Financial Feasibility of Maglev Systems in Texas

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16. Abstract
A brief description of different modes possible in the proposed TransTexas Corridor (TTC) is initiated. The main modal alternatives, which include highway, high speed rail, and maglev are discussed in detail. Alternatives for financing the TTC infrastructure are discussed. A detailed financial feasibility of a maglev system along a hypothetical corridor between DFW and San Antonio is conducted for different cost and ridership assumptions. Conclusions are provided regarding viable financing options for building and operating a maglev system along the TTC.

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INTRODUCTION

1.1 Introduction

In January of 2002, Texas Governor Rick Perry announced an aggressive plan to modernize the transportation infrastructure in the state of Texas. According to Governor Perry, "There are four critical transportation problems in Texas: traffic congestion on every major highway, hazardous material moving across our busiest highways and through the middle of our urban areas, air pollution in our industrial centers, and reduced economic activity because of the transportation obstacles businesses face." The project, dubbed the Trans Texas Corridor (TTC), is an innovative approach to transportation in a predominantly rural state.

TxDOT has been charged to find a feasible solution to this complicated task with these criteria:

- Capital, operating, and maintenance costs
- Revenues from the passenger and freight transportation
- Limited access ROW 1,000 to 1,200-feet long
- Separate truck and auto lanes
- High-speed alternative mode of travel for both passengers and freight
- Means of underground utility conveyance such as water pipelines, fiber optic communications lines, and high-voltage electric lines

This portion of the study will focus on the feasibility and evaluation of the passenger and freight traffic within the right-of-way (ROW) of the TTC, using primarily economic factors versus the benefits of each mode to relieve the growing congestion on the current IH-35 corridor from the Dallas/Fort Worth area to Laredo, Texas. The actual length of the corridor has not yet been finalized; therefore the approximate used for this study is 400 miles. Access to the TTC will be limited to prevent extended sprawl along its reach. Cost and exact path of the ROW and the underground utilities are not considered in the scope of this report. The research for this report takes place in the planning stages of the TTC.

1.2 Problem Statement

The existing conditions and the historical background of past attempts to interconnect the state's major urban areas must be taken into consideration to avoid making the same mistakes. Measurements of the infrastructure including interstate corridors, rail corridors, and airways must be acquired to adequately represent current use of the state network and estimate the future needs of the population. Public opinion must ultimately be considered for the survival of the project.

1.3 Existing Conditions

Texas metropolitan areas generally utilize rail freight more than other metropolitan areas. Houston has by far the highest share of rail freight tonnage and per capita tonnage of the top ten U.S metropolitan areas. Dallas-Fort Worth ranks third in rail tonnage per capita and fourth in rail tonnage market share. San Antonio also has a much higher-than-average dependence on rail freight.

Overall the state has a small amount of passenger rail which is served by Amtrak's Texas Eagle. Amtrak reported 246,414 riders in 2000, which was higher than in the last 10 years. The Texas Eagle runs from Chicago to San Antonio each day. The train stops at these major cities: Dallas, Fort Worth, Austin and San Antonio. The train has a travel time of 15 hours between Texarkana and San Antonio. Once in San Antonio, the train joins the Transcontinental Sunset Limited, which travels to Los Angeles, CA. [Cambridge]

Distances between major urban areas in Texas are generally too long for the average drive and very short for commuter flights. In general the mode shifts occur at distances of 150 and 300 miles from auto to rail and from rail to airline respectively. This is the approximate distance between major urban areas in the state. Increased airport security has increased boarding time, and thus the resulting factor has increased the distance of the rail to airline shift. This added propensity for rail cannot be utilized in Texas because of the extreme limitation of its rail network.

1.3.1 North American Free Trade Agreement

On January 1, 1994 the North American Free Trade Agreement (NAFTA) took effect. One of the primary objectives of the agreement was to eliminate tariffs between Canada, Mexico, and the United States on qualifying goods by the year 1998. Originating goods from Canada and Mexico would be tariff free by 2008. Qualifying goods are goods that are wholly the growth, product or manufacture of a Generalized System of Preferences (GSP) designated country. It is likely that both rail and truck freight volumes will expand at a higher-than-average rate in Texas because of the comparatively rapid population growth rate. NAFTA also strives to promote fair competition, increase investment in the territories, protect and enforce intellectual property rights, and establish a framework for further cooperation between the countries.

NAFTA related volumes are likely to increase the truck and rail volumes, since Texas shares more of the Mexican border than any other state and serves as the closest point of entry for 79% of the markets in Mexico, the United States, and Canada. Rail border crossings over an eight year period are shown in Figure 1.1.

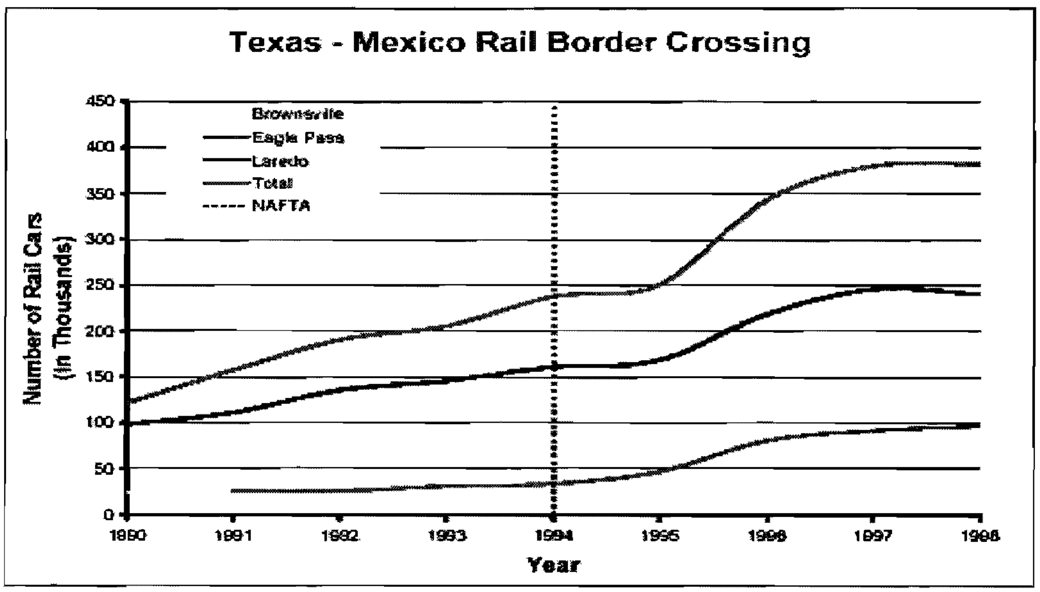

Figure 1.1: Texas-Mexico border crossing in both directions. NAFTA rail traffic data was provided by railroad companies serving areas

1.4 Historical Need

The state of Texas has made efforts to interconnect major cities; some were more successful than others. Amtrak and the Texas Triangle were two of the largest, excluding the original interstate system which was largely a federal effort.

1.4.1 Amtrak

Amtrak started service on May 1, 1971, in New York Penn Station. At that time Amtrak took over most of the passenger rail operations in the United States except for three. At this time, Amtrak is the only railroad that has passenger service in the USA.

Presently, Amtrak serves 500 stations and operates in 46 states. Amtrak owns 3% of the tracks that it operates on. The other tracks are owned by freight railroads. On weekdays, Amtrak operates up to 265 trains per day.

Amtrak was created by the US Congress in 1970 to relieve the freight railroads of passenger operations and to preserve rail passenger service over a national system of designated routes. Amtrak was to be a for-profit government corporation which was granted the right of access to the tracks owned by the freight railroads at incremental cost and with operating priority over freight trains. It has received federal subsidies for many years and is expected to make a profit but has not since it was formed.

The Amtrak Texas Eagle originates in Chicago and runs through North Texas including Dallas and Fort Worth. It connects with the Transcontinental Sunset Limited in San Antonio which also stops in El Paso and Houston.

The Texas Appropriations Committee gave Amtrak a $5.6 million "bridge" loan in 1997 to keep the Texas Eagle operating in Texas. The loan was made in order for Amtrak to work on developing its revenue-generating mail and express business. Amtrak paid back the loan and was expected to improve services in Texas.

However, Amtrak has failed to make a profit and has shown a 12% decrease on the Eagle in ridership from a year ago. The Texas Eagle makes service on time only 21% of the time, which is Amtrak's worst on-time performance rate. Amtrak is requesting $1.2 billion from Congress to keep the failing railroad running through

September 2003. Figure 1.2 is a map of the current Amtrak rail lines in Texas and adjoining states.

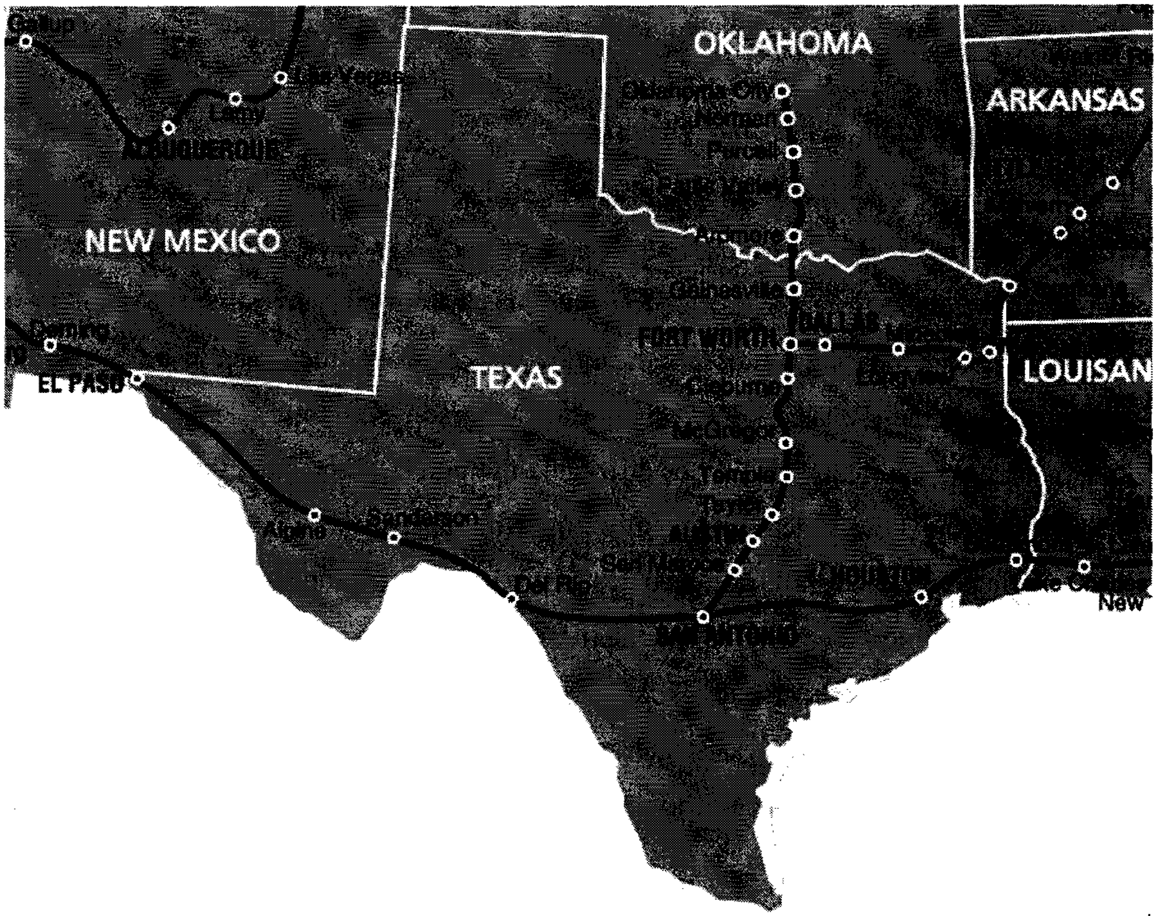

Figure 1.2: Current Amtrak rail lines in Texas and adjoining states

1.4.2 The Texas Triangle

Texas' first high speed rail (HSR) system was to connect Dallas, Houston, and San Antonio and was to be privately financed. The company that won the high-speed rail contract was the Texas Train à Grande Vitesse (TGV) Corporation. The contract was awarded in 1991. Texas TGV Corporation spent over two years of competition against a rival consortium backing the German ICE (Inter-City Express) technology. The contract would have covered the design, construction, ownership and operation of the high-speed rail system.

The State of Texas refused to allow state money to be allocated for HSR and instructed Texas TGV Corporation to secure additional funding from the private sector. The project's price was estimated at $5.6 billion. After many attempts to secure funding, the Texas High Speed Rail Authority (THSRA) granted a one-year extension to secure funding before December 31, 1993.

Texas TGV Corporation was able to get the Warburg Bank of London to issue $200 million in bonds to finance the project. A major drawback to this agreement was that the investors in Europe expected to be paid back from their investment within a two year period by Morrison Knudsen Consulting or their investment would be converted into shares of the Texas TGV Corporation. Morrison Knudsen Consulting made it known that the company would not guarantee the bonds. Therefore, the financing fell through, and the project went past the deadline with no money.

The project's overall estimated cost soared to $6.8 billion. As a result of the high cost and no way to pay for it, representatives of the state decided that the Texas TGV Corporation had failed to fulfill its August 1994 contract obligations and the 50-year HSR development contract was withdrawn. By this time, the Texas TGV Corporation had invested an estimated $40 million.

1.5 Sampling and Measurements

1.5.1 Interstate LOS

The Highway Capacity Manual (HCM) defines the quality of traffic service provided by specific highway facilities under specific traffic demands by means of level of service (LOS). The LOS characterizes the operating conditions on the facility in terms of traffic performance measures related to speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience. The levels of service range from LOS-A, which is the least congested, to LOS-F, which is the most congested and is depicted in Table 1.1. The specific definitions of LOS differ by facility type. The HCM presents a more thorough discussion of the level of service concept, also defined in the TRB.

LOS	GENERAL OPERATING CONDITIONS
A	Free flow
B	Reasonably free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

Table 1.1: Conceptual definition of LOS is based on observation of flow characteristics

Multilane Highways may be treated similar to freeways if major crossroads are infrequent, or if many of the crossroads are grade separated, and if adjacent development is sparse so as to generate little interference. Even on those highways where such interference is currently only marginal, the designer should consider the possibility that by the design year the interference may be extensive unless access to the highway is well managed. In most cases, the designer should assume that extensive crossroad and business improvements are likely over the design life of the facility.

1.5.2 Interstate Annual Average Daily Traffic

Highway design should be considered based on the traffic volumes and characteristics to be served. Traffic volumes indicate the need for the improvement and directly affect the geometric design features, such as number of lanes, widths, alignments, and grades. Information on traffic volumes serves to establish the loads for the geometric highway design.

The data collected by State or local agencies include traffic volumes for days of the year and time of the day, as well as the distribution of vehicles by type and weight. The data also include information on trends from which the designer may estimate the traffic to be expected in the future. Traffic data for a road or section of road are generally available or can be obtained from field studies.

The current AADT volume for a highway is determined when continuous traffic counts are available. When only periodic counts are taken, the AADT volume can be estimated by adjusting the periodic counts according to such factors as the season, month, or day of week.

However, the direct use of AADT volume in the geometric design of highways is not appropriate except for local and collector roads with relatively low volumes because it does not indicate traffic volume variations occurring during the various months of the year, days of the week, and hours of the day. The amount by which the volume of an average day is exceeded on certain days is appreciable and varied. At typical rural locations, the volume on certain days may be double the AADT. Thus, a highway designed for the traffic on an average day would be required to carry a volume greater than the design volume for a considerable portion of the year, and on many days the volume carried would be much greater than the design volume.

Trucks occupy more roadway space and have a greater effect on highway traffic operation than do passenger vehicles. Trucks are normally defined as those vehicles having manufacturer's gross vehicle weight ratings of 9,000 lb or more and having dual tires on at least one rear axle.

The overall effect on traffic operation as well as on pavement condition of one truck is often equivalent to several passenger cars. Thus, the larger the proportion of trucks in a traffic stream, the greater the traffic demand and the greater the highway capacity needed. For the geometric design of a highway, it is essential to have traffic data on vehicles in the truck class. Trucks can be modeled as percentages of total traffic on a given highway.

Texas has become the nation's second most populated state and added nearly as many new residents over the past decade as California. This high growth rate is likely to continue in the decades to come and therefore projections play an important role.

Projections indicate that Texas will continue to grow at rates well above the national average. By 2025, Texas is likely to add another 55 percent to its population to reach more than 32 million. The U.S. Census Bureau expects Texas to grow 60% faster than the rest nation from 2000 to 2025. AADT Projections used in this study are based on 3% annual growth, and can be seen in Table 1.2. The table also indicates the Directional Design Hourly Volume (DDHV) for the current year and the projections for 2020.

CITIES	2000 AADT	2000 DDHV	2020 DDHV
Laredo to SA	24960	1373	2479
SA to Austin	54590	3002	5423
Austin to Hillsboro	44550	2450	4425
Hillsboro to Dallas	26000	1430	2583
Hillsboro to FW	23000	1265	2285

Table 1.2: Projected traffic volumes for IH-35 - annual average daily traffic and direction design hourly volumes [TxDOT]

1.5.3 Rail Service

The AADT for freight cars that move from Laredo to DFW is assumed to be 6 to 8 cars per day from raw data for a 4 day period from a Union Pacific daily dispatch for a typical train. The observed trains moved an average of 65 cars at an average of 68 gross tons per car. The average overall length for a train was 5700 ft.

The Table 1.3 describes the typical travel times between cities in the Texas Triangle for HSR as projected by Charles River Associates, Inc.

FROM/TO	AUSTIN	DFW	HOUSTON	SAN ANTONIO
Austin	0	88	74	42
DFW	88	0	101	118
Houston	74	101	0	116
San Antonio	42	118	116	0

Table 1.3: Travel time in minutes from central business district (CBD) to CBD by HSR [CRA]

1.5.4 Airline Traffic

With the addition of HSR in Texas there will be a decrease in air ridership. Projections on air ridership are needed in order to estimate the amount of riders that will be diverted to the TTC's Maglev or HSR system.

The Table 1.4 describes air connect trips between DFW Airport and other Texas cities if HSR was absent. Charles River Associates projected the growth rates using Federal Aviation Administration (FAA) forecasts: Fiscal Years 1993-2004 and the assistance of Stanford Rederer, President of Aviation Planning and finance, Inc. Washington, D.C. Table 1.4 shows the projected flights.

CITIES	AVERAGE PLANES PER DAY	PASSENGERS PER YEAR (2000)	PASSENGERS PER YEAR(2020)
Laredo	16	70,234	126,850
San Antonio	129	3,647,094	6,587,057
Austin	240	7,000,000	12,642,779
DFW airport	2222	60,687,122	109,607,693
Love field	679	7,077,549	12,782,841
Total	**3293**	**78,481,999**	**141,747,220**

Table 1.4: Flights and total passengers leaving from each city

The largest number of diverted travelers to HSR will come from business air travelers. Overall HSR is expected to divert 25% of all travel between these cities.

Air travel is expected to increase between the TTC cities at 3% per year. The AADT for this corridor is approximately 3300 planes per day. The corridor is made up of the following airports: Austin-Bergstrom International, DFW International Airport, Dallas Love Field Airport, and San Antonio International Airport. Approximately 75 million passengers flew through these airports in 2000. Figure 1.3 depicts the projected airport trios in the proposed corridor.

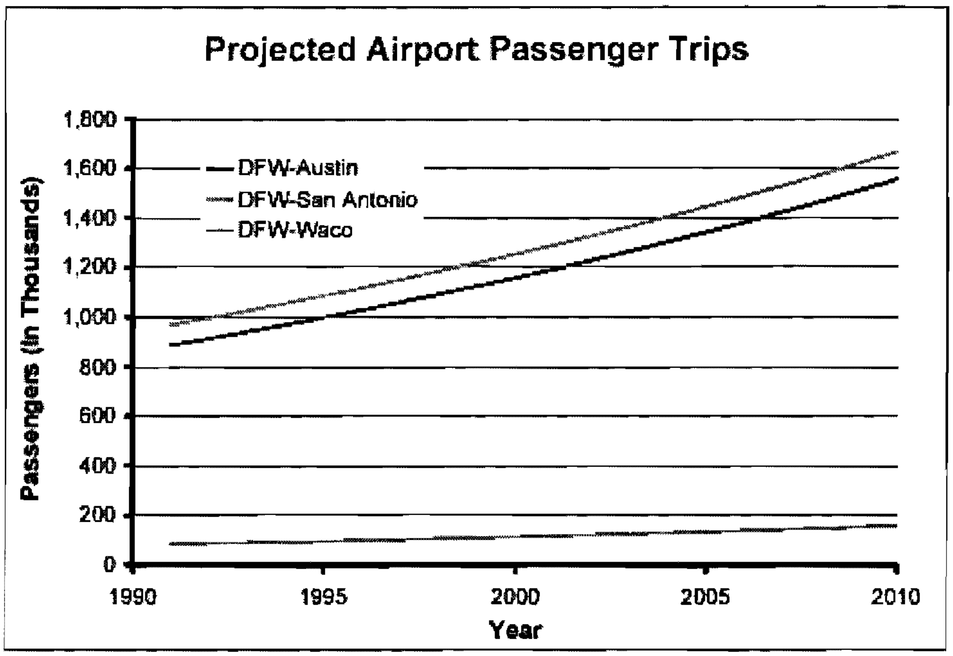

Figure 1.3: Projected trips with the study area [CRA]

1.6 Problem Consequences

The existing interstate system was designed to carry a finite number of heavy trucks during its lifespan. The exponential increase in the volume of truck traffic since the enactment of NAFTA, while economically beneficial to Texas, has accelerated the deterioration of its highway network. When the actual number of trucks that pass over the pavement greatly exceeds the number expected, the end result is a shorter lifespan of the roadway. The rehabilitation and replacement of these affected highways are on the horizon for TxDOT.

