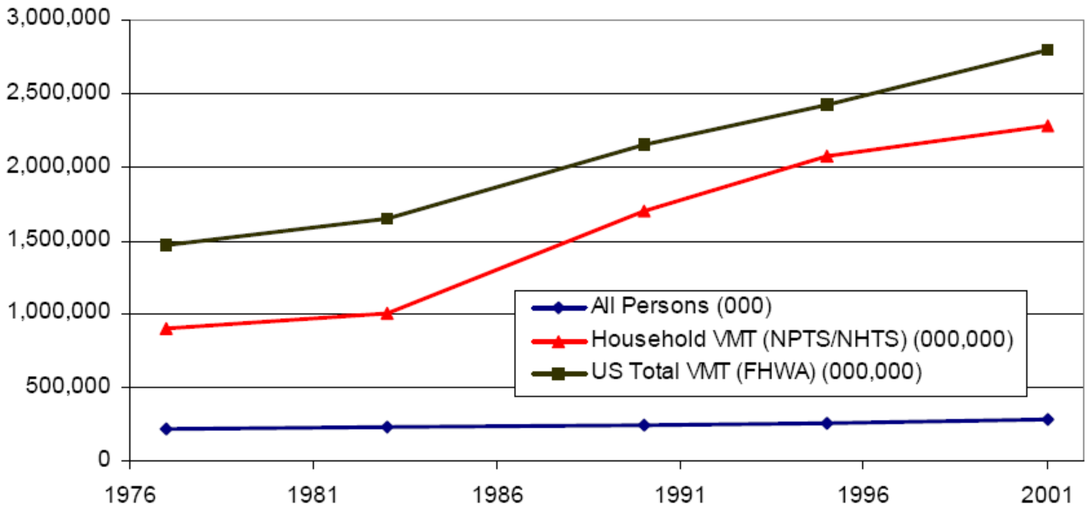
The overwhelming amount of long-distance trips made by car suggests that the time savings gained from flying does not exceed the benefits and cost-savings of driving and having the automobile available at the destination, especially when less than 300 miles. These findings also show that most long-distance travel is between destinations in the home state of the traveler. This supports a regional approach to transportation planning with a focus toward modal integration. (i.e. car-rental at train stations) High speed rail is a good alternative to these long distance trips in the 100-500 mile range. In 2000, Texas alone had over 220 Billion Highway VMT compared to 6 million passenger miles on Amtrack nationwide; 7% of travel in Europe is by train; In the U.S. it is 0.3%.[60] Amtrack ridership, however, has steadily been increasing in recent years with shares of ridership in the Boston–New York market jumping from 17 to 33 percent since 1997, getting the attention of politicians and the public alike.

Currently, the majority of riders in America travel by car or airplane, often on overcrowded highways and through congested airports. As population growth and shifts have occurred and travel has increased, these systems have become stressed. In the early 1980s, Americans clocked 1.5 trillion vehicle miles traveled (VMT) and by 2004, VMT had increased 94 percent to just under 3 trillion. **Figure 19** offers a glimpse at the rise in VMT over the past 30 years with respect to population growth. This drastic rise is due to such

[59] U.S. Department of Transportation. National Household Travel Survey, 2001-2002.

factors as sprawl causing further commutes, more women entering the workforce, and greater automobile ownership and availability. The 2001 NHTS data shows this demand leveling off but this may not necessarily mean an abatement of traffic congestion, in fact it will get substantially worse. As congestion increases on a segment of

Figure 9: Population and VMT Changes (millions)



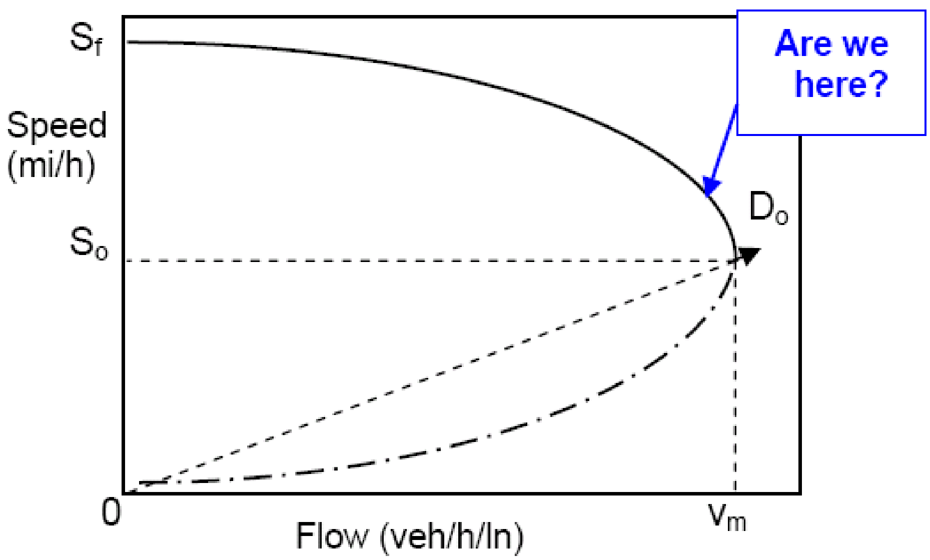
Source: VMT from Table VM-1, FHWA Highway Statistics Series, http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm. NHTS/NPTS data from Summary of Travel Trends 2001 National Household Travel Survey.

road, the sensitivity of the system to relatively small increases in demand is heightened. **Figure 10** shows the classic speed-volume curve as indicated in the Highway Capacity Manual. This curve, while based on the performance of a single roadway segment, may reflect aggregate roadway system performance to some extent. This would suggest, depending on which point on the curve from Sf to Do best represents current aggregate conditions, that more minor increases in flow or demand (moving to the right parallel to the

[60] U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*, annual editions,

x axis) may be resulting in more significant decreases in speed (moving down parallel to the y axis).[61] It suggests that, as the transportation system approaches high volume it is more fragile to minor increases in demand. Smaller increases may be producing larger responses in terms of increased congestion or slowed speed.

Figure 10: Standard Roadway Speed-Volume Relationship



Source: Highway Capacity Manual 2000, Transportation Research Board, National Research Council.

To achieve more efficient use of aircraft and to offer more varied and frequent service airlines use regional hubs to meet travel demand. This hub and spoke practice has accentuated traffic peaking as flights from several origins are brought together within a short period of time at a single airport. If peaking and adverse weather conditions converge, delays at one airport can cause backups to ripple throughout the air travel system.

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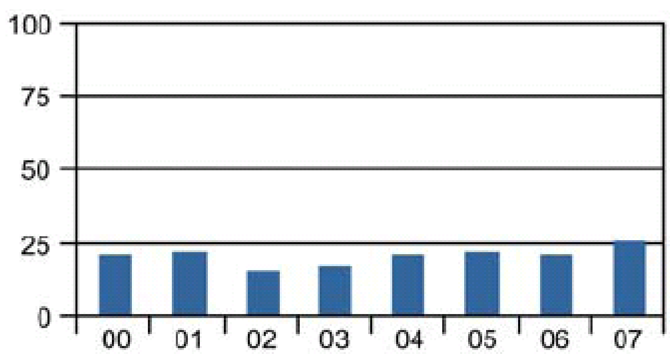
available at http://www.fhwa.dot.gov/ohim/ohimstat.htm.

Moreover, commuter/regional carrier growth strains the airport and airways system, contributing to congestion and delay by using up valuable landing slots that could be reserved for larger planes on more profitable, long-haul flights. The public is likely to encounter greater costs, diminished convenience and quality of service, and possibly diminished safety if strategies are not planned now that take account of developing domestic and international travel needs. From 2000 to 2007 flights have been delayed an average of 23% of the time at a cost of $8 billion dollars a year to American businesses and the aviation industry.[62] **(Figure 11)** Airlines lose money on short-haul flights because the energy required to take-off and land does not justify the distance. If airlines could use a system of codesharing to implement HSGT feeder routes to airport hubs, congestion could be drastically reduced saving the airline industry billions.

