INNOVATIVE TECHNOLOGIES IN TRANSPORTATION

by

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16. Abstract
An historical overview of the transportation infrastructure of the United States and Texas is provided. Data for trends in transportation is analyzed and projections for the future are postulated. A survey of current technologies in transportation is conducted. A detailed report on Fuel Cells and Maglev systems, the two most promising technologies in transportation is provided. The report concludes with recommendations and conclusions regarding the future of intercity and intracity transportation in Texas.

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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Chapter 1

HISTORICAL OVERVIEW OF TRANSPORTATION INFRASTRUCTURE

1.1 Introduction

The history of transport systems is a history of evolutions within revolutions. Revolutions can be seen in the technological mutation from the mail-coach to the steamship to the railroad to the automobile to the airplane. These have transformed and extended the spatio-temporal range of commercial and private activities, leading to unprecedented levels of performance in terms of speed, quality of service, spatial division of activities, and integration of economic spaces. The evolutionary envelopes within these revolutionary jumps reveal a process of gradual replacement of old technologies (within each revolution) by new and innovative systems along structured and ordered development trajectories that can be formalized by simple mathematical models. Older transportation systems are made obsolete through technological advance (and economic development), and new ones are introduced that are better adapted to the continuously changing social, economic, and environmental boundary conditions. For example, catalytic converters and anti-lock braking systems were considered innovative technologies 30 years ago. Today, the evolutionary path of the automobile has been such that all gasoline powered automobiles are equipped with catalytic converters, and over 80% of all new passenger vehicle models have anti-lock braking systems. It is the advancement of technology that has determined the trajectory of both the revolutions and the evolutions in our transportation system.

Previous studies suggest an intriguing evidence of long-term regularities in the evolution, diffusion, and finally, the replacement of several families of technologies that have historically constituted our transport system, thus facilitating a prospective and tantalizing look into the future. These studies have established that both the revolutions and evolutions in transportation as seen over the last few centuries can be modeled using logistic functions.

First, we will examine the results of some of these studies to establish the veracity and accuracy of using logistic models for predicting both the revolution and the evolution in transportation. Next, we will detail how logistic models work and how they can be used to predict market acceptance, and the rate of diffusion of any technology. We will also discuss how these models can be modified to include the effects of many competing technologies. Finally, we detail how to use these models for our study.

1.2 Historical Revolutions in Transportation

The first major transportation revolution we consider for historical predictions occurred with the age of canals. Canals represented a fundamental infrastructure construction effort towards reducing natural barriers in order to connect coastal and inland waterways in an interconnected transportation infrastructure grid. At the same time, canals were the first powerful motor of the industrial age. Waterways facilitated new flows of goods, unprecedented exchanges between regions, specialization of labor, and access to more distant energy and raw material resources. Local fuel-wood shortages were resolved by substituting with coal, a higher energy-density fuel, the transport of which was made possible by canals. The age of canals started about two centuries ago and lasted almost one hundred years. By the end of the 19th century most national canal systems were in place and many links were already being decommissioned. Eventually the canals had to yield to the vicious competition from railroads, including hostile takeovers.

The first railways were constructed in the 1830s and they were able to extend the range, speed, and productivity levels previously achieved with canals. In time, the United States was covered with an elaborate network of railway systems. Together with railways, a new era of coal, steam, steel, and the telegraph began. The great railway era lasted until the 1930s. Despite further construction of railway lines in developing countries, the global railway network has (because of the decommissioning of lines in industrialized countries) remained constant, at a level just under 1 million miles since the 1930s. Railways have consequently lost their dominant position (around 80 to 90 percent of all passenger and ton-mile transported in the 1920s and 1930s) in the transport sector throughout the world.

Around the turn of the 19th century, the automobile was born and became the symbol of modern industrial development along with oil, petrochemicals, electricity, the telephone, and assembly-line (Fordist) manufacturing. Following the development of road infrastructure, the automobile again facilitated an increase in the speed and performance of the transportation system. The flexibility of an individual mode of transportation became affordable for a wider social strata, and it was only about three decades ago that some of the disadvantages of the automobile became socially transparent.

The last in this sequence of infrastructure revolution is air transportation. Once more, air transportation also promoted an increase in the productivity level of the transport system in terms of speed, range, and comfort. However, its associated infrastructure is "dematerialized" to right-of-way air corridors, with only control and communication and the connecting nodes to other transport modes (airports and hubs) relying on physical structures.

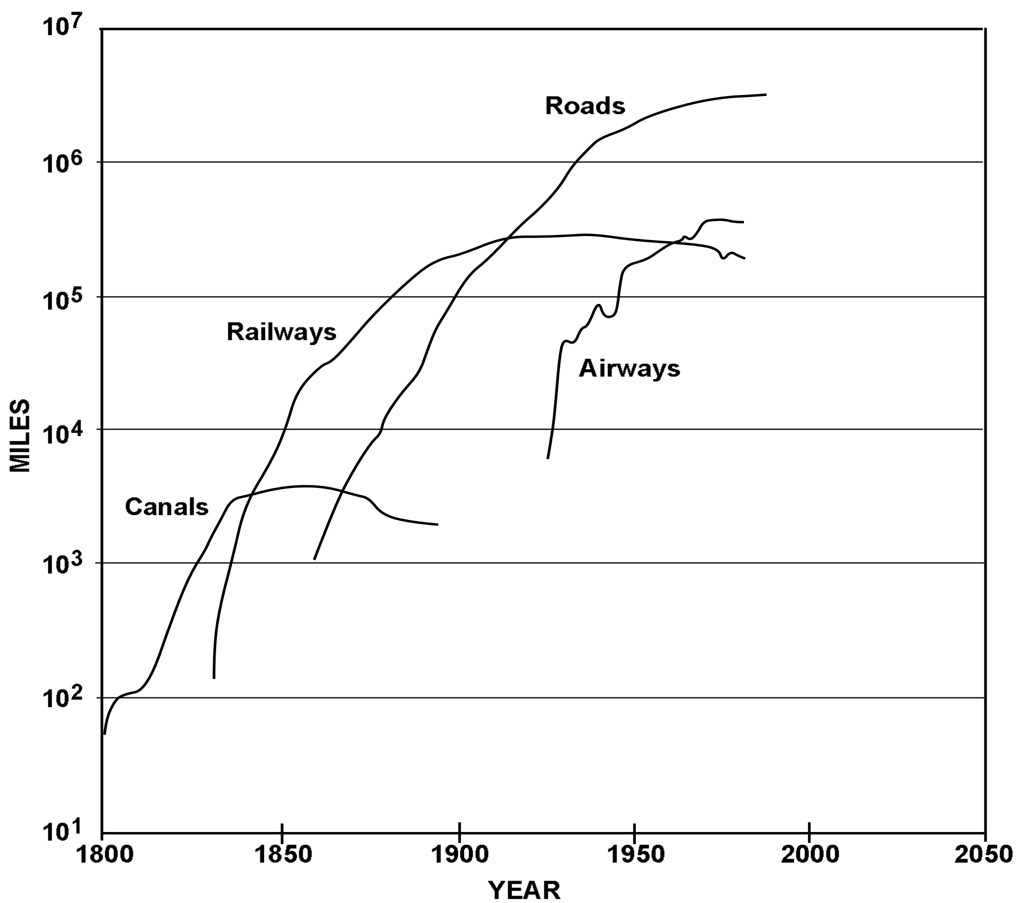

Figure 1.1 Length of canals, railroads, surfaced roads, and federal airways in the U.S. [Adapted from: Grübler & Nakicenovic (1991).]

Figure 1.1 illustrates the development of the four major transport systems for the U.S., represented by the growth in length of their respective infrastructures. The length of all four increased by more than four orders of magnitude over the last two centuries. Each successive mode of transport expanded into an infrastructure ten times larger than the previous one. It is also interesting to note that new infrastructures overtook existing ones only when the latter started saturating, e.g., canals and railways in the 1840s, and railways and surfaced roads in the 1920s.

The first canals were built in the 1780s and reached a total length of 4,000 miles by 1870 before saturating and then declining; thus the expansion of canals lasted about 90 years. The first railroads were built in the 1830s and saturation started in the 1920s; again about 90 years later. By 1929 the total length of railroads was more than 300,000 miles. Thus, railways saturated at almost ten times the level of canals. Since then rail infrastructure has undergone a phase of rationalization, and railways have experienced losses in market shares and volume, both for freight and passenger transport. In fact, railways have virtually disappeared from the U.S. market in intercity passenger travel, and consequently the size of the railway network in the U.S. has decreased by about one-third, to some 200,000 miles.

The first high quality roads of significant length were introduced a century ago. Today, surfaced roads are approaching saturation with about 4 million miles in the U.S., again larger by more than a factor of ten than the maximum length of railways. Each successive transport infrastructure was thus not only an order of magnitude larger than the one it replaced, but it also provided a service that was almost ten times faster.

How do these data for each transportation revolution look when transformed using a fractional logistic function? The deceptively simple answer to this question is provided in Figure 1.2, which shows the expansion of the three physical infrastructures in the U.S. normalized with respect to their respective saturation levels (by plotting the relative length as a percentage of the saturation level). The succession of individual infrastructure development can be described in terms of three S-shaped logistic growth pulses (actual data are thin lines, estimated logistic curves are thick lines). The development of canals, relative to the achieved saturation level, was much quicker than the expansion of railways and roads. The time constant of growth, Δt, is about 30 years for canals, 55 years for railroads, and 64 years for surfaced roads. The midpoint of the individual infrastructure growth pulses (i.e., the time period of their maximum growth rate) are spaced at 55-year intervals, as are their periods of saturation of expansion.

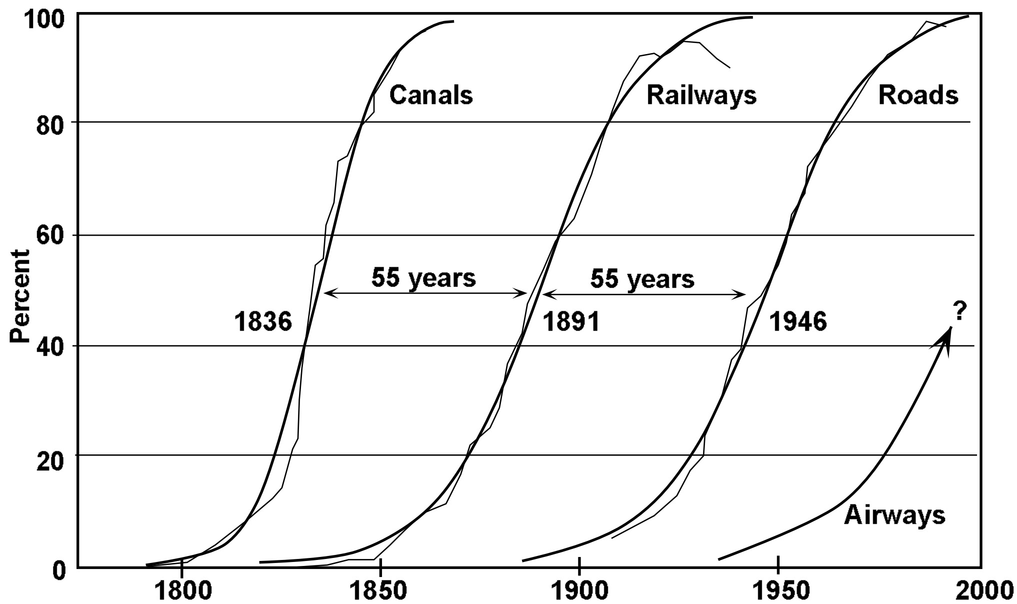

Figure 1.2 Growth to limits of canals, railroads, and roads in the U.S. Actual data are thin lines; estimated logistic curves are thick lines.

[Adapted from: Grübler (1991)]

It is remarkable that the saturation and onset of decline of all three infrastructures coincides with the beginning of prolonged economic recessions (i.e., in the 1870s, 1930s, and 1980s). At the same time these periods of structural discontinuity see the emergence of new transport systems: surfaced roads around 1870 and air transport in the 1930s. If we agree with Plutarch that history repeats itself, then one could expect the maturing point of air travel and the emergence of a new transport infrastructure within the next few years.

In periods of structural discontinuity, where old mature systems saturate and new ones are born, a powerful image of the innovation triggering effects of recessions/depressions prevails. The successive dichotomy of "boom" periods of economic growth, followed by recessionary, even depression periods is known as "long waves" or Kondratieff waves in economic development [Haritos (1987)].

The life cycles between birth, growth, and saturation and the start of senescence (decline) of infrastructures are indeed very long, often spanning periods in the order of a century. The duration of senescence can be even longer. The most vital of the structures, however, are here to stay. Their immortality is marked by providing different services than originally envisaged. More than a century after the canal age, the remaining inland waterways are used for leisure activities, transport of low-value goods, and irrigation. There are more sailboats today than there were in the heyday of ocean clippers, but they have entered a different market niche serving as pleasure boats. They do not carry any commercial goods, nor transport people for their work trips.

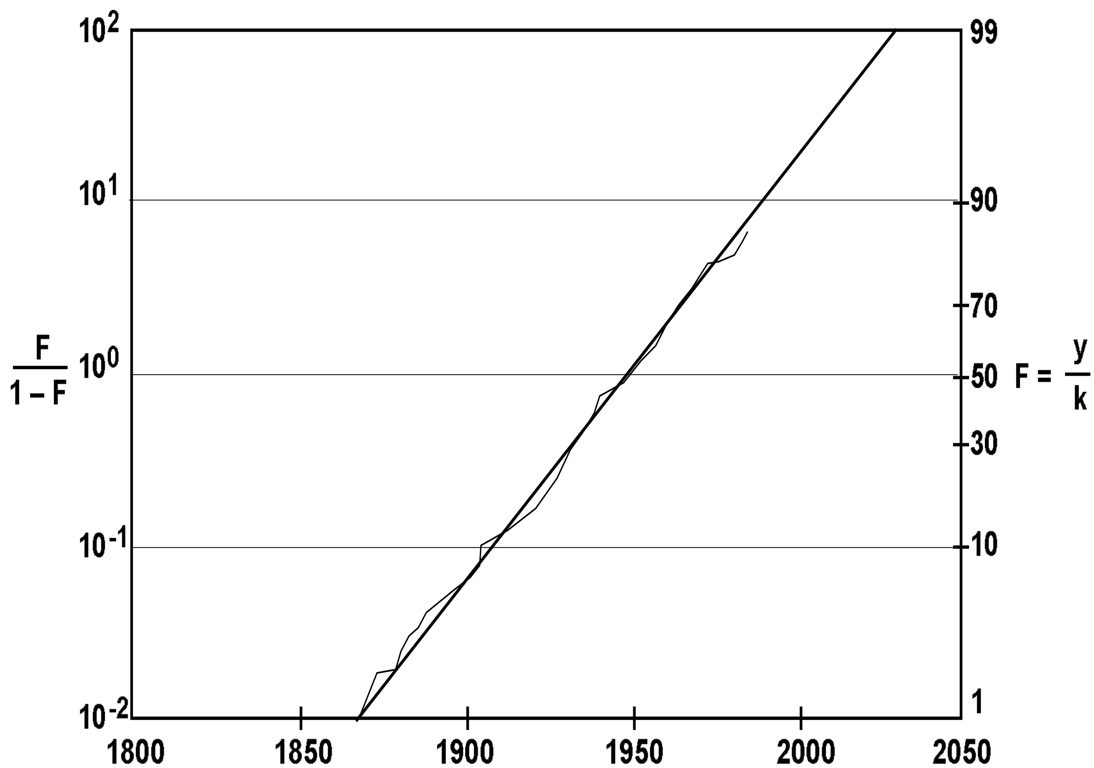

Figure 1.3 Growth in length of all transportation infrastructures in the U.S. in fractional share of ultimate saturation level, logistic transform. Actual data are thin lines, estimated logistic curves are thick lines. [Adapted from: Grübler (1990).]

Despite the complex picture that emerges when analyzing the evolution of individual infrastructures which overlap in their growth, saturation, and decline phases, it is interesting to note that the length of the total transport infrastructure again proceeds along an ordered evolutionary growth envelope, as shown in Figure 1. 3.

Here the growth in the length of all transport infrastructures is analyzed by using an S-shaped growth model (a 3 parameter logistic function). A linear transformation of the S-shaped growth or substitution process in the form of f/(1 — f) on a logarithmic scale is presented, where f is the fractional growth (market share) achieved at any particular point in time. The ratio of growth (current market share) achieved over the growth (total market share) remaining to be achieved, when plotted on a logarithmic scale, reveals the logistic growth or substitution process as a secular linear trend with small annual perturbations.

Figure 1.3 presents an expanding niche in which individual transport infrastructures rival for relative positions with respect to their share in the length of all infrastructures. It portrays a remarkable behavior in the evolution of transport infrastructures in the U.S., in that the saturation and later decline of individual infrastructures (canals first and later also railways) has up to the present been "filled" by the growth of newer infrastructures consistent with the logistic envelope of Figure 1.3. This feature is frequently observed in the evolution of dynamic, self-organizing systems in chemistry or biology. The growth of this envelope proceeds with a Δt of 80 years, i.e., slower than the growth of any individual infrastructure (ranging from a Δt of 30 years for canals to 64 years for the surfaced road network). Should this process continue to unfold as it has in the past, saturation of roadways would occur around 2030 at a level of around 5 million miles, i.e., with a value around 25 percent higher than at present [Nakicenovic (1988)]. (It has been estimated at a 90 percent probability that the saturation level will be between 4.6 and 5.2 million miles [Marchetti (1987)].)

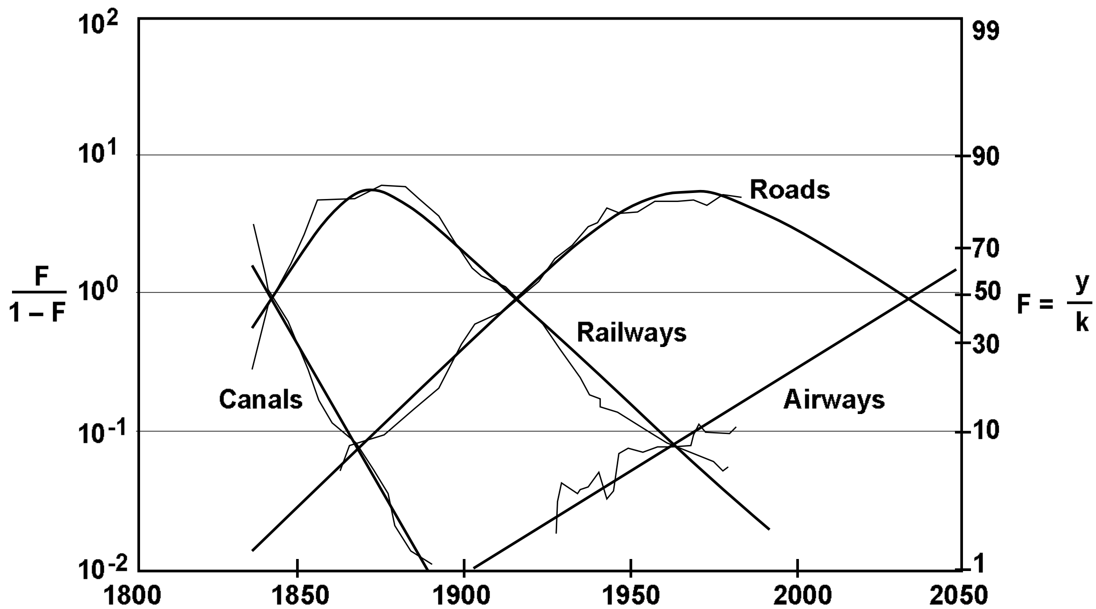

Figure 1.4 Substitution of transport infrastructures in the U.S., shares in length, logistic transformation. Actual data are thin lines, estimated logistic curves are thick lines. [Adapted from: Nakicenovic (1988).]