Congestion in urban areas increases as a direct result of the bulkier and slow moving trucks. Many of these trucks carry hazardous materials near densely populated areas, thus creating the potential for disaster. The size differential between trucks and automobiles also hinders visibility. The number of trucks entering Texas cannot legally be curbed, and is increasing much faster than predicted, so the problem will only compound.

With the existing problems of the interstate system increasing exponentially, a new system is needed more than ever. Rehabilitation and replacement of the existing roadways won't solve the problems at hand. Increased capacity, decreased congestion, higher speeds, and safer driving conditions can only be accomplished by a new system that can accommodate the needs of the traveling public. Doing nothing at this point is not an option.

1-7 Funding

A project of this scale will require a variety of sources to draw funding. Several obvious sources were named by Governor Perry, but inventive sources should also be reviewed.

1.7.1 Exclusive Development Agreement

The state will make a contract with a group to do all or a portion of the following: design, construct, operate, maintain, or finance the transportation project. The state will conduct a needs assessment for the project and will submit a request for proposals (RFP) from the competing groups on how they will complete the project. The state will then select the group that best accommodates the RFP.

1.7.2 Toll Equity

Toll equity makes projects more attractive for private investors by sharing toll revenue and will supplement project funds to help pay for the corridor.

1.7.3 Regional Mobility Authority

Regional Mobility Authority creates partnerships with urban areas to finance, build, operate, and maintain new toll projects, which will complement and support the corridor.

1.7.4 Texas Mobility Fund

Texas Transportation Commission is allowed to issue bonds to accelerate construction on major highway projects. Monies raised from these bonds can be used to finance road construction on state maintained highways, publicly owned toll roads and other public transportation projects. Funds for the Texas Mobility Fund will be provided by the state legislature.

1.7.5 Lease

Areas along the corridor may be leased to private companies to provide services such as fuel, lodging, and restaurants. The property could be leased at a premium rate, because the proprietors of these establishments would have a local monopoly.

1.7.6 Parcel Services

Tri-State II high-speed feasibility study produced key factors in the over all make up of the system. Fares, on-board services (OBS), and parcel services each contribute to the revenue of the system. OBS supply the food and drinks on the train and is expected to cover the full cost of operations including contractor's profit. Parcel services include but are not limited to the following: bank clearings, legal documents, organs, tissues and other bio-medical products, broadcasting and media equipment, convention materials, production parts, and other time sensitive items.

These packages can be shipped in what is known as a "Brute" at a size of 6 feet by 6 feet by 3 feet, which holds on average 432 parcels. Price per parcel is $30. There can be four parcels per cubic foot with 20% capacity. Generally 10% of gross revenue is reported as profit. [MnDOT] Table 1.5 shows the revenue for the proposed corridor given 2020 volume.

NUMBER OF PARCELS PER BRUTE	NUMBER OF RAIL CARS	PRICE PER PARCEL	REVENUE PER TRAIN
432	6	$30.00	$77,760.00

Table 1.5: Revenue for proposed corridor by shipping with the brute system [MnDOT]

1-8 Environmental Impact

The Environmental Protection Agency (EPA) has established the National Ambient Air Quality Standards (NAAQS) for criteria pollutants under the Clean Air Act 1990 and establishes an adequate margin of safety to protect the public health.

Tarrant and Dallas counties are the only non-attainment counties that are located within the study corridor. Both counties are non-attainment due to the high volumes of ozone. [Parsons] Ozone pollution is a key component of smog and is typically at its highest levels during the daytime hours and summer months. Ozone is not emitted directly into the air; instead it is formed by sunlight heating primarily Oxides of Nitrogen (NOx) and Volatile Organic Compound (VOC) emissions. NOx is produced almost entirely as a by-product of high-temperature combustion.

Common sources of NOx include automobiles, trucks, and marine vessels, construction equipment, power generation, industrial processes, and natural gas furnaces. VOC includes many organic chemicals that vaporize easily, such as those found in gasoline and solvents. They are emitted from several sources, including gasoline stations, motor vehicles, airplanes, trains, boats, petroleum storage tanks, and oil refineries.

The concentration of ozone in the air is determined by the amount of reactants, in addition to weather and climatic factors. A combination of intense sunlight, warm temperatures, stagnant high-pressure weather systems, and low wind speeds cause ozone to accumulate in harmful amounts.

1.8.1 Highway

In May 2001, the 77th Texas Legislature established the Texas Emission Reduction Plan (TERP), which is the latest effort to help reduce air pollution in Texas. TERP will administer a program of grants and incentives for improving air quality throughout the state including on the highways. The program may pay incremental costs on the purchase or lease of "clean" heavy duty vehicles as well as light duty vehicles that meet stablished emissions levels. Its funds may also be used to support the repowering of on-road and off-road diesel vehicles with cleaner engines and assist in establishing infrastructure for qualifying alternative fuels. [TxDOT]

In the future, TxDOT plans to further reduce its own emissions by using hybrid electric passenger vehicles, dedicated alternative fuel vehicles, ultra low sulfur diesel, and emerging technologies for off-road equipment. [TxDOT]

1.8.2 High Speed Rail

Three factors that are typically considered when looking at HSR are noise pollution, air pollution, and energy consumption.

Noise is sound which is considered undesirable for a variety of reasons, but usually because of intensity levels. The decibel (dB) is the standard unit used to measure noise, and the A-weighted decibel (dBA) is used to describe the effect of sound on a human. When looking at HSR the sources of noise are wheel to rail noise, aerodynamic noise and electrical noise. Wheel noise can be modeled using 30-log Speed. Aerodynamic noise can be calculated using 60-log Speed. [Regional Science]

Noise pollution from high-speed rail will generally lower property values in some locations as well as loss of sleep, lower productivity, psychological discomfort and annoyance for the residents living close to the railway tracks. While it is impossible to put a price tag on any of these factors, they must be considered when placing a track near residential areas. [Regional Science]

Since high-speed rail is electrically powered it can be assumed that there is practically no mobile pollution source. The actual pollution will be reflected in the increased electrical energy demand by HSR at point pollution sources across the state.

Power plants will have to generate more electricity in order to meet this demand. Trying to figure out which of the 135 electrical power plants will supply the power will be difficult, since Texas receives power from nuclear, natural gas, coal and lignite, and water flow. Each power source employed by the electrical plants has very different environmental impacts, and all are under intense government regulation. [Regional Science]

1.8.3 Maglev

Similar to HSR, the environmental aspects impacted by Maglev are noise pollution, air pollution, and energy consumption.

All current mass transit trains produce three primary categories of noise: motor, rolling, and aerodynamic. The first two types of noise are eliminated with the use of a Maglev train. The Maglev train uses an electric motor which produces no noise pollution. There is no wheel contact with a rail therefore there is no rolling noise. The only noise produced by Maglev is aerodynamic noise and is only significant when it reaches 125 mph and higher speeds. [Parsons] The Transrapid Maglev train peaks at 98 dBA at a distance from the guideway of 82 feet and speed of the train at 270 mph. Even at a speed of 155 mph the Maglev train is quieter then a typical commuter train passing at 50 mph. Figure 1.4 compares the A weighted decibel rating of Maglev to other high speed trains.

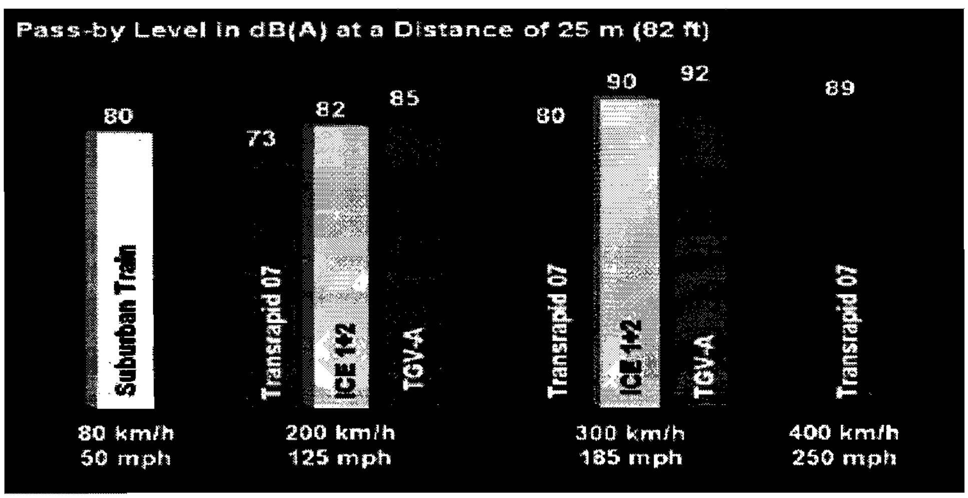

Figure 1.4: Noise levels for various technologies

All of this noise is produced by the aerodynamic design of the train itself. The trains themselves create very little noise, less then freeways and airports, even during the accelerating and braking of the train.[1] Since the train runs on electricity it lacks the noise produced by an engine, therefore when approaching a town at a moderate speed, noise produced is barely louder then the normal noise level.

Maglev is powered by substations connected to the state's electrical power grid. The substations receive power from a power plant which turns the mobile pollution sources of cars into a point source. Reducing the number of cars on the road, and therefore pollution, is a major goal of implementing Maglev technology. [Parsons] The train also does very little damage to the surrounding environment. The trains are propelled by electricity, not by burning fuel, and so they emit no harmful pollutants as they pass. The Maglev train is adaptable to any area that it may pass through, so there is no need for much of the earthwork or grade crossings that is often needed with conventional trains. Maglev trains are also more energy efficient, requiring fifty percent less energy per person than an automobile and seventy percent less than an airplane.

Critics have questioned the efficiency of Maglevs with respect to noise, environmental degradation and safety. In answer to these concerns, Maglev trains produce small amounts of pollution and are one of the safest modes of transportation. According to the California High-Speed Rail Authority (CHSRA) there is almost no danger in this respect. Conventional trains are generally regarded as the safest form of transportation available today and Maglev trains are even safer than traditional trains. Magnetic levitation technology in Germany is estimated to be seven hundred times safer then auto travel and twenty times safer than air travel. The original type of support, propulsion, braking and guidance system, enclosing the vehicle on the guide way all contribute to the virtual impossibility of ordinary derailment, even in the event of total power failure. Also since the propulsion system is run from a control center and trains are isolated on directional lines, collisions between two trains are almost impossible.

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[1] Hanson, California High Speed Rail Authority (CHSRA)

1.9 Public Opinion

The public opinion of a mode can make or break a project. Each mode will have its own intended set of customers to win over.

1.9.1 Highways

To maximize effectiveness of the environmental decision-making process, the public along with TxDOT and the resource agencies must create new partnerships and depart from traditional methods of planning, coordination and review. Ecosystem mitigation and compensation should be important parts of this approach. The public, TxDOT and resource agencies must look for "win-win" solutions that work toward fulfilling objectives that benefit the corridor and the environment and strive to avoid or minimize adverse environmental impacts. Databases, existing inventories and other sources are used to identify tracts of land suitable for acquisition or conservation. This will compensate for unavoidable impacts resulting from the corridor, according to TxDOT. The TTC project will need to promote:

- Protection, conservation and restoration of important natural and cultural resources.
- Wise management and sound stewardship of natural, biological and cultural resources, while providing a range of goods and services such as recreation and transportation.
- Ecologically sustainable development for current and future generations.

Objectives of the ecosystem and cultural resources must:

- Establish collaborative interagency relationships to promote healthy ecosystems preserve historic refuges, support safe and efficient multi-modal, multi-use transportation systems and encourage wise economic growth while recognizing Texas' social and cultural diversity.
- Focus agency programs to establish collaborative approaches that enhance and protect natural and cultural resources while providing better transportation options for the public.

•Emphasize through public outreach how the successful integration of ecological, cultural and socio-economic values makes Texas a better place to live and work.

1.9.2 High Speed Rail

As Texas highways continue to get more congested, HSR will have to be presented as an alternative to reduce the over crowded roadways and pollution we face today. However, in order for HSR to receive funding it needs to gain public support in the state of Texas.

Some reasons why people commute by automobile are: people value their time. People find it very difficult to wait for a bus compared with waiting in stop and go traffic. Rapid transit is not viewed as rapid and is not a cost effective alternative. Typically rail transit averages 22 mph and may only have a top speed of 55 mph. The public will have to be convinced that HSR will decrease their travel time considerably for them to switch modes. Both travel time and out of pocket costs weigh the most to the over all acceptance of the new system. A trip through the proposed corridor of 400 miles gives the passenger two polar options, plane or auto. The current out of pocket cost runs approximately $92 for a one-way trip by plane. The travel time for a car is over five hours. With these two factors HSR will need to stress the point that by traveling on the alternative mode they can arrive much faster than in their car and at a lower cost then flying. [Slater]

Special interest group, such as DERAIL (Demanding Ethics, Responsibility, and Accountability in Legislation) lobbied in strong opposition to the Texas TGV project. The resistance was founded on classical NIMBY (Not In My Back Yard) beliefs. Noise and infrastructure is believed to drop property values and hurt farming and ranching. Mitigation is expected in any large scale project involving reclaiming land by the state. The Texas TGV Environmental Impact Study (EIS) included over 4,000 public participants and provided a total of 15,000 separate comments at the 39 different public hearings. This over whelming response shows the need to involve the public and interest groups in all steps of this project. [Perl]

1.9.3 Maglev

The general public knows very little about Maglev or how it works. Their understanding of it is limited because Maglev is a new technology. The major difference between Maglev and rail trains is the propulsion and guideway systems. A misconception of the Maglev propulsion system is that it emits high concentrations of magnetic radiation. This is not true. It has been documented by the FRA that the magnetic radiation experienced by the riders on a Maglev train is similar in magnitude to the radiation emitted by the earth. Figure 1.5 shows a comparison of magnetic fields of common items.

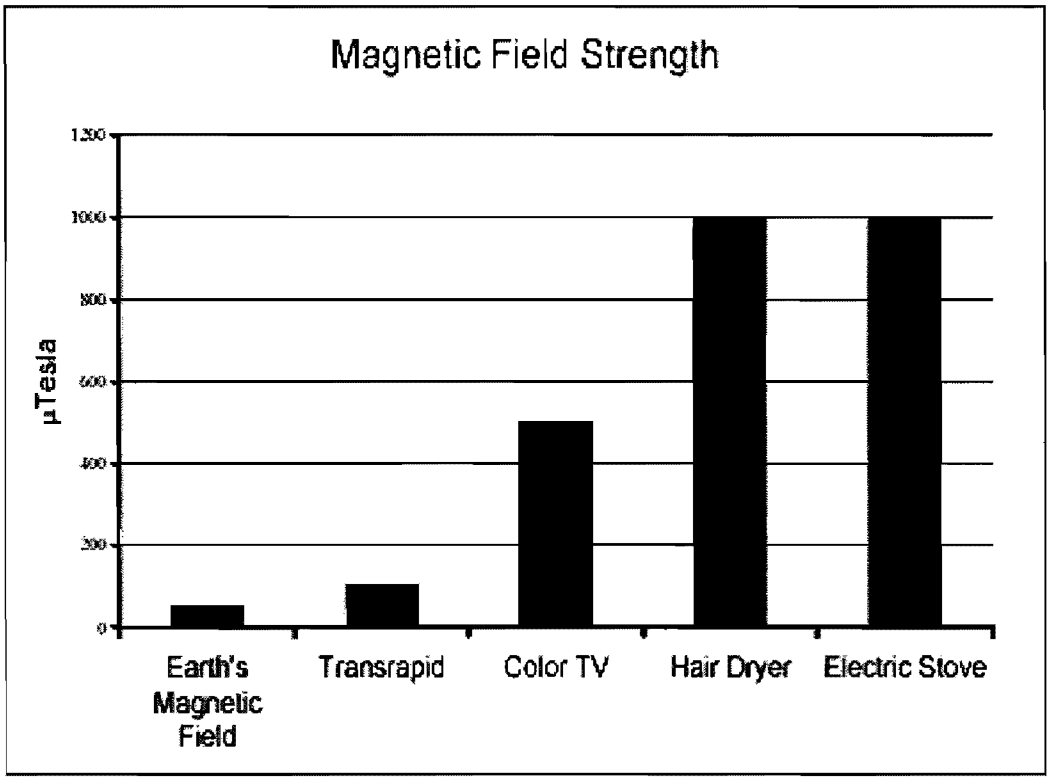

Figure 1.5: Comparison of ambient magnetic field strength between a Maglev train and common household items [Transrapid]

1.10 Right-of-Way Costs

TxDOT plans to purchase property for all components of the corridor as soon as possible so that the land is preserved for future generations of the project. The ROW will be acquired through public private investment, which includes financing by utilities, railroads, developers, and landowners. Its cost is based on the assumption that the corridor will be a controlled access facility on a new location. The estimate is also based on the assumption that no land will be purchased near major metropolitan areas. At least 146 acres per mile of ROW will be required for the 1,200 foot corridor at a cost range of $20,000 to $65,000 an acre for acquisition. TX DOT has estimated ROW costs for the entire corridor to be anywhere from $11.7 billion to $38 billion. ROW costs will not be included in this preliminary study of the corridor, as it will be fixed relative to the corridor design.

1.11 Future Conditions

1.11.1 Highways

Texas has become the nation's second most populated state and added nearly as many new residents over the past decade as California. This high growth rate is likely to continue in the decades to come and therefore projections play an important role.

Projections indicate that Texas will continue to grow at rates well above the national average. By 2025, Texas is likely to add another 55 percent to its population to reach more than 32 million. The U.S. Census Bureau, projects that Texas will grow 60 percent faster than rest of the nation from 2000 to 2025. Fig 1.6 gives an indication of the increasing trend in the US in terms of Vehicle Miles Traveled (VMT).

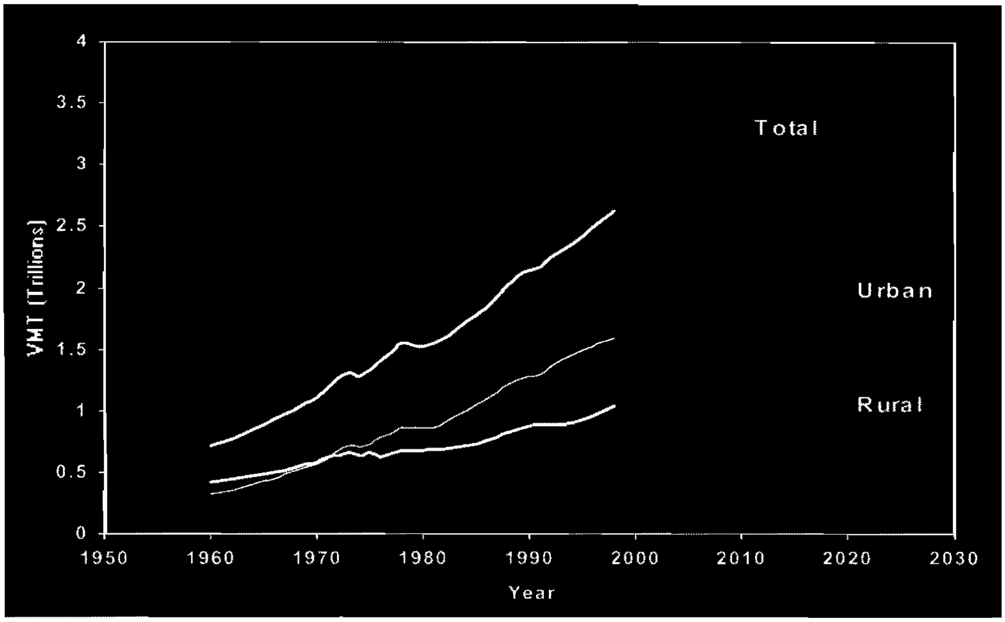

Figure 1.6: Annual VMT (Trillions)

1.11.2 Rail Freight

Future rail freight traffic in the state of Texas is expected to increase due to increasing populations and the growth in freight associated with NAFTA. However, for decades rail freight has lost considerable market share to highway freight. Unless this trend changes traffic congestion in the cities and on the highways will continue to get worse. Rail freight traffic is expected to increase by one-half through 2020, with losses to highway freight of 0.74% per year. This means that still more trucks will be moving freight volume and Texas highways will be more congested.

1.12 Related Needs

Exact locations and degree of use for each need may vary with location and amount of traffic and are not directly in the scope of this report. These suggestions are listed to aide in future consideration for the corridor.

1.12.1 Toll Systems

There are several toll options including actuated and direct contact (traditional) billing. Additionally, there are the two basic payment schemes "pay as you go" and "payment upfront." Pay as you go requires the traveler to slow down to pay an attendant at each junction and requires several payments during the trip. Payment upfront requires the traveler to pay for the entire length of the toll way. This system would likely prove cumbersome for such an extensive network. A benefit that can be applied to both systems is the prospect of speed enforcement by using the travel time between booths.