Figure 11: Percentage of Flights Delayed



Note: A delay constitutes 15 minutes of delay or more.

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[61] Polzin, Stephen E. PHD. 2006 April. "The Case for Moderating Growth in Vehicle Miles of Travel". Center For Transportation Research; Univeristy of South Florida. Prepared for U.S. Department of Transportation.

[62] United States Department of Transportation. Bureau of Transportation Statistics: The Intermodal Transportation Database. http://www.transtats.bts.gov/HomeDrillChart.asp.

Source: Bureau of Transportation Statistics: The Intermodal Transportation Database

Congestion on highways and airports wastes time and fuel and increases pollution. It can constrain mobility to the extent that economic growth and productivity could be adversely affected. Although system management, ITS, and capacity improvements may provide some relief, adding more highway lanes and building new airports in or near the larger cities is becoming increasingly difficult with land so costly and scarce. Adding new highway capacity in urban areas typically costs more than $15 million per lane-mile. Exclusive reliance on flying and driving, particularly in the most densely traveled intercity corridors, has exacerbated environmental problems and constrained capacity causing the transportation system to be more gridlocked and winglocked.

Maglev can contribute to meeting the transportation needs of the future while improving the efficiency and lengthening the life of existing highway and air facilities. The United States Interstate System is over 50 years old in some sections and very little money is going to be coming in to state transportation budgets to repair and replace the vast sections that need it, says Bob Daigh, TxDot district engineer for Austin area. This is a pivotal point to change the direction transportation planning can take in the coming decades. From 1954 through 2001, federal funding for Interstates totaled over $370 billion (2001 dollars).[63] In all, aviation received $15.9 billion (including bailouts) from the feds in 2003; highways got $31.6

[63] Siggerud, Katherine. 2002. "Highway Infrastructure:Physical Conditions of the Highway System Have Improved but Congestion and Other Pressures Continure," Testimony Before the Subcommittee on Highways and Transit, Committee on Transportation and Infrastructure, House of Representatives.

billion; Amtrak—which nearly shut down in July 2002—limped away with just over $1 billion.[64] There is definitive bias toward spending money on

automobile and air travel at all government levels in the U.S. Congestion is getting worse and over-reliance on one ground transportation system has left little choice but to use the taxed interstate system for almost all regional travel. Great change can be driven by federal transportation planning and spending requirements but the government must first make a commitment to allot more funds to transit. Investment in maglev development can invigorate U.S. technological expertise and facilitate the conversion of defense industry skills towards the solution of infrastructure problems. A high speed maglev train would connect to the air and highway networks, smoothing their operations while reducing air and highway congestion, air pollution, and energy use. Maglev, which is capable of approaching the high speed of the airplane, while offering some of the flexibility of the automobile, can be provided to add capacity in dense intercity corridors. It is more likely than high-speed rail to attract medium-distance travelers from air, as well as some drivers from the highway and has the most potential to complement existing transportation systems and help meet transportation demand with few environmental impacts.

ENVIRONMENTAL CONCERNS

Environmental problems such as diminishing air quality stem from such high use of fossil fuels for air and highway travel. Many highway improvements made possible by federal funds are contingent upon having a positive impact on air quality. At one time more lanes

[64] Tindall, Blair. 2003. "Trains, Plains, and Pains." Sierra Magazine.

were thought to alleviate congestion and speed traffic resulting in less air pollution, but this argument has proven not to hold true. Motor vehicles and power plants generate most of the "greenhouse gases"—primarily carbon dioxide—that are causing changes in the Earth's climate. Despite efforts to reduce tailpipe pollution, emissions of carbon dioxide from vehicles actually increased between 1990 and 2003.[65] The transportation sector is currently responsible for one third of the carbon dioxide produced in the United States—and this percentage is expected to grow to 36 percent by 2020.[66] Flying creates 13 percent of transportation-generated carbon dioxide worldwide and other aviation gases include hydrocarbons, nitrogen oxides, and sulfur dioxide, which contribute to acid rain. "When flights were banned following September 11, skies cleared significantly."[67] Commercial jet engines also deposit pollution in crucial areas near the ground. According to the Natural Resources Defense Council, a single jet landing, taxiing, idling, and taking off can cause as much pollution as a car traveling 5,600 miles And in an odd twist, some of today's quieter, more fuel-efficient aircraft engines generate an average of 40 percent more smog-forming nitrogen oxides than the engines they replaced.

Europe has had success in replacing a number of medium distance flights with high-speed trains. The Velaro Train in Spain has the propulsive capacity to travel the 625 kilometer (388-mile) distance between Madrid and Barcelona in two-and-a-half hours. Air travel is expected to end soon on this route as has happened when travel times have been

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http://www.sierraclub.org/sierra/200311/trains.asp

[65] Energy Information Administration, Emissions of Greenhouse Gases in the United States 2003, p. 22, available at http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html.

[66] Pew Center on Global Climate Change, Reducing Greenhouse Gases from U.S. Transportation, May 2003, p.iii, available at http://www.pewclimate.org/docUploads/ustransp.pdf.

massively reduced between other major cities by high-speed rail, like Berlin and Hamburg -- to the benefit of both the environment and the climate. Siemens estimates that the train, assuming it is carrying an average load of passengers, will emit only 30 kilograms (66 pounds) of carbon dioxide per passenger. The figure for air travel along the same route is 85 kilograms [187 pounds] per passenger.[68]

Each megaregion has special issues it needs to make a priority. The Texas Triangle (San Antonio-Houston-Dallas/Fort Worth), for example, needs to collaborate across hundreds of miles on water issues, including protection of such resources as the Edwards Aquifer. The Triangle's recent ozone nonattainment designation and unhealthy levels of fine particulate pollution serve as a wake-up call, alerting citizens, the business and university communities and local officials to the urgent need to address the region's air quality problems.[69] This means that the state is in danger of losing federal transportation funding if it does not take immediate steps to improve air quality over heavily traveled corridors. As the Triangle continues to grow, it must make sure that air pollution does not tarnish the region's high quality of life. Can the Triangle region be among the "best places to live in America" when the American Lung Association includes it on a list of the nation's metro areas with the worst ozone pollution, and smoggy summer days making it unsafe for children to play outside? [70] **Figure 12** shows the nonattainment areas as of 2004.