Within an expanding niche, individual transport infrastructures compete for their relative importance (measured by their respective share in the total infrastructure network) by replacing previously dominant transport infrastructures. Figure 1.4 presents the structural evolution of the transport infrastructure in the U.S., organized with the help of a multivariate logistic substitution model. This particular representation shows the relative importance of competing infrastructures and the dynamics of the structural evolution process over the last 160 years. In any given period, there is clear market dominance (i.e., more than a 50 percent share) and at the same time a simultaneous spread of transport activities over two or three different systems. Thus, while competing infrastructures are all simultaneously used, their mix changes over time.

Another observation from Figure 1.4 is that the phasing out of transport infrastructures apparently takes increasingly longer time constants. While the decline in the relative importance of canals proceeded with a Δt of 45 years, that of the railways already required a Δt of 80 years. The decline in the relative importance of road infrastructure is expected to be an even longer process with an estimated Δt of 130 years. As a result, the maxima in the share of total infrastructure length between railways and surfaced roads is about 100 years, indicating the considerable time span involved in the transition from the dominance of one infrastructure system to the next. Based on this assumption one could expect the period of maximum dominance for airways to occur around the year 2040. This immediately raises the question of what could be the next dominant infrastructure system evolving after that: high-speed maglev, supersonic aircraft, or some other competing new system?

The difference in the dynamics (Δts) of the growth of individual infrastructures and their relative shares in total infrastructure length may appear at first sight as a contradiction. However, this difference is the result of the complex coupled dynamics of total infrastructure growth, and the growth and decline rates of individual transport infrastructures. As the total length of infrastructures increases, even the rapid growth of individual infrastructures, such as airways, will translate only into slower growth rates in their relative shares. Once the growth rates of an individual transport infrastructure fall behind the growth of the total system, their relative share starts to decline. In the case of railways the share in total infrastructure length began to decrease in 1870, whereas the railway network continued to expand until the end of the 1920s. Similarly, the length of the surfaced road network still continues to increase (despite being close to apparent saturation) at relatively low rates, although its relative share started to decrease in the 1960s.

Thus, the total length of an individual infrastructure can still be growing, and even be decades away from ultimate saturation and subsequent senescence in absolute network size, but its share in the total length of the whole transport system has already begun to decline. The saturation and decline in relative market shares precedes saturation in absolute growth in a growing market (an expanding niche). This implies that the eventual saturation of any competing technology may be anticipated by the substitution dynamics in a growing market, such as for railways as early as 1870 and for roads as of 1960. The infrastructure substitution model presented in Figure 1.4, may, therefore, be considered as a precursor indicator model, for the long-term evolution and fate of individual infrastructures.

We conclude this discussion on the long-term (centuries) revolution of transport infrastructures in the U.S. by pointing out how both simple and multivariate logistic functions can be used to predict the overall state of the transportation infrastructure. This analysis not only provides an insight into the growth of individual transportation infrastructure, but also how substitution effects can start the decline of one mode while the next revolutionary mode is on its ascendancy. The logistic equations also clearly show the regularity in the rise and fall of the importance of individual transport infrastructures. This regularity appears consistent even during very disruptive events like the depression of the 1930s or the effects of major wars. The conjecture is that this stable behavior may be the result of an invariant pattern in societal preferences with respect to individual transport infrastructures, resulting from differences in the performance levels (seen as a complex vector rather than represented by a single measure) inherent to different transport infrastructures and technologies.

In the next section we examine how evolutionary improvements of technologies in the short-term (decades) can be analyzed and forecast using logistic functions.

1.3 Technological Substitutions and Evolutions in Transportation

A general model for technological substitution (i.e., the acceptance and wide spread use of a technology in any industry) can be closely modeled using a simplified form of the original Volterra-Lotka equation [Marchetti (1988)]:

$$\frac{dN_i}{dt} = \alpha_i N_i - \beta \sum_{j=1}^{n} \lambda_{ij} N_i N_j \qquad \text{(Equation 1)}$$

The properties of the solutions to these equations have been described by Montroll and Goel (1971) and more recently by Nakicenovic (1988). For our purposes, is the number of substitutions that can occur for the "species" of technology i (e.g., the total number of automobiles that could be outfitted with a certain technology), is the rate of growth of i in the absence of predation (competition from a competing technology), and is the cross-section of interaction between "species" population i and "species" population j.

A physically intuitive example of a special case (The Malthusian Case) can be built for a population of automobiles that can be outfitted with a new technology, say a GPS-based navigation system. Other things being equal (such as economic, societal, and environmental variables), the rate of this transformation is proportional to the number of automobiles that could be outfitted with the device immediately and the total number of automobiles that are not outfitted with the device. A further assumption is that all automobiles will be ultimately outfitted with the device. Using homogeneous units, we can define N(t) as the number of autos with GPS units at time t and $\overline{N}$ as the total number of auto that have the potential to be outfitted at time t=0 before the technology substitution starts. The "multi-species" Volterra-Lotka equation simplifies to the "single-species" Verhulst equation:

$$\frac{dN}{dt} = \alpha N(\overline{N} - N) \qquad \text{(Equation 2)}$$

Whose solution is

$$N(t) = \frac{\overline{N}}{1 + \exp(\alpha t + \beta)} \qquad \text{(Equation 3)}$$

Where is integration constant sometimes also written as, is a constant independent of the size of the population. Dividing both sides of the equation by , extracting the exponential term, and taking the logarithm, we can obtain:

$$\ln\frac{f}{1-f} = \alpha t + \beta \qquad \text{(Equation 4)}$$

Where *f* is given by

$$f = \frac{N}{\overline{N}} \qquad \text{(Equation 5)}$$

$\overline{N}$ Is the "niche" and the growth of the "population" is given as the fraction of the niche it fills. The graph of this simple case is shown in Figure 1.5.

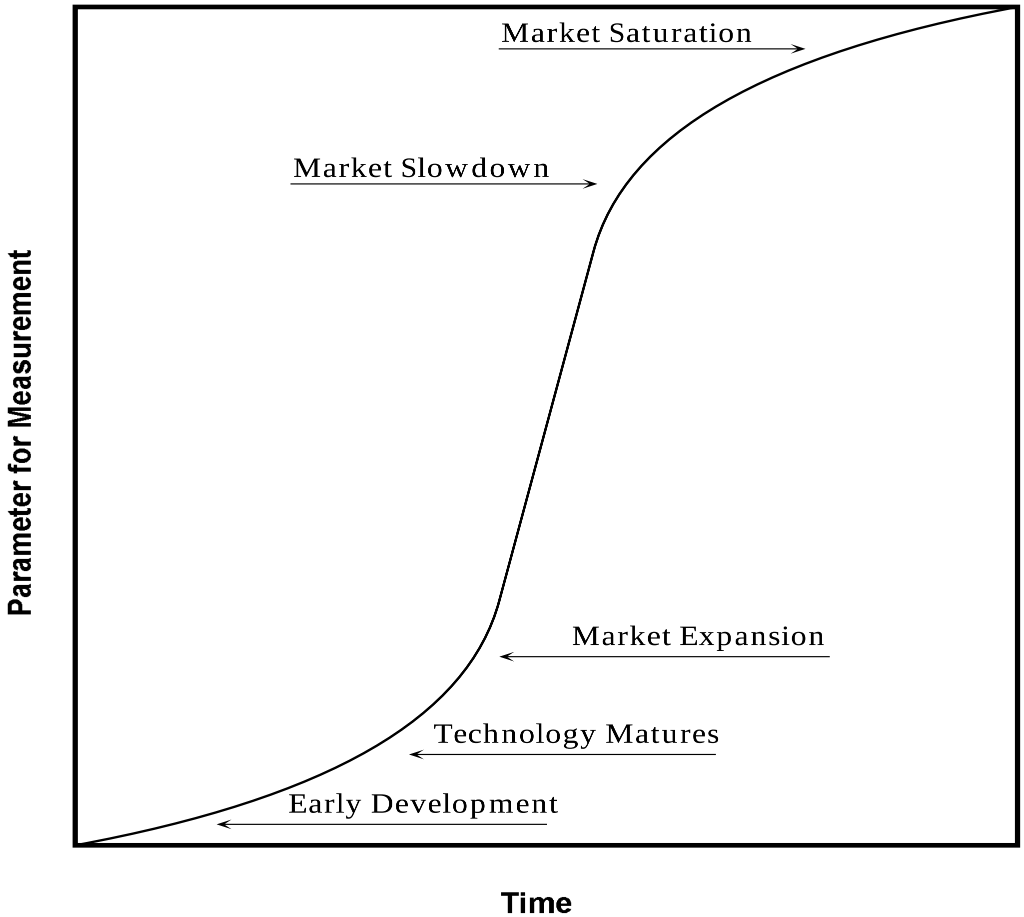

Figure 1.5 Various stages in the diffusion of new technology in the market place. This is the classic S-shaped logistic function (as represented in the log-function of equation 3) plotted on a linear scale. A log transform will give a straight line with a slope equal to alpha (α) and the intercept equal to beta (β),

(Data source: Equation 4)

The previous analysis has been done with the assumption that there are no competitors ("single-species"). Similar analysis can be done for two or more competitors (similar technologies competing for the same population of autos), and it can be shown that the resultant function is of the form:

$$f_j(t) = 1 - \sum_{i \neq j} \frac{1}{1 + \exp(-\alpha_i t - \beta_i)} \qquad \text{(Equation 6)}$$

1.4 Organization of Report

This report is organized into six chapters. Chapter 1 provides the historical and mathematical framework for this report. In Chapter 2 we examine trends in transportation by looking at historical data. Chapter 3 provides a survey of some of the innovative technologies that would impact transportation over the next few decades. Chapter 4 deals with the changes expected in automobile and its use as an intracity personal transportation system. The issue of intercity transportation is discussed in Chapter 5 where Maglev systems are examined in detail. Chapter 6 concludes this report by providing recommendations to TxDOT for consideration in their state wide planning and implementation of transportation services.

1.5 Conclusions

The examples of long term diffusion and substitution of transportation modes that have been presented here are for data from the United States. However, Grübler and Nakicenovic (1991) have shown that the development of a particular techno-economic trajectory follows similar paths in countries with fundamentally different social and economic relations, technological bases, and initial conditions. The underlying common thread present in all these examples of transportation substitution is that the substitution is successful only when the new mode is faster by a factor of ~3 compared to the old mode it replaces. This would suggest that the TTC (Trans-Texas Corridor) should not be designed just for the relief of busy corridors (or just to provide a bypass for congested "hot-spots"), but more fundamentally, it should provide for intercity travel speeds of over 150 mph (240 kmph). Therefore, the high-speed passenger and freight system envisioned in the TTC should take on a much more significant role than it has been accorded.

Chapter 2

TRENDS IN TRANSPORTATION

2.1 Introduction

In the next chapter, a survey of technologies that could be enlisted for future forms of transportation in Texas will be presented. Of these technologies, two will be considered in greater detail in succeeding chapters. Before considering these technologies, it is helpful to analyze the historical trends in transportation to underscore why alternative modes of transportation should be given serious consideration. These trends will illustrate future problems that may be faced by the current modes of transportation.

2.2 Factors for the Growth in Driving

One of the results of increase in driving is Congestion. People typically think that an increase in population is one of the greatest causes of traffic congestion. This belief could easily be called the "congestion myth" because data suggests that population growth is the least of several factors that cause congestion. Nevertheless, population does have an effect on congestion, and looking at the trend in population growth can give us an idea of the future of congestion.

The graphs in Figure 2.1 and Figure 2.2 shows the population of United States and Texas respectively plotted against time in years. As the graphs indicate, the population of the United States has been increasing steadily and is currently close to 280 million. If this trend in population continues, the United States will reach a population of 300 million by 2020. Following the same path, Texas currently has a population of about 22 million. By the year 2020, Texas could reach a population of 26 million.

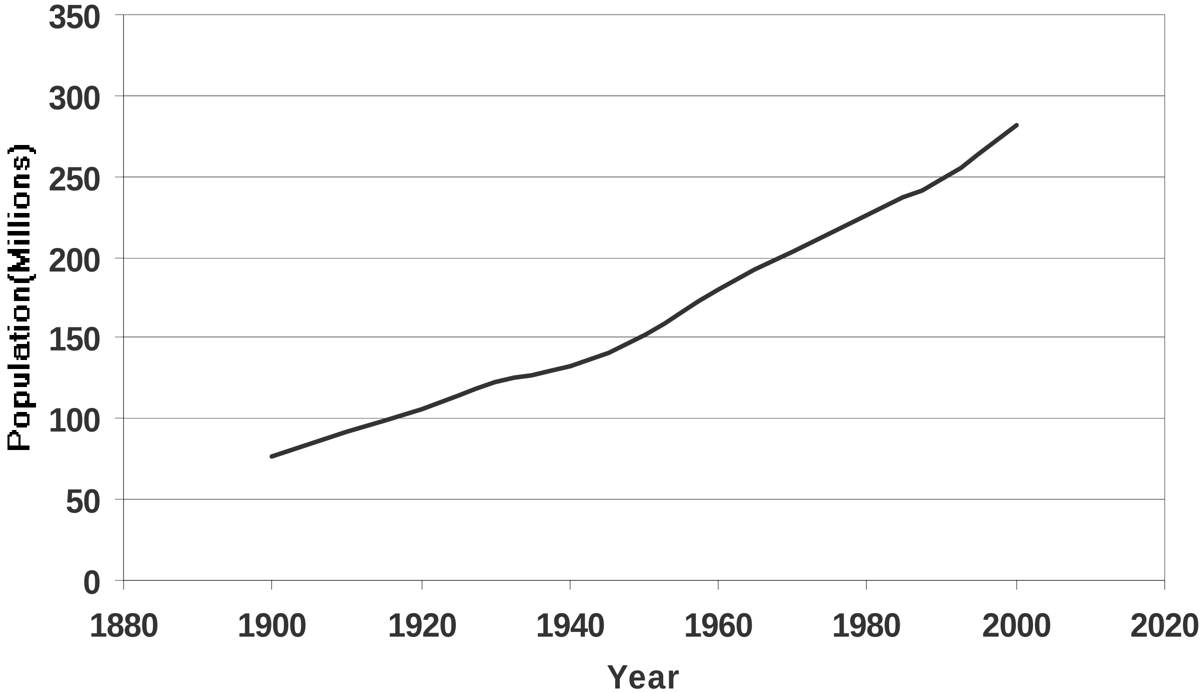

Figure: 2.1 Population growth in U.S. vs. time, (Data source: BTS)

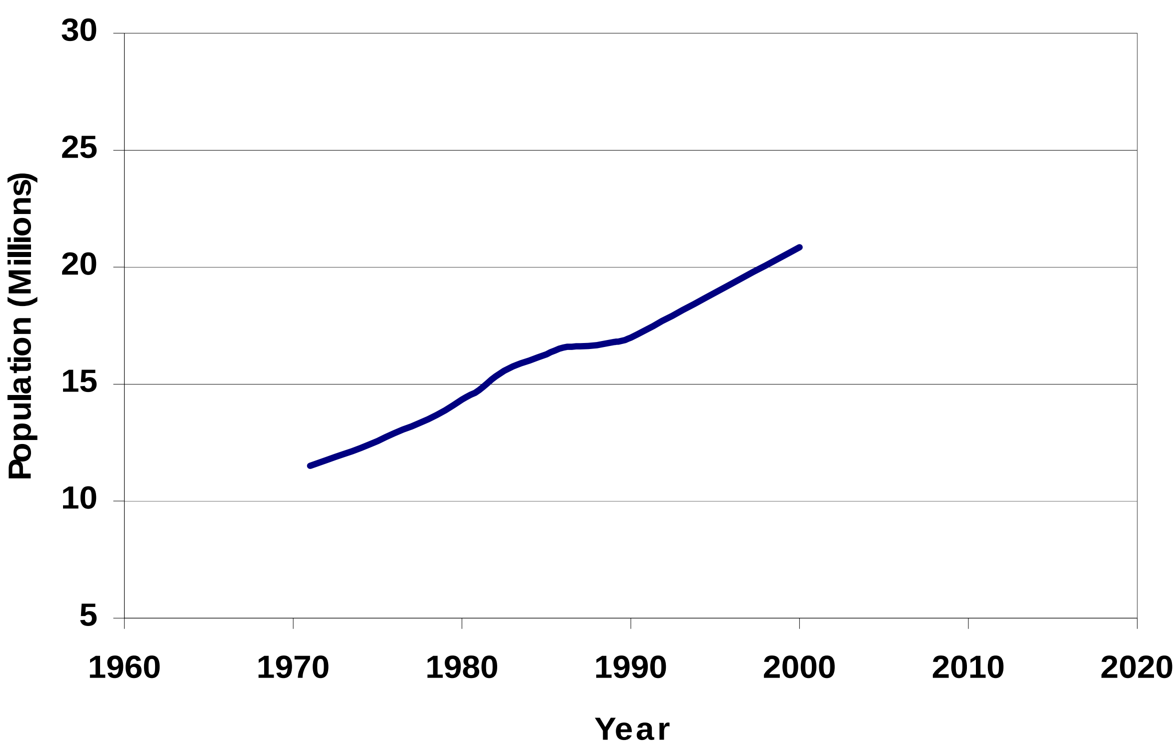

Figure 2.2 Population growth in Texas vs. time, (Data source: BTS)

It is natural to assume that as the population increases, so does the number of drivers. Data also suggests that the increase in driving is faster than the increase in population, indicating that other factors besides population contribute to congestion. The following graphs illustrate this phenomenon.

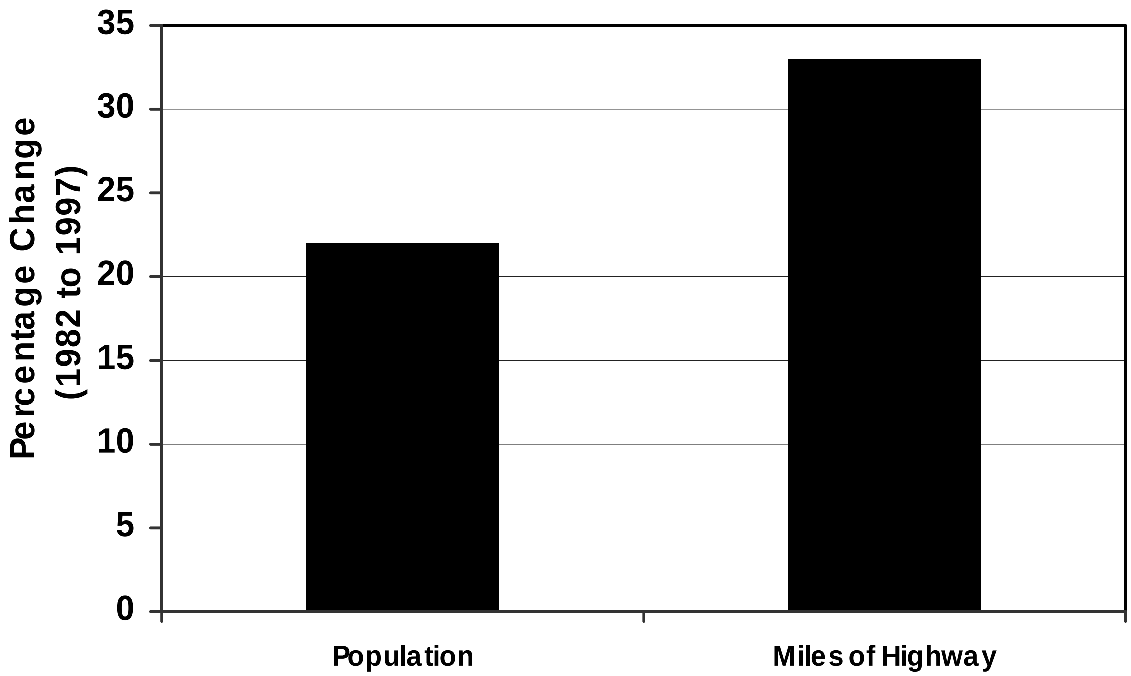

Figure 2.3 Percent change in population and percent increase in the miles of highways constructed, (Data source: BTS)

The graph in Figure 2.3 shows the percentage change in population and percentage change in highway lane miles. The graph indicates that while there was a 22% increase in population from 1982 to 1987, there was a 33% increase in highway miles. This indicates that the amount of highway construction during the said period was growing more rapidly than population.