1.12.2 Highway Traffic Management

A state of the art transportation facility will require an equally advanced management system. Intelligent Transportation System (ITS) has been in use around the state for years, and the most reliable and cost effective parts of the system.

Dynamic message signs (DMS) allow drivers to use real-time information to make informed travel choices and help improve the traffic flow for all motorists. They may also be used to address traffic concerns, including recurring congestion, accidents, weather, and maintenance work. A DMS can be used in conjunction with Lane Control Signals. These are rectangular signals mounted above each lane displaying symbols to help guide motorists into the appropriate lanes on the freeways.

Highly reflective fixed signs will also be needed to complement the advanced transportation computer network. These signs can be shared with DMS to warn of hazards for particular routes. Cameras located along the corridor can locate or verify incidents. This tool provides a quicker response time for emergency personnel or courtesy patrol.

Limited access of the corridor will require several accommodations to protect and aide stranded motorists. Emergency call boxes will be needed along all auto and truck lanes in groups of four for each direction and both types. Courtesy patrols will also be needed in higher numbers than on traditional Interstates.

Hazardous Materials Response Teams will be needed in the event of an incident or spill. Hazardous materials are chemical or biological substances, which if released can pose a threat to public health. These chemicals are used in industry, agriculture, medicine, research, and consumer goods. Hazardous materials come in many forms such as explosives, flammable and combustible substances, poisons, and radioactive materials. These substances are most often released as a result of transportation accidents. Hazardous materials are transported daily on our roadways and railways, so any area is considered vulnerable to an accident. According to OHMS, the isolated nature of the TTC will require teams that can respond quickly to the scene to contain the damage to be stationed along the corridor.

1.12.3 Connections

The limited access nature of the TTC requires spurs to the main corridors; see Figure 1.7. Any onramps, transit stations, or freight yards should be located along these spurs so that the ingress-egress time to reach the corridor does not increase to that of airports. The locations of these spurs should be limited, but politics may require more than necessary to give some benefit to towns along the corridor.

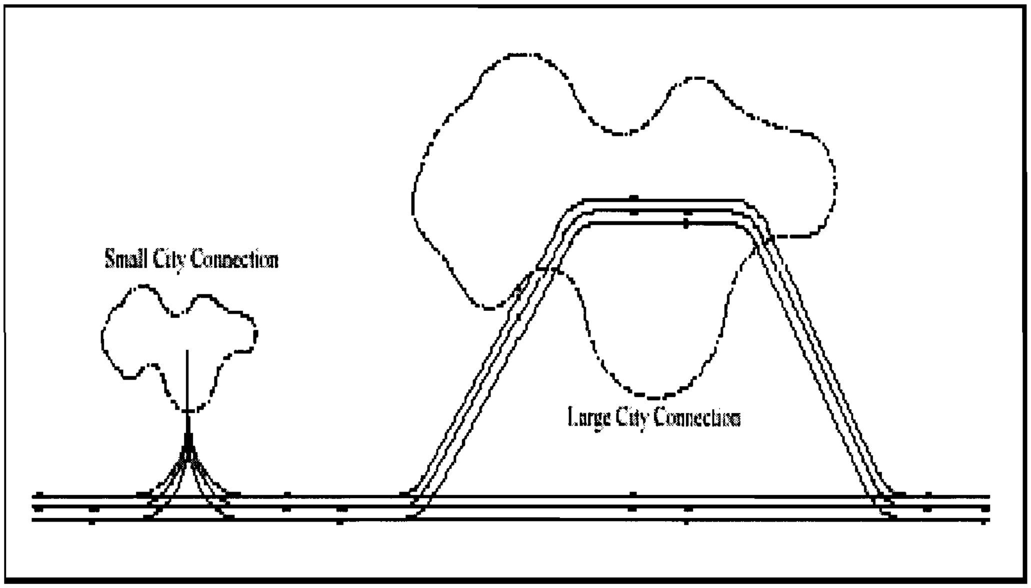

Figure 1.7: Conceptual ingress and egress to cities along the TTC

1.12.4 Traveling Accommodations

Most drivers require time to rest during long trips, federal law mandates rest for professional drivers. Facilities including rest stops, refueling stations, hotels, and restaurants must be made available along the highway portion of the corridor. These facilities should also be combined to central locations at intervals along the corridor. They may require additional land to be purchased and can then be leased to private companies as an additional source of revenue. The contracts will be very lucrative because the hotels and restaurants will have a localized monopoly on the customers.

CHAPTER 2
DESCRIPTION OF ALTERNATIVES

2.1 Highway

2.1.1 Cost and Design

The estimated corridor costs are based on a typical section of the highway and the projected number of interchanges and bridge structures. Typical sections will vary over the length of the corridor, which may result in a different cost per mile. Average unit bid data for pavement, grade separated bridge structures, and interchanges was used for the estimate. Items such as signing, striping, landscaping and drainage are included as a percentage of the total cost.

Pavement cost for the proposed truck traffic portion of the corridor has been estimated by TxDOT to be $3,105,000 per centerline mile. This will consist of two 42 feet wide roadway sections, each comprised of two 13 foot lanes, 4 foot inside shoulders, and 12 foot outside shoulders. According to this estimate, pavement costs are approximately $63.00 per square yard for the chosen design depth. Thus, according to TxDOT, the cost per lane mile for the designated truck lanes is $480,000.

The proposed passenger vehicle roadway will consist of two 56 feet sections comprised of three 12 foot lanes, and 10 foot inside and outside shoulders, for a pavement cost of $1,093,000 per centerline mile. This estimate suggests that the pavement will cost $16.63 per square yard for the chosen design depth, resulting in $117,100 per lane mile.

2.2 High Speed Rail

2.2.1 Cost

HSR will run 150 mph with two power cars and six passenger cars. Amtrak currently runs the same configuration in the Boston-DC corridor. There are 50 seats per car and therefore 300 seats per train. The estimated cost per car is $30 million. The estimated cost per seat is $70,000, where as the estimated airplane seat cost $350,000, as per the costs given by Tristate.

The average stopping distance of a nine car train is 6.25 miles with headway of 5 miles. The capacity of a single rail line is 58 trains over the 400 miles of track connecting Dallas to Laredo. Charles River Associates estimated for the Texas TGV project that in 2010, the corridors would carry 14 million people and generate $618 million in annual revenues. The diversion of traffic from other modes was found to be 11 percent from auto and 61 percent from air. These figures show the market potential for high-speed rail in Texas.[1]

High-speed rail costs are in large debate within the United States because it has yet to be developed here. The figures provide in Figure 2.1 show a comparison between states that are currently reviewing high-speed rail as a mode alternative. The total cost includes initial investment, operating and maintenance expenses, and continuing investments.

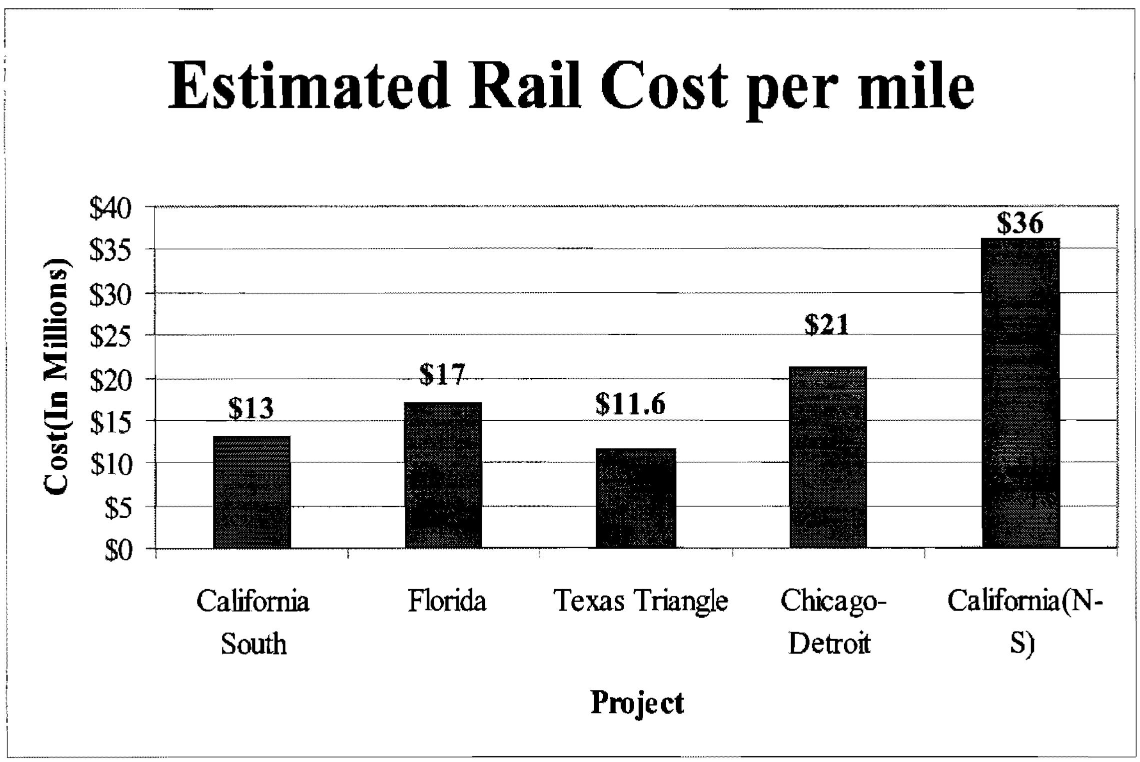

Figure 2.1: High Speed Rail projects in America

[1] Perl, California Rail Authority

The costs for completed rail projects are as follows. Taiwan, Hamburg-Wurzburg, and TGV Est. are mostly surface rail. Table 2.1 depicts costs for completed HSR projects. The Korean rail is 46% tunnel and 26% viaducts. The ROW for this study is considered mostly surface.

NO	HSR PROJECTS	ROUTE LENGTH (MILES)	COST PER ROUTE MILE (MILLIONS)	TOTAL COST (BILLIONS)
1	Taiwan High Speed	215	$129	$28
2	Hamburg - Wurzburg	NA	$97	NA
3	TGV Est. Phase 1, France	194	$23	$4
4	Seoul-Pusan, Korea	258	$77	$20

Table 2.1: HSR projects around the world

Table 2.2 lists capital costs estimated for the construction of the Tri-State II system. Track work is the highest cost factor in estimating the price per mile for the high-speed rail system. These figures estimate for a 400 mile track at $6 million per mile to be $2.5 billion for track work. It is less expensive when constructing multiple track lanes due to the shared roadbed cost.

NO.	ITEM	UNIT	UNIT COST (MILLIONS)
1	Rolling Stock	Per car	$ 2.7
2	Track Work	Per mile	$ 4.6
3	Stations I. Full design II. Terminal	 Each Each	 $ 1.6 $ 3.3
4	Signal System Installation	Per mile	$ 1.6

Table 2.2: Capital costs for Tri-State II project

Table 2.3 was created by the Tri-State II to show the cost of running the high-speed system on a daily or per mile basis. An additional cost is accrued in the number of staffed stations. They state that to require a station to be staffed there would need to be a minimum of 100,000 passengers per year that would use the facilities.

NO	ITEM	UNIT	COST PER UNIT
1	Crew Cost	Shifts/day * rates/hr * multiplier	2.5
2	On Board Services	Train Mile	$2.63
3	Track & ROW Maintenance	Train Mile	$7.38
4	Train Equipment Maintenance	Train Mile	$6.25
5	Fuel & Energy	Train Mile	$3.05
6	Station Personnel	-	$410,000
7	Sales / Marketing	Passenger	$4.76
8	Insurance	Passenger Miles	$0.02
9	Administration	Costs Except Insurance	10%

Table 2.3: O&M costs for the Tri-State II project

2.2.2 Design

The design of the high-speed rail consists of several components from the foundation to the electrification. The following is a basic description of the construction of these elements that are considered in the cost estimate for the design.

2.2.3 Foundation

The fundamental part of the rail system is its foundation. The sub-structure consists of three main elements: the formation, the sub-ballast and the ballast. These can be constructed at ground level "at grade" or it can be an embankment or cutting. A camber is provided in both cases to ensure adequate runoff to the drains provided on each side of the line. [Trainweb]

2.2.4 Ballast

The ballast is made of granite stones, rough in shape to provide locking of the stones to reduce movement. Loads on the rails can be as high as 55 tons for passenger rail traffic. The ballast is laid to a depth of 9 to 12 inches and weighs about 2700 lbs per cubic yard. The track form consists of two steel rails, secured on sleepers, or crossties, so as to keep the rails at the correct distance apart and capable of supporting the weight of trains.

2.2.5 Sleepers

There are various types of sleepers and methods of securing the rails to them. Wooden sleepers are normally spaced at 25 to 30 inch intervals and will last up to 25 years. Concrete is the most popular of the new types of sleepers. Concrete sleepers are much heavier than wooden ones, so they resist movement better. They work well under most conditions but there are some railways that have found that they do not perform well under the loads of heavy haul freight trains. They offer less flexibility and are alleged to crack more easily under heavy loads with stiff ballast. This will not be a problem due to the inability to move heavy freight at high speeds on this design. They also have the disadvantage that they cannot be cut to size for turnouts and special track work. A concrete sleeper can weighs up to 700 lbs compared with a wooden sleeper that weighs about 225 lbs. Installing and securing the rails in tension minimizes expansion. If the tension is adjusted to the correct level, equivalent to a suitable rail temperature level, expansion joints are not normally needed. Special joints to allow rail adjustments are provided at suitable locations. Rail tends to creep in the main direction of travel so "rail anchors", or "anti-creepers", are installed at intervals along the track. They are fitted under the rail against a base plate to act as a stop against movement. [Trainweb]

The spacing of concrete sleepers is about 25% greater than wooden sleepers. Concrete sleepers are the best for this region due to the large temperature fluctuation. Steel sleepers where considered but found to be suitable only where speeds are 100 mph or less. Sleepers amount to about 2400 per mile of track. [Trainweb] Figure 2.2 illustrate a typical cross section of a double track HSR line.

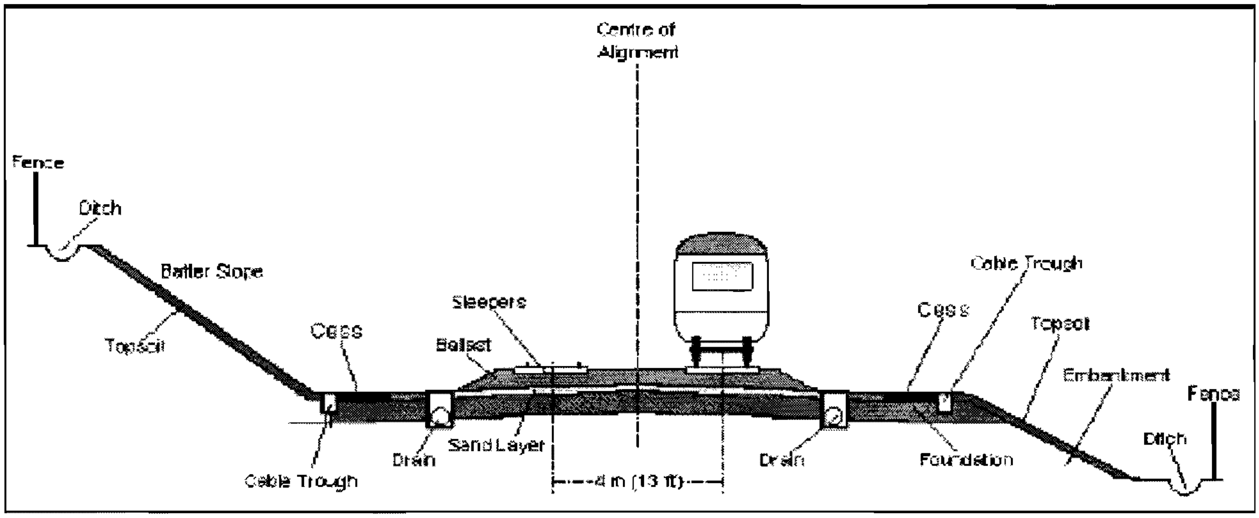

Figure 2.2: Cross section of double track railway alignment

The rail is of the "flat bottom design" with wide base, web and rounded head it is both stable and durable. The rail rests on a cast steel plate, which is screwed or bolted to the sleeper. Rail Track, the infrastructure owning company in the United Kingdom, has adopted UIC60 rail, which weighs 125 lbs per yard, as its standard for high-speed lines. The rail weight varies from 80 to 90 lbs per cubic yard at a price of $46.55 per yard. Rail is welded into long lengths, which can be up to several hundred yards long, according to Trainweb. Figure 2.3 is a depiction of a typical cross section of one HSR line.

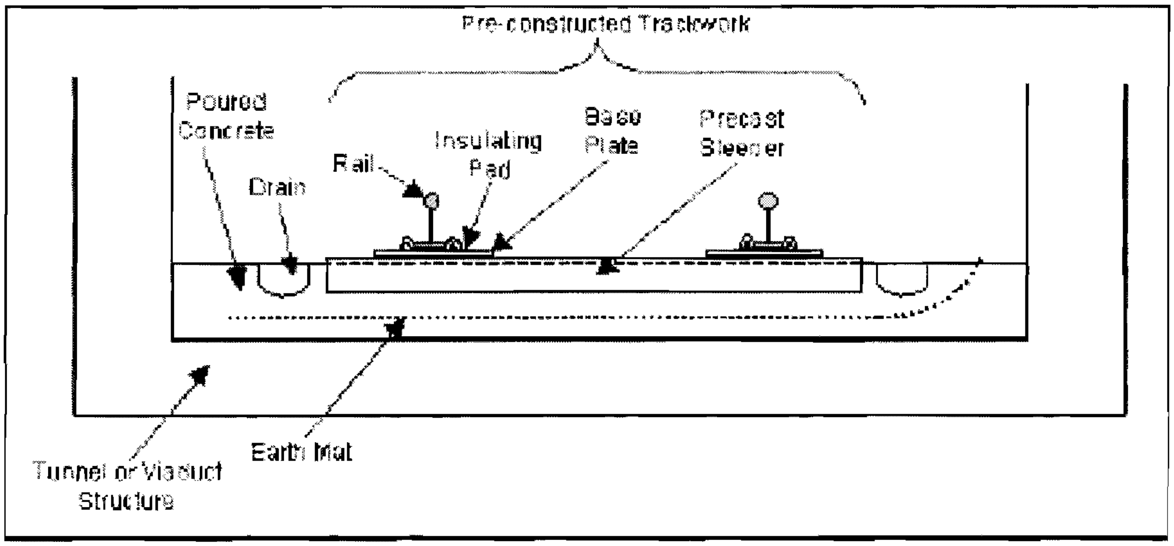

Figure 2.3: Modern slab track system, showing the pre-constructed track which is suspended in the structure while concrete is poured around it.

Superelevation on a standard track is 6 inches of cant equal to 6 degrees. Turnouts and crossings of the rail lines them selves where not considered in this project due to the uninterrupted point-to-point wrought. [Trainweb]

2-3 Maglev

For Maglev systems, weight is everything. The train cars are made of aluminum or fiber reinforcement and other materials to reduce the weight. The train cars can carry either passengers or cargo, although the weight capacity is much lower than conventional cargo trains. Weight is mainly an issue of maintaining the magnetic levitation. The lightweight design also helps in quicker acceleration. At speeds of 300 mph air resistance becomes the dominating force for the train's motion. As such, the train cars have very aerodynamic lead cars. The cars are often very short in height, as another method for reducing the air resistance on the train. The trains have a very high rate of acceleration and deceleration. The deceleration limit is actually set to the maximum allowable acceleration for the passengers. Another benefit of Maglev is that it has a high-energy efficiency. This is primarily due to the fact that the Maglev systems were designed to not experience friction. By levitating the trainset, the train and track do experience friction. The magnetic propulsion also makes the train the only moving part. As opposed to conventional engines where many parts move and cause friction, which significantly reduces the efficiency of the engine.

While the actual trains do not release polluting emissions, they do require large amounts of electricity. And electrical generation does have pollution involved. However, the environmental benefit is that the pollution from electrical generation is less than conventional combustion engines. This impact is also reduced by the fact that generation plants are stationary sources of pollution, and much easier to monitor and reduce as such.

2.3.1 Cost

All costs have been derived with reference to Baltimore Washington Project as reported in June 2000. The capital cost is expressed in year 2000 dollars which also include engineering, design and construction management, spare parts, and training. An online prospectus stating the costs for the project and other associated studies was put up on the Baltimore Washington Maglev website. Before estimating the costs for a Texas Maglev system, let us take a brief look at the costs associated with the Baltimore Washington Maglev project.

2.3.1.1 Baltimore Washington Maglev Project

Certain underlying assumptions were made with regard to this project. These are stated as follows:

- 40-mile steel guideway
- 3 stations, one each at Union Station, Washington D.C., Camden Yards in Baltimore and BWI International Airport
- 18 hour operation
- A fleet size of 6 with each trainset having 3 sections
- 40% contingency for technology and construction

The service scenario for the Baltimore Washington Maglev project was projected as follows:

- Operating hours: 18 hours daily/7 days a week
- Peak hour headway: 10 minutes
- One-way trip time: 19 minutes
- Total frequency per week 318 round trips
- Seating capacity: 312/trainset

Keeping the above assumptions and scenarios in mind, the capital costs, O&M costs and energy costs were derived. Since these are the only costs that we will cover in our design for Texas, we have only included these costs from the Baltimore Washington Project study in this report.