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[67] Tindall, Blair. 2003. "Trains, Plains, and Pains." Sierra Magazine. http://www.sierraclub.org/sierra/200311/trains.asp

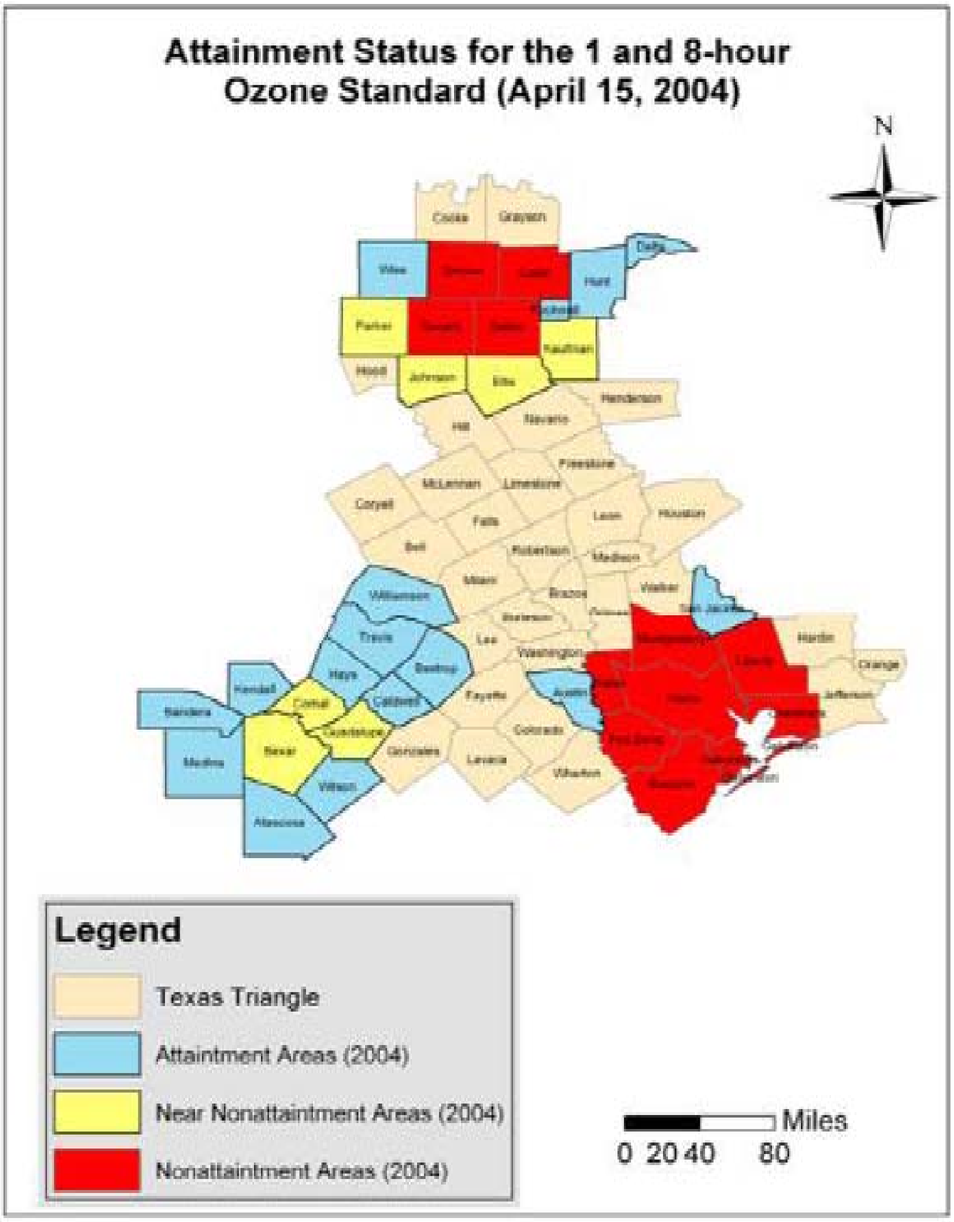
[68] BusinessWeek.com. 2007 April 5. "Is Energy Guzzling TGV the Wrong Answer." http://www.businessweek.com/globalbiz/content/apr2007/gb20070405_879375.htm

[69] Pierce, Neal. Oct 29th, 2006. "There is A High Speed Rail Connection We Are Missing." Viewpoint Outlook. Houston Chronicle.

[70] Pierce, Neal. Oct 29th, 2006. "There is A High Speed Rail Connection We Are Missing." Viewpoint Outlook. Houston Chronicle.

Maglev is electrically powered and would be virtually independent of petroleum-based fuels if the energy used was harvested without the use of petroleum. Overall, trains

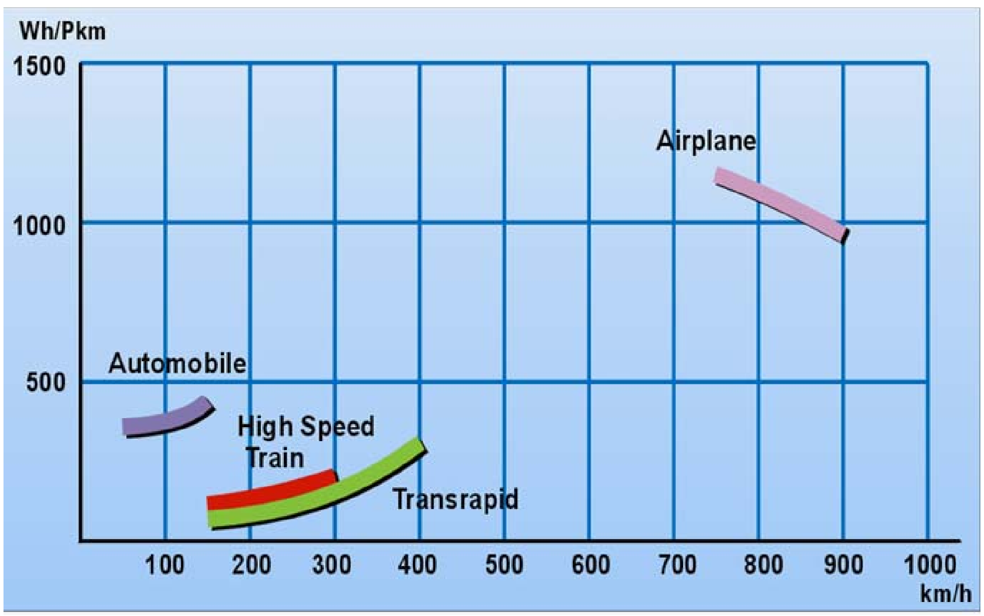
Figure 12: Nonattainment Areas in the Texas Triangle (2004)



Source: University of Texas

produce a fraction of the carbon dioxide per passenger-mile of cars or planes. The energy for Amtrak's electric trains is generated by hydroelectric, coal, nuclear, and other means. While rail power isn't pollution-free, its emissions can be controlled at the source more efficiently than the emissions of, say, millions of individual vehicles. As shown in **Figure 13**, maglev uses less energy than high speed rail, 3 times less than an automobile, and five times less than an airplane. It will be important to develop transportation alternatives that reduce petroleum dependency. Current petroleum-dependent intercity aviation and highway transportation technologies account for 64% of total petroleum use. Transportation-related petroleum use remains high at a level 38.5% above U.S. petroleum production contributing to a trade deficit and dependence on oil imports with national security implications.

Figure 13: Primary Energy Consumption



Source: Transrapid International

Chapter 6: Key Issues to Address for a Maglev System to Work in the Texas Triangle

There are issues that act as barriers to implementing new technologies like maglev such as the perception that it is highly expensive and unworkable when compared to rail or that it can't provide heavy freight service like traditional rail can. Here is a study of some top issues that affect the implementation of maglev in the Texas Triangle.

REPEAL OF THE WRIGHT ORDINANCE

When DFW International opened in 1974 as a result of pressure from the FAA to build one regional airport between Dallas and Fort Worth, every airline, except Southwest, moved to the new, larger airport. At the time Dallas and Ft. Worth set out to build this massive new airport, there was concern that airlines would be reluctant to give up flying from the far more convenient Dallas Love Field located in the urban core. American Airlines finally agreed to move operations to DFW in exchange for a federal law that prevented any airline from flying out of Love Field to any outside states beyond those bordering Texas. The Wright Amendment is a 1979 federal law making it illegal to fly from Southwest's home airport, Love Field in Dallas, to points beyond the four states surrounding Texas, plus Alabama, Mississippi, and Kansas.[71] A fledgling airline known as Southwest had arrived on the scene and started service at Love Field, much to the chagrin of the vastly more powerful AA. Southwest's home base at Dallas Love Field was prevented from offering flights to anywhere outside the hops shown in **Figure 14** (although the Shelby amendment added AL and MS to the list). The limits were expanded in 1997 and 2005, and a law repealing the amendment was enacted in October 2006. That law eliminates some of the restrictions and leaves others intact until 2014. As a result of this law, Southwest Airlines fiercely fought the THSRA's high-speed rail initiative that had begun in the 1990s for Texas. These short distance flights were their main income generator and, with the Wright Ordinance in effect,

Figure 14: Flight Range of Southwest Airlines as Imposed by the Wright Amendment

Source:http://www.646industries.com/mt/beyond_s/archives/the_wright_amendment.html

Southwest would be competing for a decreasing amount of potential riders. In some cases, high speed trains have eliminated short-haul air competition. "Germany's InterCity Express (ICE) trains shut down Lufthansa's Hanover-Frankfurt flights permanently."[72] Reports by the FRA cite that HSR pulls most of its potential ridership from pre-existing flight routes in the 50-600 mile range.