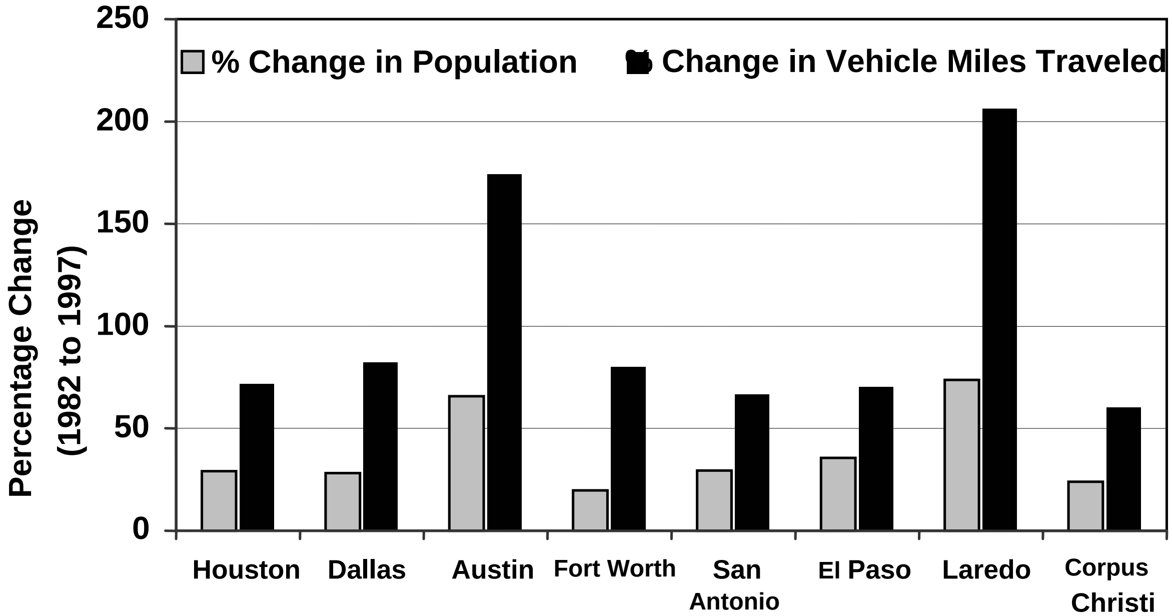

Figure 2.4 Population growth and increase in population in major cities in Texas, (Data source: TxDOT)

Figure 2.4 compares the percentage change in population with percentage change in vehicle miles traveled (VMT) in some of the major cities in Texas. All across the state, the percentage of change in VMT is at least double that of the change in population. Reasons for that phenomenon may be found in Figure 2.5.

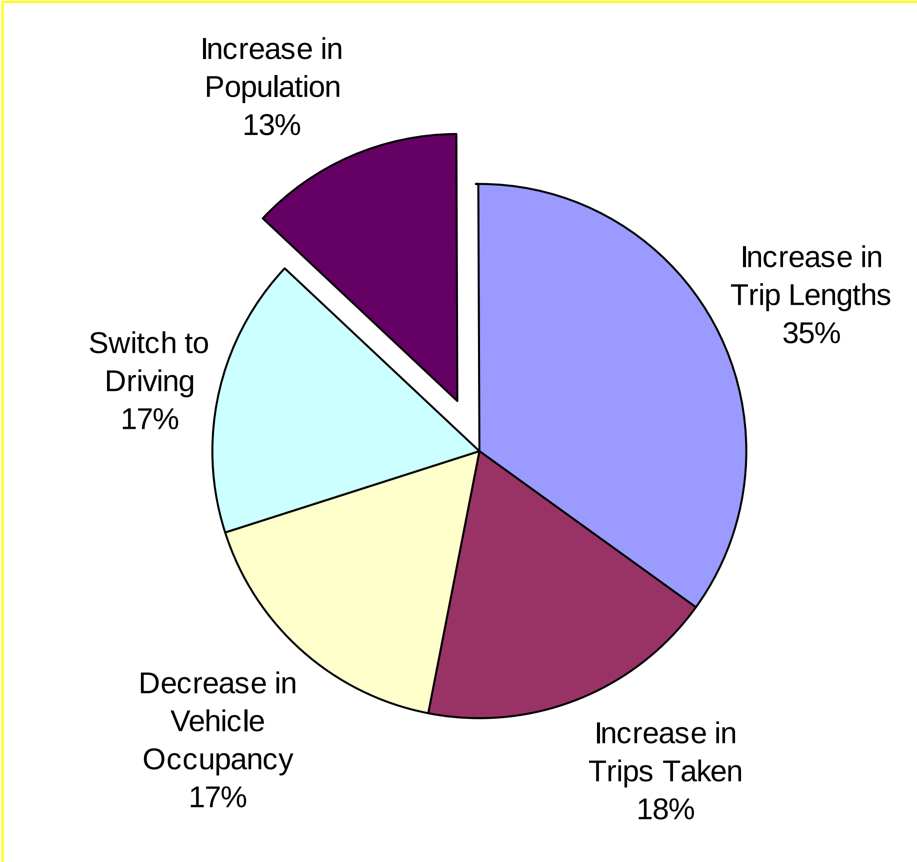

Figure 2.5 Factors for increase in driving, (Data source: BTS)

Figure 2.5 depicts the relative weights of the various factors that are responsible for the increase in driving. This U. S. Bureau of Transportation Statistics (BTS) data dispels the population myth, pointing out that an increase in population is the least factor for the growth in driving. An increase in trip lengths is the greatest reason for the growth in driving. Other factors include an increase in the number of trips taken, a decrease in vehicle occupancy, and a number of people switching from other modes of transportation to driving.

Part of the reason for the increase in driving and the decrease in vehicle occupancy has to do with the nature of households. There are more licensed drivers per household today than ever before. At the same time, these drivers are more likely to have their own cars than drivers of the past. Figure 2.6 illustrates this situation of American drivers.

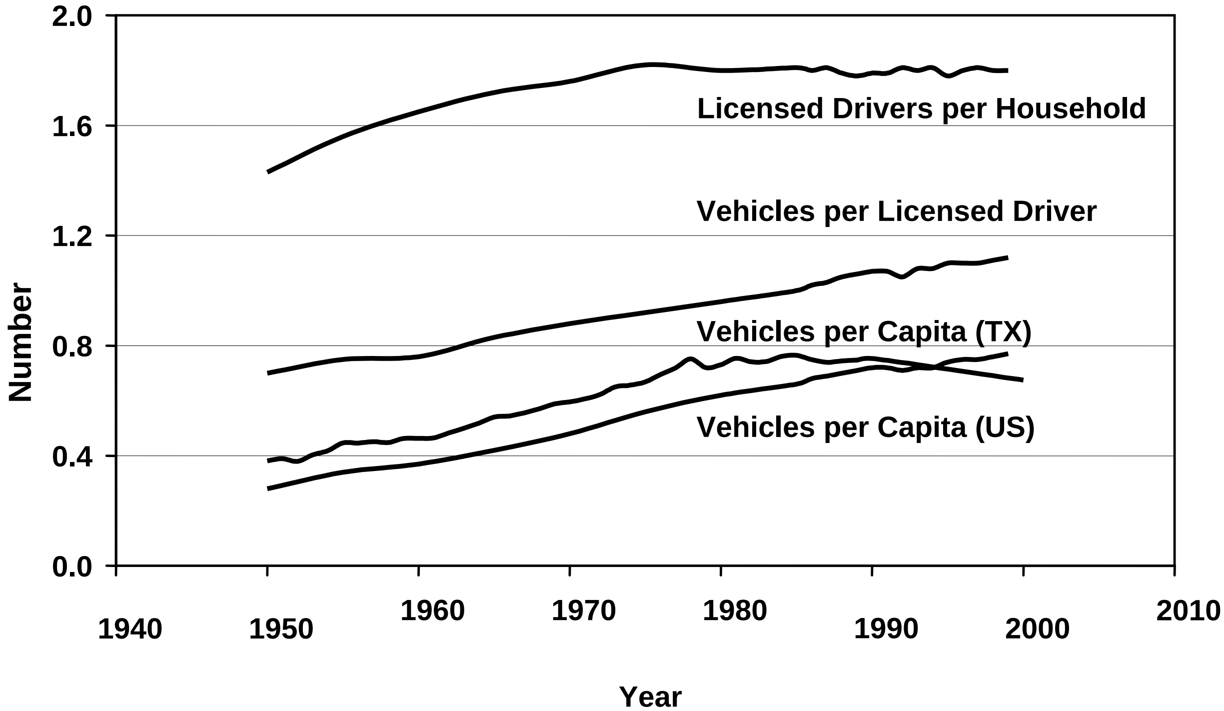

Figure 2.6 Vehicles and licensed driver ratios, (Data source: BTS)

2.3 Number of Registered Vehicles

Figure 2.6 shows the vehicles per capita in Texas and the U.S., number of vehicles per licensed driver and number of licensed drivers per household from 1950 forward. As the graph illustrates, the vehicles per capita in the U.S. is currently around 0.8, more than twice the amount of that in 1950. Licensed drivers per household have also increased, with an average of 1.8 per household. In Texas, the vehicles per capita is about 0.6. Due to more licensed drivers per household and the increasing vehicles per capita, there will be more vehicles on the highways.

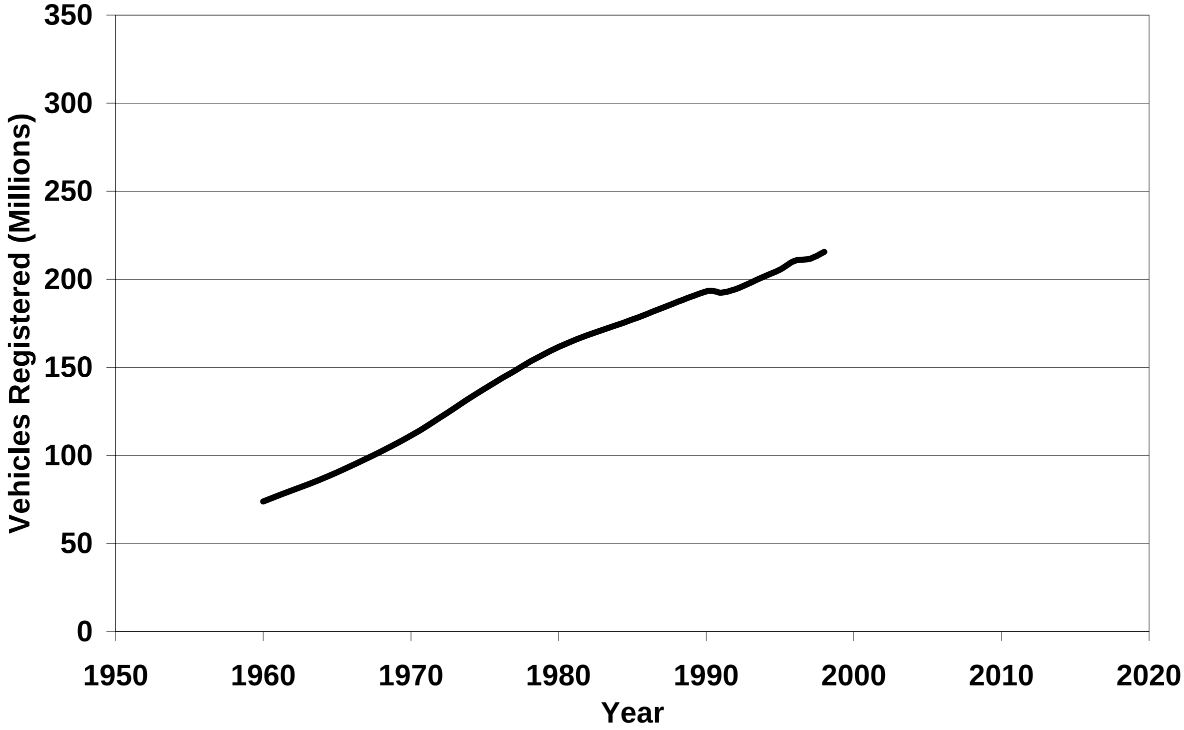

Figure 2.7 Total vehicles registered in the U.S., (Data source: BTS)

Figure 2.7 shows the number of vehicles registered in the U.S. (in millions) as a time series. As the graph indicates, currently, there are about 220 million registered vehicles in the United States. By the year 2020, there will be more than 300 million. The number of registered vehicles are increasing as a result of increases in vehicles per capita as well as the growth in the number of licensed drivers.

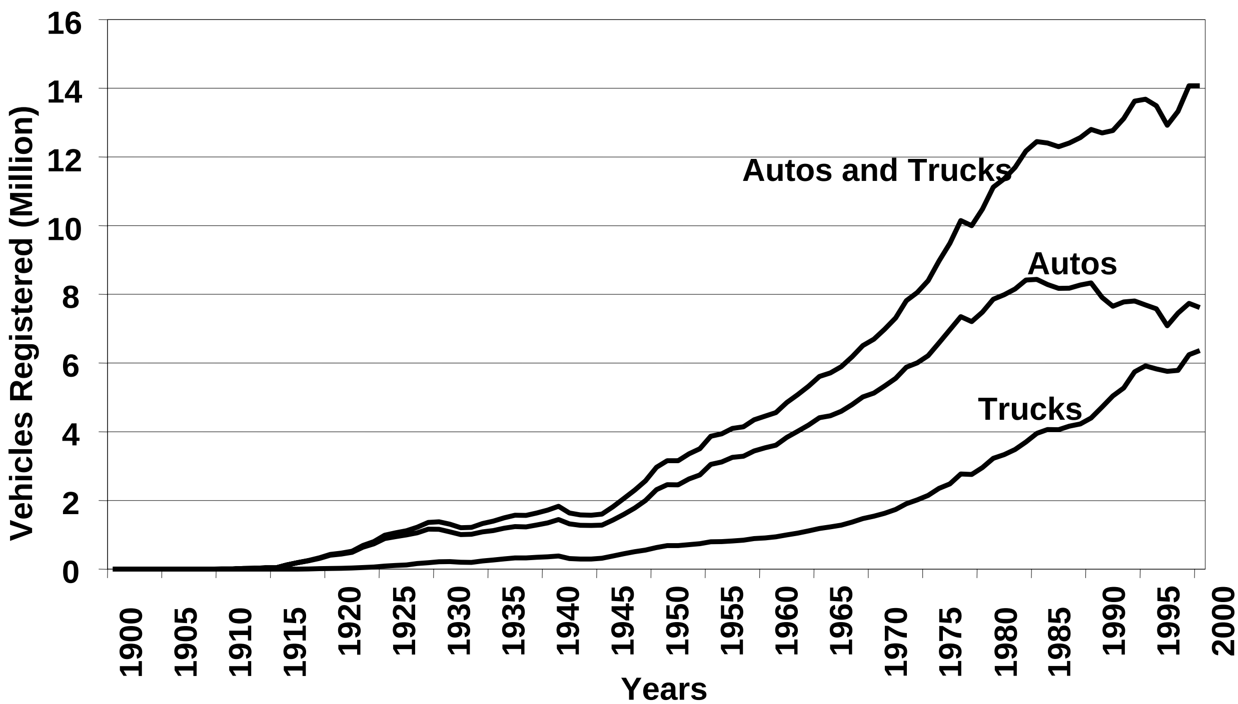

Figure 2.8 Vehicles registered in Texas vs. time, (Data source: TxDOT)

Figure 2.8 shows the number of vehicles registered in Texas from 1915 to 2000. Also the number of trucks and autos registered has been separated. Currently, there are approximately 14 million vehicles registered in Texas. Both the number of automobiles and trucks are growing. The distinction between trucks and automobiles is necessary if one is to fully grasp the impact that vehicles are having on the roads. Truck traffic is more detrimental to the pavement than automobile traffic. One pass of an 18-kip ESAL (Equivalent single axle load) is equivalent to 5,000 passes of a passenger car.

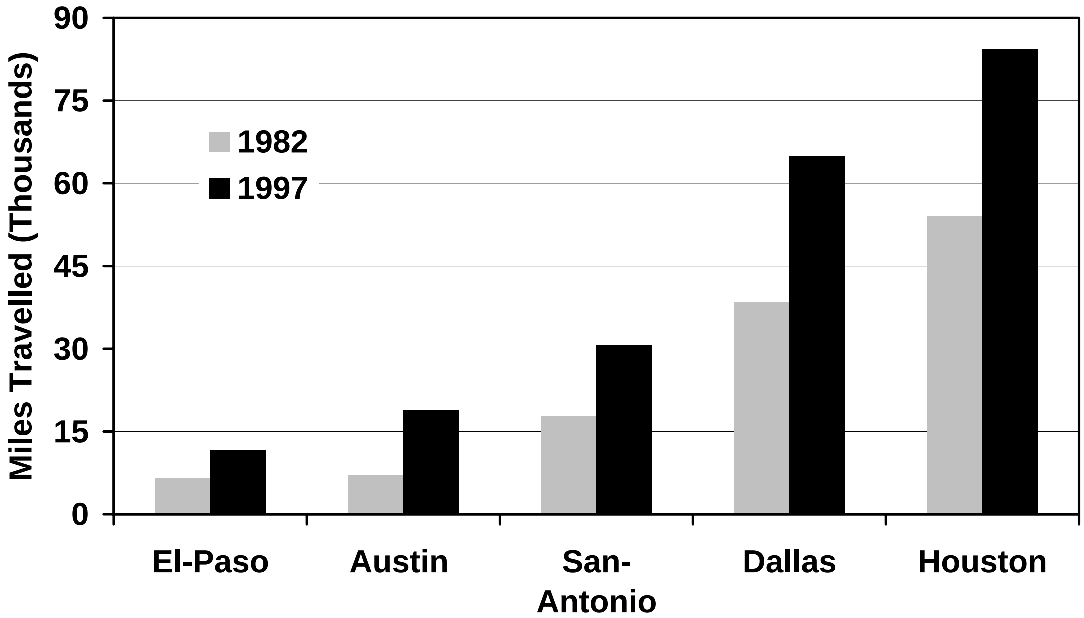

Figure 2.9 Vehicle miles traveled in major cities in Texas, (Data Source: TxDOT)

Figure 2.9 shows the increase in the vehicle miles traveled form 1982 to 1997 in some of the major cities in Texas. As the graph illustrates, five major cities in Texas witnessed a tremendous increase in vehicle miles traveled between 1982 and 1997.