2.3.1.1.2 Capital Costs

The capital costs for the project were derived by building up the costs of the subsystem using a work breakdown structure and a numbering system. The capital costs are given as "neat cost" and costs with contingency. All costs such as vehicle, propulsion system, power, operation control, communication technology, guideway structure, civil site work, documentation, training and spare parts are included in capital costs. Additional costs such as engineering, design and construction management are also included in capital costs under "neat" costs. The neat cost gives the cost of the infrastructure without taking into account the contingencies.

For the project, all costs have been escalated at 3% per year to 2006, the midpoint of the construction schedule. An overall contingency of 40% has been considered for the sake of convenience. Table 2.4 gives the capital costs for the Baltimore Washington Maglev project.

PARTICULARS	NEAT COST	CONTINGENCY(40%)	TOTAL COSTS
Transrapid-08 Maglev vehicle	$138	$55.40	$194
Propulsion System	$367	$147	$515
Operation Control Tech.	$72.20	$28.80	$101
Guideway Infrastructure	$1,176	$470	$1,646
Communication/ Control Tech.	$2.70	$1.10	$3.75
Stations	$109	$43.80	$153
Construction Mgmt.	$147	NIL	$147
Project Eng. Costs	$68.90	NIL	$68.90
Training/Document/Spare Parts	$40	NIL	$40

Table 2.4: Capital costs for the BW Maglev project (all costs in millions)

2.3.1.1.3 Operating and Maintenance Costs

One of the most important criteria to be approved for federal funding is to have a self-sustained system with revenue covering the operating costs, including maintenance and replacement costs. The O&M costs are inclusive of trainset operating cost, fixed facility operating cost, maintenance management, guideway infrastructure management, vehicle maintenance, propulsion/energy system maintenance, operation control system maintenance, station maintenance, other facility maintenance, general repairs, janitor services, general administration, insurance and legal claims etc. Table 2.5 and Table 2.6 show the operating costs and maintenance costs, respectively, for the Baltimore Washington Maglev project.

SUBCATEGORY	TOTAL COSTS	W/40% CONTINGENCY
Trainset Operating	$1.15	$1.60
Fixed Facility Operating	$2.65	$3.75

Table 2.5: Operating costs for the BW Maglev project (all costs in millions)

SUBCATEGORY	TOTAL COSTS	W/40% CONTINGENCY
Maintenance Mgt.	$1.50	$2
Guideway	$2	$2.90
Vehicle	$5	$7.10
Propulsion/ Energy	$2	$2.80
Control/ Communication	$1.30	$1.80
Stations	$0.20	$0.40
Other Facility Maintenance	$1.60	$2.20

Table 2.6: Maintenance costs for the BW Maglev project (all costs in millions)

2.3.1.1.4 Energy Costs

Energy costs are also divided into trainset energy consumption and fixed facility energy consumption. Trainset energy consumption is based on two major parameters, namely total energy consumption and peak demand load for power supply. Annual energy consumption costs for fixed facilities generally include expenses occurred to maintain daily operation such as lighting, air conditioning, and general facility equipment operations. Table 2.7 shows the energy costs incurred for the Baltimore Washington Maglev project.

SUBCATEGORY	CHARGE CATEGORY	TOTAL COSTS	W/40% CONTINGENCY
Trainset Energy Consumption	Non-peak	$2.80	$3.85
	Peak	$2.95	$4.10
Fixed Facility Energy Consumption	Net total	$1.25	$1.75

Table 2.7: Energy costs for the BW Maglev project (all costs in millions)

2.3.1.2 Proposed Maglev Project for Texas

The need for a transit system has never been as badly felt in the state of Texas as today. We have already seen in Chapter 1 the problems related to highway congestion, pollution etc. If these issues are not seriously addressed, they could lead to problems of epic proportions in the not so distant future. Keeping this in mind, we have outlined a Maglev system for the state of Texas, which runs from Dallas to Laredo, along a 430 mile corridor with 5 intermediate stops. This section covers the costs of building such a system in Texas from scratch. For our study, we have estimated capital costs and O&M costs (Note that energy costs have been included in O&M costs for our study for the sake of convenience).

As in the case of the Baltimore Washington Maglev project, we have made certain underlying assumptions with regard to the Dallas-Laredo Maglev project. These assumptions are as stated below:

- 30 minute headways
- 16 hour operation
- Train seating capacity = 318
- Average operating speed = 185 mph
- 30% contingency costs
- 10 trainsets with 3 sections each
- Elevated guideway, 2-line operation

For the project, the ROW, and land acquisition cost are not included in the estimation. All the costs are escalated at 2.81% per year to 2010.

2.3.1.2.1 Capital Costs

All costs are included that are required to construct and operate the system. They include vehicles, propulsion system, energy supply, operation control system, communication technology, guideway infrastructure, civil site work, stations, documentation, training, and initial spare parts. The technology and systems costs are derived from the testing of the Transrapid based system over the last 25 years. The Maglev technology for this project used TR08 Maglev Vehicle, and all of the associated propulsion, energy supply, communication, and control systems for operation of the vehicle. The local pricing of labor for the project is estimated for the civil structure and site work. The quantities of the materials required for the project is based on the structural and foundation design requirements. Table 2.8 shows capital costs for the Texas Maglev project. The total estimated capital costs for the project is $24.1 billion. (Other costs have not been included in the table)

PARTICULARS	TOTAL COSTS(millions)	W/30% CONTINGENCY
Guideway	$4,785	$6,221
Substation	$42	$54.60
Siding and Fencing	$2	$2.60
Transrapid-08 trainset	$231	$300
Capital station	$104	$135
Administrative	$2,480	$3,224
Propulsion system	$3,160	$4,108

Table 2.8: Capital costs for Texas Maglev project (all costs in millions)

2.3.1.2.2 Operating & Maintenance Costs

For the ease repair and maintenance, the tracks for the Maglev project are expanded into three tracks instead of using two tracks. This help to regulate the vehicle without any delay at the time of construction or repair. For the project, a contingency level of 30 percent is applied to the cost. Table 2.9 shows the O&M costs for the Texas Maglev project.

PARTICULARS	TOTAL COST	W/30% CONTINGENCY
Stations	$85.50	$111
Guideway	$15.40	$20
Trainsets	$17.10	$22.30
Labor	$4.40	$5.70
Energy	$32	$41.60

Table 2.9: O&M costs for the Texas Maglev project (all costs in millions)

2.3.2 Design

The Maglev system is divided into two categories according to its levitation and propulsion system. They are Electro-Dynamic Systems (EDS) and Electro-Magnetic Systems (EMS).

2.3.2.1 Electro-Magnetic Systems

EMS works by using the attractive forces of magnets that run on a T shaped guideway. In this system, electromagnets lie on both sides of the vehicle, and ferromagnetic stator packs along the underside of the guideway. When the electromagnets are activated, an electrical current passes through the guideway, the electromagnets are attracted upward to the guideway, and the vehicle levitates.

2.3.2.2 Electro-Dynamic Systems

EDS works by using the repulsive forces experienced by two magnets in close proximity to each other. The trainset is then propelled forward via a charge run along the track. One particular advantage of EDS is that the system inherently requires many components to be integrated into the guideway. It is also an ideal time to integrate linear synchronous motors into the guideway. LSM motors are the preferred motors for high-speed Maglev systems. The EDS system runs on a U-shaped guideway.

2.3.2.3 Trainset

The vehicle has two end sections and usually four to eight middle sections. Although the body design varies according to the end use (passenger, cargo), the undercarriage and all remaining components are identical. Each end section is fitted with a driver's compartment, vehicle on-board operation control system and the payload area for passengers, cargo, or freight. Middle sections are similar in overall composition to end sections but do not have the driver's compartment and on-board Operation Control Systems (OCS). Dimensions of typical Maglev trainsets are shown in Table 2.10.

PARAMETERS	END SECTION	MIDDLE SECTION
Length	26.99m	24.77m
Width	3.70m	3.70,
Height	4.16m	4.16m
Empty Weight	48.0t	47.0t
Payload capacity	14.0t	17.5t
Total weight	92 + 2 wheelchairs	126
No. of seats	62.0t	64.5t

Table 2.10: Transrapid trainset dimensions [Transrapid]

The dimensions of the sections of the Transrapid maglev train are shown in Table 2.11 as follows:

PARAMETERS	2 SECTIONS	6 SECTIONS	10 SECTIONS
Length	53.98 m	153.06 m	252.14m
Empty weight	96t	284t	472t
Payload capacity	28t	98t	168t
Total weight	124t	382t	640t
No. of seats*	128-184	up to 688	1192

Table 2.11: Dimensions for different sizes of the Transrapid trainset

2.3.4 Guideway

The guideway is manufactured from welded steel or reinforced concrete beams and reinforced concrete supports and foundations. The guideway track gauge is 9.2 feet with a double track center-to-center distance of 16.7 feet when speeds are up to 310 mph. The minimum radius of curvature is 1148 feet. At 186 mph, the radius increases to 1.0 miles. When the trains are a maximum speed of 310 mph the radius of curvature will increase to 2.75 miles. Guideways can be elevated or at-grade. There are two designs for elevated guideways and one design for the at-grade guideway, standardized by Transrapid. The cross section of these different types of guideways is shown in Figure 2.4.

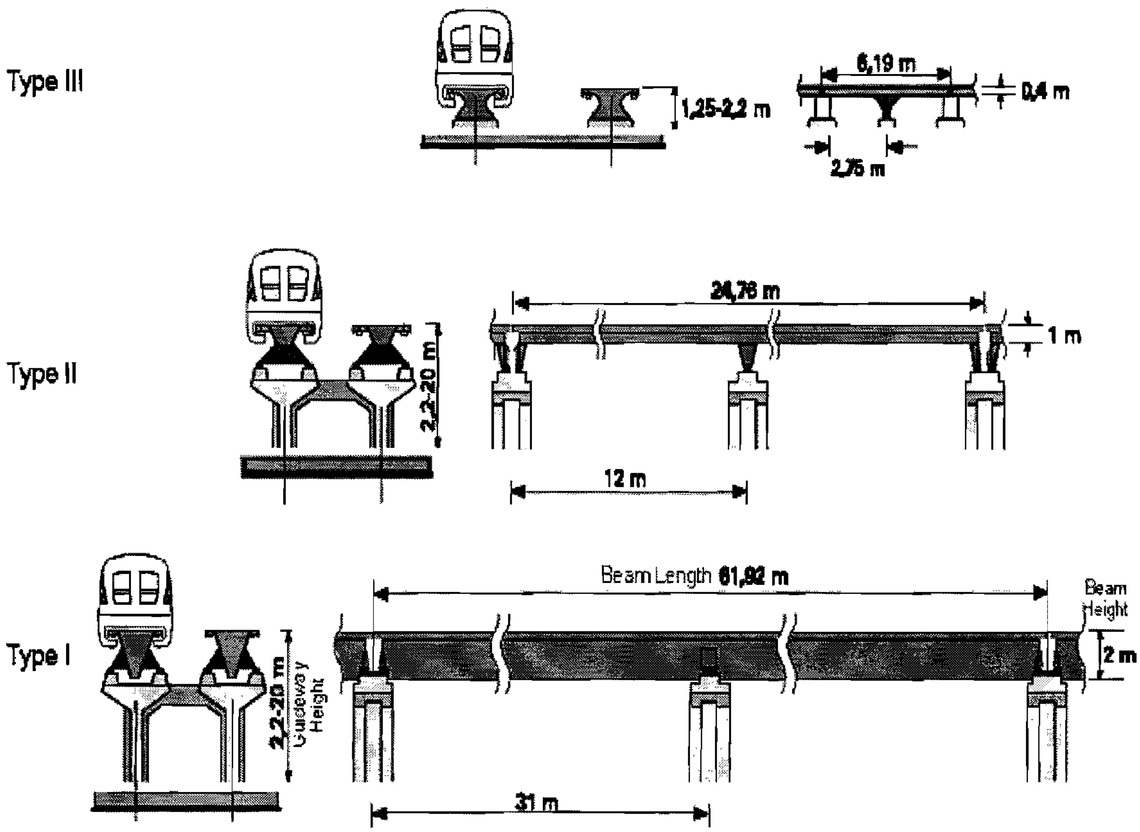

Figure 2.4: Elevated and at-grade guideway design [Transrapid]

2.3.4.1 Elevated Guideway

The standard elevated guideway beam is from 25 m to 62 m long. The height of the guideway ranges from 2.2 m to 20 m without special civil structures. An additional civil structure such as a bridge is needed for the height to reach 20 m or span 31 m or above. The guideway track is typically constructed on the foundation with individual substructures of one column per track. A minimum guideway height of 6.7 m is required for an overpass so that truck traffic can pass underneath. The substructure of guideway is designed to meet the local traffic, environmental, and earthquake standards.

Transrapid has 2 designs for elevated guideways, namely Type 1 elevated and Type 2 elevated.

2.3.4.2 At-Grade Guideway

The at-grade guideway beam is 6.2 m long and has continuous foundations. The height for at-grade guideway is from 1.35 m to 2.20 m high. The at-grade guideway has fixed foundations as bridges, tunnels, stations. The total weight for a 6.2 m long steel guideway beam is 9 ton. Table 2.8 contains the three different types of guideway structures and their specific dimensions.

2.3.4.3 Switches

Bendable switches are used to allow low and high speed transfer of trains from one track to another without stopping or waiting. The Transrapid switches consist of special steel guideway beams that are elastically bent using electromechanical setting drives to effect the turnout position. Transfer tables move parallel to their original position using electromechanical drives to allow revenue trains or maintenance vehicles to access to multiple tracks. Figure 2.5 is a picture of the Transrapid switch.

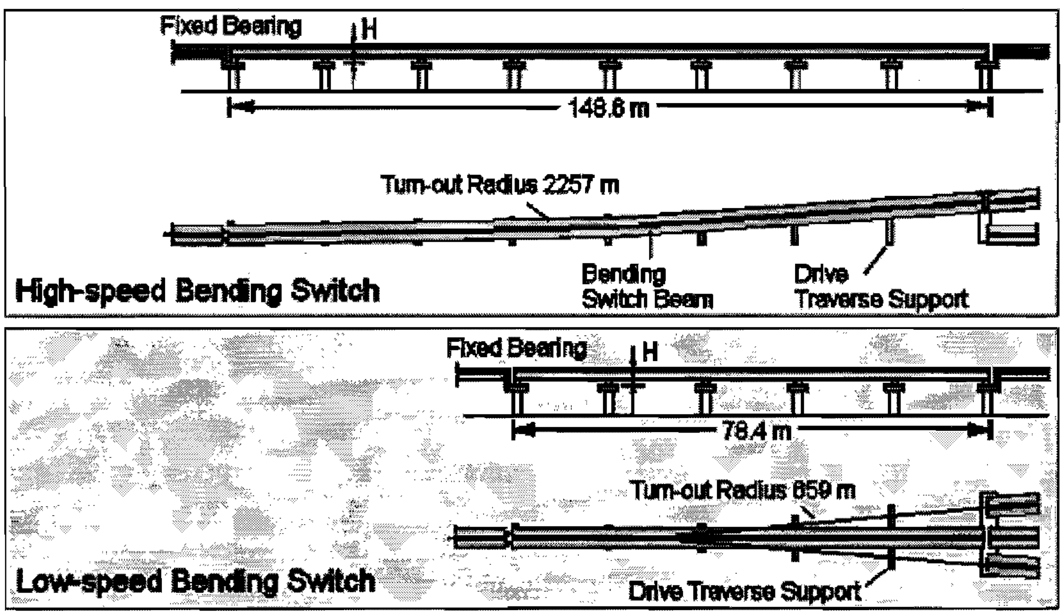

Fig 2-5: Guideway bending switches

2.3.5 Levitation

The propulsion uses electro magnetic forces to levitate the trains to a 3/8 inch gap. Levitation is maintained by long stator packs embedded in the guideway and magnets on the train. The vehicle guideway is a T-guideway where the vehicles wrap completely around the track. The trains are automatic and computer controlled using control systems that are transmitted to the trains using digital radio transmission (38 GHz). Figure 2.6 shows the vehicle undercarriage components for a Transrapid system and the framework for levitating the trainset.

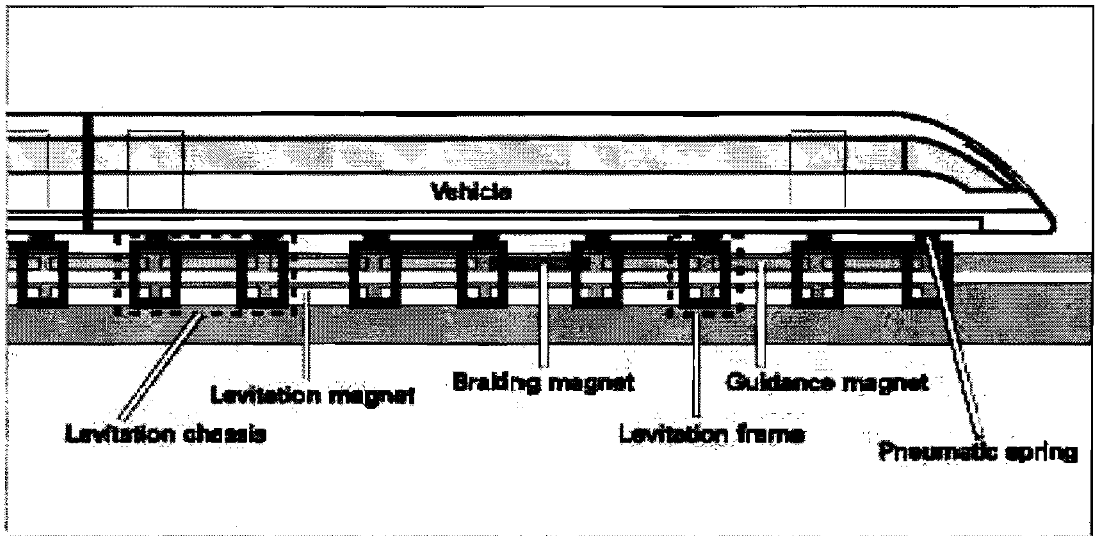

Figure 2.6: Vehicle undercarriage components

2.3.6 Propulsion System

Based on German Transrapid system, the propulsion and braking use synchronous longstator linear motor. The motor produces an electromagnetic traveling field that propels the vehicle along the guideway. Ferromagnetic stator packs and three phase stator windings are mounted on both sides along the underside of the guideway. With the help of converters in substations along the route, the amplitude and frequency of the alternating current could be changed allowing the vehicle to accelerate smoothly from standstill to full speed. By slowing down the traveling field, the motor becomes a generator and the vehicle is smoothly stopped without contact. If the public power or propulsion system failed, independent backup brakes in each vehicle section stop the train in the next available stopping area.

The propulsion components were fitted along the route according to the local topography and performance requirements. The substations are installed at intervals of 6-31 mile along the route based on the train interval, speed profile, and load factors. In addition, the substations contain energy supply components, maintenance personnel, and spare parts. The substations receive 23 kV power from the energy supply system and convert it into the proper format to propel the train. The propulsion control system both controls and monitors the position of the train at all times.

The route is divided into propulsion segments through the spacing of the substations. Each propulsion segment is divided into smaller motor section, usually between 0.31 mile and 1.24 mile in length. The longstator windings on the right and left sides of the guideway are fed independently from the substation and physically offset with respect to each other. This helps to smooth the transition between motor sections and even if one side fails, the other has sufficient reserve to propel the train through the segment. Wayside switch stations switch propulsion power from one section to the next as the Transrapid train proceeds. The propulsion power is independently supplied by the substation converters to the longstators on the right and left sides of guideway. If an individual converter fails, or even the entire substation fails, the next substation can provide power in its place, thereby allowing the vehicle to reach its destination.

2.3.7 Substations

A substation could have up to 4 propulsion blocks, one per track per direction, depending on the track layout. For the project, there will be 2 high powers, 1 medium power, and 1 low power propulsion blocks installed.

The wayside equipment provides the feedback from the substations to the individual propulsion segments. It includes switchgear, cables, two longstators motor winding (right and left) with stator packs underneath the guideway, and the switch stations. The feeder line switchgear connects or disconnects the propulsion block from the route components and ensures the safe interruption of the braking energy flow during a safe shutdown of the propulsion system.

The cables connect the converters in the propulsion blocks to the stators and supply energy to the various wayside components. The cables are normally laid in one cable trench for single-track guideway and one or two cable trenches for double track guideway.

The stators consist of the laminated steel stator packs bolted to the underside of the guideway, the three phase longstator windings mounted to the stator packs, and the connection cabling to the switch stations. Since the stator packs are physically bolted to the guideway beam, they are included in the guideway system. The three phase stator windings are prefabricated aluminum cabling formed together and mounted in a grounded harness to the stator packs.

2.3.8 Speed

The design speed of the Maglev is 340 mph with an operating speed of 310 mph. The operational train headway is 5 minutes and is dependent on the number of stations and track alignment. Because the technology is not the limiting factor, the train's acceleration and braking can be set by the comfort conditions placed on the system by the operators. During normal operation the trains accelerate and brake with similar values. However during emergency braking the trains can increase the braking values and still maintain a comfortable deceleration. Ride comfort parameters include a typical acceleration less than 3 ft/s^2 and a typical braking less than 2.5 ft/s^2. Vertical acceleration is limited to 2ft/s^2 in a crest and 4 ft/s^2 in a sag curve.