With the repeal of the most restrictive provisions of the Wright Ordinance, there is

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[71] Southwest Airlines. www.southwestairlines.com. http://www.swamedia.com/swamedia/story_leads.html
[72] Tindall, Blair. 2003. "Trains, Plains, and Pains." Sierra Magazine. http://www.sierraclub.org/sierra/200311/trains.asp

a real possibility that these two adversarial transportation providers can become partners in the long-distance Texas Triangle travel market. "Driven by the increasing fuel, labor, and capital costs of operating large jets to go short distances, and the wear and tear on equipment and crews of multiple landing and take off, U.S. air carriers are looking at the option of selling a flight's second or third leg as a train ride"[73] Flights lose money on short-haul flights because the vast majority of energy usage is during take-off and landing. Codesharing is a way airlines can reserve a limited number of seats on a train, bus, or commuter rail to bring people from the region to the transportation hub or disperse them into the region once they arrive. It is a way to offer multimodal through-ticketing, fast connections and simple timetables. "Where Amtrak service is available, it may not only be a less-costly alternative to a short-hop airplane ride, it may well be more convenient because it will deliver its customers, in most cases, directly to a downtown area, where many train stations are already located." [74] Some airlines such as Continental and KLM already offer code-sharing with European high-speed trains and the ability to earn frequent-flier miles.[75] The idea behind this proposition is that airline passengers wanting to fly to/from major domestic/overseas destinations have to go through the Dallas-Fort Worth or Houston International hubs and if high speed rail can bring them in as fast as airline feeder systems can and at lower cost, then there might be a trade-off: Major airlines would not have to fly feeder routes, passengers would have direct service (with such things as one-time baggage

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[73] Repass, James P. "Planes to the Trains Coming to America?". Railway Age. http://www.railwayage.com/jan01/planes_to_the_trains.html.
[74] Repass, James P. "Planes to the Trains Coming to America?". Railway Age. http://www.railwayage.com/jan01/planes_to_the_trains.html.
[75] Soriano, Cesar G. 2007 March 29 "European Rail Lines Taking a Giant Leap". USA Today.

check-in), the high speed rail system would make use of the airlines' highly sophisticated reservation systems, and a true surface-air synergy might be developed.

PROVIDE FREIGHT SERVICE

Over the next 20 years, a major increase in freight movements from Asia into the western United States' ports is anticipated. The western ports are not equipped to handle such an increase in freight, and thus more and more freight will begin to move through the Texas Gulf port. Over the next 20 years, freight tonnage on Texas highways is projected to increase 85 percent, and freight tonnage on the Texas rail system is expected to increase 68 percent due to increased port traffic and the effects of NAFTA. Based on these projected increases, Texans will need an Intermodal transportation system capable of adapting to all the various transportation demands.[76]

Several states have determined that public investment in the freight rail system is the most effective use of transportation resources, as improving rail efficiency can have the important public benefits of enhanced mobility, safety, and economic competitiveness. In addition, states that have the ability to invest in the freight rail system often find it easier to attract private-sector equity for rail investments as it creates an environment where both the public and private sectors can pool resources more effectively, share risks and rewards more equitably, and distribute costs and benefits more efficiently. This further enhances transportation efficiency and economic vitality. However, the lack of clear guidance on

[76] TXDot. TTC Report to the Texas Legislature. Meeting the Texas Transportation Challenge. 80th Texas Legistlature.

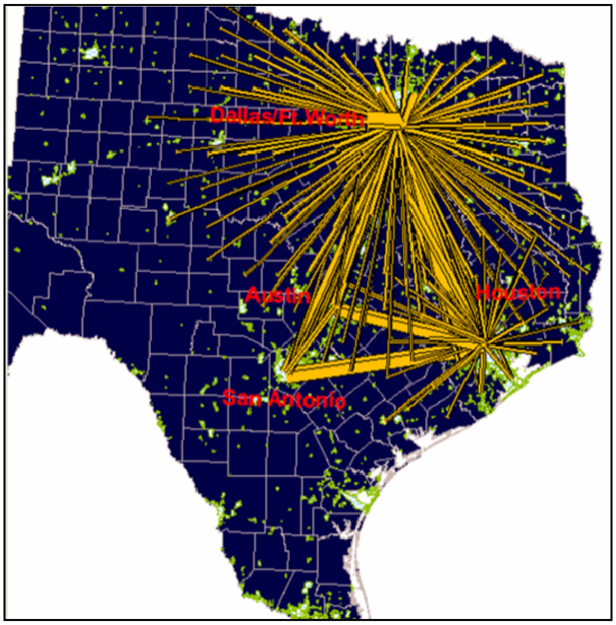
whether TxDOT can invest in the construction, maintenance, or operation of rail systems not owned by the state hinders the ability of the department to comprehensively address transportation needs and deficiencies across all modes and limits its ability to make comprehensive, system-wide improvements.[77] A recent multi-state study on the present and future effects of freight, specifically trucks, on the I-10 corridor from coast to coast found that, "The continued trend toward a service economy, where reliability is essential, will increase the volume of freight traffic on highways at a projected pace nearly twice that of automotive traffic by 2025. Worsened highway congestion and capacity constraints impose costs on producers and consumers, and worsen conditions for the traveling public."[78] One of the main strategies listed was to focus on diverting freight off highways and avoid policies that would shift freight from other modes to highways. **Figure 15** shows the flow of commodities across Texas with the overwhelming majority transferred among the Triangle cities via the interstate highway system.

A Texas Triangle Maglev would remove much of the freight off of congested highways if it could show a lower cost of shipping in terms of distance and time as well as employ an efficient truck-to-maglev/maglev-to-truck loading and unloading system. A maglev freight car currently can carry 15 tons of cargo. This carrying capacity is only one-fifth the freight carrying capacity of the average U.S. freight car, which is 84 tons, but the advantage of speed could make this a more viable solution to just-in-time shipping practices required for many parts orders. This would restrict maglev, in the beginning, to carrying mail

[77] TXDot. TTC Report to the Texas Legislature. Meeting the Texas Transportation Challenge. 80th Texas Legistlature.

[78] Wilbur Smith Associates. National I-10 Freight Corridor Study. Joint effort by Eight State DOTs. http://www.i10freightstudy.org.

Figure 15: Mega-Regional Freight and Commodity Flows



Source: Yaro 2006

and light-weight freight of the sort carried by UPS and Federal Express, and shipped by airplane. But, it is a matter of perhaps 10 years before the maglev could be developed with a freight payload carrying capacity of 50 tons, meaning it could carry capital goods. This would make maglev part of the freight carrying network. We must acknowledge the need for large-scale investments in physical infrastructure targeted to areas where they are needed most – major, multi-state, multi-use trade and travel corridors. Trade is the economic heart of a region and if the veins are clogged, the heart suffers.