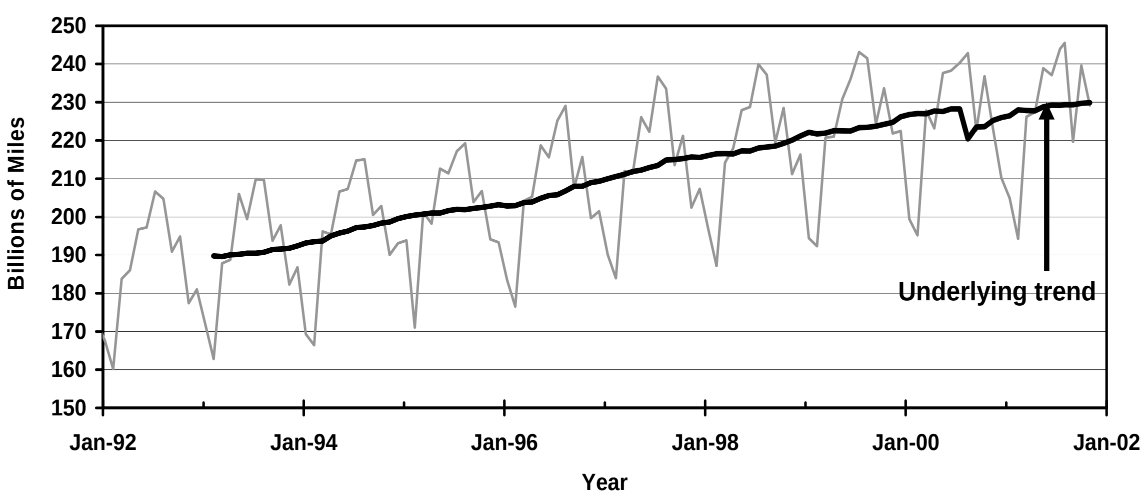

Figure 2.10 Vehicle miles traveled in Texas vs. time, (Data source: BTS)

Figure 2.10 shows the VMT in the U.S. from 1992 to 2002. The estimate for January, 2002 shows 220 billion vehicle miles traveled on the U.S. highways. This amount is a 30 billion point increase over the estimate of 1993. For the most part, the increase in vehicles miles traveled has remained steady. In order to get a clearer vision of the areas most seriously affected, figure 2.11 breaks this trend up into urban and rural sectors.

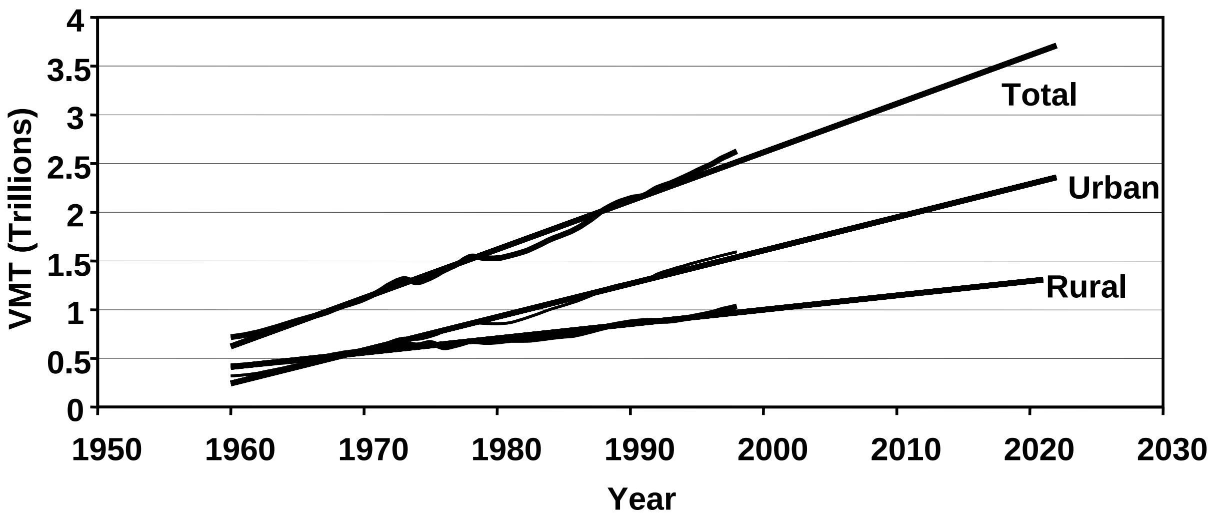

Figure 2.11 Vehicle miles traveled in urban and rural areas in the U.S. vs. time, (Data source: BTS)

As figure 2.11 illustrates, the urban sector is witnessing a much greater increase in vehicles miles traveled than the rural sector. Figure 2.12 illustrates the increase of VMPT for trucks.

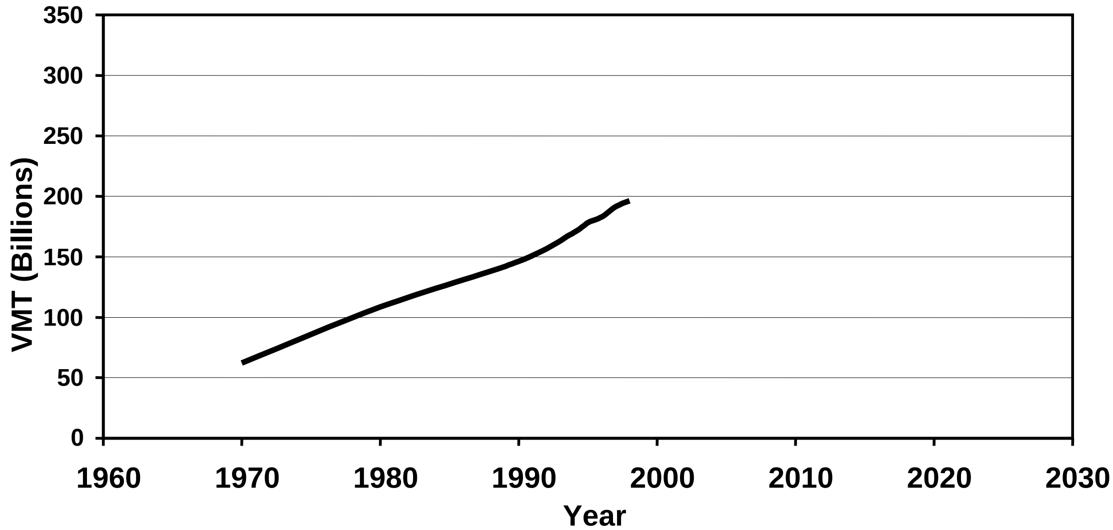

Figure 2.12 Vehicle miles traveled by the trucks in the U.S. vs. time, (Data source: BTS)

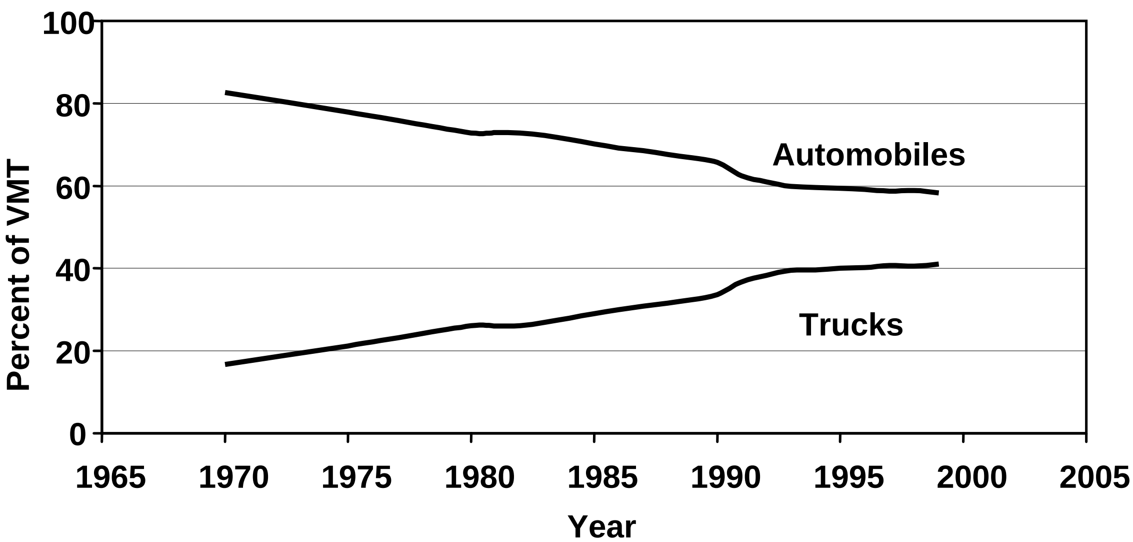

Figure 2.13 Percentage of VMT for autos and trucks, (Data source: BTS)

Figure 2.13 indicates the proportion of VMT by Automobiles and Trucks from 1970 to 2000. Trucks traveled about 200 billion miles in 2000, making up 40 % of the total vehicle miles traveled. While the percentage of automobiles is higher than the percentage of trucks, the percentage of automobile VMT is decreasing while the percentage of truck VMT is increasing. Looking towards the future, the percentage of vehicle miles traveled by trucks could increase by more than 400% by the year 2020.

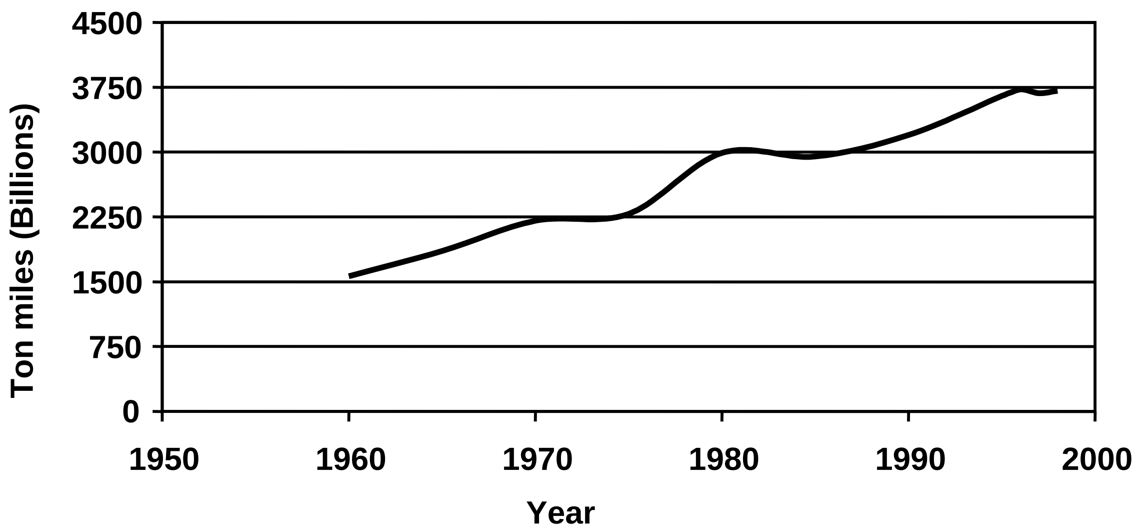

Figure 2.14 Ton-miles of freight carried vs. time, (Data source: BTS)

Figure 2.14 illustrates the increasing ton-miles of freight transportation. In the last forty years, the ton miles of freight have increased by over 50%. This trend promises to keep growing in the future.

Figure 2.15 breaks down the ton miles of freight into three different methods of transportation: rail, truck, and water.

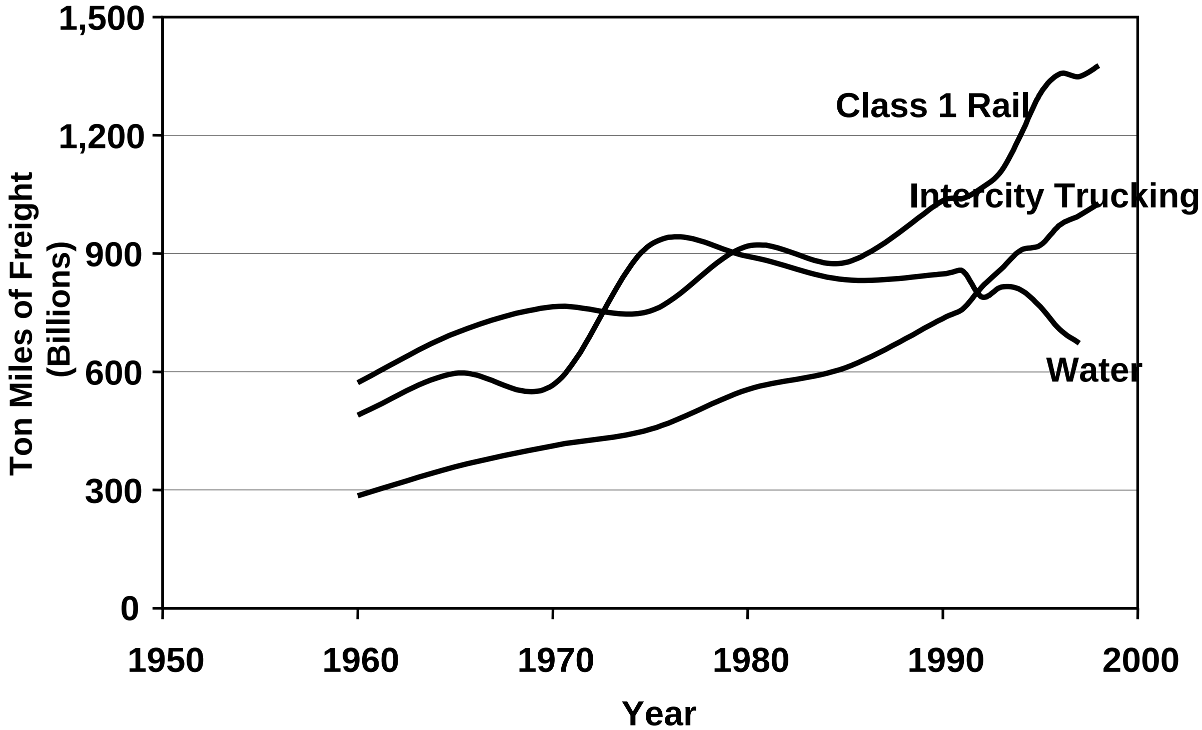

Figure 2.15 Modes of transportation for ton miles of freight carried vs. time, (Data source: BTS)

While barge/ships are the cheapest means of transporting freight, it is used much less frequently than rail or intercity trucking because it is relatively slow, and limited in the regions it can serve. Intercity trucking is currently behind first class rail transportation; however, trucks are catching up quickly.

Comparing the percentages of the U.S. NAFTA trade and various modes (truck, rail, pipeline, air, water, etc) used for transportation shows that trucks are the major carriers of freight both in terms of value and weight. Figure 2.16 illustrates this statistic for Texas roadways.

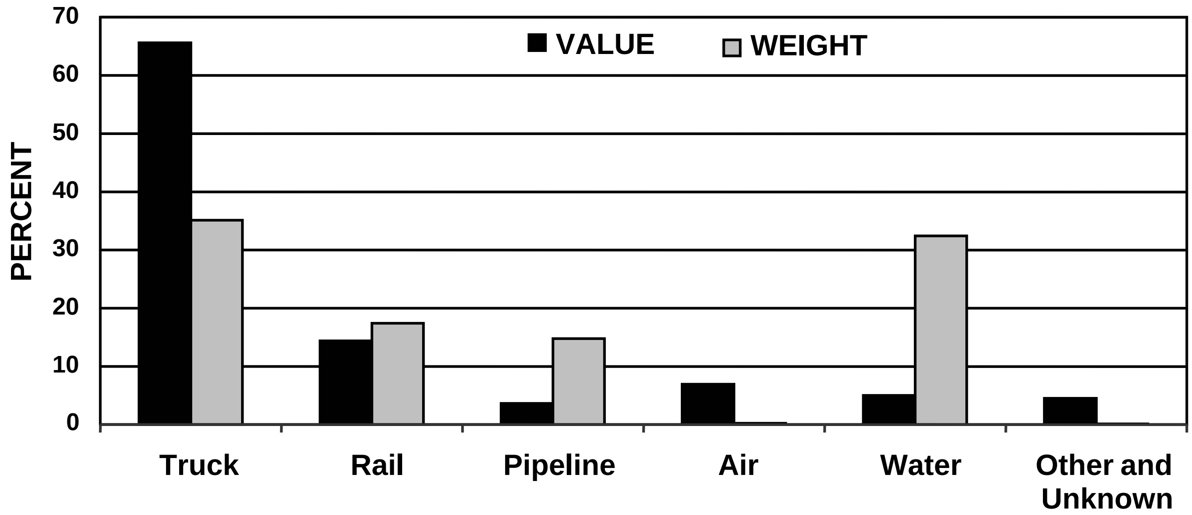

Figure 2.16 Percentage of NAFTA freight transported in Texas by various modes, (Data source: BTS)

Figure 2.16 shows the percentage of freight transported through various modes of transportation in Texas. The graph shows, that Texas relies a great deal more on trucks to transport freight than any other mode of transportation.

2.4 The Congestion Index

While all of these statistics on vehicles illustrate the growing trend in traffic congestion, it is helpful to analyze the congestion index as well. The following charts illustrate the congestion index for a variety of cities in Texas.