2.3.9 Power

Power requirements are dependent on the number of sections, and the speed that the train is traveling. For a ten section train power requirements are 16.1 MW at a constant speed of 250 mph. The power is brought to guideway via substations located along side the track. The propulsion force is powered by the substations while the train car's onboard batteries power the levitation and guidance magnets. The batteries also power the environmental controls, lights, and controls. However, when the trains travel at a speed less than 50 mph, or are stopped at a station, the power is supplied from a power rail that is located along side the guideway. At speeds above 50 mph, the batteries are charged by a magnetic field that causes power to be induced into the car batteries.

The 23 kV of electricity required for the internal energy supply and propulsion system is drawn from the public power grid. The energy power system contains high voltage switching equipment to connect to public grid. It also contains input transformers, medium voltage switch gear, compensation and filtering equipment, route power supply for wayside equipment, and control system for the energy supply equipment. The energy supply system is installed in the substation.

2.3.10 Operation Control

The fully automated Operation Control System (OCS) controls all aspects of the Transrapid operation. The OCS utilizes a radio based signal which is safer than a human based operating system. The OCS maintains the train's speed within the operating specifications and provides a safe and unobstructed travel path.

2.3.11 Communication Control Technology

The radio data transmission systems operate at 38 GHz. It also transmits the communication signal from the vehicle to the central operation facility and vice-versa. There are two vehicle control systems on board that are connected to separate antennas on either end of the vehicle. These antennas connect with radio transmission masts set at 1.25 mile intervals along the guideway. The OCS also collects maintenance and failure information. This information is then sent to a maintenance archive and scheduling system at the Central Maintenance Facility. The control of the Transrapid system is divided into safety-relevant and non safety-relevant functions.

CHAPTER 3
ANALYSIS OF ALTERNATIVES

3-1 Highway

Texas is considered to be the crossroads of North America because it accommodates 79% of all US-Mexico trade traffic. As international traffic increases as a result of the North American Free Trade Agreement, and population increases at 30,000 residents per month, the existing road and bridge system will not be sufficient to serve the projected traffic volumes on IH-35. These high truck traffic volumes also deteriorate the conditions of the existing roadways much faster than passenger vehicles, according to TxDOT.

The TTC will provide a route for cross-state travel without passing through metropolitan areas. There are several advantages to removing through traffic from the city. It will relieve congestion on existing roadways, improving conditions for intercity commuters and highway maintenance. It will also remove hazardous materials from densely populated areas and improve air quality by reducing emissions in the city. [TxDOT]

The fundamental design of the corridor is the separation of passenger vehicles and trucks by divided lanes. Each section will have sufficient structural capacity such that only overlays and surface texture maintenance will be required throughout the design life of the corridor. [TxDOT]

Trucks that are transporting goods and commodities through Texas will have two exclusive 13 foot lanes on a 42 foot wide roadway section that is designed to handle severe loads. This will relieve congestion, allowing for faster and safer travel, as per TxDOT. Passenger vehicles will have three 12 foot lanes on a 56 foot wide roadway section, and will also benefit by faster and safer travel.

The IH-35 corridor is restricted in many locations by urban growth and cannot be widened. If the required capacity cannot be met it does not make much sense to spend state highway funds to replace a highway that will not improve congestion. The

TTC can provide an alternate route for through traffic and relieve the load on the existing system. Also, monetary incentives from the federal government are promoting research for alternatives to existing highway systems and TxDOT should not miss this opportunity to receive federal funds.

Americans have seen tremendous changes since the authorization of the Interstate Highway System in 1956. They have come to rely on the highway system to accommodate their traveling needs. The highway section of the corridor will operate the same as the existing Interstate Highway system, only much safer, faster, and more efficient due to the separation of trucks and autos. This alternative will work in the future because it is an improved highway.

Environmental and permitting issues for the TTC will be addressed in an extensive environmental review so that adverse environmental impacts can be minimized or avoided. Acquiring ROW cannot significantly affect planned growth or land use, natural, cultural, recreational, historic or other resources. Nor can it relocate significant numbers of people, involve air, noise or water quality impacts, or have any significant environmental bearing. The impacts of the highway can most likely be considered a categorical exclusion based on past experience of highway construction.

The costs for operating and maintaining highways consist of roadwork operations and highway reconstruction. Roadwork cost will include all materials and equipment required for maintaining the highway, the salaries and benefits for the employees who perform the work, roadway striping, signing, and traffic signals, and preservation expenditures such as crack sealing and resurfacing. Signing of the TTC will incorporate ITS to provide drivers with current roadway, traffic, and weather information. Examples of ITS include dynamic message signs, electronic toll collection, traffic management centers, incident detection algorithms, and other smart systems. The number of smart systems required for the corridor is dependent upon highway design. Highway reconstruction costs will include the demolition and rebuilding of failed structures. Rehabilitation and preventive maintenance on highways are covered under Category-1 funding by TxDOT, which states that rehabilitation funds can be used for highway main lanes, frontage roads, structures, signs, pavement markings, and striping. Figure 3.1 is a graphical representation of maintenance cost for TxDOT districts for IH-35.

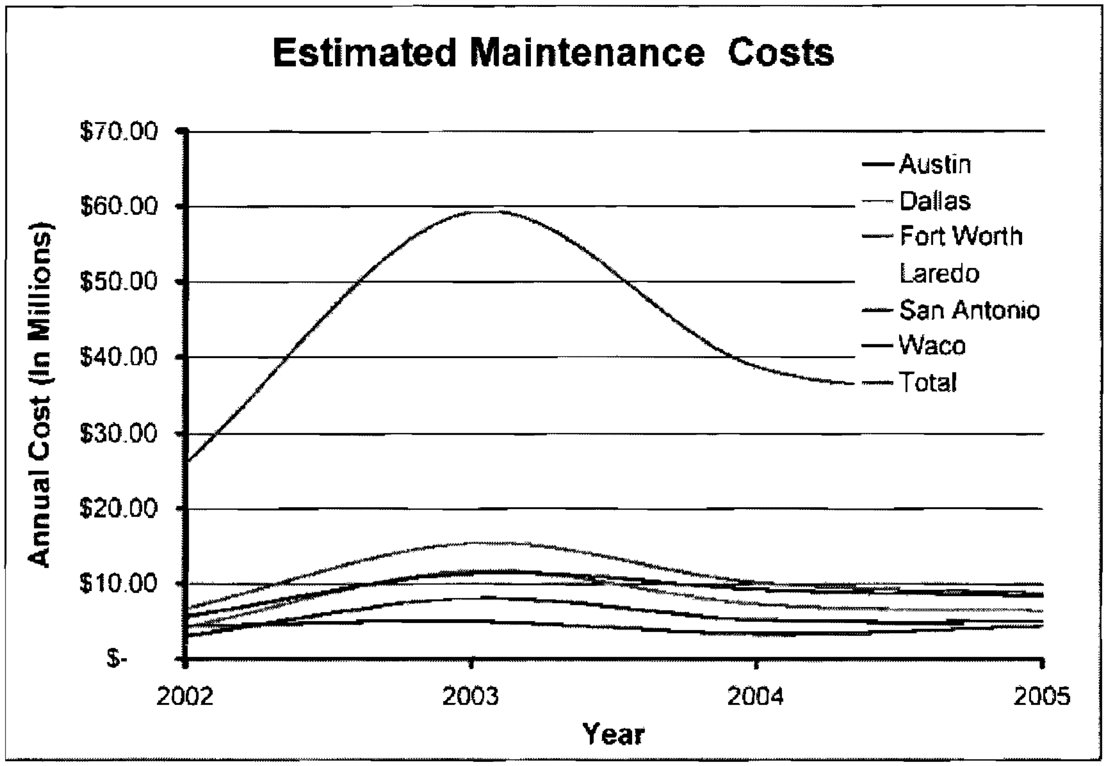

Figure 3.1: Maintenance cost for IH-35 [TxDOT]

<u>3-2 High Speed Rail</u>

HSR has advantages in that it is faster than a car for longer distances and faster than an airplane for short distances but with longer access time in the airports. HSR can carry more people while using less space than an interstate highway. HSR consumes less energy and produces less pollution compared to autos and airplanes.

HSR will only work efficiently on high speed tracks and is limited when placed on regular rail. HSR has not been proven extensively in the US, which makes planning, designing, and financing very difficult. HSR in Europe and Japan has been successful connecting densely populated areas.

Other than the north-eastern coast, only the Los Angles-San Diego corridor has the required population density to make HSR successful in the USA. HSR will only move traffic from the airlines but not significantly from the highways which will not improve the congestion on Texas' highways.[1]

If HSR is not installed in the TTC, then some of the potential riders will continue to use the airline industry and IH-35 to get to the other Texas cities in the corridor. Congestion and air pollution along IH-35 will continue to get worse. HSR offers an option for the auto passenger to get off the highway. Doing nothing will not improve the present situation; it will only make it worse.

HSR may not work in the future. American cities were organized around the capabilities and the design of the car, unlike Europe and Japan which are organized around rapid transit. The USA will have to spend enormous amounts of capital to restructure the cities for a transit system to work. In the USA it is cheaper to travel by car than it is in Europe or Japan. The average cost for gasoline in the USA is $1.40 per gallon, however in Europe one can expect to pay $1 per liter or $4.80 per gallon.

In the USA we even enjoy relatively cheap air fares. This can be attributed to the highly competitive airline industry. Air fares in the USA are approximately 20% to 50% cheaper than Europe and Japan for the same distance traveled, with the exception of NYC to Washington, D.C.

The recent history of passenger rail in this country has not been favorable for HSR. Amtrak's ridership in this country has been low throughout its 31 years. Most people that travel routes served by Amtrak would rather drive or fly. This is due to the longer time that it takes to travel by rail thus affecting people's perception of rapid rail. Amtrak has failed to operate without receiving huge sums of government subsidies. With the economy in the state that it is in, it will be harder for HSR to find the funding that it needs in Washington, D.C.

HSR train sets were designed to carry passengers and not freight. HSR trains were designed to be light so that high speeds could be attained. This study found no

[1] High-Speed Rail, Forth Worth

sources that have looked at and/or published any information regarding moving freight on HSR. HSR will have to comply with all aspects of the National Environmental Policy Act (NEPA). This alternative will have to address: air quality impacts, water quality impacts, protected species, soils and unique geological features, hazardous waste, noise, vibration, impacts on wildlife habitat and vegetation, archeological and historic sites, land use, governmental plans and polices, utilities, public services and facilities.

The life cycle for the system is 30 years. With routine maintenance the structure will be repaired as needed. The cost of the repairs to equipment and infiltrator are based on their usage, estimated by per train mile projections. Table 3.1 shows estimates per year in 2020 given occupancy at different capacities. The design uses 50% capacity because it was found to best represent the usage over the entire day taking into account peak periods.

The maintenance costs are the largest portion of life cycle costs at about 60% of total operational cost. Fuel and energy consumption is roughly 15% of the operating budget. All costs are a factor of how many trains will make the trip during the year. This factor is very difficult to estimate with accuracy. The estimated ridership is 1.75 million people in the year 2020. This number was found by looking at the projected market share that HSR would have multiplied by the current travel volumes of car and air. The totals were then projected to the year 2020 using a 3.13% growth factor. The break down of operating cost multipliers is found in the cost section of HSR.

The costs of on-board services are to be covered by the sale of food and drinks on the train, as well as the contractor's profit. Parcel services will also supplement the operating cost. After the initial investment in the projects capital is repaid, HSR will provide a profitable stock to its investors. Ticket sales along with parcel service will contribute to $90 million in annual income.

3-3 Maglev

Maglev is a high speed option that could connect the major cities across the state. It would allow travel between all the stations along the corridor. With a traveling speed of up to 300 mph, this alternative is also the fastest. Maglev trains would be able to quickly run cargo along the corridor. The only difficulty with moving cargo would be breaking up the weight to allowable loads per car.

The Maglev system would greatly reduce travel time between the densely populated areas in Texas. If we were to do nothing, the heavy trucking would still occur on IH-35 and the highway would continue to require regular maintenance. If the current trucking loads on IH-35 continue, it will wear out its useful life, and a new stretch of highway will have to be built much sooner than it should. This new highway will likely continue the pattern of high maintenance and also drastically undershoot its design life. For such a heavy shipping route, the Maglev system will likely have to have extra strong foundations and a very tough guideway, but it will not have to undergo the constant repairs and resurfacing the current highway does. The Maglev guideway could more easily meet an adequate design life and, although expensive, would be easier to replace after the design life is exceeded. There is not really a do nothing alternative because the current traffic on IH35, which this design corridor would relieve, will require replacement.

There is no doubt that Maglev is far superior to any other currently existing ground surface transportation technology. They require less maintenance and are much more energy efficient. In the future, the Maglev systems will likely operate much better than now. Even a few systems in operation will also start a rapid decline in price and an increase in the quality of the system. Maglev is a new idea not yet in service, and holds great potential for the future.

Maglev offers a dramatic savings in time. It is common for traffic engineers to view inaccessibility in units of travel time as opposed to distance. A shop that is 15 minutes and 10 miles away via mainly highway high speeds is just as likely to be visited as a shop 2 miles away via a heavily congested collector road.

Due to the length of the proposed corridor, the differences in characteristics of land environmental and permitting complications cannot be easily defined. The most noticeable complications, nonspecific to land, are noise and visual pollution that an elevated Maglev train will produce. However, the visual pollution that the elevated track will produce will be minimal because the route alignment will be outside of the major urban areas, and will only become a problem when the track enters an urban area to pick up passengers at stations. As with visual pollution, the noise pollution will only become a problem when the alignment reaches an urban area.

Permitting complications arise due to the development stages of Maglev; however, it can be assumed that the guideway is comparable to a bridge with respect to permitting.

3.3.1 Capital cost estimate

The capital cost is estimated by referring to the cost of the Baltimore Washington Project reported in June 2000. The capital cost is expressed in year 2000 dollars that includes engineering, design and construction management, spare parts, and training cost. For the project, the ROW, and land acquisition cost are not included in the estimation. All the costs are escalated at 2.81% per year to 2010.

All costs required to construct and operate the system are included in the estimate. The costs include vehicles, propulsion system, energy supply, operation control system, communication technology, guideway infrastructure, civil site work, stations, operation and maintenance facilities, documentation, training, and initial spare parts. The technology and systems costs are derived from the testing of Transrapid based design over the last 25 years. The Maglev technology for this project uses the TR08 Maglev Vehicle, and all of the associated propulsion, energy supply, communication, and control systems for operation of the vehicle. The local pricing for labor for the project is estimated for the civil structure and site work. The quantities of the materials required for the project is based on the structural and foundation design requirements. The guideway includes all substructures and superstructures. However, the guideway excludes any required river crossing, embankment, earth excavation, and tunnels that are roughly estimated as miscellaneous cost under the guideway infrastructure.

For repair purposes, the tracks for the Maglev project are expanded into three tracks instead of using two tracks. This helps to regulate the system so that no delay during repair of the guideway will be experienced.

There are 318 seats per Maglev train, and estimated cost of $23.1 million. Thus, the estimated cost per seat is $72,000. The guideway infrastructure for 400 miles comes to 78.7% of total capital cost. The guideway infrastructure per mile per lane is calculated to be $12 million. The total guideway cost amounts to $6.2 billion for the entire corridor.

For the project, contingency level of 30 percent is applied to the cost. The total cost for the Maglev Project from Dallas Forth Worth to Laredo, Texas came out to be $18.5 billion for 3 tracks. The contingencies approximately added $5.4 billion to the neat construction cost. Table 3.1 gives a brief summary of the costs of building the guideway, keeping in mind the contingencies.

DESCRIPTION	COST(BILLIONS)
Capital cost subtotal	$16.0
Design & Construction Fees	$2.4
Neat Construction total	$13.1
30% contingency	$5.3
Total with 30% contingency	$18.4
Total with 2.81% escalation to year 2010	$24.1

Table 3.1: Capital costs escalated to year 2010

Maglev systems have an estimated project life of 50 years. This number is taken from the typical project life of bridges. Maglev systems inflict little damage to the rail and surface as it is a contactless technology. The structure does still suffer from taking the cyclic loadings as trains run across it. Because Maglev structures are typically elevated, sometimes only 5 feet, and the lifetime damage to the elevating substructure is very similar to that on a bridge. Over this project life, there will be some extra costs for maintenance and repair, operation, and labor. The estimated values for 2020 in these areas are discussed below. All of these numbers are derived from calculations made on the California inter airport system. Using that projects estimated costs for the year 2020 and estimated ridership, a cost for each seat mile traveled on a Maglev system was approximated. The calculations assumed that the yearly travel for the other system averaged out at 85% occupation for the year. These cost per seatmile values were then used to estimate this projects operation and maintenance costs for the year 2020.

Repair and maintenance are the big selling point for Maglev systems. Because the trainset do not touch the guideway surface, except for small distances in EDS, there is negligible damage to the guideway. The same is true for the trainset in that the friction and scraping of contact does not take place. A majority of the repair on Maglev will be on the components that do take forces. These are primarily the magnets, both on the train and in the track, which do take the loading weight and then distribute it via the substructure to the foundation. The loading and unloading on the track magnets can wear on the concrete and casing that holds it in place in the structure. The trains' on-board magnet supports have to be designed to take prolonged heavy prolonged forces, as if there was a wheel that made surface contact there. A portion of the repairs will also take place on the train car's surface. The cars are taking heavy loads form the air drag due to traveling at 300 mph. Both the train car surface and all the system's magnets have to be checked regularly to make sure that they are operational. A lot of the costs come from these routine check-ups. As Maglev systems develop around the world, the repair costs for materials and likely labor will begin to drop. The estimated maintenance cost for the year 2020 is displayed in Table 3.2.

The operation costs shown in Tables 3.2 and 3.3 are broken down into energy, labor, and total operational costs. The labor cost does look relatively low, but considering the trains operation is primarily automated, the only real labor costs are from monitoring the train's progress both on-board and off-board and the servicing staff. In addition to the fact that the train travels at 300 mph not giving a lot of time per trip for staff to accumulate hours. The energy costs were also surprising in that they were quite high. It is likely that on this project, the costs may go down as the average distance between stops is greater allowing for an overall higher average speed and lower energy use per mile.

	DESCRIPTION	COST PER SEAT-MILE	COST PER YEAR(MILLIONS)
Maintenance	Guideway	$0.0110	$15.4
	Equipment	$0.0122	$17.1
System Operations	Total	$0.0261	$36.6
	Labor	$0.0031	$4.4
	Energy	$0.0028	$32.0
	Grand Total		**$69.1**

Table 3.2: Estimated O&M costs for the year 2020

O&M COSTS	UNIT	COST PER UNIT(MILLIONS)	QUANTITY	COST PER YEAR(MILLIONS)
Total	Station	$9.8	5	$49.2
Labor Costs	Station	$6.1	5	$30.5
Energy Costs	Station	$0.3	5	$1.5
Total Fixed Costs	N/A	$14.3	N/A	$14.3
Fixed Labor	N/A	$2.7	N/A	$2.7

Table 3.3: Overall maintenance costs for the year 2020

3.4 Intangible Benefits

3.4.1 Noise Reduction

Like many other environmental impacts, Maglev systems would reduce and centralize the noise pollution. The noise from Maglev is generally based upon the aerodynamics of the train, because the noise from the propulsion and levitation components is virtually non-existent. An object traveling at 300 mph does make a significant amount of noise. Anyone who has ridden in an airplane has heard the sound of air resistance at 500 mph or above. While Maglev will not be quite as loud, it will be barely elevated off the ground, and thus make noise pollution significant around the guideway. The major advantage though is away from the track. The noise will be centralized around the individual train sets, the advantage is that the noise is condensed into spaced out sets that come and go very quickly. Also most Maglev designs don't operate at full speed in densely populated areas. If the Maglev train is centered in the ROW, the remaining distance will act as a buffer to the surrounding areas.

3.4.2 Hazardous Cargo

The routes will be located away from densely populated areas. Elaborate monitoring systems intrinsic in Maglev will also assure that it is much safer than through the local highways or traditional HSR. Compared to cars, trains in general have fewer accidents. The monitoring systems and the wrap around guideway make Maglev significantly safer than other modes. The primary drawback of using Maglev for hazardous cargo is that at speeds up to 300 mph an accident would drastically increase the possible area requiring containment.

3.4.3 Travel Time

In the modern world one of the most prized commodities is time, which is why Maglev systems are expected to succeed. Maglev services could be charged at the cost of transport plus the time savings. Transportation engineers commonly use travel time as a description of distance. Compared to automobiles on the highway, Maglev would operate at least 4 times as fast. That is a 75% reduction in travel time. While that would not matter much for short trip, but it means that a person could travel from Dallas to San

Antonio in an hour as opposed to 5 hours. It is common for businessmen to travel between Dallas and Fort Worth for business meetings; Maglev would also make it feasible to travel to Austin or San Antonio for a meeting as well. The cost to ride a Maglev system and ingress-egress time would be key factors in such usage.