INTER-GOVERNMENTAL COLLABORATION AND POLITICAL LEADERSHIP

For a Maglev system to get off of the drawing board here in Texas there must be collaborative planning across all areas that will be affected as well as a solid funding source.

The State of Texas has shown in the past that it is not interested in funding a High-Speed train system with state money but welcomes private investment. They may be more willing if there were stronger support at the federal level which could possibly materialize in the near future, but that remains to be seen based on the success of projects in Pittsburgh and Baltimore-Washington, D.C. Even so, federal government spending on passenger rail has historically been meager compared to highway spending. ISTEA and subsequent TEAs have reinvigorated the federal focus on rail, but it will take an understanding of the need for an interstate high speed ground transportation system to receive the level of funding that highways have. From its inception, the U.S. Government has aided and promoted innovative transportation for economic, political, and social development reasons. In the nineteenth century, the Federal Government encouraged railroad development to establish transcontinental links through such actions as the massive land grant to the Illinois Central-Mobile Ohio Railroads in 1850. Beginning in the 1920s, the Federal Government provided commercial stimulus to the new technology of aviation through contracts for airmail routes and funds that paid for emergency landing fields, route lighting, weather reporting, and communications. Later in the twentieth century, Federal funds were used to construct the Interstate Highway System and assist States and municipalities in the construction and operation of airports. In 1971, the Federal Government formed Amtrak to ensure rail passenger service for the United States. The answer might possibly be a re-structuring of Amtrack to design, operate, and maintain the interstate, or at least interregional, maglev system. In a speech to Congress, Former Secretary of Transportation Mineta states, "We will engage the country's technology leaders by inviting them to join a new Transportation

Technology Forum. This forum will bring new innovation and energy to designing transportation solutions – to begin building the world's most technologically sophisticated transportation system."[79] Strong support from the federal level is a requirement of getting a project of this magnitude planned and built.

Another challenge is to collaborate in planning for future infrastructure, energy, and resources at the mega regional level. The first step would be to identify emerging mega-regions, such as the Texas Triangle, and the relationships that define them. In addition, strategies should be developed that address challenges, cooperation, financing methods, and new governance. The Texas Triangle as a mega region is better equipped to handle issues of long distance freight, nonattainment on certain corridors, and water quality. Cultural cohesion creates the potential for collaboration among the metro regions of the Triangle to address land use, transportation, and environmental concerns but local jurisdictions are often competing for economic development and other priorities. Local officials have little incentive to make decisions in the best interest of the Triangle area as a whole. Federal policies need to be implemented to underpin megaregional coordination and planning. Unmanaged growth, a futile effort to address congestion with a single highway-focused strategy, and lack of regional coordination leads to erosion of the region's quality of life, serious public health impacts due to air pollution, and even the risk of losing federal highway funds. The alternative route is a coordinated regional effort to improve air quality, land use and transportation planning. This leads to healthy air and an improved overall quality of life for the region's citizens.

[79] Mineta. 1997. Secretary Of Transportation. Speech to Congress.

ALTERNATIVE TO HIGH-SPEED RAIL

What separates High Speed Rail from Maglev? It is clear that intercity high speed ground transportation is next major transportation upgrade in the United States but the debate is still alive as to which is the better choice. Supporters of high speed rail claim that rail is approaching the speed of maglev and is much cheaper considering existing infrastructure and lower capital costs. Also, many studies done by the FRA in the 1997 report, high speed ground transportation for America, support high speed rail for its higher benefit/cost ratio to maglev. This study, however, did not consider the impacts of a host of economic and non-economic factors. Many of the potential benefits—lower noise, and cleaner air—are social not consumer benefits, so the ticket price cannot pay for them. Since that time, the successful commercial operations of the demonstration line in Shanghai, China along with advancements in the technology and commercial optimization have changed some key assumptions. The systems are quieter, more cost efficient, have lower specific energy consumption than traditional wheel-on-rail systems, and are virtually impossible to derail." [80] Maglev has been found to be faster, safer, quieter, and, most importantly, cheaper than high speed rail. It has been designed from the outset to overcome the limitations of steel-wheel systems.

[80] Houchell, Oliver. 2006. "Traveling in a Straight Line". Architectural Design. Volume 76. Issue 1. John Wiley & Son Ltd.

Speed

The top speed for land vehicles is held by the experimental Japanese JR-Maglev MLX01 magnetic levitation train for 581km/h (361mph) set in 2003. Recently, on April 3rd, 2007, the French TGV broke its old record clocking in at 574.8km/h (356mph).[81] **(Figure 16)** The top speed of the two vehicles differs only slightly, but the safe traveling speed of the vehicle is what should be considered in interregional planning. At higher speeds, even 125mph, track contact is critical and minor warping from summer heat or even debris on the track can cause derailment. The French train with wheels was a tour de force, but not practical. Miles of track had to be adjusted to the nearest millimeter at a huge cost. Typically, high-speed trains travel at top service speeds of between 250km/h and 300km/h (155mph to 186mph).

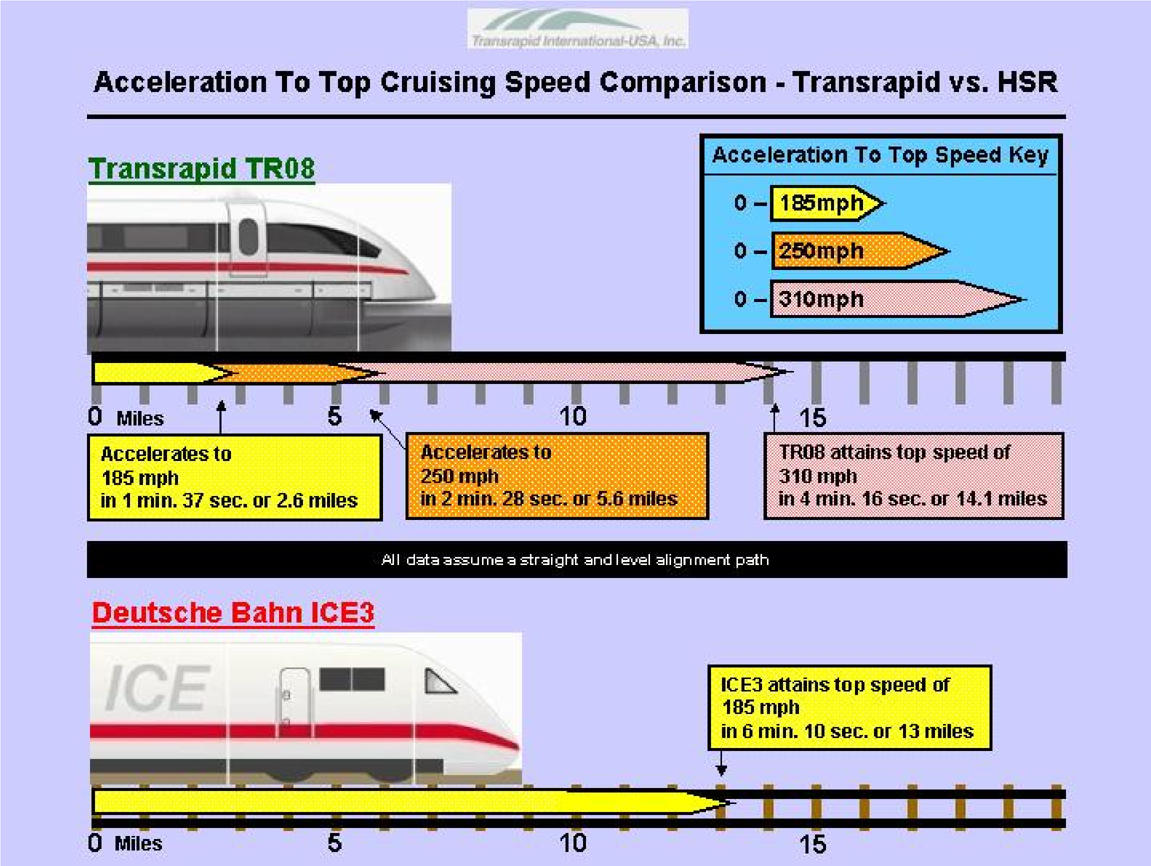
Figure 16: World Speed Record on Manned Trains

Source: BBC News

[81] BBC News. 2007 April 3. "French Set New Rail Speed Record". http://news.bbc.co.uk/1/hi/world/europe/6521295.stm

The Shanghai Maglev Train currently in operation attains a top service speed of 431 km/h or 268 mph. The Shanghai Maglev is also confined to the 30km (18.6 mile) initial operating segment and will be able to reach higher speeds when the route is extended to Hangzhou. The top speed for a Transrapid Maglev is 550km/h (342mph) making it the only form of ground transportation that can compete directly with short-haul regional air travel times and cruising speeds.