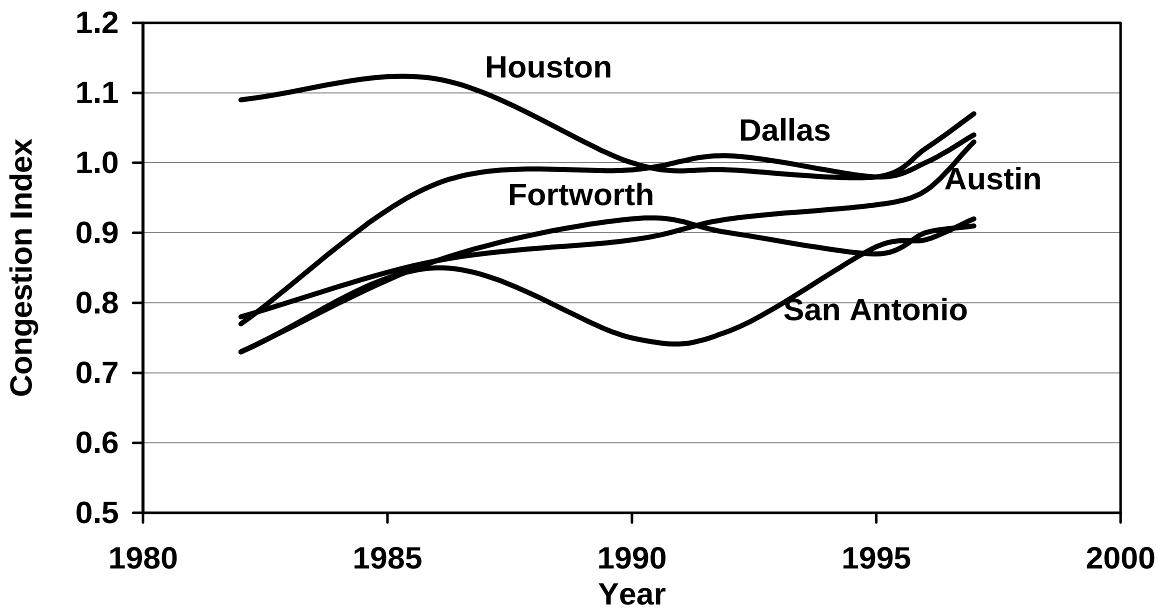

Figure 2.17(A) Congestion index for major cities in Texas, (Data source: TTI)

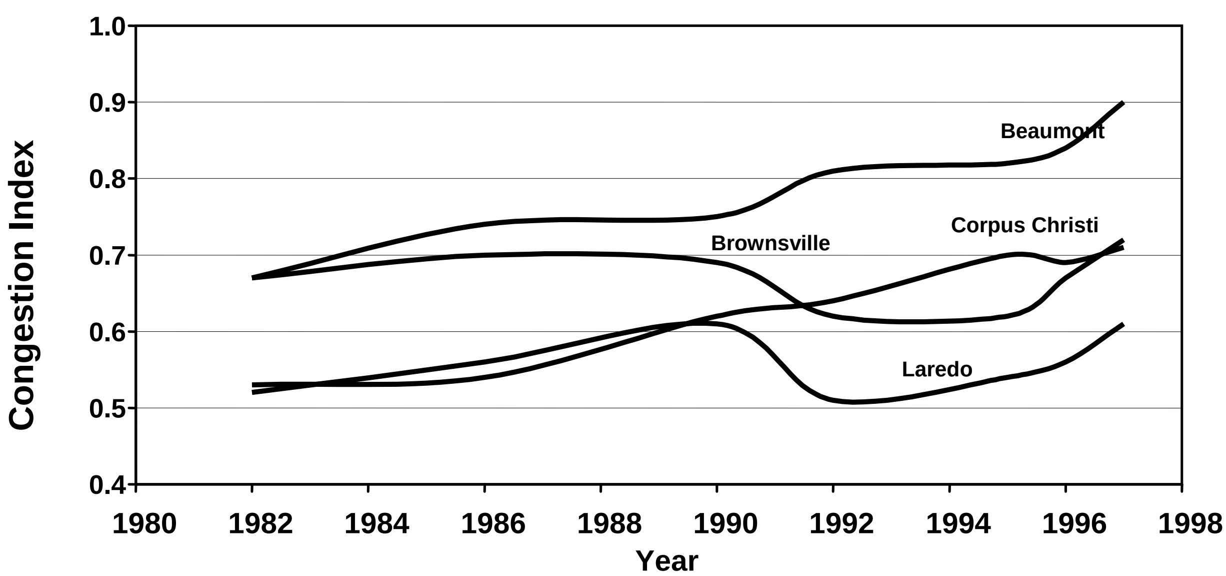

Figure 2.17(B) Congestion index for major cities in Texas, (Data source: TTI)

Figures 2.17(A) and 2.17(B) indicate the congestion index for some cities in Texas from 1982 to 1997. The congestion index is the ratio of the travel demand to the capacity of roadways during peak periods. From 1982 to 1993, most of the metro cities first show an increase and then a decrease in the congestion index. However, the years between 1995 and 1997 witnessed a constant increase in the roadway congestion index. An index value greater than 1.0 indicates problematic congestion. While Brownsville, Corpus Christi, and Laredo appeared to be less than 1 in 1997, Beaumont's index ran dangerously close to 1.0. A look at the other graph reveals that Dallas, Austin, and Houston were already in the danger zone in 1997. Fort Worth and San Antonio were each at an index of .9, slowly approaching 1.0.

2.5 Consequences of Congestion

Congestion wastes time, energy, and money. Figure 2.18 illustrates the average time it takes drivers to travel to work in the United States.

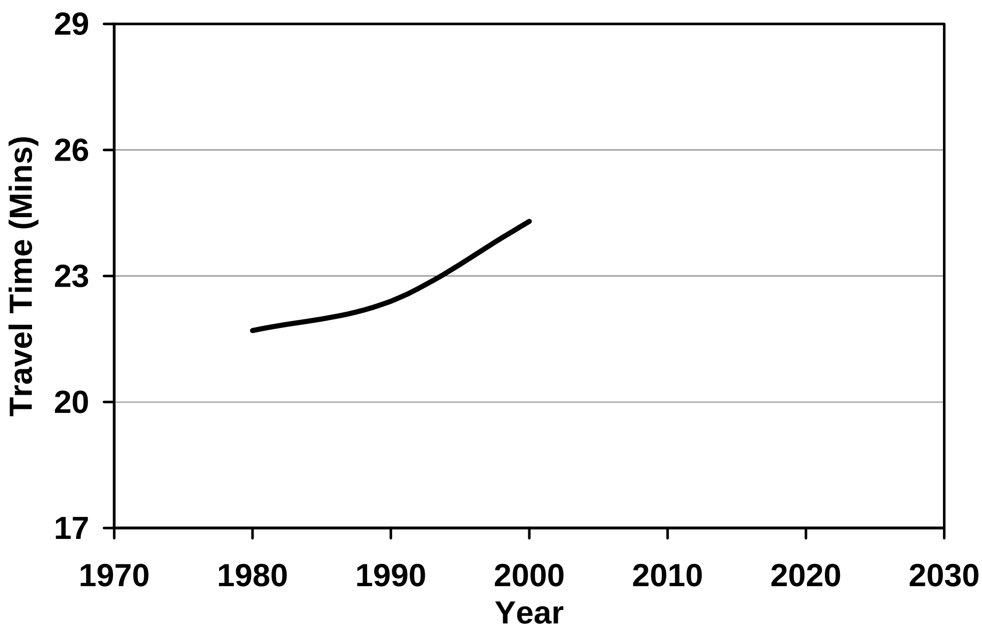

Figure 2.18 Average travel time to work in the U.S. (Data Source: BTS)

Over the last two decades, the average travel time to work in the U.S. has increased from 22 minutes to 24 minutes. If we project this rate into the future, the average time could increase to 27 minutes by 2020.

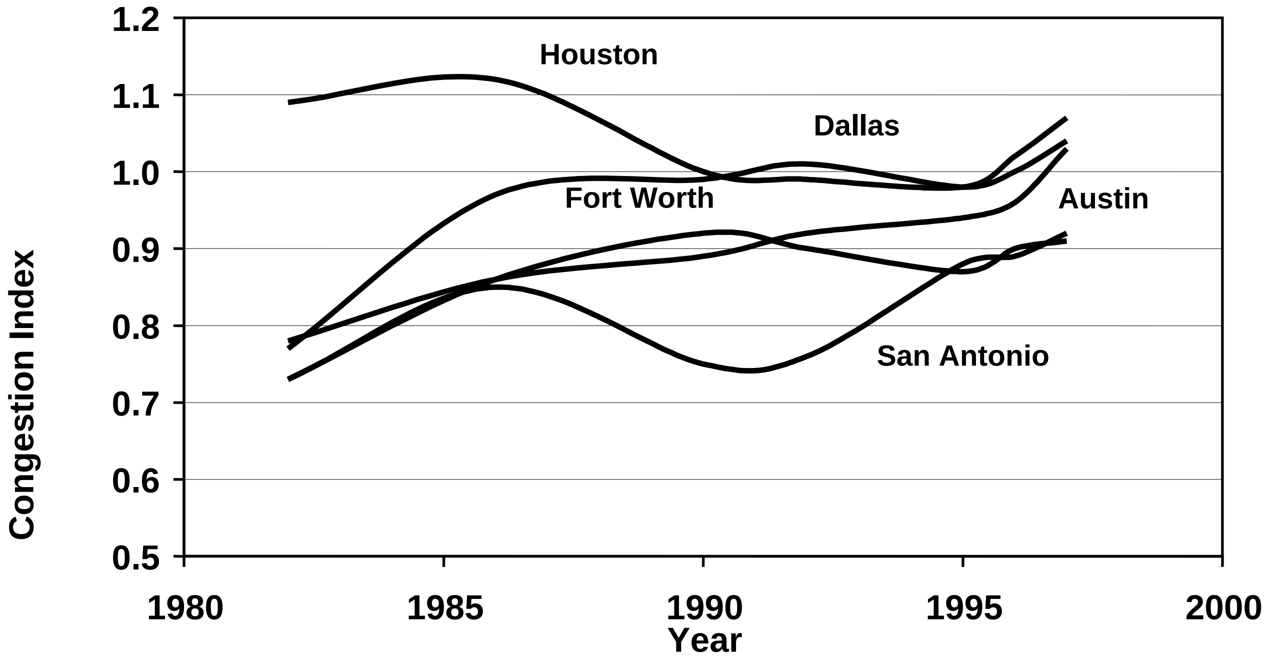

Figure 2.19 Fuel wasted due to congestion vs. time, (Data source: TTI)

Figure 2.19 shows millions of gallons of fuel wasted due to congestion from 1982 to 1997. According to this graph Dallas, Fort Worth, San Antonio, Austin, and El Paso have all witnessed a significant increase in the amount of fuel wasted due to congestion. Dallas has shown the highest increase in the amount of fuel wasted, going from 30 million gallons wasted in 1982 to 165 million gallons wasted in 1997. San Antonio went from wasting 15 million gallons in 1982 to 60 million gallons in 1997. Austin and Fort Worth followed similar trends. El Paso witnessed the smallest increase in wasted fuel.

Wasting fuel and time in traffic raises a variety of concerns. One concern is large amount of money lost annually. Figure 2.20 illustrates the annual congestion cost per driver in major Texas cities. The graph takes into consideration both the wasting of fuel and time.

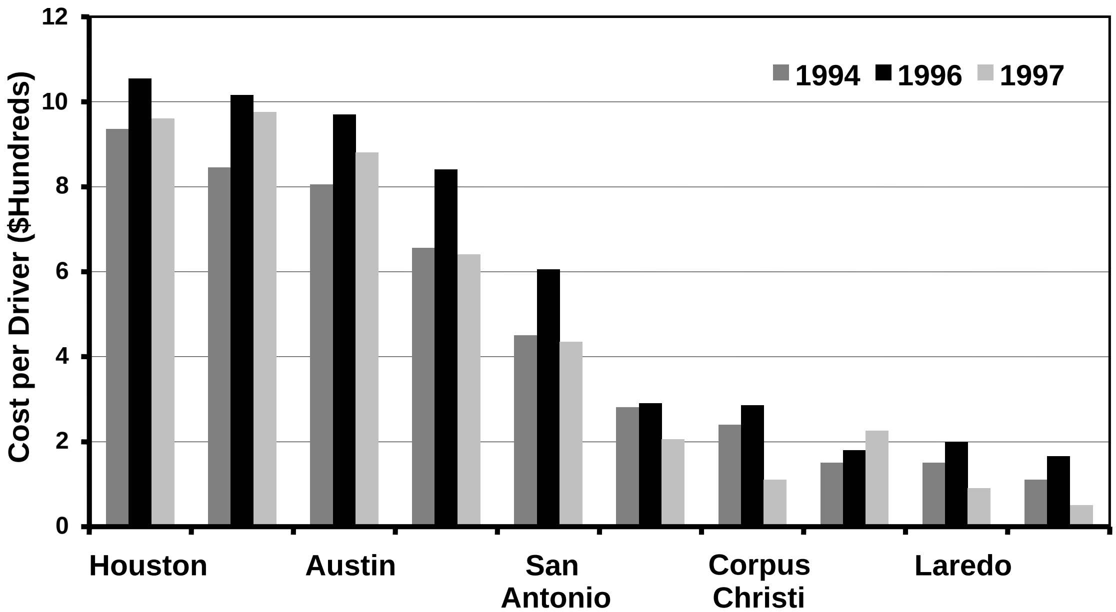

Figure 2.20 Congestion cost per driver in Texas, (Data source: TTI)

The cost of congestion is felt in other areas as well. As congestion increases, so does the cost of truck freight and service operations. These costs have negative impacts on the manufacturing industry and the service sector, and are passed on to the consumers.

2.6 Fuel Consumption

Of course, an increase in gasoline prices is not just due to the amount of fuel that is wasted because of congestion. Gas prices rise as fuel becomes scarcer and more difficult to access. As the U.S. does not produce enough petroleum to rely on its own resources for consumption, fuel must be purchased from foreign countries. The following graph illustrates this problem.

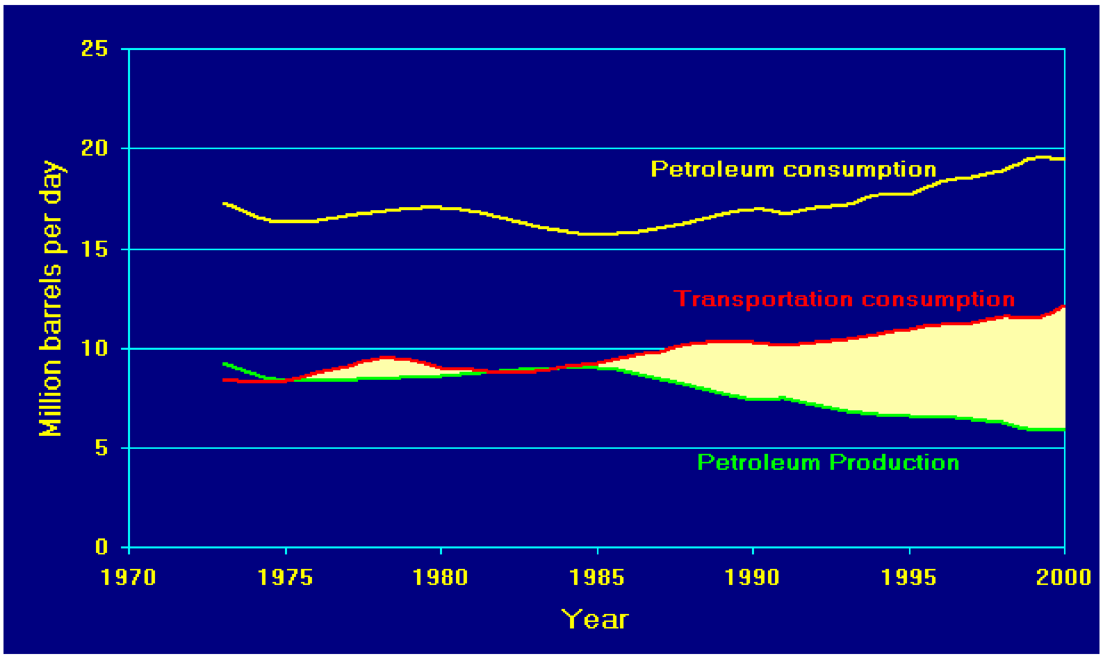

Figure 2.21 Petroleum production and consumption in the U.S., (Data source: DOT)

As shown in Figure 2.21, the U.S. consumption of petroleum far exceeds its production, with the transportation sector consuming a great percentage of the petroleum consumed. Figure 2.22 specifically looks at the amount of energy that is consumed by the transportation sector alone each year in the U.S.

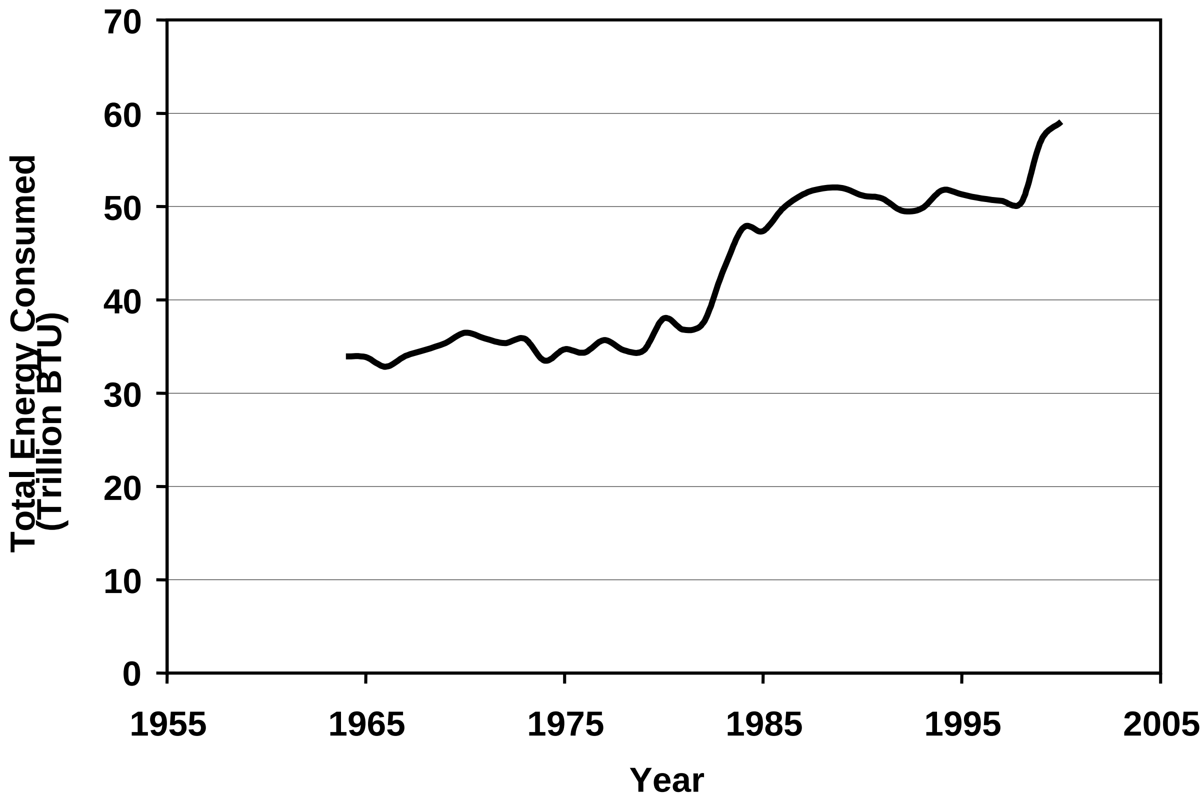

Figure 2.22 Total energy consumed by transportation sector,

(Data source: DOE)

Figure 2.22 illustrates the total energy consumed by the transportation sector from 1960 forward. The transportation industry's yearly consumption of energy resources has increased significantly since the 1960's.

Figure 2.23 demonstrates the domestic demand for gasoline by mode of transportation, breaking up transportation into categories of "highway" and "non-highway."

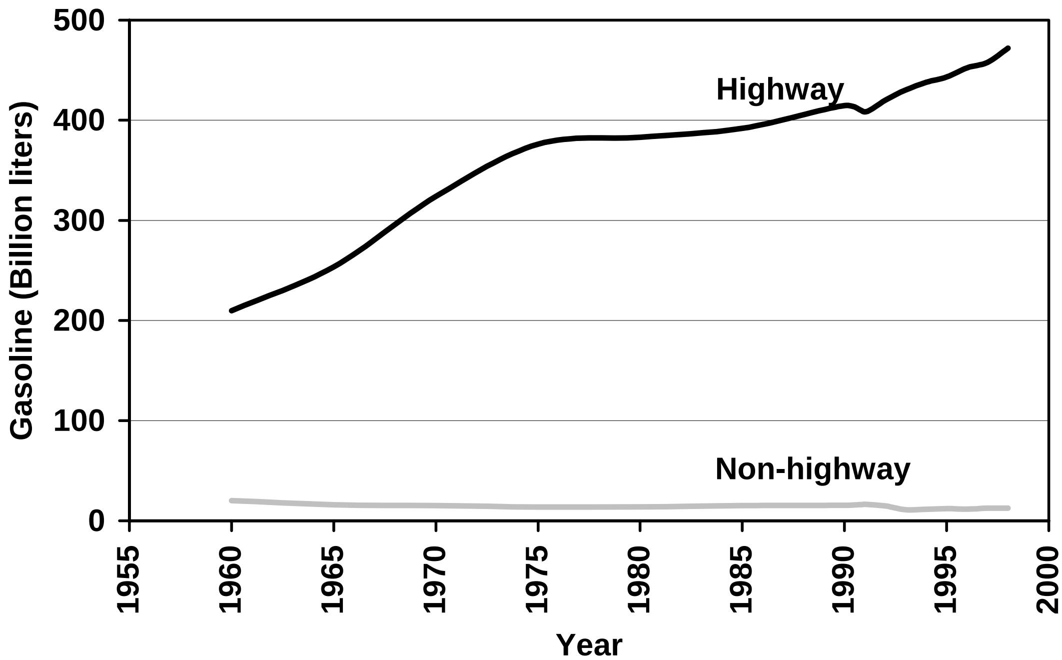

Figure 2.23 Domestic demand for gasoline by mode of transportation, (Data source: BTS)

According to the graph, the demand for gasoline by highway modes of transportation increased linearly from 1960 to 1975. After that time, the increase was slower. Between 1990 and 1992, the demand for gasoline by highway modes of transportation dropped but since 1992, the demand for gasoline by highway modes of transportation has increased linearly. By contrast, the demand for gasoline by non-highway modes of transportation has remained almost constant since 1960, decreasing by just a minimal amount. The overall demand for gasoline by non-highway modes of transportation is significantly less than the overall demand for gasoline by highway modes of transportation.