3.4.4 Creates Jobs

The creation of a larger arterial through Texas will require workers to operate, manage, and repair the stations and train sets. The jobs that would be adversely affected would be other transport systems. Air travel would still dominate the long distance travel; trucking companies would still have to transport the cargo to and from the stations. The drivers would have a less congested route to carry their goods across the states, even during peak traffic hours.

The biggest impact would likely be smaller air carriers that cover the planned corridor routes, where cost and freedom of travel would likely affect the impact on the system. Busing companies may also feel a smaller impact, in part because they would also be able to use the system to move people. They may also restructure their operation by configuring smaller routes to bring people to transit stations.

3.4.5 Increased Trade

The TTC has the potential to make transport cheaper. This would allow companies to ship farther for the same price, or save money on the current shipping price. It would also effectively reduce the distances between suppliers and consumers. Not only is the transportation cheaper and faster, but the ability to meet face to face would also increase. By making trade easier and cheaper in the state, the overall trade in the state will increase.

3.4.6 Increased Safety

Maglev has two major concerns: it can move at 300 mph and it is not in direct surface contact. For these reasons, the trains are highly monitored. Maglev guideways are operated only one way at any given time, as it would catastrophic if two trains collided head-on at 300 mph.

Maglev systems are also operated by a central control station as monitored by an onboard conductor. This means that trains on the same track would be operated by one system, and would continuously communicate between all trains on the same stretch of rail. Although Maglev could be operated without an onboard staff, the trains are typically manned to monitor the train's conditions and the track conditions.

While Maglev typically operates at comfortable decelerations, it is possible for a train to stop extremely fast. A Maglev train traveling full speed could come to a complete stop so quickly that it would likely be fatal to some passengers. Although if a guideway has been discovered to be damaged such that the train may derail, it could make that stop to prevent derailing risking only a few passengers. The fatality rate would be much less, and repairs would be cheaper than a 300 mph derailment.

Maglev guideways are generally designed to prevent derailment or tipping. For instance, EMS systems operate on a T-shaped guideway. The trains actually are wrapped around the guideway. The train can glide and bump along the sliders on it, but cannot leave the guideway without substantial damage to either the train or the guideway or the train itself.

3.4.7 Centralize the Major Maintenance Needs

The biggest damage to our highways is the heavy cyclic loadings the road experiences as large trucks pass over it. These loadings weaken the roadway all the way to the foundation over time. On a highway with a large amount of trucks, like I-35, the surface often takes a beating and requires regular maintenance and resurfacing.

The typical damage starts as the sub-surface portions of the road settle creating a dip in the road surface. From there it is just a matter of time before the surface begins to break apart. Without repairs, the damage will develop into potholes, which are devastating to vehicles at highway speeds.

With Maglev, the train does not contact the guideway surface, and therefore reduces the damage to the guideway. The structure does undergo a heavy cyclic loading fatigue that reacts similarly to a bridge, but does not require as much structural maintenance due to the more uniform distribution of the load. These structures will eventually need to be completely replaced.

Most of the required maintenance is generally in the elevation and propulsion systems. Guideways require repair when damaged by an outside force, an example would be if a train contacted the guideway with its skids. There is not much that can be done about repairing or maintaining the damage form the heavy cyclic loads.

Carrying cargo on Maglev is effective at accumulating weight and redistributing it since the weight from multiple trucks can be loaded onto one train creating one effective loading cycle. Magnets allow for a more uniform distribution of weight versus using wheels. The current weight requirements for cargo on Maglev would also mean that the structure would undergo less stress than the typical heavy truck.

3.5 Implementation Risks

3.5.1 Trucking

The trucking industry may reject the proposal due to the toll facilities established on the highway, even though the toll road may save the trucking companies money in the longer run. If trucks are forced to take the new corridor instead of the existing facility, their lobbyist may challenge the proposed relocation of trucks.

3.5.2 Rail

The Governor's proposal of including freight lines would receive backlash from rail industry because it competes with present rail businesses in the proposed corridor. The rail industry would find this threatening to their current commerce in the rail network. They would see this proposal as unfair competition from a government owned rail line, which would receive government subsidies, and would lobby heavily against the plan. HSR is unable of running freight at this time. The infrastructure needed to accommodate such weight at high speeds is not possible without a more stable train to track connection, like that of the Maglev.

3.5.3 Airlines

The Texas High-Speed Rail Authority is representative of what this project can expect from its opponents. The Texas TGV faced scrutiny from the courts, where Texas-based Southwest Airlines launched three lawsuits against the Texas High-Speed Rail Authority. These lawsuits showed the true combativeness that the new rail would bring to the market. Southwest Airlines was attacking the proposal in a public forum, as opposed to the behind the scenes political tactics. This aggressiveness makes it clear to the identity of the opposition... Southwest Airlines, which since deregulation has consistently performed as America's most profitable air carrier, correctly perceived much to be at stake in another travel mode's arrival in its home state.

In the routes to be serviced by the Texas Triangle Southwest Airlines has a 44% share of the Airline market. They would have the most to lose by the instillation of an alternative mode of transportation. Feldman reported that at the time, 6.6 percent of Southwest's total traffic was either originating in or destined to the cities that Texas TGV would serve and that 26.7 percent of Southwest's passengers flew to or from Texas, where 180 out of the carrier's 1,400 daily flights originated. Little wonder, then, that Southwest viewed Texas TGV as "enemy No. 1" and fought the project "down and dirty." [Perl]

Southwest's outspoken chairman, Herb Kelleher, did not mince words, or threats, regarding his opposition to the Texas TGV. Calling high-speed rail supporters "economic illiterates," he went on to challenge Texas TGV's claims head on:

"They are saying that the roads and the airways will be so congested that the train will be the best alternative... So I have no ambition, no imagination, and no ingenuity." "If that's the case, I'll just buy some 757s and double the number of seats between Houston and Dallas. The whole thing is just so ludicrous!"

Southwest's current structure of using a standard airplane for all of its routes would make it difficult for such an expansion to 757s. An additional tactic was used when San Antonio mayor Nelson Wolff floated the idea of using improvement fees to provide rail access into his city-owned airport. To this news Kelleher publicly threatened to pull all of Southwest's flights out of San Antonio. These accounted for 30 percent of San Antonio's scheduled air service. Kelleher told a meeting of his own employees that if the Texas TGV obtained any assistance form the municipality," San Antonio could become a train town instead of a plane town." [Perl]

It is difficult to tell which side truly won in the litigation brought against the Texas TGVA. Even without winning in court, Southwest's legal actions had put Texas TGV's required fundraising behind schedule. Helen Ng reported "Congressional pressure helped to kill a federal subsidy for Texas TGV, because it was allegedly damaging to Boeing's friend and customer, Southwest Airlines." [Perl]

Texas TGV's "investment grade" ridership forecast by Charles River Associates helps to explain why Southwest Airlines and its colorful chairman devoted so much effort to battling a mode, which was publicly disparaged as an unworthy competitor. This study predicted that Texas TGV's lines would carry 14 million people and generate $618 million in annual revenues by 2010. Diversion of traffic from other modes ranged from 21 percent to 31 percent, among five different scenarios, leading Charles River Associates to note, "This is a very significant travel impact for a single new transportation facility serving a large existing market; it will have important impacts on the amounts of air pollution and energy consumption involved in transporting intercity travelers in Texas, and it will have potentially significant impacts on the congestion levels at airports and on interstate highways in future years." [Perl]

3.4.4 Public Use

Public outcry may come in many forms. Tax payers may oppose the multi-billion dollar proposal, because they may not recognize the potential financial gain for the State of Texas. Homeowners near the corridor will lose property in order to establish the right of way. The plan, if implemented, may approach some communities and cause disruption with noise and construction. Business owners may challenge the corridor if it has a negative impact on their business. Many cities will not be included in the connection of the corridor and will miss out on the possible increase in commerce opportunities.

Environmental groups may challenge the construction of the corridor in fear that the plan will affect the ecosystem of the surrounding areas. Steps must be made in order to minimize the negative impact on the environment. People may avoid the system if they are accustomed to regular routes. The out of pocket cost due to toll and ticket cost might deter commuters.

CHAPTER 4

SURVEY OF FINANCING ALTERNATIVES

The TTC, being a statewide system, requires huge capital investment and innovative forms of financing. The financing tools proposed for funding the corridor are toll equity, regional mobility authority, and Texas Mobility Fund. Other methods of funding suggested include concessions, federal grants, and leasing right of way. It is beyond the scope of this study to discuss the funding alternatives for the TTC. However, a general discussion of potential funding and financing sources for the proposed Maglev route is presented in this chapter. The potential funding and financing sources in sections 4.1, 4.2, and 4.3 are cited from "South East High Speed Rail Corridor Feasibility Report" prepared by the North Carolina Department of Transportation (26).

4.1 Potential Funding Sources for Capital Costs (26)

Funding sources are those which do not have to be repaid. They are usually used to cover the capital costs. Such funding is obtained in the form of grants. These are referred to as *subsidies* throughout this report. Sections 4.1.1 through 4.1.7 list the various funding sources that may be available for the capital costs.

4.1.1 Federal Funds

Federal funds are the grants provided by the federal government. There are some federal regulations that require matching grants at state and local levels for a project to secure these grants.

4.1.2 State Funds

State funds are grants from the state government. The main source of revenue for the state to fund transportation projects is through gasoline tax and other vehicle related taxes. A part of these revenues are allocated for transportation projects. Since many projects compete for these funds, obtaining a budgetary allocation may be difficult.

4.1.3 Local Public Funds

Local funds are grants that do not need to be repaid, although securing local general revenue may be difficult and depend on the project's local support.

4.1.4 State/Local Tax Revenue

A legislated tax or fee can be imposed on a dedicated revenue source. Such a tax will provide a steady stream of revenue that can be used to pay back the capital costs. Such a funding source is relatively stable and easy to forecast. Securing such a funding may be difficult due to political compulsions. Any state tax used for issuing debt requires legislation, which requires voter approval.

4.1.5 Local Value Capture Methods (Real Estate Tax, etc.)

Tax can be imposed on the revenues resulting from enhanced real estate development due to improvements in transportation corridors. Special assessment districts can be created for imposing real estate taxes. The funds generated would typically cover cost for station improvements. Transportation corridors improve the economic activity in the surrounding areas. Hence, the property tax revenue generated from that area increases. Tax increment financing is the allocation of incremental tax revenues to transportation projects.

4.1.6 Regional Taxation Districts

Similar to tax increment financing but on a broader scale, a regional taxation district is established to pay for the costs of infrastructure development, often spanning the entire region benefiting from the infrastructure. Approval of a referendum is required only in the districts.

4.1.7 Sale or Lease of Development Rights

The property owned by the state around the new transportation corridor can be sold or leased to a private entity for development. This would provide a steady stream of revenues for funding the capital costs or to make payments on debts. However, the purchase price may be lower than that could be obtained at a later stage of development.

4.2 Potential Financing Sources for Capital Costs (26)

Financing sources are those which are used to cover capital costs and have to be paid back over a period of time. A common tool used to raise capital is the issue of bonds. The terminology *bond* is used throughout this report to represent this form of financing. Sections 4.2.1 through 4.2.9 list various financing sources for capital costs.

4.2.1 Tax Exempt Revenue Bonds

Tax exempt revenue bonds can be issued to finance the capital costs. Federal taxes are waived on the interest income from such bonds, resulting in lower interest rates. Tax exempt revenue bonds offer a relatively stable and guaranteed form of financing for the capital costs. Higher total value of bonds can be issued for the same revenue as the interest rates are lower than taxable bonds. Such bonds are usually backed by dedicated tax revenue.

4.2.2 Project Finance

Revenue bonds can be issued backed solely by the revenues generated by the transportation project. These bonds may be tax exempt or taxable depending on the ownership of the transportation system. Since the revenues of the system may not be stable, project financing may be considered risky by the investors. As the bonds are not backed by dedicated tax revenues, securing such funds would have lesser political interference.

4.2.3 General Obligation Bonds

General Obligation bonds can be issued to pay for investments in public transportation facilities, and are backed by the full faith and credit of the state. Thus, the risk is transferred from the project to the state. However, any excess revenue generated would be directed back to the state. Such bonds generate relatively more interest from the investors as they would analyze the state's credit risk before making an investment.

4.2.4 State Guarantee

Project financing can be backed by a state guarantee. The guarantee would be effective if the revenues generated by the system are not sufficient to pay for the annual payments for the bonds. A state guarantee lowers the risk associated with the project, which would attract investors, and reduce the interest rates on bonds.

4.2.5 Export Financing

Export/Import banks offer financing for purchase of equipment, technology or service from foreign countries. Loans are offered with favorable financial terms so that both the vendor and the buyer may be benefited.

4.2.6 Vendor Financing

The suppliers of equipment or technology may offer financing for a project to encourage the sales of their products. Acquiring such a form of finance often requires a lease agreement with the supplier. Vendor financing may be used for purchase of rolling stock, signaling systems, etc. The rate of interest for the finance may be higher than that for tax-exempt revenue bonds.

4.2.7 Equipment Leasing

Substantial cost savings in the financing of facilities and equipment can be achieved in the United States through the use of a tax-oriented lease. Tax benefits can be claimed by the lessor in the form of depreciation deductions. The lessee can get tax benefits too, as the lease payment is deducted as an expense. Realization of tax benefits results in lower cost of financing.

4.2.8 Private Equity

Finance for capital costs may be raised by private equity investment. This is achieved by issuing of shares of common stock. However, the shareholders would have some control over the project if private equity investment is used.

4.2.9 Loans

Loans can be obtained from commercial banks for financing of infrastructure projects. Although these loans are typically offered for five to eight years, longer payback periods may be secured for infrastructure projects. Commercial loans have higher interest rates than bonds. Also, the bank would assess the risk involved before lending for any particular project.

4.3 Potential Revenue Sources for Operating Costs (26)

Revenue sources are those funds raised as a result of the normal operation of the Maglev service. Typical revenue sources include fare box, advertising, and on-board/in-station concessions. Sections 4.3.1 through 4.3.5 lists the various revenue sources for operating costs.

4.3.1 Fare Box Revenue

Fare box revenue is the main source for operating costs. The total amount of revenue generated by the ticket price during the normal operation of a transportation system constitutes fare box revenue. The revenue estimates depend on the accuracy of ridership forecasts, which are often difficult to predict. The ridership depends on various factors such as ticket price, level of service of the system, etc.

4.3.2 On-Board and In-Station Concessions, Advertising

On-board concessions would involve the sale of goods and services on the train such as food, beverages, and telephone service. In-station concessions would involve such sales as food, beverages, telephone service, books and magazines, parking, etc. The space in and around the stations can be sold for advertisements. The revenue generated may be used for maintenance and operation of stations. These revenues are relatively more predictable. However, the total amount of revenue generated by advertising may not be significant.

4.3.3 High Speed Parcel Transport

The high speed of Maglev trains may be used for express delivery of parcels. The revenue generated from high speed parcel transport can be used for operation and maintenance costs. The revenue generated may not be very high as the Maglevs have to compete with air transportation in this sector.

4.3.4 Lease of Right-of-Way

The state can lease a part of the right-of-way to railroad operators for freight rail operations. The railroad pays the annual lease amount that would provide a steady stream of revenue. The railroad would also take the responsibility for maintenance of right of way for the lease period.

4.3.5 Parallel Uses of Right-of-Way

The longitudinal rights along parts of right-of-way can be leased to firms in telecommunications, power, or gas utility industries. This would provide predictable revenues for a long period of time.

4.4 Public-Private Partnership (Alameda Corridor) (27)

The Alameda Corridor is located in southern Los Angeles County, California, running from the Ports of Long Beach and Los Angeles 20 miles north to downtown Los Angeles, primarily along and adjacent to Alameda Street. The project extends through or borders the Cities of Vernon, Huntington Park, South Gate, Lynwood, Compton, Carson, and Los Angeles, and the County of Los Angeles.

The Alameda Corridor Transportation Authority (ACTA) was created in August 1989 in response to the growing concern regarding traffic congestion in the port area. From the outset, it was designed as a freight only rail expressway to alleviate the intense freight traffic between the Ports of Long Beach and Los Angeles. The Alameda Corridor is operated by a partnership between the Ports of Long Beach and Los Angeles, Burlington North and Santa Fe Railroad, and Union Pacific Railroad.

The Ports of Long Angeles and Long Beach are the two busiest seaports in the United States. The number of cargo containers moving through the ports in 2001 was 9.6 million units. The ports project the volume of cargo containers would increase to 24 million units by 2020.

Before the completion of Alameda Corridor, there were 20 to 35 daily train trips on the branch lines serving the ports. The Alameda Corridor is designed to accommodate the 100 daily train trips to and from the ports projected for 2020, with trains averaging 30 to 40 mph.

The Alameda Corridor was funded by both public and private sources including $1.16 billion in revenue bonds sold by ACTA, a $400 million loan from the U.S. Department of Transportation, $394 million from the ports, and $347 million in grants administered by the Los Angeles County Metropolitan Transportation Authority. Bond debt service will be paid through fees collected from the railroads for the transportation of cargo containers outside of southern California (28).

The Alameda Corridor was the first such joint venture of its kind and successfully demonstrated what innovative financing could do for ground surface transportation in America. It went a long way in changing the views and inhibitions regarding such joint ventures.

CHAPTER 5

FINANCIAL FEASIBILITY ANALYSIS

5.1 Selection of Route

The route considered for the study runs from Dallas-Fort Worth to Laredo and covers a distance of 435 miles. There are three stations along the way, in Waco, Austin, and San Antonio, and two terminals, at Dallas-Fort Worth and Laredo. Maglev trains would be used for the project. It covers the principal cities of central Texas and runs along the major north–south corridor through Texas, starting close to the Oklahoma border in the north, to the border with Mexico in the south.

Certain assumptions have been made with regard to the study route. These assumptions are as follows

- Right of way is available (cost of right of way not considered).
- Transrapid system and trains are used.
- Beginning of project – 2005.
- Beginning of operation – 2015.
- Capital investment at midpoint of construction phase (2010) has been taken into consideration. Capital investment will be required throughout the design and construction phase. Since a detailed timeline regarding these phases is not available, it is assumed for the calculation purposes that the entire capital investment is made at the mid point of construction phase.

- The average annual inflation rate calculated for years 1991 to 2000 from the Consumer Price Index is 2.81%. All costs in this report are in 2000 dollars escalated using the above value. The effect of taxes which may be applicable is not considered. The value of 2.81% is considered as the effective rate of interest in all the calculations (29).

5.2 Scenarios for Financial Analysis

Costs from the BW Maglev project have been considered and used to derive the cost for the selected route. However, the costs shown for Texas have been derived using local guideway construction costs for concrete infrastructure. Two different scenarios have been considered for each segment, i.e., costs derived from the BW Maglev costs and the Texas Maglev costs. Costs have been estimated for both scenarios and presented in the form of charts in Appendix C (30, 31). These costs were then applied to the segment considered from Dallas-Fort Worth to Laredo.

Revenue is calculated considering current travel trends in Texas and is based on different headway and ridership assumptions. An average ticket price has been considered for the whole length of the route. For any project to be implemented, the benefit to cost ratio should be greater than one. Thus, an estimation of the revenues generated is important to derive the benefit to cost ratio.

The different scenarios considered are described below.

- The cost estimate for a Maglev system between Dallas-Fort Worth and Laredo is derived using the BW Maglev costs in the first scenario.

- The cost estimate for a Maglev system between Dallas-Fort Worth and Laredo is derived using local construction costs in Texas in the second scenario.

The analysis is done with 30-minute headway and 20-minute headway for each of the above scenarios.

5.3 Ridership Assumptions

Before looking into the specifics of the scenarios, it is important to state the assumptions that have been considered for each of the scenarios.

- 16 hour daily operation has been considered.
- The relationship between ticket price and ridership is assumed to be linear. The relationship is generally non linear and depends on several factors such as elasticity, propensity of riders, and level of service. However, at present, the exact relationship for this particular project is not known. Hence a linear relationship is assumed for the sake of simplicity.
- Average ticket price for the entire route length is considered for the purpose of analysis. The ticket price range of \$50 to \$100 was fixed based on the average one-way domestic airline fares between the cities considered in the corridor (32).

It is assumed that ridership increases if the headways are shorter, even for the same ticket price. For the ordinary traveler, frequency of service is a very important consideration. For example, for a ticket price of \$100, the ridership is assumed to be 50% of capacity if the headway is 30 minutes and the ridership increases to 60% of capacity if the headway is decreased to 20 minutes. However, decreasing headway means increasing fleet size or reducing the break period for the trains, both of which would involve more expenditure. The annual ridership for the selected route, calculated with the above assumptions ranges from 3.71 million to 9.47 million. These ridership assumptions are comparable with the high-speed rail ridership forecasts for 2010 for Texas TGV (33).