Figure 17: Acceleration to Top Cruising Speed Comparison



Source: Transrapid International

Safety

The danger with conventional rails has historically been derailment and collisions, both head-on and with stationary trains. With Maglev this is not possible. Maglev is designed so that the vehicle wraps around the guideway making derailment nearly impossible, even at the highest speeds. A German ICE train recently caused humdreds of fatalities when it derailed and slammed into an overpass due to a damaged steel wheel. Also, a head-on collision is impossible as the propulsion system only operates in one direction at any one time. There was an episode in late 2006 where a German train collided with a maintenance car killing some of the passengers. There is a redundancy check built into the program where two vehicles cannot occupy the same space in time on the track, but the maintenance car was not included in this system. It was a simple programming oversight that caused a terrible accident. Also, the at-grade nature of steel wheel on rail systems has contributed to many conflicts with other modes of traffic, pedestrian, auto, or bicycle. Grade separation prevents the trains from colliding with pedestrians and vehicles.

Noise

With the traditional wheel-on-rail system a lot of noise comes from interaction with the rail during acceleration, travel, and braking. With maglev, the main sound is the air friction hitting the nose of the craft. Inner-city applications are possible at speeds around 200km/h since there are very little external sound impacts. **Table 4** displays a comparison between railway and maglev decibels produced at specific operating velocities.

Table 4: Noise Comparison Between Maglev and Railway

Operating Velocity (km/h)	Railway [a]	Maglev [b]
100	72	---
160	79	74
200	83	77.5
250	88	---
280	89	---
300	91	84.5
400	---	92

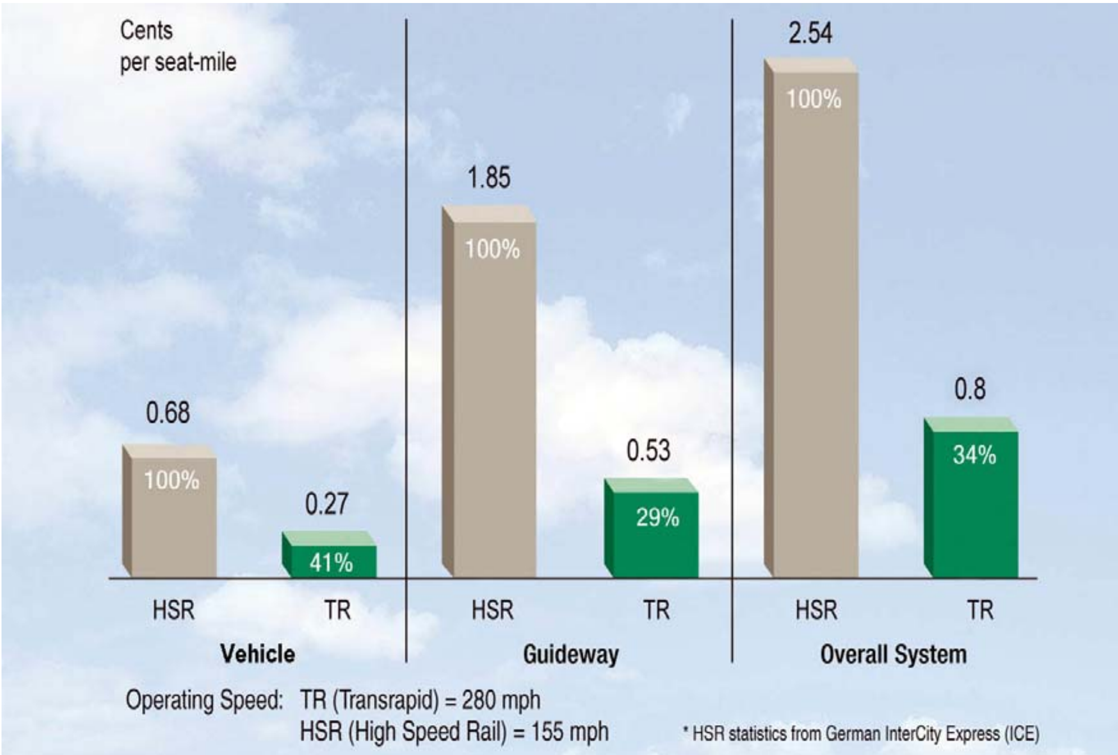
Note: [a] Measured by Germany Noise Institute
[b] Measured at Shanghai Demonstration Line

Source: Luguang, Yan

Costs

The most basic cost improvement over rail is on a cent per seat mile basis coming from the speed advantage. Also, there is a lower cost in terms of new infrastructure partly because of the ability to follow existing rights of way. In fact, a recent FRA report on maglev stated that "although the cost of Maglev appears high, studies of recent high speed rail systems in Germany envision that New HSR might approach, or even exceed, Maglev in cost."[82] The maglev can climb steeper grade and hug tighter radii at full speed than can high-speed rail. Maglev has a gradient climb ability of 10% in comparison to 4% with normal rail. This means less cuttings and embankments and all the costs that they entail. Due to the technology involved, the maintenance costs of a maglev guideway are less than either roads or rail. This is because the vehicle never touches the surface of the guideway and there is no mechanical wear and tear. Once built, there is little maintenance since there are no moving parts involved in the actual propulsion of the vehicle. This reduces costs in terms of parts and labor. Operations costs are kept to a minimum as well since a conductor is not needed and schedules and stops can be completely automated. In addition, as shown in **Figure 18** overall system cost in terms of cents per seat-mile is less for maglev than it is for high-speed rail.

Figure 18: Cents Per Seat-Mile Comparison Between Transrapid And HSR



Source: Transrapid International

[82] FRA Report to Congress. 2005 September. "Costs and Benefits of Magnetic Levitation."

The cost reduction technologies of the super conducting maglev under development for commercial use in Japan are even more pronounced. Four major innovations are achieved with the second-generation Maglev 2000 system over the first generation Japanese and German systems:

1. Much lower guideway cost—$12 million per mile, compared to $40 million to $60 million per mile.
2. Much faster payback times—5 years instead of 50, by carrying piggyback trucks.
3. Electronic switching of vehicles at high speeds from the main guideway to off-line stations for loading and unloading.
4. Ability to use existing, conventional railroad tracks for Maglev vehicles.[83]

Utilization of ultra-strong fiber-reinforced concrete eliminates the need for ferroconcrete and allows for up to 40% reduction in weight resulting in great reduction in construction costs of viaducts. Blending fibrous material with concrete gives this new concrete greater durability and load resistance and once these low-cost, pre-fabricated guideway beams and piers are mass-produced, cost fall further. Freight cars can also be attached to the back of high-speed intercity rail will greatly increase the revenue earned from each run. Finally, an exciting new means of electronic switching from the main guideway to secondary guideway, without any mechanical movement of the guideway's structures improves speed, reliability, and lowers overall cost.