Figure 2.24 breaks down the energy consumption of the highway modes of transportation into two categories: 1) Autos and light vehicles, and 2) Buses and trucks.

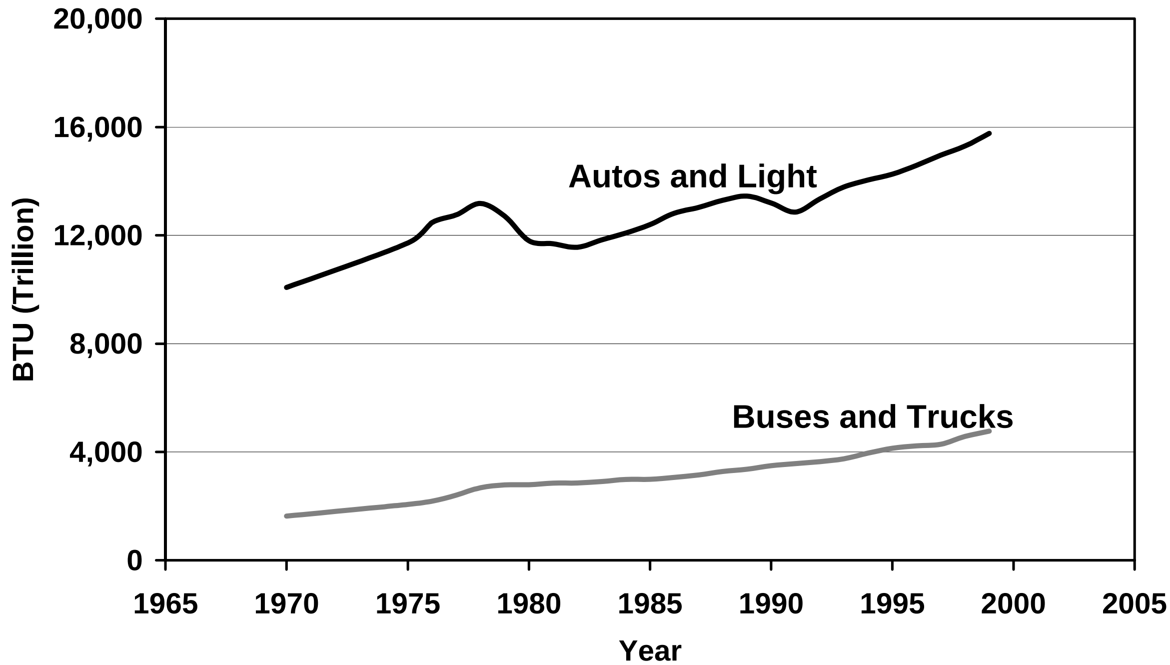

Figure 2.24 Total energy consumption, (Data source: BTS)

The demand for gasoline has been somewhat erratic for autos and light vehicles, but there has been an overall increase in consumption. Buses and trucks however, have witnessed a steadier increase over time.

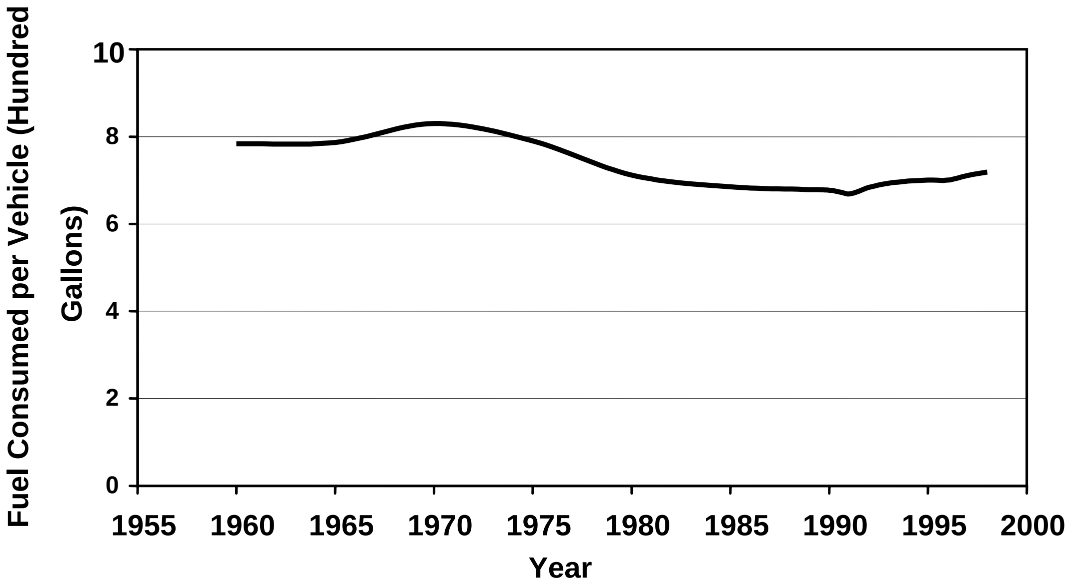

Figure 2.25 Fuel consumed per vehicle, (Data source: BTS)

In consideration of the fact that VMT is increasing, this chart illustrates that fuel efficiency is also, increasing. Figure 2.26 illustrates the increase in fuel consumption per capita.

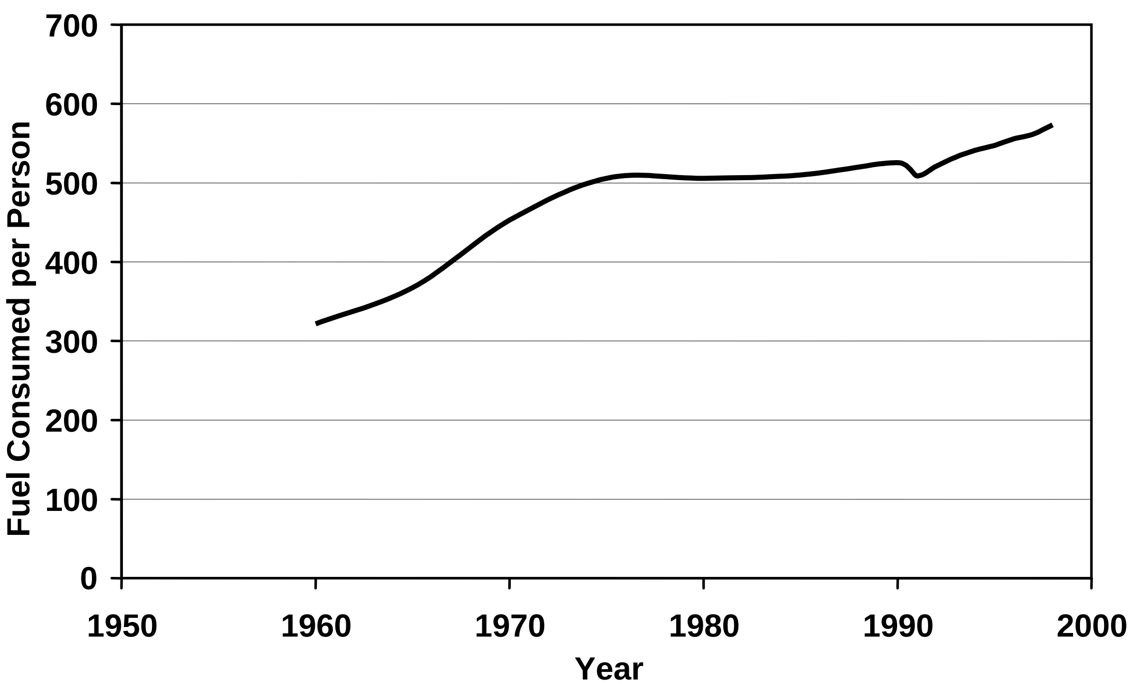

Figure 2.26 Fuel consumed per capita, (Data source: BTS)

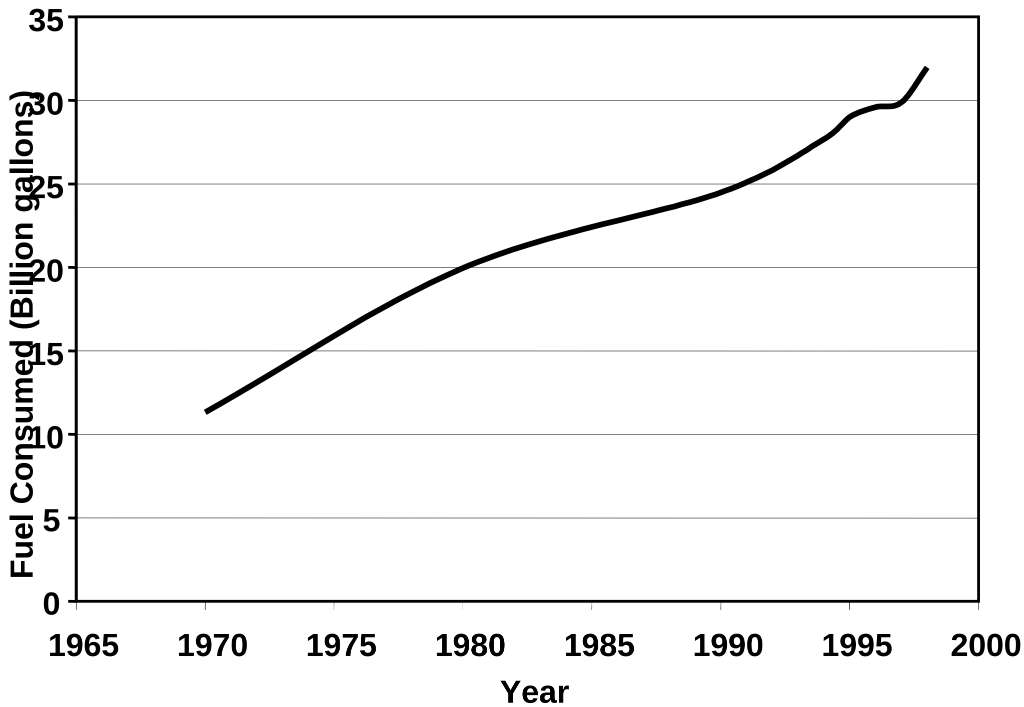

Figure 2.27 Fuel consumed by trucks, (Data source: BTS)

As shown in Figure 2.27, from 1970 to 2000, the trucking industry has witnessed an almost a 270% increase in fuel consumption.

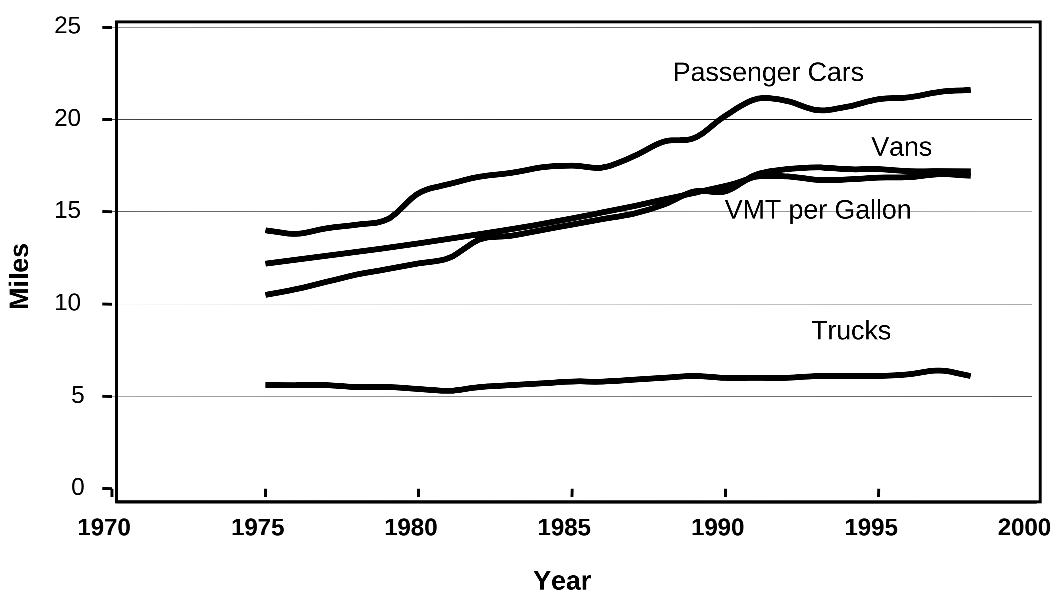

Figure 2.28 Miles traveled per gallon, (Data source: BTS)

Figure 2.8 illustrates that while trucks are witnessing a rise in their consumption of fuel, they are not experiencing an increase in miles traveled per gallon of fuel. Unlike other vehicles, their fuel efficiency is not increasing.

2.7 Alternate Fuel Vehicles

Vehicles of this type offer a way for consumers to do their part in alleviating energy related problems in the U.S. Figure 2.29 illustrates the number of alternate fuel vehicles sold throughout the U.S.

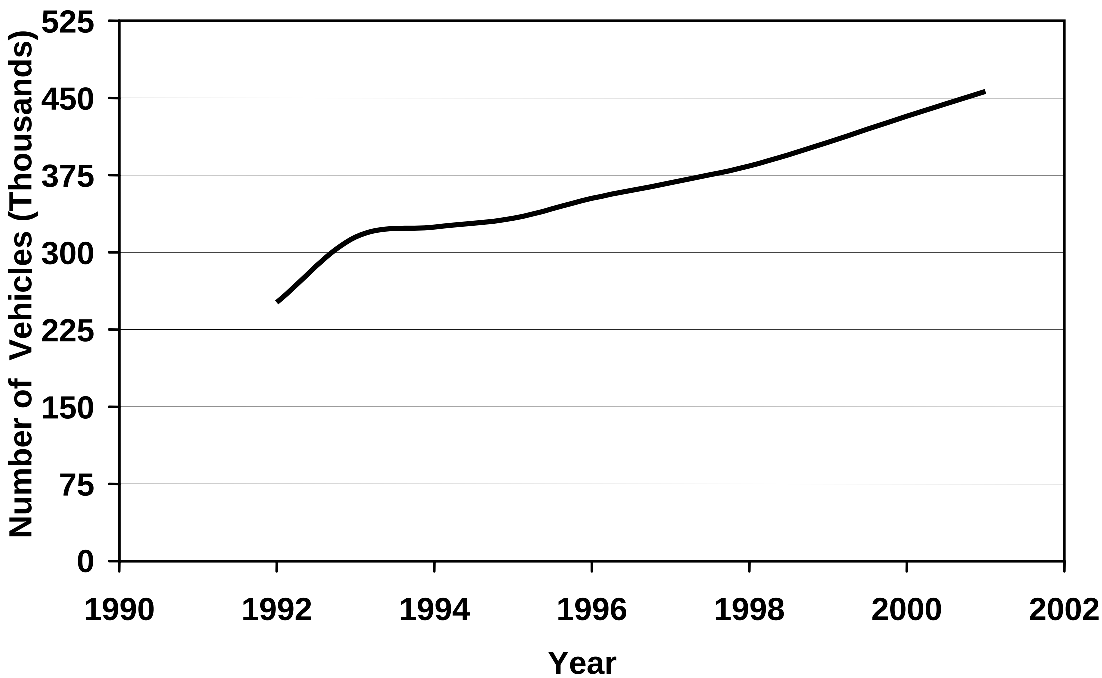

Figure 2.29 Alternate fuel vehicles sold in Texas, (Data source: BTS)

Figure 2.29 shows the number of Alternative vehicles sold in the US from 1992 onwards. From 1992 to 1993, there was an initial surge in the market for alternate fuel vehicles. Since 1993, the purchase of alternate fuel vehicles has risen gradually. Vehicles using alternate fuel touched a figure of around 450,000 by year 2001.

A variety of drivers seek out alternate fuel vehicles. Figure 2.30 illustrates the different types of vehicles that are using alternate fuel.

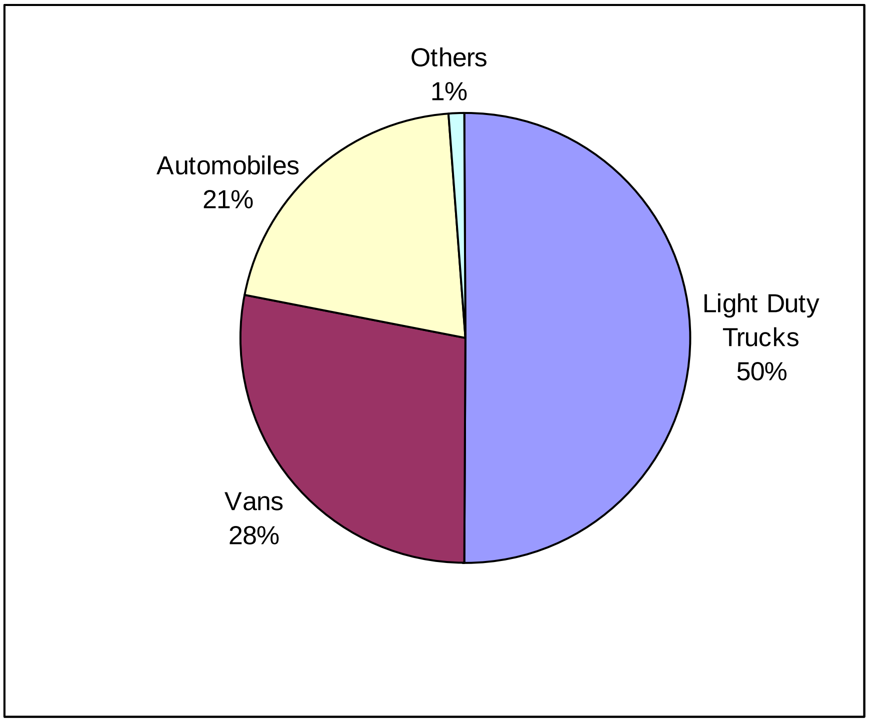

Figure 2.30 Alternate fuel consumption by various modes of transportation, (Data source: BTS)

As the pie chart indicates, 50% of alternate fuel vehicles are light duty trucks. The next major users are vans at 28%. Automobiles follow with 21%.