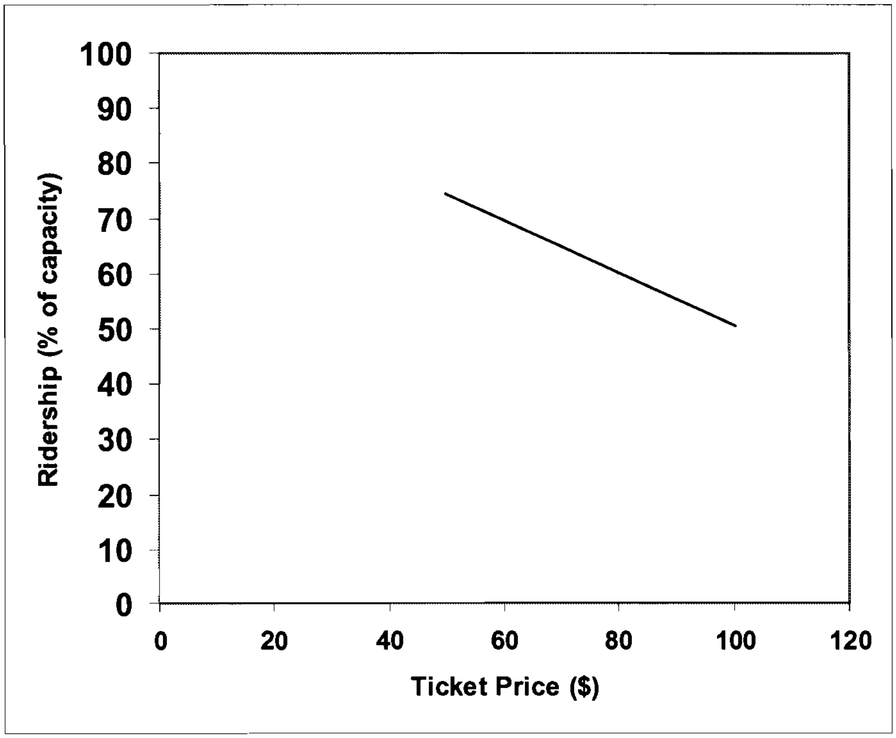

Figure 5.1: Estimated ridership for 30-minute headway

Figure 5.1 shows the estimated ridership for 30–minute headway. The ridership is assumed to be 50% of capacity at an average ticket price of $100 and increases to 75% of capacity at an average ticket price of $50.

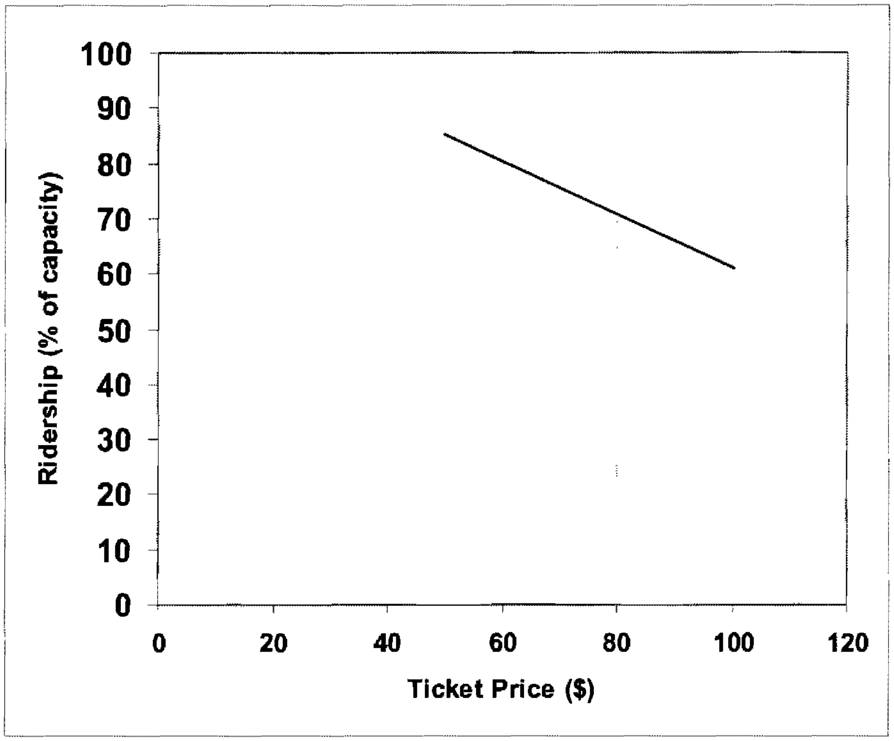

Figure 5.2: Estimated ridership for 20-minute headway

Figure 5.2 shows the estimated ridership for 20–minute headway. The ridership is assumed to be 60% of capacity at an average ticket price of $100 and increases to 85% of capacity at an average ticket price of $50.

5.4 Financial Analysis

The financial analysis is done for each of the scenarios with the assumptions stated above. The annual payment required to repay the loan (for the capital cost) is calculated for a 30 year and a 50 year payback period. The average annual operation and maintenance costs are added to this payment to obtain the annual revenue required in order to run the Maglev system and also make annual payments so that the capital costs are recovered at the end of the payback period.

The revenue generated is calculated for various ridership assumptions and the corresponding ticket price. This revenue will be used for operation and maintenance and also to repay the capital cost which was paid for by issuing bonds or other means of financing. Basically, the fare-box revenue is used to fund operation and maintenance costs and to repay the bonds. The funds remaining after paying for operation and maintenance costs can be used to repay the bonds. However, this amount is not always sufficient to fund the entire capital costs. The remaining amount of the funds that have to be procured is designated as the subsidies. The subsidies are funds procured through grants that need not be returned.

The annual payment required to recover the capital cost is calculated using the equation for uniform-series capital recovery factor given below (34).

$$A = P\frac{i(1+i)^N}{(1+i)^N - 1}$$

Where

- A = End-of-period cash flows (or equivalent end of period values) in a uniform series continuing for a specified number of periods. Here the letter A implies annual.
- P = Present worth of money, i.e., the equivalent worth of one or more cash flows at a relative point in time defined as present.
- i = Effective interest rate per period.
- N = Number of compounding periods.

For this analysis,

- i = Inflation rate = 2.81 %.
- N = Payback period – 30 years or 50 years.
- P = Capital cost at the middle of construction phase (2010).
- A = Annual payment required to recover the capital cost.

The annual operation and maintenance cost is added to the value of A to obtain the annual revenue requirement. The farebox revenue is calculated from the ridership values and average ticket price. This amount is subtracted from the annual revenue requirement to obtain the amount of subsidies required. This is explained for one particular scenario and the sample calculations are shown below.

- Route length, L = 435 miles.
- Average Speed, V = 185 mph.
- Cycle time, C, is the time required for a Maglev train to complete one round trip, C = 2 * 435 / 185 = 4.7 hours.
- Headway, H = 20 minutes.
- Train Capacity (Transrapid Train sets) = 318 seats.
- Hours of Operation = 6 A.M. to 10 P.M. = 16 hours.
- Number of train sets required = C / H = (4.7 * 60) / 20 = 14.1, i.e., 15 trains.
- Since Maglev trains have no contact with the guideway and very few moving parts, the chances of breakdown can be expected to be low. However, two spare trains are added to the required number of trains for emergency.

- Number of train sets required = 17 trains.
- Capital cost derived for construction in Texas (2000 dollars), P = \$18,804 million.
- Operation and maintenance cost (2000 dollar) = \$175 million.
- Inflation rate, i = 0.0281.
- Payback period, N = 30 years.

Annual payment required to recover the capital cost

- A = $P\dfrac{i(1+i)^N}{(1+i)^N - 1}$
- A = $18804\dfrac{0.0281(1+0.0281)^{30}}{(1+0.0281)^{30} - 1}$
- A = \$ 936 million.
- Annual revenue requirement = 936 + 175 = \$ 1,111 million.
- Ridership = 85% of capacity.
- Annual ridership = 9.47 million trips.
- Average ticket price = \$50 per trip.
- Total fare-box revenue = 50 * 9.47 million = \$ 474 million/year.

The fare-box revenue can be used for operation and maintenance and to repay part of the capital cost funded by financing sources such as bonds. The remaining amount, which cannot be repaid by the system, has to be subsidized. This amount is designated as subsidies.

- Subsidies = 1111 – 474 = \$638 million.

The above process is repeated by varying the capital cost, headway as follows

1. Costs from Baltimore-Washington Maglev; headway = 30 minutes.
2. Costs from Baltimore-Washington Maglev; headway = 20 minutes.
3. Costs from Texas Maglev; headway = 30 minutes.
4. Costs from Texas Maglev; headway = 20 minutes.

The results are tabulated in Tables 5.1 through 5.8 for different values of ridership and average ticket price. The amount of subsidies and bonds are shown as charts in Figures 5.3 through 5.6.

Table 5.1: Annual revenue requirements for 30-minute headway using cost estimate from the Baltimore-Washington Maglev project

Units – million $, Base Year 2000

Capital Cost	O & M Costs per year	Annual Payment		Total Revenue Required / Year	
		30 year payback	50 year payback	30 year payback	50 year payback
35,468	155	1,765	1,329	1,920	1,484

Table 5.2: Different funding scenarios for varying ridership estimates for 30-minute headway using cost estimate from the Baltimore-Washington Maglev project

Ridership (% of Capacity)	Annual Ridership (millions)	Average Ticket Price	Funding Source	Funds (million $) 30 yr payback	Funds (million $) 50 yr payback
75	5.57	$50	Subsidies	1,641	1,205
			Bonds	279	279
70	5.20	$60	Subsidies	1,608	1,172
			Bonds	312	312
65	4.83	$70	Subsidies	1,582	1,146
			Bonds	338	338
60	4.46	$80	Subsidies	1,563	1,127
			Bonds	357	357
55	4.09	$90	Subsidies	1,552	1,116
			Bonds	368	368
50	3.71	$100	Subsidies	1,549	1,112
			Bonds	371	371

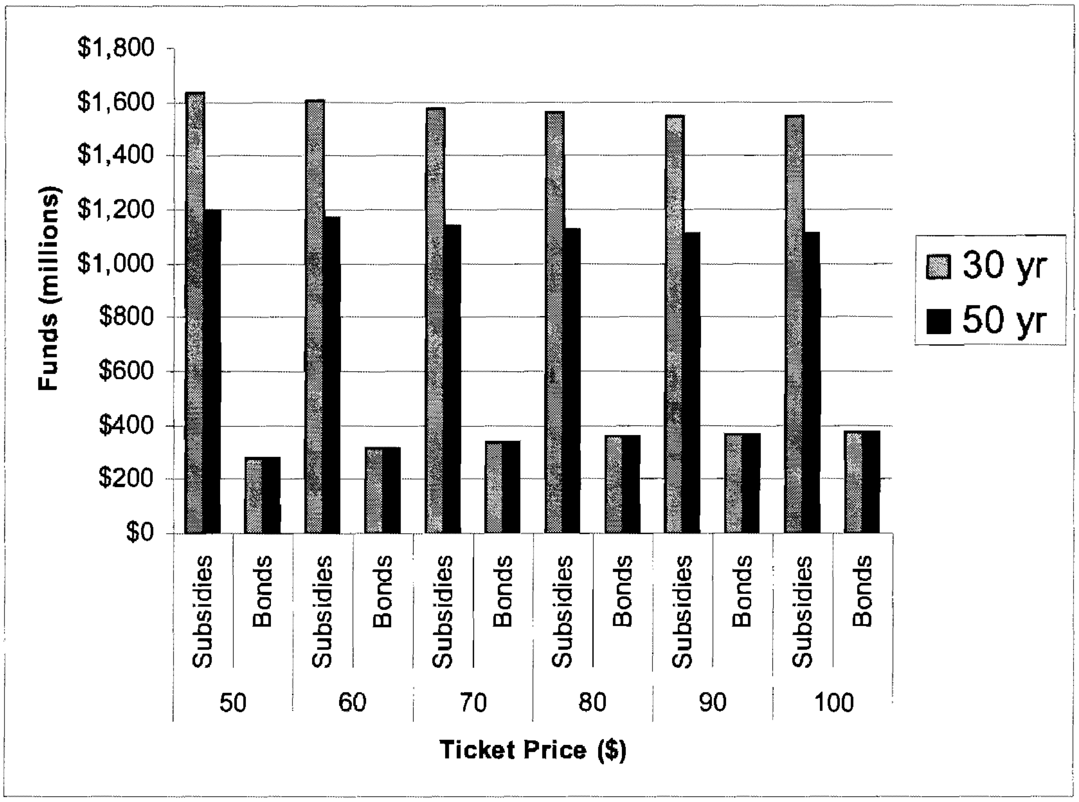

Figure 5.3: Payback scenario for headway of 30 minutes with costs derived from the Baltimore-Washington Maglev project

Table 5.3: Annual revenue requirements for 20-minute headway using cost estimates from the Baltimore-Washington Maglev project

Units – million $, Base Year 2000

		Annual Payment		Total Revenue Required / Year	
Capital Cost	O & M Costs per year	30 year payback	50 year payback	30 year payback	50 year payback
35,666	175	1,775	1,337	1,951	1,512

Table 5.4: Different funding scenarios for varying ridership estimates for 20-minute headway using cost estimates from the Baltimore-Washington Maglev project

				Funds (million $)	
Ridership (% of Capacity)	Annual Ridership (millions)	Average Ticket Price	Funding Source	30 yr payback	50 yr payback
85	9.47	$50	Subsidies	1,477	1,038
			Bonds	474	474
80	8.91	$60	Subsidies	1,416	977
			Bonds	535	535
75	8.36	$70	Subsidies	1,366	927
			Bonds	585	585
70	7.80	$80	Subsidies	1,327	888
			Bonds	624	624
65	7.24	$90	Subsidies	1,299	860
			Bonds	652	652
60	6.69	$100	Subsidies	1,282	843
			Bonds	669	669

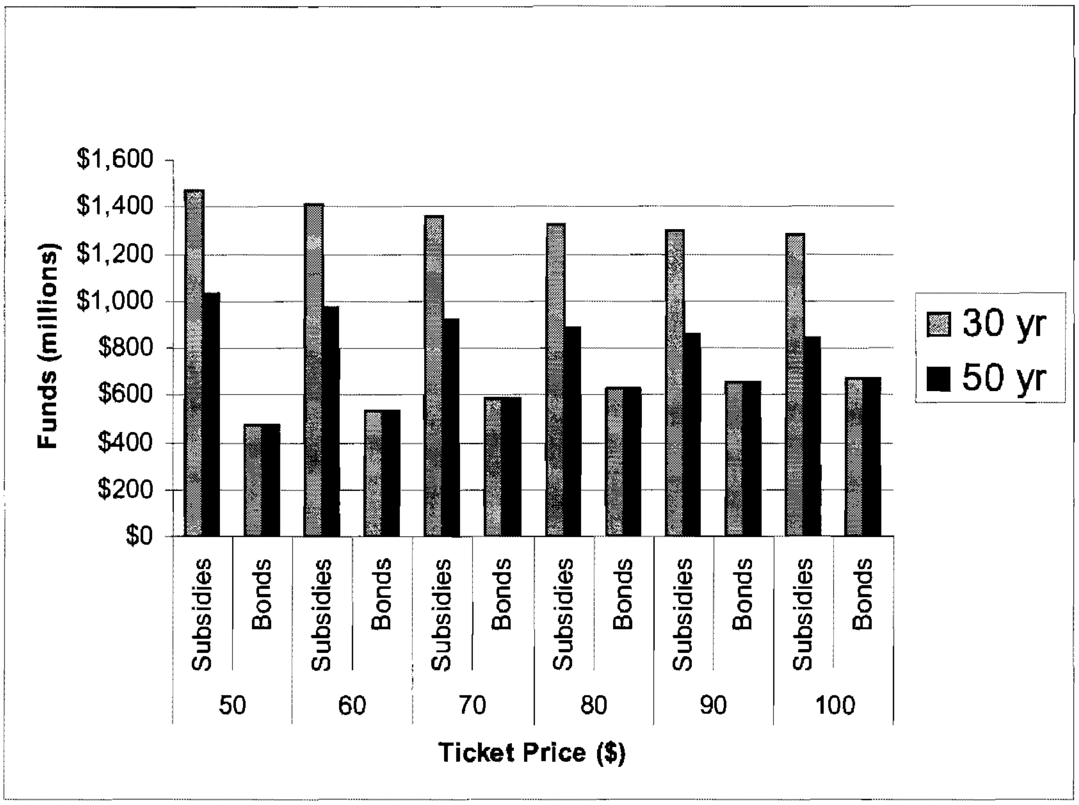

Figure 5.4: Payback scenario for headway of 20 minutes with costs derived from the Baltimore-Washington Maglev project

Table 5.5: Annual revenue requirements for 30-minute headway for the Texas Maglev project

Units – million $, Base Year 2000

		Annual Payment		Total Revenue Required / Year	
Capital Cost	O & M Costs per year	30 year payback	50 year payback	30 year payback	50 year payback
18,606	155	926	697	1,081	852

Table 5.6: Different funding scenarios for varying ridership estimates for 30-minute headway for the Texas Maglev project

				Funds (million $)	
Ridership (% of Capacity)	Annual Ridership (millions)	Average Ticket Price	Funding Source	30 yr payback	50 yr payback
75	5.57	$50	Subsidies	802	573
			Bonds	279	279
70	5.20	$60	Subsidies	769	540
			Bonds	312	312
65	4.83	$70	Subsidies	743	514
			Bonds	338	338
60	4.46	$80	Subsidies	724	495
			Bonds	357	357
55	4.09	$90	Subsidies	713	484
			Bonds	368	368
50	3.71	$100	Subsidies	709	480
			Bonds	371	371

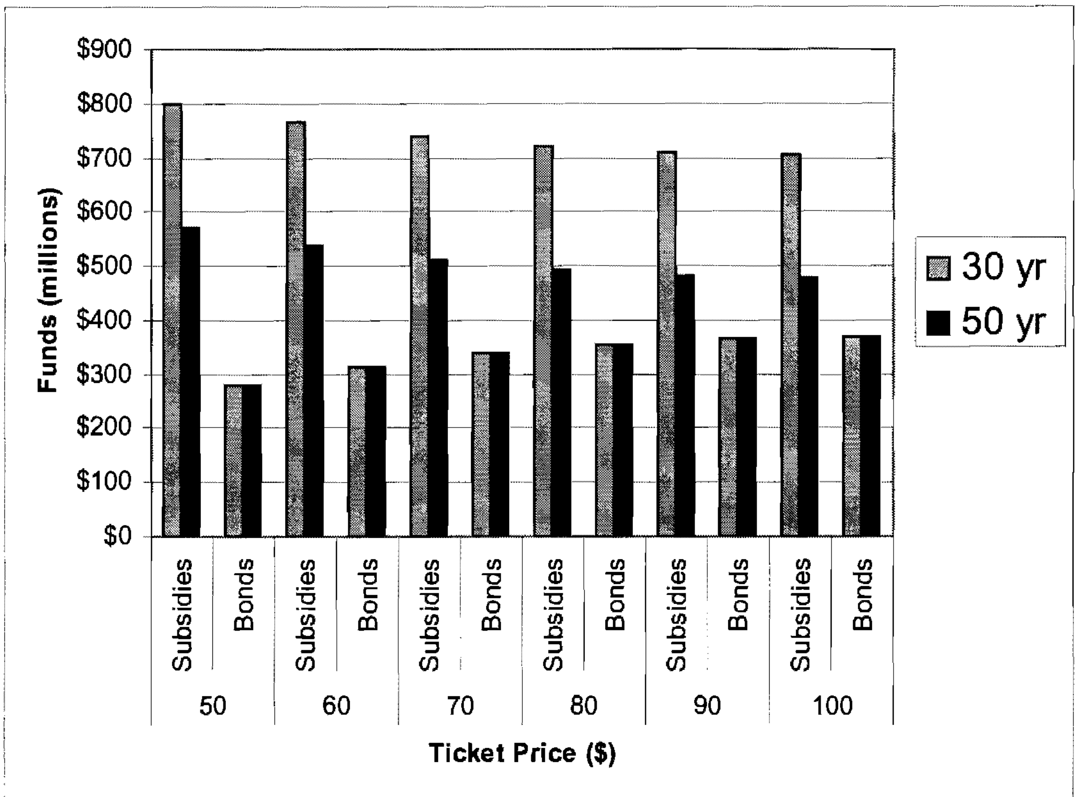

Figure 5.5: Payback scenario for headway of 30 minutes for the Texas Maglev project

Table 5.7: Annual revenue requirements for 20-minute headway for the Texas Maglev project

Units – million $, Base Year 2000

		Annual Payment		Total Revenue Required / Year	
Capital Cost	O & M Costs per year	30 year payback	50 year payback	30 year payback	50 year payback
18,804	175	936	705	1,111	880

Table 5.8: Different funding scenarios for varying ridership estimates for 20-minute headway for the Texas Maglev project

				Funds (million $)	
Ridership (% of Capacity)	Annual Ridership (millions)	Average Ticket Price	Funding Source	30 yr payback	50 yr payback
85	9.47	$50	Subsidies	638	406
			Bonds	474	474
80	8.91	$60	Subsidies	576	345
			Bonds	535	535
75	8.36	$70	Subsidies	526	295
			Bonds	585	585
70	7.80	$80	Subsidies	487	256
			Bonds	624	624
65	7.24	$90	Subsidies	459	228
			Bonds	652	652
60	6.69	$100	Subsidies	443	211
			Bonds	669	669

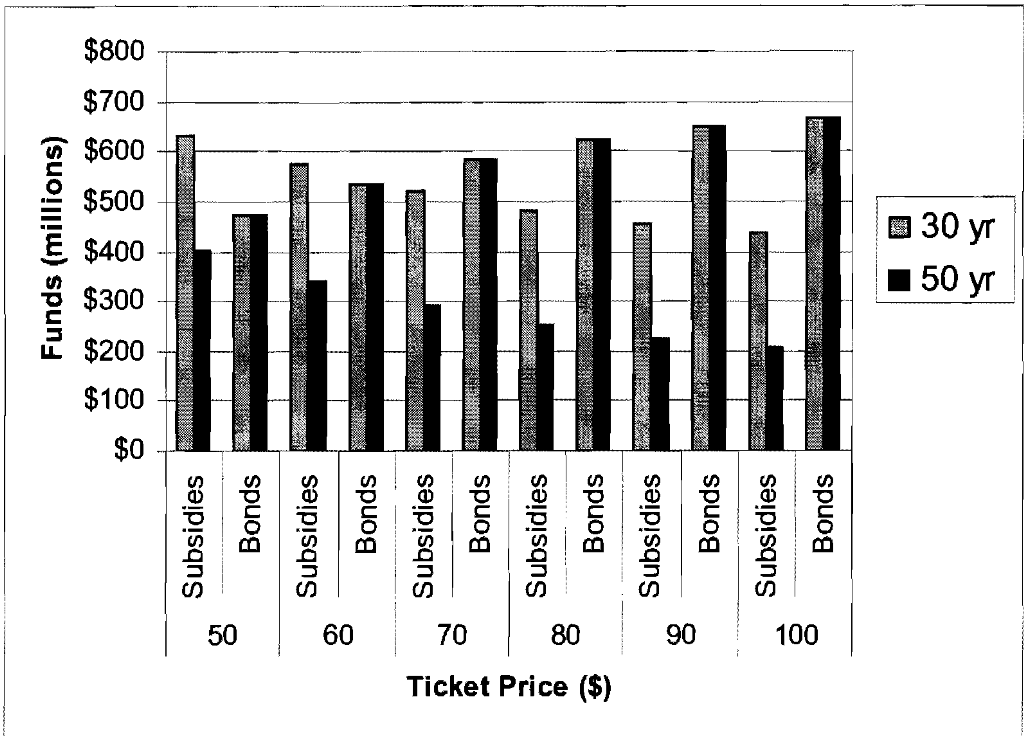

Figure 5.6: Payback scenario for headway of 20 minutes for the Texas Maglev project

5.5 Discussion of Results

The results of the analysis can be read from the charts in Figures 3.3 through 3.6. The x-axis contains the average ticket price ranging from $50 to $100 with a $10 interval. For each of these ticket prices, the amount of funds paid by subsidies and amount of funds paid by bonds are represented in the form of bar graph, for 30-year payback period and 50-year payback period.