[83] Central Japan Railway Company (JR Central). 2004 May 11. "Cost Reduction Technologies of the Superconducting Maglev." http://www.21stcenturysciencetech.com/articles/Summer03/Maglev2.html.

TRANS-TEXAS CORRIDOR

The Trans-Texas Corridor is the States' most ambitious project to date described as a 1,200 foot wide, 6,400 km (4000mile) long, multiuse transportation system estimated at 50 years to develop. It is designed to move people and freight much faster and more safely through Texas stretching all the way from Mexico to the Oklahoma border. As currently envisioned, each corridor will include as many as six lanes for passenger vehicles and up to four lanes for large trucks. Corridors also will have up to six rail lines for high-speed passenger rail between cities, high-speed freight, and conventional commuter and freight transit. Another unique component of each route will be a 61-meter (200-foot)-wide dedicated utility zone for water, oil, and gas pipelines, and transmission lines for electricity, broadband, and other telecommunications services.[84] The proposed system may incorporate existing and new highways, freight and passenger railways, and utility rights-of-way. "Transportation officials expect the project to improve the existing Texas transportation network and provide congestion relief for the State's busy metropolitan area."[85] Development of the corridor has an estimated price tag of $144.2 billion to $183.5 billion and the Texas Department of Transportation (TxDOT) plans to use public-private partnerships to finance the project. A private Spanish-American consortium of firms, Cintra-Zachary, has signed a contract to build, operate, and maintain the corridor for 50 years. This information from the master plan for TTC-35 was only made public after 175 Freedom of Information Act requests were filed by citizen groups and news media.

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[84] Palacio, Antonio. July/ August 2005 . "Trans-Texas Corridor.U. S. Department of Transportation. Federal Highway Administration. Vol 69. No. 1. http://www.tfhrc.gov/pubrds/05jul/07.htm.

This project has sparked much debate about the future of transportation and transportation funding in the State of Texas. Recently a 2-year moratorium on private toll roads won approval in the Texas House and Senate halting eight near-term projects in the State, including the Trans-Texas Corridor.[86] This moratorium will study the pros and cons of private equity financing for transportation projects. There are two themes central to the debate over the Trans-Texas Corridor: (1) the non-compete agreements inherent in the contract, and (2) the large amount of right-of-way required for this project.

The proposed routes of the Trans Texas Corridor generally parallel interstate routes and pass around instead of through dense urban corridors. Opponents of the plan say this will do nothing to improve traffic congestion within the city and will even exacerbate the crises if allowed to continue. Non-compete agreements built into the nature of a Comprehensive Development Agreement (CDA) stipulate that "TxDOT will not improve any roadways that run parallel to the TTC for the duration of Cintra's lease, unless those improvements had already been approved prior to the signing of the contract."[87] People say this jeopardizes our free highway system and will allow it to crumble to dust forcing people to use the tolls roads that will, by nature, have very poor access to cities. Instead of benefiting the economy like Rick Perry states, it will relegate Texas cities to sights that people pass as they speed through Texas.

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85 Palacio, Antonio. July/ August 2005 . "Trans-Texas Corridor.U. S. Department of Transportation. Federal Highway Administration. Vol 69. No. 1. http://www.tfhrc.gov/pubrds/05jul/07.htm.

86 Associated Press. 2007 April 11. "House Passes 2-year Moratorium on Private Toll Roads." http://news8austin.com/content/your_news/default.asp?ArID=182303

87 Gorman, Peter. 2007 Jan 10. "Detours on a Super-Highway." Fort Worth Weekly.

The right-of-way required for this project is huge, 1,200 feet in some places. The typical corridor section will require 146 acres of right of way per mile and the total anticipated right of way for the 4,000 miles of corridor is 584,000 acres. Much of this is pristine Blackland Prairie farmland. Moreover, farmers and ranchers will have to contend with a huge barrier cutting their land in two by way of eminent domain. Sections of the contract reveal that interchanges will be sparse to improve the efficiency of the roadway. Cintra-Zachary has not stated how far apart these interchanges will be nor are they required to build the access over or under the TTC-35 toll way. Farmers will have to transport equipment along an unspecified number of miles of frontage road to the nearest interchange to farm the land on the other side meaning bankruptcy for some and, at the very least, traffic problems.

A maglev system would have the capacity of the Trans-Texas Corridor without the cost, land disruption, environmental impact, and political boondoggle. The non-compete agreement could be used to limit a maglev system from ever being built in the Texas Triangle. The Trans-Texas corridor proposal does include high-speed rail, but it is a poor investment because it would not generate enough ridership from existing air and highway travelers; it simply isn't fast enough. This may be a moot point though because the sections that have been made public show that Cintra will not be obligated to build more than four car and truck lanes "until and unless it is demonstrated that there is a demand for high-speed rail, commuter rail, freight, and utilities."[88] It won't happen because it is not possible demonstrate that a high-speed rail line in Texas will have the demand to make a return on

[88] TTC contract. Between Cintra-Zachary and the State of Texas.

the private capital, operating, and maintenance investment. To build such a system would take federal funding of capital costs, as shown in the 1997 FRA HSGT study, and only then, would it be profitable for a private company to operate and maintain. To move forward with the Trans-Texas Corridor would likely mean the end of any HSGT hopes for the Texas Triangle.

Chapter 7: Conclusion

Continued population growth will bring significant demographic changes, with implications for the way we plan our cities, metropolitan regions, and transportation systems. For example, according to Reconnecting America, the swelling cohorts of Baby Boomers and "Echo-Boomers" (aged 24-34), as well as immigrants and non-white populations that are fueling much of America's projected growth, are the same groups that exhibit a preference for urban living in proximity to cultural amenities, jobs, and transit.[89] Moreover, as shown from the 2001 NHTS study, populations are not only growing, they are becoming more mobile, leading to a demand for faster, more efficient infrastructural links, whether within the city center, between the city and the airport, or between cities.

It is clear based on reports by the Federal Railway Administration that there will be increased funding and support from the federal government for High Speed Ground Transportation systems to link major cities in the 50-600 mile range. The debate in the United States and many other countries around the world right now is whether to go with High-Speed rail or Maglev. Countries such as Japan and Germany, ironically the pioneers of Maglev in terms of development, already have a superb rail infrastructure and would have less total benefit gained from a transportation overhaul to Maglev. Countries like the United States and China with vast land areas would, however, have much to gain. "China is in a railway-building boom, adding hundreds of kilometers a year in an expansion that rivals the

[89] Regional Plan Association, "America 2050: A Prospectus," New York: September 2006.