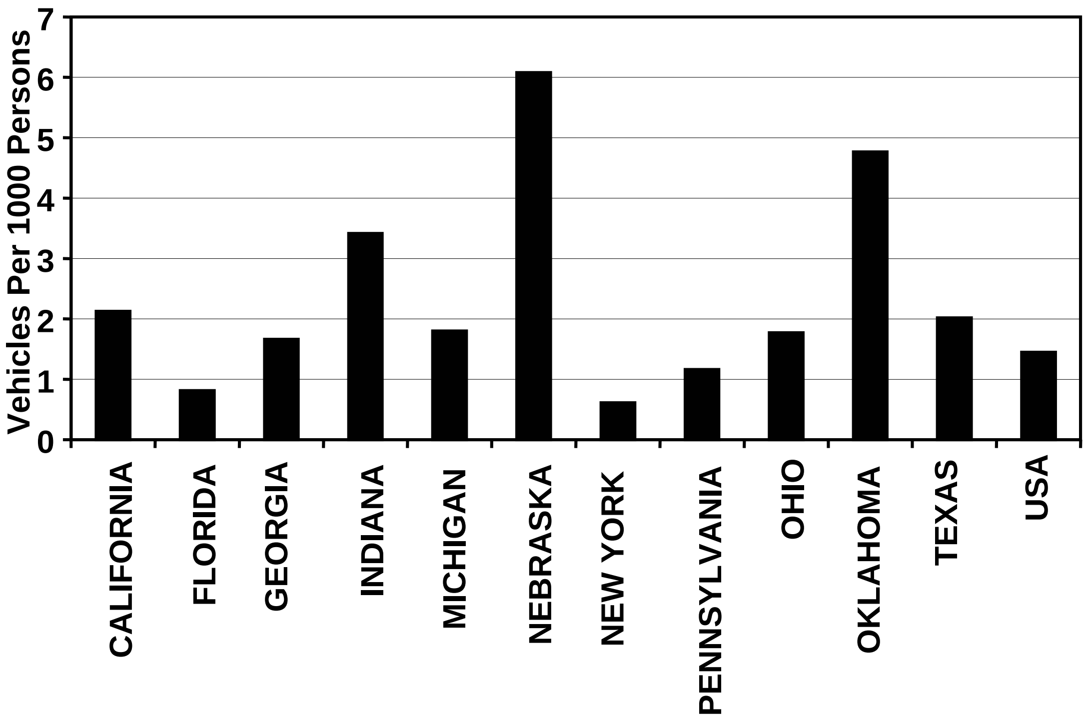

Figure 2.31 Alternate fuel vehicles purchased per state,
(Data source: DOE)

California is the leader in the market of alternate fuel vehicles with Texas following close behind. However, these statistics change somewhat when the number of alternate fuel vehicles is normalized with the population of each state. When this is considered, as shown in Figure 2.31, Nebraska comes in highest followed by Indiana and Oklahoma.

Alternate fuel vehicles employ a variety of different resources that take the place of petroleum. The following graph gives us an idea of the different kinds of resources being used and suggests the popularity of each.

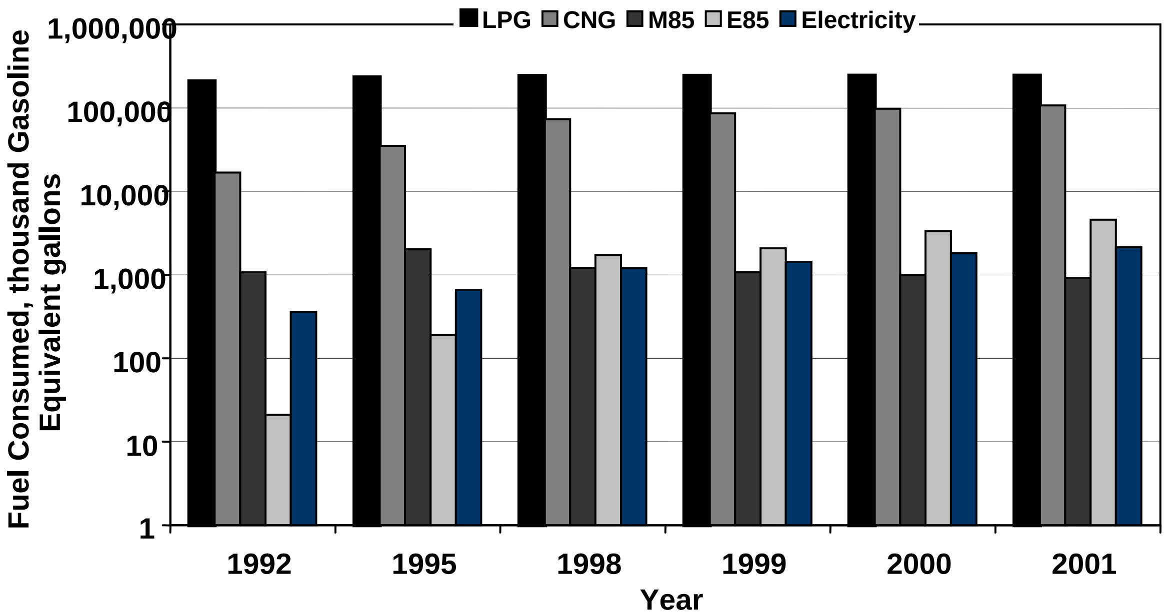

Figure 2.32 Fuel used for alternate fuel vehicles, (Data source: DOE)

Among the different types of alternate fuel used (LPG, CNG, E85, M85, and electricity), liquefied petroleum gas (LPG) is the most widely used, followed by compressed natural gas (CNG). The use of M85 has stabilized over the years. Both E85 and electricity have recently become increasingly popular. Figure 2.33 illustrates the increase in electricity consumption for alternate fuel vehicles.

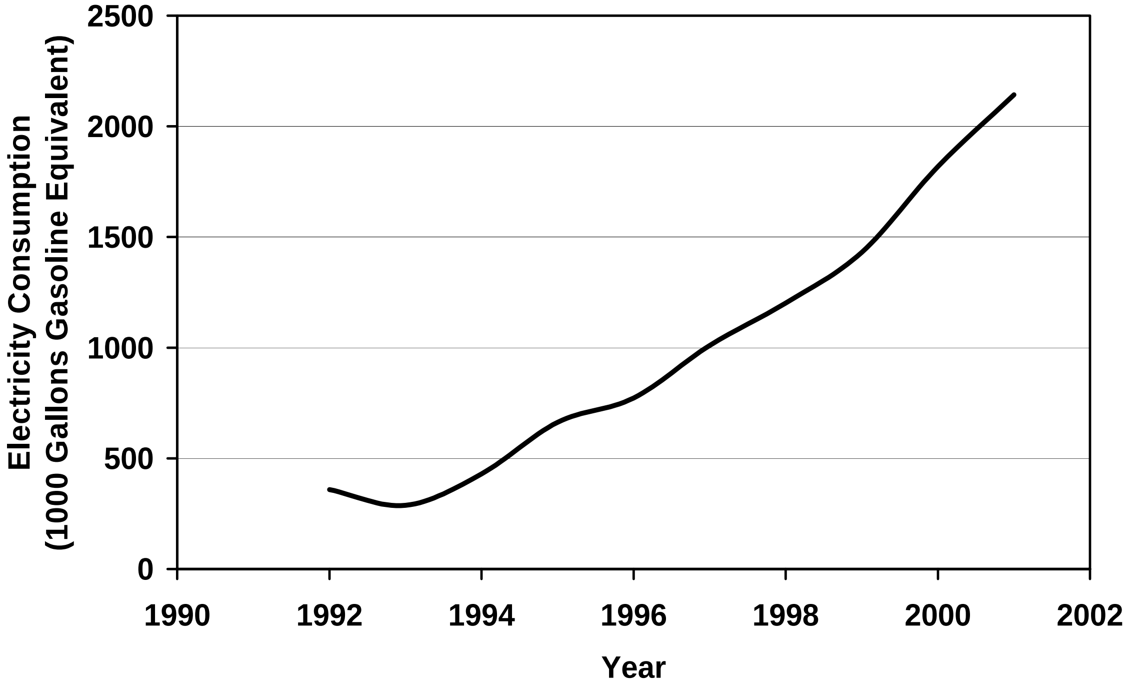

Figure 2.33 Electricity consumption by alternate fuel vehicles,
(Data source: DOE)

Figure 2.33 shows the amount electricity consumed (in gasoline equivalent gallons) in the U.S. As the graph indicates, the alternate fuel vehicle market has witnessed a tremendous increase in the use of electricity. From 1992 to 2001 the consumption of electricity for alternate fuel vehicles quadrupled.

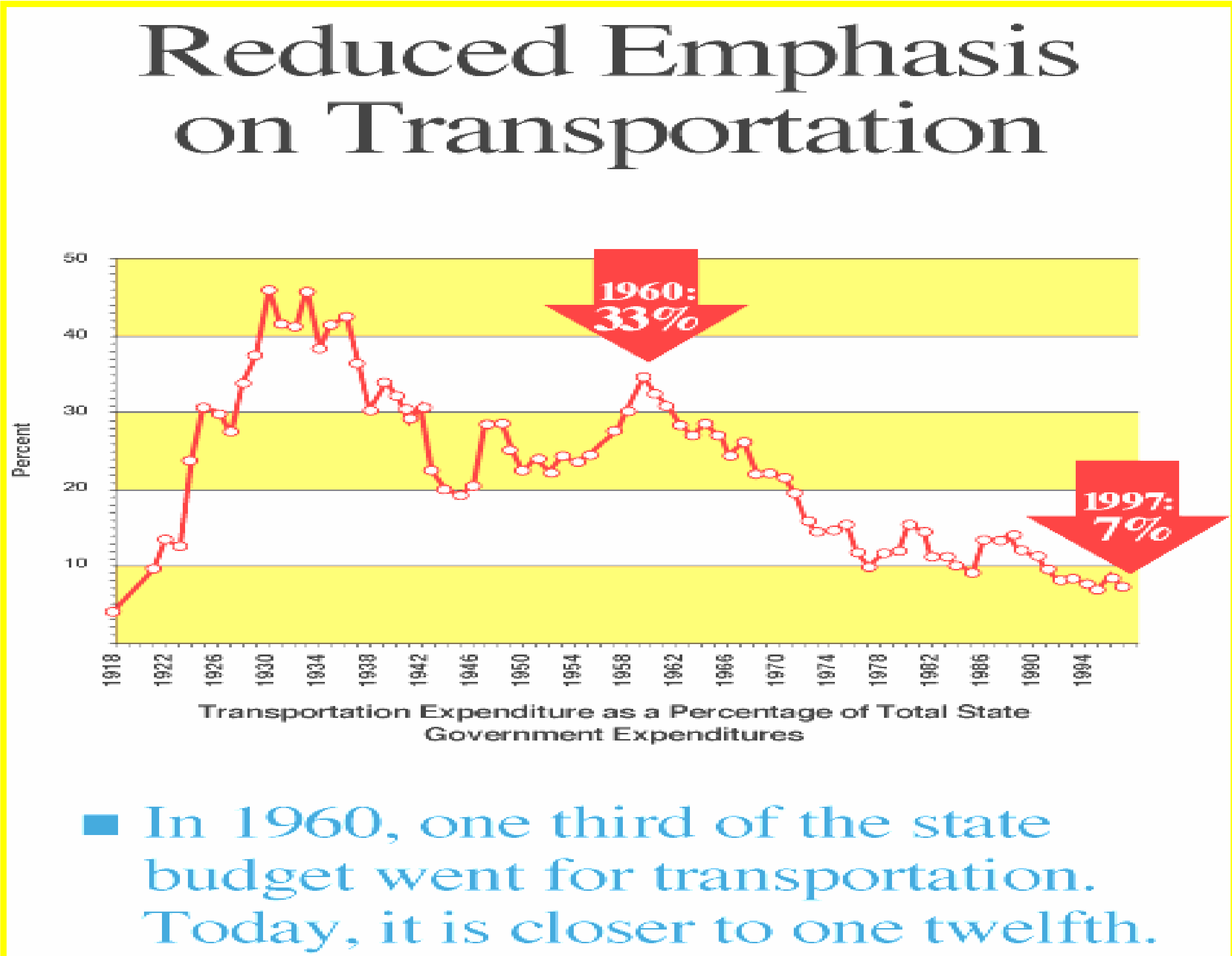

Figure 2.34 Money spent on transportation, (Data Source: TX DOT)

Figure 2.34 illustrates the percentage of money the state of Texas has allocated to the transportation sector since 1918. A major percentage of money was spent on the transportation sector when the interstate issue was being built. Since then, a negligent attitude has been shown towards the transportation sector. Funds allotted for the transportation sector reached an all time low in 1997 of 7%.

When the Texas initially increased its spending in the transportation sector, it raised gasoline tax rates to balance the increase. However, as the gasoline tax rate has remained the stagnant for a long time. Figure 2.35 illustrates this situation and also compares the rates of Texas with averaged rates of other states.

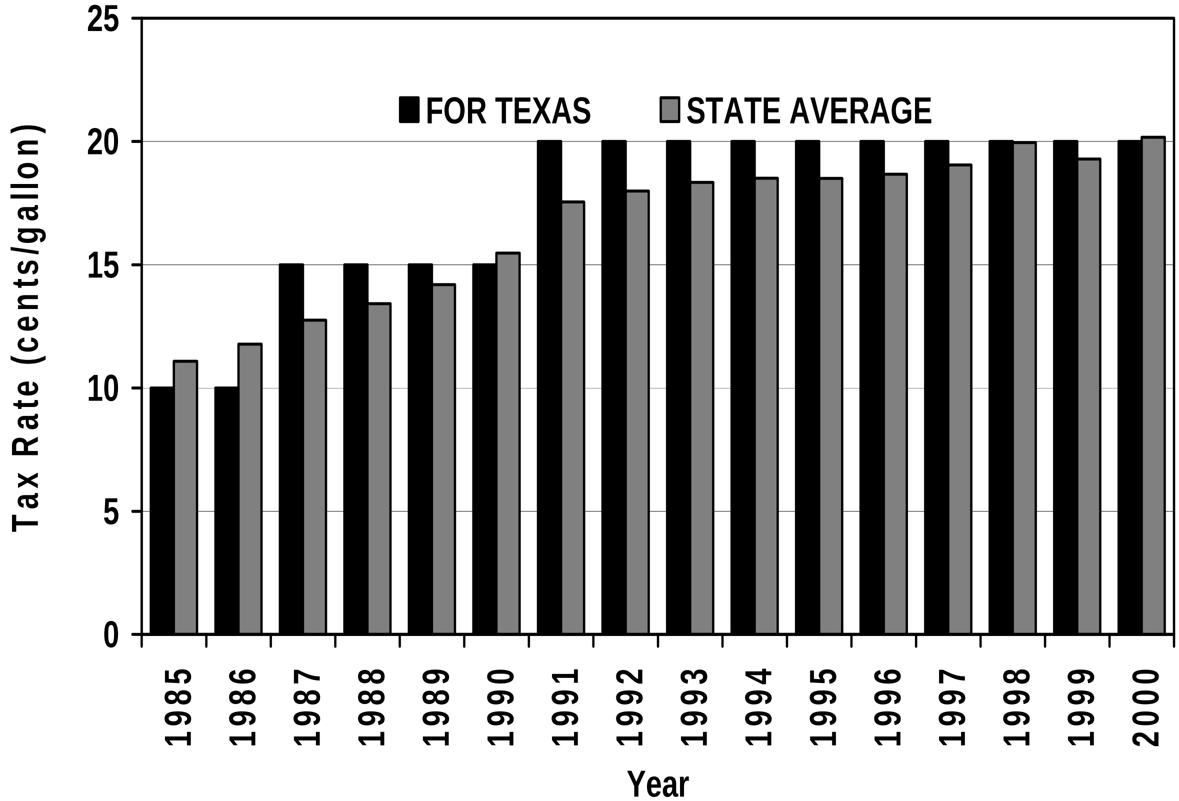

Figure 2.35 Gasoline tax rates, (Data Source: BTS)

Figure 2.35 indicates, Texas fell below the state average in gasoline tax rates until 1991. Further, not all the revenues collected from gas tax goes to transportation (some of it is earmarked for other agencies such as DPS).

If roads are becoming over crowded, the logical answer seems to be to build new roads. Unfortunately, this solution is self defeating. Building new roads actually increases the traffic volume. The following discussion illustrates this phenomenon.

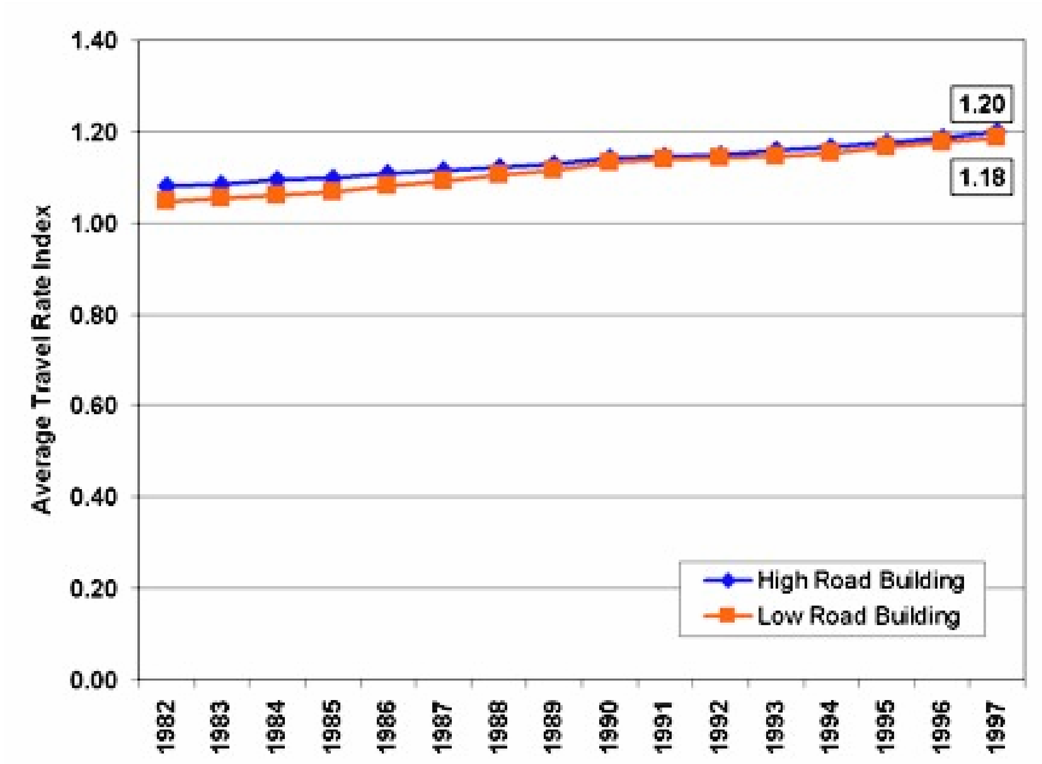

Figure 2.36 Travel rate index, (Data Source: TTI)

Figure 2.36 shows the Travel Rate Index from 1982 to 1997 for two cases – high road building areas and low road building areas.

As this chart indicates[1], the high road-building areas increased road capacity per person by 28%, while the low-road building areas actually decreased road capacity per person by 11%. However, the high road building areas witnessed higher congestion levels than the low road-building areas. Both groups experienced congestion during rush hour traffic at about the same levels.

People are attracted to new roads. When new roads are built, people who would generally avoid driving during high congestion times suddenly take to their vehicles. Others join the new roads hoping to save time. Over a period of time, congestion increases.