Here, subsidies represent the fraction of funding that does not have to be repaid. Bonds represent the fraction of funding that must be repaid by the revenues generated by the normal operation of the Maglev system. The part of investment financed by various sources such as revenue bonds has to be recovered from the system. Although this is represented as bonds, there are various other financing sources as discussed earlier which may be used to fund the capital costs.

Here is an illustrated example of reading these charts. Consider Figure 4.6 above. This represents a payback scenario for an estimated headway of 20 minutes for the Texas Maglev project.

Suppose the ticket price is $50 and 30 year payback period is considered we can read in Figure 4.6 that an amount of $630 million/year has to be subsidized and $470 million/year will be the revenue generated by the system which can be used to recover the capital costs.

To find the least ticket price with a payback period of 50 years for which the subsidies are less than 30% of total funds –

- For a 50 year payback period the total annual revenue required = $877 million
- Figure 4.6 shows that for 50 year payback period, the amount of subsidies for a ticket price of $80 is $250 million/year which is 29% of total cost.

For this case, the ticket price has to be at least $80 for subsidies to be less than 30%. Similarly various cases can be studied by varying the attributes in the chart.

The general trends that can be seen from the Figures 4.3 through 4.6 are as follows

- As the ticket price is increased, the percentage of subsidies required decreases in spite of a decrease in ridership.

- The fraction of funds that have to be subsidized decreases as the total cost of the project is decreased.

5.5.1 Sensitivity Analysis for Effective Interest Rate

The effective interest rate used in the analysis is 2.81%. The feasible regions will be affected if the value of effective interest rate is varied. The feasible regions are calculated for effective interest rates of 3%, 4%, and 5% and presented in Figures 5.7 and 5.8.

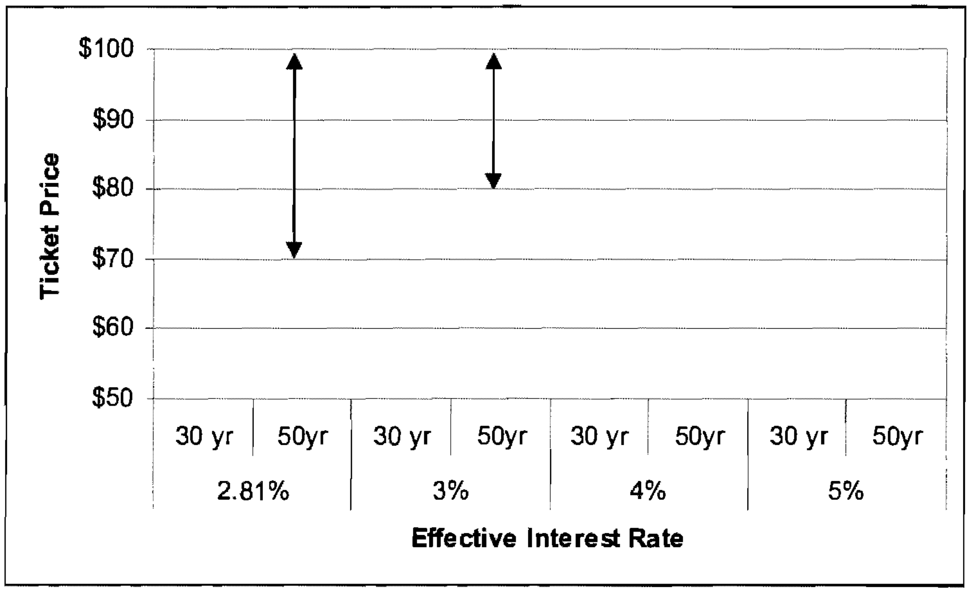

Figure 5.7: Sensitivity of effective interest rate for headway of 30 minutes for the Texas Maglev project

Figure 5.7 shows that for Texas Maglev project with 30-minute headway, there is no feasible region for 30-year payback period. For 50-year payback period, the feasible region decreases for 3% effective interest rate and there is no feasible region for effective interest rates of 4% and 5%.

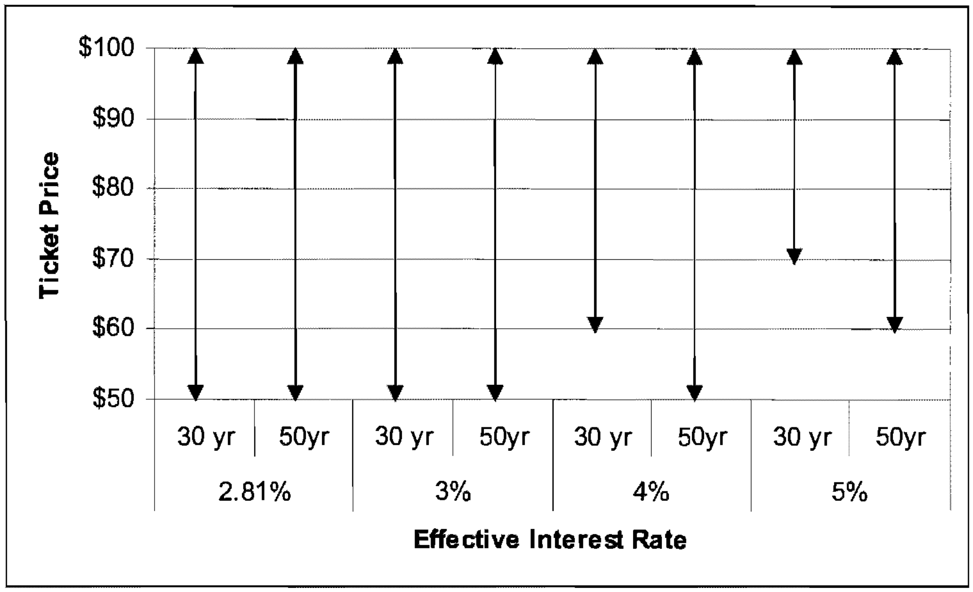

Figure 5.8: Sensitivity of effective interest rate for headway of 20 minutes for the Texas Maglev project

Figure 5.8 shows the feasible regions for Texas Maglev project with 20-minute headway. The feasible region decreases for 4% and 5% effective interest rate for 30-year payback period. For 50-year-payback period, there feasible region decreases only for 5% effective interest rate.

The results are more sensitive to variation of effective interest rate with 30-minute headway than with 20-minute headway.

5.5.2. Gas Tax Subsidies

The feasibility of the Maglev system depends on the amount of funding that can be subsidized. In other words, the maximum percentage of subsidies that is acceptable has to be defined. Based on the example of Alameda Corridor, this value is assumed to be 60%. A feasible solution exists only if the fraction of subsidies required for the system to break even is less than or equal to 60%.

The subsidies are the funds that are provided in the form of grants and need not be paid back by the system. Various funding sources are discussed earlier, one of which is state funds. The state tax on gasoline in Texas as of 2003 is 20 cents/gallon (35), of which about 12-13 cents are used for transportation. A part of the gas tax revenue may be used to fund the Maglev system. This will divert a part of funds from other competing expenditures and may be opposed. The other option would be to increase the gas tax to generate more revenue. The total revenue generated depends on the amount of gasoline sold/consumed. An increase in price might decrease the consumption. However, if the increase is nominal the total sales might not be affected drastically. Further, there is also a possibility of increase in demand of gasoline over next few years.

The average daily gasoline sales in Texas for the years 1998 to 2002 are shown in Table 5.9. The average annual gasoline sales are estimated by the average of those five years.

Table 5.9: Average Daily Gasoline Sales in Texas (36)

Year	Average Gasoline Sales in Texas (million gallons/day)
1998	30.17
1999	31.86
2000	30.16
2001	31.18
2002	32.07
Average	31.09

Average gasoline sales per year = 31.09 * 365 = 11,437 million gallons

The above quantity is assumed to be constant for the payback period of the project and the amount of gas tax increase required for funding the subsidies is calculated for various feasible solutions. Tables 5.10 and 5.11 show the increase in gasoline tax for funding the subsidies for Baltimore-Washington costs and Texas Maglev costs respectively.

The gas tax increase required to subsidize the Maglev ranges from 1.86 cents/gallon for the least conservative scenario to 14.46 cents/gallon for the most conservative scenario.

Table 5.10: Gasoline Tax Increase with Baltimore-Washington Costs

		Annual Subsidies Required (million $)		Gas Tax Increase (Cents/Gallon)	
Headway (min)	Average Ticket Price	30 year payback	50 year payback	30 year payback	50 year payback
30	$50	1,641	1,205	14.46	10.62
	$60	1,608	1,172	14.17	10.33
	$70	1,582	1,146	13.94	10.10
	$80	1,563	1,127	13.77	9.93
	$90	1,552	1,116	13.68	9.84
	$100	1,549	1,112	13.65	9.80
20	$50	1,477	1,038	13.02	9.15
	$60	1,416	977	12.48	8.61
	$70	1,366	927	12.04	8.17
	$80	1,327	888	11.69	7.83
	$90	1,299	860	11.45	7.58
	$100	1,282	843	11.30	7.43

Table 5.11: Gasoline Tax Increase with Texas Maglev Costs

Headway (min)	Average Ticket Price	Annual Subsidies Required (million $) 30 year payback	Annual Subsidies Required (million $) 50 year payback	Gas Tax Increase (Cents/Gallon) 30 year payback	Gas Tax Increase (Cents/Gallon) 50 year payback
30	$50	802	573	7.07	5.02
	$60	769	540	6.78	4.73
	$70	743	514	6.55	4.50
	$80	724	495	6.38	4.34
	$90	713	484	6.28	4.24
	$100	709	480	6.25	4.20
20	$50	638	406	5.62	3.58
	$60	576	345	5.08	3.04
	$70	526	295	4.64	2.60
	$80	487	256	4.29	2.26
	$90	459	228	4.05	2.01
	$100	443	211	3.90	1.86

CHAPTER 6

CONCLUSION

The following is the summary of the various financial scenarios for funding of the Maglev system.

- Since Maglev is a relatively new technology and there are no commercial Maglev systems in United States, the cost estimate is only approximate and likely to change by the time this project is implemented. However, as with any nascent technology, the cost of building the Maglev system is likely to decrease in the future with advances in technology.
- The revenue estimates are calculated from ridership assumptions on the basis of ticket price and headway. This is done to provide an overall idea of feasibility for the project. For more accurate revenue estimates, the ridership values have to be estimated with other established methods. Since there is no precedent of high speed surface transport system in Texas, accurate ridership estimation may be difficult and may not be reliable. Hence, the feasibility analysis is done for a range of ridership and ticket price rather than one particular value.
- The analysis shows that it may not be possible to build the Maglev system entirely through private investment. Some form of state support is necessary for a private investor to fund the project. This fraction of funding, which is called subsidies in the report, ranges from 39% to 85% for 30 year payback

period and 24% to 81% for 50 year payback period. These values represent the best and worst case scenarios for the ridership and ticket price variations considered.

- The Alameda Corridor project had 47% of the funds in the form of bonds. Although the total investment for Alameda Corridor is a lot lower than this project, if Alameda Corridor funding is considered as a model for price subsidies, the optimum value of ticket price and ridership for which the Maglev system may be financially feasible can be found. The fraction of subsidies required for the Texas Maglev project have to be more than that for the Alameda Corridor project.
- If we consider that subsidies of 60% or less is feasible, the following are the range of feasible solutions for assumed ridership and ticket price
    1) For Baltimore-Washington Maglev costs and 30-minute headway, no feasible solution is present.
    2) For Baltimore-Washington costs and 20-minute headway, no feasible solution exists for 30-year payback period. For 50-year payback period, the Maglev system is feasible for ticket price of $80 to $100.
    3) For Texas Maglev costs and 30-minute headway, no feasible solution exists for 30-year payback period. For 50-year payback period, the Maglev system is feasible for ticket price of $70 to $100.

4) For Texas Maglev costs and 20-minute headway, the Maglev system is feasible for ticket price of $50 and above for both 30-year and 50-year payback period.

- The analysis showed that gas tax increase could be used for funding of Maglev system. However the decision makers will have to be convinced about the benefits of implementing the Maglev system in Texas for justifying the tax increase. The Maglev has certain benefits in addition to the potential benefits of the Trans Texas Corridor. Due to its high speed, the Maglev will provide time savings for certain types of trips. The travel time savings is significant for business travelers. Maglev systems would create lower noise compared to high-speed rail. The noise from Maglev is generally based upon the aerodynamics of the train, because the noise from the propulsion and levitation components is virtually non-existent. Maglev guideways are generally designed to prevent derailment or tipping. The increased safety is one of the advantages of Maglev over high-speed rail. Maglev can be used for freight transportation which would reduce the number of trucks, which are the main cause for wearing of pavements, thus reducing the annual highway maintenance costs. Further research needs to be done to determine if the value of the above benefits is equal to or greater than the cost of subsidizing the system.

APPENDIX A

ABBREVIATIONS

Abbreviations

dB Decibel

dBA A-weighted decibel

DMS Dynamic Message Signs

EDS Electrodynamic Systems

EPA Environmental Protection Agency

FAA Federal Aviation Administration

FRA Federal Railway Administration

GSP Generalized System of Preferences

HCM Hwy Capacity Manual

ICE Inter-City Express

ITS Intelligent Transportation System

NAFTA North American Free Trade Agreement

NAAQS National Ambient Air Quality Standards

NOx Nitrogen Oxides

OBS On Board Services

OHMS Office of Hazardous Materials Safety

RFP Request for Proposal

ROW Right-of-way

TERP Texas Emission Reduction Plan

THSRA Texas High Speed Rail Authority

TGV Train à Grande Vitesse (French for High Speed Rail)

TTC Trans Texas Corridor

TxDOT Texas Department of Transportation

VOC Volatile Organic Compound

APPENDIX B

RIDERSHIP PROJECTIONS FOR TEXAS TGV

Ridership Projections for Texas TGV

The Texas High Speed Rail Authority awarded a fifty-year high speed rail franchise to the Texas TGV Corporation on 28 May 1991. Texas TGV was a consortium made up of Morrison Knudsen (USA), Bombardier (Canada), GEC-Alsthom (France/UK, builder of the Train à Grand Vitesse (TGV)) and a group of financial institutions comprising Crédit Lyonnais, Banque IndoSuez, Merrill Lynch, and others.

The Texas TGV project was designed to connect the Texas Triangle, i.e., the cities of Dallas-Fort Worth, San Antonio, and Houston. No state funding was available for the project. A study was carried out by Charles River Associates with regard to estimated ridership and revenues generated to give a better idea of how the project would prove beneficial to the state of Texas. The study was described by the Texas High Speed Rail Corporation as "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" (37). Table B.1 gives the estimated ridership for 2010 from the Charles River Associates study. However, the project was shelved in 1994 due to lack of funds (38).

The ridership forecast by the Charles River Associates had five models. The models vary in terms of alternative alignments, station locations, and connectivity to air service at Dallas-Fort Worth International Airport (DFW Airport). Model 2 and Model 3 are based on variation in the alignment between Dallas-Fort Worth and Houston, hence not considered for this project.

Table B.1: Ridership forecast for high speed rail in 2010 (39)

	Model 1	**Model 4**	**Model 5**
DFW - SA	2,177,000	2,799,000	1,284,000
AUS-SA	1,196,000	1,196,000	1,196,000
DFW - AUS	2,619,000	3,228,000	1,785,000
TOTAL	5,992,000	7,223,000	4,265,000

Model 1: Service to DFW Airport fully integrated with American Airlines (AA), including on-line reservation system screen presence. High speed rail (HSR) service would substitute for American Airlines flights between the Texas Triangle cities and DFW airport.

Model 4: Model 1 as above; with HSR service fully integrated with Delta Airlines in addition to American Airlines, including the substitution of HSR service for Delta flight within the Texas Triangle.

Model 5: Service provided between major cities in the Texas Triangle. There is no DFW Airport station to connect HSR service to long-haul carriers at DFW Airport. Instead, there is a station located off the property just south of DFW Airport.

APPENDIX C

COST OF MAGLEV INFRASTRUCTURE

Table C.1: Cost estimate for Texas Maglev for 30-minute headway derived from Baltimore-Washington costs (10)

	Unit Cost (million $)	DFW to Laredo (million $)
Capital Costs		
Guideway (centerline-mile)	33.60	14,616
Substation every 29 miles (per station)	2.80	42
Transrapid-08 trainset (each)	23.10	277
Capital station (each)	20.80	104
Administrative	24.80	2,480
Propulsion system	Lump Sum	3,160
Total	-	20,679
Adding 30% Contingency, Total Capital Cost	-	26,883
Capital Cost for year 2010 @ 2.81 % inflation rate	-	35,468
Operating Costs		
Operation and maintenance (per year)	69.00	69
Operation and maintenance per station (per year)	17.10	86
Annual operation and maintenance costs	-	155

Table C.2: Cost estimate for Texas Maglev for 20-minute headway derived from Baltimore-Washington costs (10)

	Unit Cost (million $)	DFW to Laredo (million $)
Capital Costs		
Guideway (centerline-mile)	33.60	14,616
Substation every 29 miles (per station)	2.80	42
Transrapid-08 trainset (each)	23.10	393
Capital station (each)	20.80	104
Administrative	24.80	2,480
Propulsion system	Lump Sum	3,160
Total	-	20,795
Adding 30% Contingency, Total Capital Cost	-	27,033
Capital Cost for year 2010 @ 2.81 % inflation rate	-	35,666
Operating Costs		
Operation and maintenance (per year)	90.00	90
Operation and maintenance per station (per year)	17.10	85
Annual operation and maintenance costs	-	175

Table C.3: Cost estimate for Texas Maglev for 30-minute headway derived from local costs for construction in Texas (10, 11)

	Unit Cost (million $)	DFW to Laredo (million $)
Capital Costs		
Guideway (centerline-mile)	11.00	4,785
Substation every 29 miles (per station)	2.80	42
Transrapid-08 trainset (each)	23.10	277
Capital station (each)	20.80	104
Administrative	24.80	2,480
Propulsion system	Lump Sum	3,160
Total	-	10,848
Adding 30% Contingency, Total Capital Cost	-	14,103
Capital Cost for year 2010 @ 2.81 % inflation rate	-	18,606
Operating Costs		
Operation and maintenance (per year)	69.00	69
Operation and maintenance per station (per year)	17.10	85
Annual operation and maintenance costs	-	154

Table C.4: Cost estimate for Texas Maglev for 20-minute headway derived from local costs for construction in Texas (10, 11)

	Unit cost (million $)	DFW to Laredo (million $)
Capital Costs		
Guideway (centerline-mile)	11.00	4,785
Substation every 29 miles (per station)	2.80	42
Transrapid-08 trainset (each)	23.10	393
Capital station (each)	20.80	104
Administrative	24.80	2,480
Propulsion system	Lump Sum	3,160
Total	-	10,964
Adding 30% Contingency, Total Capital Cost	-	14,253
Capital Cost for year 2010 @ 2.81 % inflation rate	-	18,804
Operating Costs		
Operation and maintenance (per year)	90.00	90
Operation and maintenance per station (per year)	17.10	175
Annual operation and maintenance costs	-	175

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