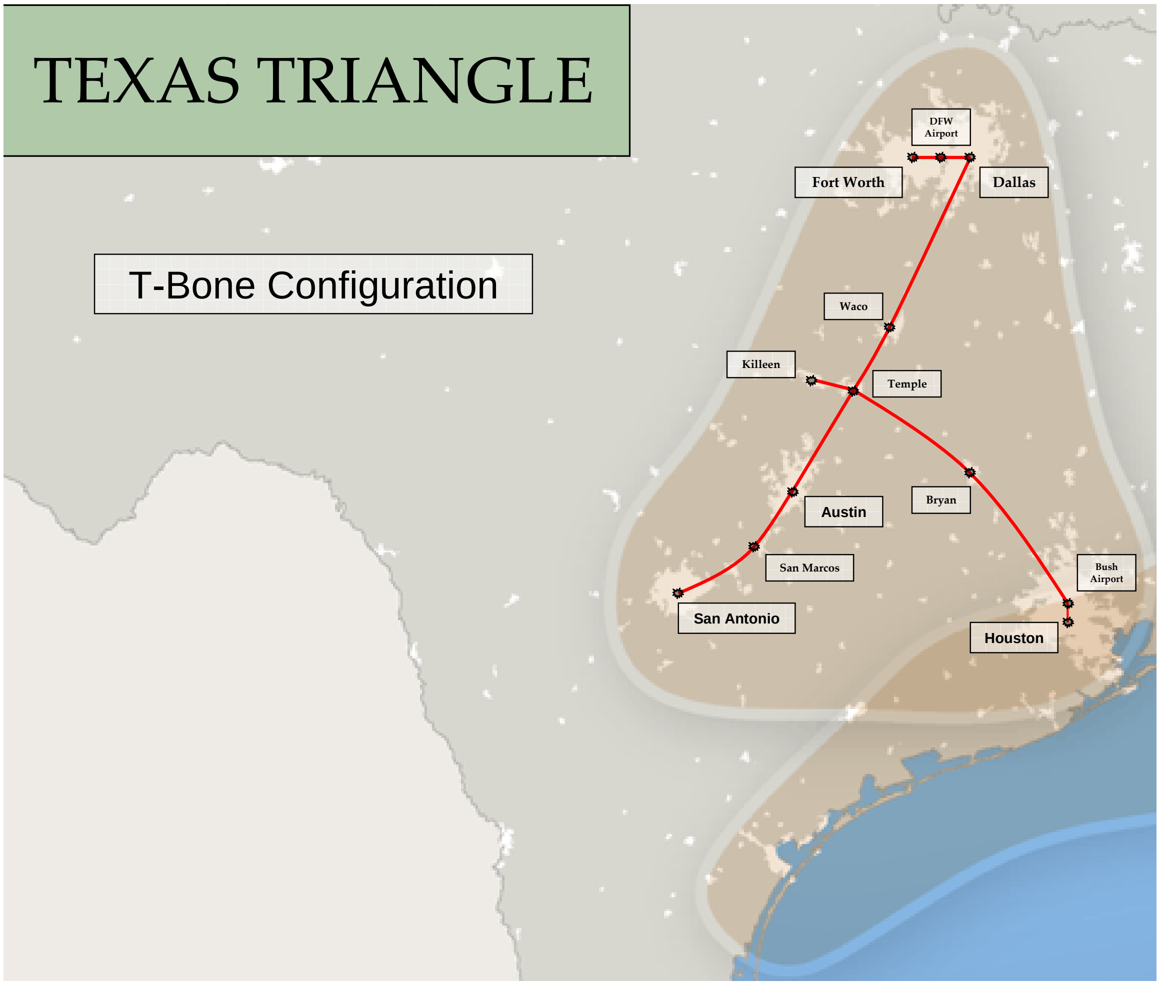
construction of railroads in the 19th century American West."[90] In the United States, there are very few high-speed rail lines and current Amtrack service, with the exception of the new Northeast Acela, can't even compete with highways for door-to-door travel time. Also, there are many populated urban centers within close proximity that would be great candidates for HSGT as identified in a report by the FRA in September of 1997 entitled "High-Speed Ground Transportation for America."

The Shanghai Maglev Train has proven to the world that Maglev technology is mature, safe, and reliable. It has shown critics that Maglev is a workable solution to inter and intra city traffic congestion and can reduce the need for expensive highway improvements. The 30km of the Shanghai maglev came with an overall price tag of US $1.2 billion at 40-60 million/km, but it is predicted that the per-km costs of the extension to Hangzhou will be significantly lower. In fact, costs are estimated to be lower than new German (ICE) HSR per kilometer costs.

In the past, the Texas legislature has shown a commitment to bringing high speed ground transportation to the Texas Triangle. Intergovernmental cooperation and coordination will be required to make a Maglev project feasible in Texas. Reluctance on the part of Texas to use state public funds for a large scale non-highway transportation improvement could begin to change if federal funds become available and increasing air quality problems are not mitigated. Independent studies done for the THSRA and TGV in the mid-90s suggest the Triangle HSGT could attract as much as 25% of current air and

[90] Associated Press. 2007 Jan 10. "Report: China likely to start work on high-speed Beijing-Shanghai train this year."

Figure 19: T-Bone High Speed Corridors



Source: Drawn by Author on Regional Plan Association Map

highway traffic. This amount of ridership would make the operation quickly profitable for a private company to come in and manage operations and maintenance. **Figure 19** shows the T-Bone Configuration first proposed during the TGV bid in 1994. The time savings from a maglev route are displayed in **Figure 20**. A simple calculation of the total cost assuming 20 million per mile yields, 4.3 billion for the Killen-Houston line, and 5.8 billion to build the Dallas-San Antonio line, for a total cost of 10.1 billion dollars.

Figure 20: Trip Time Comparison

Killeen –Houston Airports (~215 Miles) Driving time: 3.9 hrs Maglev (straight):42 min. Maglev (30% off):59 min. HSR (straight): 69 min. HSR (30% off): 103 min.
Dallas- San Antonio (~290miles) Driving time:5.3 hrs Maglev (straight):56 min. Maglev (30% off):79 min. HSR (straight):94 min. HSR (30% off): 139 min.

Maglev speeds: 310 mph / 220 mph
HSR speeds: 186 mph / 125 mph

Source: Transrapid International

During TGV's bid in the 90's Bob Neely, executive director of the THSRA, said "the Dallas-Fort Worth-Houston leg of the system, understandably, would be No. I on the construction list, because that route is the one with the largest revenue potential. The other two legs of a triangle would then be built, to bring San Antonio and Austin into the system." The very first hurdle to receiving federal funding would be to convince the FRA to redraw the South-Central and Gulf Coast High Speed Corridors. Currently, Houston is grouped with New Orleans and Mobile, while DFW/San Antonio are grouped with Oklahoma City and Little Rock. Only designated corridors are eligible for federal funding and the absence of a corridor connecting Houston to the other Texas cities shows a lack of understanding of the Triangle Mega-Region and the opportunities inherent in their greater connectivity. The increased sharing of resources could only strengthen the interdependent Texas Triangle industrial structure. The flow of people and ideas would also contribute to the already present cultural cohesion felt among Texans. Imagine living in Austin and being able to go watch a game, visit a museum, or eat at a restaurant in DFW or Houston within an easy commute of under one hour. High demand for such a service could easily be imagined. As evidenced from European High Speed routes of similar length and condition, intercity air travel between the triangle cities could be virtually eliminated saving airlines and taxpayers in monetizable and non-monetizable (i.e. air pollution, noise, visual impact, etc.) costs. Airlines would benefit from reduced congestion on the runway and a highly efficient feeder system that efficiently and reliably could both collect and disperse people throughout the region. Taxpayers would benefit from reduced highway improvement costs and emissions. Land use impacts from the TTC corridor and future sole reliance on highways could also be eased with a Texas Triangle Maglev Train. The images on the following pages, **Figures 19 and 20**, have the same capacity but far different external costs and effects. The future direction of transportation planning and financing needs greater study and attention in the next few years. Further research should be done as to cost savings of the maglev alternative, specifically in targeted areas such as Congestion and Expansion Savings to DFW International Airport with the Texas Triangle Maglev Train. We are at a crucial point in the evolution of the city to change the direction of destructive human settlement and transportation practices, to wait to long and the momentum may be too great. A maglev system for the Texas Triangle is not just a dream of futuristic high speed trains. All evidence points to it being practical and, considering all external impacts of current air and auto travel, an economically justifiable alternative.

Figure 21: Three-Car Transrapid Maglev Train

Source: Transrapid International

Figure 22: Six-Lane Highway

Source:http://www.southernenvironment.org/cases/scdot_reform/traffic.jpg

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