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[1] This chart, and the information accompanying it in this paragraph and the next, can be found in a report published by The Surface Transportation Policy Project at http://www.transact.org/Reports/constr99/sheetiv.htm

Despite the self defeating efforts of construction, the drive for building new roads continues to grow. Figure 2.37 illustrates how much money is spent on constructing new roads and maintaining old ones in Texas.

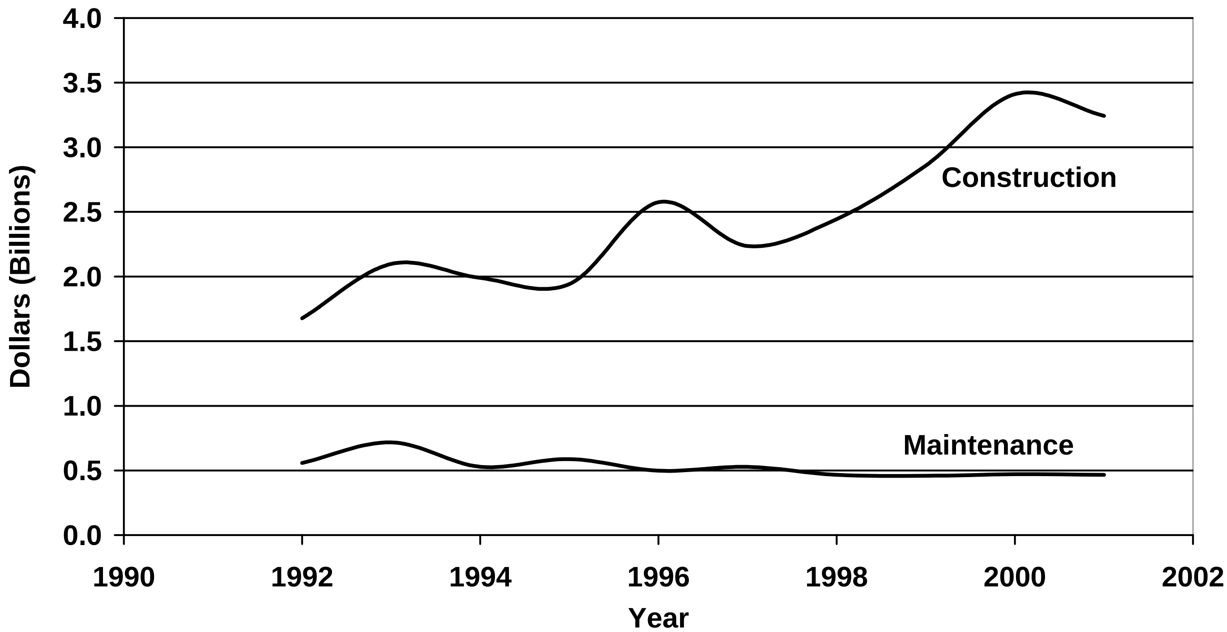

Figure 2.37 Road construction and maintenance in Texas, (Data Source: TX DOT)

According to this graph, Texas spent almost 3.5 billion dollars in the year 2000 on road construction. The amount spent on maintaining roads, however, seems to be decreasing.

2.8 Conclusion

While the current rate of diffusion of alternate fuel vehicles (or hybrids) as a mode of transportation is extremely slow (these vehicles account for a fraction of a percent of the total number of vehicles on the road), there are other factors that could accelerate the rate of their acceptance with the consumer - the most important of which is the price of gasoline.

After studying the global production and consumption patterns of oil, Campbell and Laherrere (1998), two analysts with the oil industry, arrived at a startling conclusions. Their extensive analysis effectively debunks alarmist theories that we are about to run out of oil. Their data suggests that the world is not running out of oil - at least not yet. But they also conclude that the end of the abundant and cheap oil on which all industrial nations depend is near. They estimate that the switch from growth to decline in oil production will happen within the next decade. Meanwhile, global demand will continue to rise at more than 2% annually. Their somber conclusion:

> *The world could thus see radical increases in oil prices. That alone might be sufficient to curb demand, flattening production for perhaps 10 years. (Demand fell more than 10 percent after the 1979 shock and took 17 years to recover.) But by 2010 or so, many Middle Eastern nations will themselves be past the midpoint. World production will then have to fall.*

These trends in the transportation industry indicate that driving is increasing throughout the U.S. Factors for the increase in driving are varied. However, the result is an increase in congestion, and a waste in fuel, time, and money. Texans appear to be seeking ways to alleviate the problems associated with fuel wastage by purchasing alternate fuel vehicles. Alternate fuel vehicles may continue to grow in popularity in the future.

Chapter – 3

SURVEY OF TECHNOLOGIES

In this chapter we explore some of the innovative technologies that may shape the next major transition in transportation.

3.1 Automated Highway and Vehicle Systems

Introduction

Traffic congestion is becoming a major problem in the United States. Frustrations associated with congestion and concerns about safety, convenience, and pollution accelerate with the traffic. Automated Highway Systems (AHS) provide answers to the problems associated with highway congestion by warning passengers of possible traffic problems, coordinating traffic signals within a community, and providing information that will increase the response time of emergency vehicles. AHS has the potential to increase driver and passenger safety, increase capacity, and reduce congestion. A variety of systems and technologies exist under the general category of AHS. In this section, we will provide a brief overview of some of these systems as well as discuss some of the related technologies such as hands-off driving and adaptive cruise control.

A. Intelligent Transportation Systems

The U.S. Department of Transportation states that Intelligent Transportation Systems, or ITS, should "promote the implementation of a technically integrated and jurisdictionally coordinated transportation systems across the county."[1] The following is a list of systems that could enhance the low of traffic and improve communication throughout the transportation sector.[2]

[1] "Intelligent Transportation Systems." 22 June 2002. <http://www.iowaontrack.com/questions.htm>

[2] The following summarizes the information provided by ITS Deployment Tracking at <http://itsdeployment2.ed.ornl.gov/its2000/definitsions.asp>

1. *Freeway Management Systems:* Freeway Management Systems employ personnel in Freeway Management Centers to electronically monitor traffic conditions. Through a variety of technologies, including Variable Message Signs, Highway Advisory Radio, and In-Vehicle Signing, their personnel have the ability to provide travelers with information to help them avoid congestion.

2. *Incident Management Systems:* Incident Management Systems specifically target problems such as collisions, disabled vehicles, and debris. When operators become aware of a problem impeding traffic, the appropriate response agency is alerted and provided with the best route possible to the site to remedy the situation and redirect the traffic.

3. *Traffic Signal Control:* With the help of Traffic Signal Control, traffic can be coordinated along urban arterials, networks, and the Central Business District. Traffic Signal Control adjusts the amount of green light time per street based on either historical traffic conditions or real time emergencies.

4. *Regional Multimodal Traveler Information Systems:* These information systems collect real time traffic information and make it available to travelers to allow them to plan their routes accordingly. A variety of technologies including broadcast radio, the Internet, and cable TV make this information accessible.

5. *Transit Management Systems:* Transit Management Systems electronically monitor transit vehicles to check the actual location of the vehicle against its scheduled location. If a transit vehicle is behind schedule, measures can then be taken to alert potential travelers and suggest an adjusted route for the transit vehicle. This system will also be helpful in emergency and maintenance situations that involve transit vehicles.

6. Electronic Toll Collection: In Electronic Toll Collection, roadside technology identifies a particular vehicle and charges its driver's toll account accordingly. This system could reduce traffic delay at toll collection plazas, reduce the need for drivers and public agencies to handle money, and reduce toll agency costs. A common payment media would need to be established between collecting agencies.

7. Electronic Fare Payment: Electronic Fare Payment allows travelers to electronically pay for travel related fares and parking fees. This technology eliminates the need for both travelers and public agencies to handle the money required for these transactions.

8. Highway Rail Intersections: Automated systems can be employed to better coordinate traffic control signal systems with rail movements. Roadway travelers can be alerted in advance of the timing of railway crossing closures. These systems may also improve the warnings that are already given at highway-rail intersections.

9. Emergency Management: Emergency Management Services monitor emergency vehicle traffic patterns, apprising drivers of the best route possible. With this system, both emergency notification and response time can be improved.

The implementation of any or all of these systems could lead to a more efficient, less congested, and safer driving experience.

B. Hands-Off Driving [3]

Hands-off driving allows drivers to take on the roles of passengers for most of their driving experiences. With this technology, cars can travel independently of their driver's manipulation for most of the ride. They can change lanes, accelerate, and decelerate in order to adjust to surrounding traffic conditions. This technology can be implemented in a variety of ways. The two most probable approaches involve cameras and magnets.

In the camera system, cars are equipped with small television cameras, a computer, and vehicle-control actuators. All these devices work together to maneuver the vehicle and keep it within the lane markings. Hands-off driving can easily be implemented with this system as the only technological changes that need to be made within the highway system are inside the cars themselves.

In contrast, the system that employs magnets would require structural changes on the actual highway. In a magnet-based system, vehicles are kept in place by magnets that are embedded along the center of the lane. Magnets are placed 1.2 centimeters apart, and the vehicles can stay on track with less than 7.5 centimeters of error. The cost of magnet implementation would be about $10,000 per lane mile. While this technology may seem expensive, it is much cheaper than the cost of building new lanes, which is estimated at $1 million per lane-mile.

The benefits to hands-off driving are four fold, providing answers for concerns about safety, traffic congestion, pollution, and economics. In the United States, 40,000 people are killed and 5 million people are injured each year in automobile crashes. Ninety percent of these crashes are the result of human error. Hands-off driving could significantly reduce the number of accidents that are a result of human error.

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[3] All of the information on hands-off driving comes from Bob Bryant's article "Actual Hands-off Steering: And Other Wonders of the Modern World" published in Public Roads Online. The information can be accessed at <http://www.tfhrc.gov/pubrds/pr97-12/p32.htm>

Reducing the number of accidents would save lives and money. The cost of auto accidents is about $150 billion each year. The cost of congestion can be estimated at about $50 billion each year. By reducing the number of accidents and the amount of congestion on highways, hands-off driving could save a significant amount of money.

Safely decreasing the space between vehicles on the highway from one vehicle length to half a vehicle length, thereby doubling or even tripling highway capacity could alleviate congestion. As congestion often results in accidents, this would also promote safety.

As congestion decreases, so would pollution. Vehicles that move together in a tight automated platoon have a dramatic reduction in aerodynamic drag that could reduce tail-pipe emissions by 20 to 25 %.

Hands-off driving was successfully tested recently. In 1997, the National Automated Highway System (NAHSC) demonstrated hands-off driving and other intelligent transportation technologies in San Diego. The demonstration was successful, and 98% of the riders said they believed the technologies could improve highway safety, while 87% felt that the technologies could reduce congestion on highways. Companies that participated in the demonstration include Eaton Vorad, Houston Metro, Honda, The Ohio State University Transportation Research Center, and Toyota.

Figure 3.1 Adaptive Cruise Control

C. Adaptive Cruise Control

While the technology used in hands-off driving may seem somewhat alien to our current means of operating vehicles, another technology exists that is not so difficult to imagine. Adaptive cruise control, or ACC, is an extension of the existing cruise control feature found in most cars. While cruise control helps the driver maintain a consistent speed, ACC helps the driver to adjust to the speed of the car in front. The system controls the accelerator, engine power train, and vehicle brakes to maintain a desired time (or distance) gap between the vehicle ahead. Figure 3.1 (above) is a picture of adaptive cruise control.

The ACC system is equipped with a microwave radar (or a laser) unit to monitor the vehicle ahead of it. The radar or laser reads the distance and speed of the vehicle ahead, and a computer adjusts the car's movements to match. The driver of the car can override ACC at any time simply by braking. Figure 3.2 illustrates the mechanics of such a radar system.

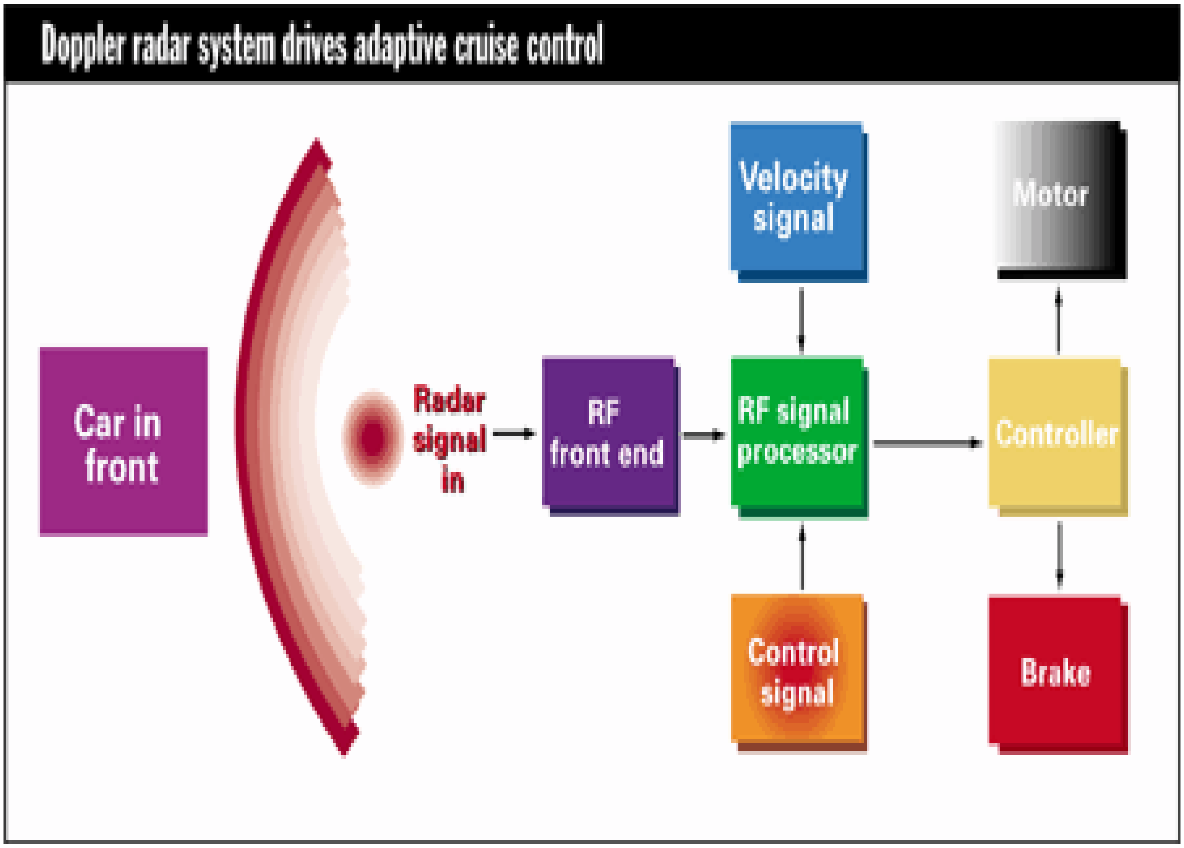

Figure 3.2 A schematic showing how Doppler Radar System works

Another technology that may be employed with or without ACC is CWS, or Collision Warning System. CWS simply warns the driver through visual or audio signs that a collision is imminent and braking and evasive steering are needed. Currently, most commercial vehicles are equipped with CWS.[4]

The benefits of ACC and CWS are easy to see. Like hands-off driving, ACC limits highway congestion. Figure 3.3 illustrates the increase in capacity that can be achieved when ACC is employed. When cars are not equipped with ACC, capacity of a lane is between 2200 to 2400 passenger cars per hour. With ACC, the capacity can increase to over 3200 passenger cars per hour per lane.

[4] "Beyond Cruise Control." The Economist 359.8227 (2001): 33-37.

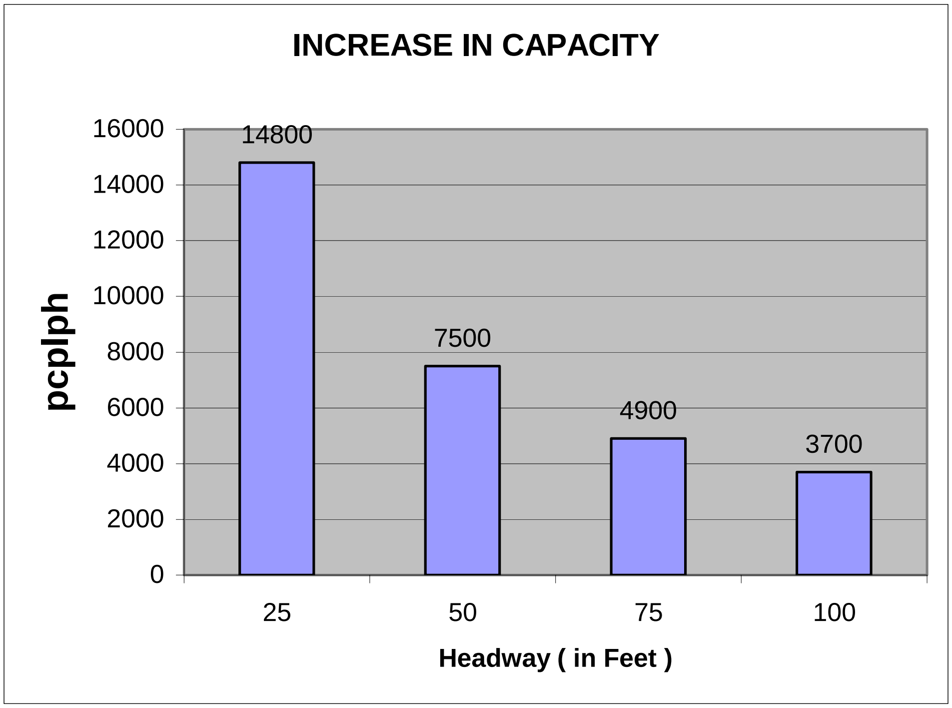

Figure 3.3 Increase in capacity due to Adaptive Cruise Control

Like hands-off driving, CWS could reduce the number of accidents per year. By warning the driver of potential problems, CWS reduces the accidents that result from human errors, such as being distracted or falling asleep.

Adaptive Cruise Control has been successfully tested in a recent demonstration project. A hundred drivers were instructed to use the ACC feature installed in Chrysler Concorde Sedan vehicles in their natural driving environment. Some drivers tested the technology for two weeks; others tested it for five weeks. Surveys were conducted after the project, and the results indicated that drivers would not use ACC in dense traffic conditions. However, when traveling above 35 mph, drivers used ACC for about half of the distance traveled.

Currently, the USDOT, General Motors, and Delphi Automotive Systems are collaborating on a five year, $35 million research project that will design and test a fleet of ten high powered vehicles equipped with high-tech collision warning systems.[5]

Companies involved with ACC include TRW Automotive Electronics, Delphi Delco Electronics, Bosch, Daimler Chrysler, and Haldex Brake Systems. Eaton Vorad Technologies are currently experimenting with CWS. On average, the cost of implementing ACC and CWS is $2000-$3000 per vehicle.

Conclusion

The implementation of any or all automated highway systems could drastically improve the condition of today's highways. With ITS, ACC, CWS, and hands-off driving, roads could become safer and more efficient. Congestion and pollution could significantly be reduced. Automated Highway Systems offer exciting possibilities for the future of transportation.

3.2 Alternate-Fueled Vehicles

Introduction

The transportation industry in the United States faces a challenge in the use of energy resources. Petroleum, the traditional fuel used, is an exhaustible resource that is liable to increase in price as it decreases in availability. The transportation sector accounts for two-thirds of the total consumption of petroleum in the U.S.

Pollution from the emissions of internal combustion engines is also a major concern due to its negative impact on the environment and the health of people.

These concerns with traditional Internal Combustion (IC) vehicles have paved the way for alternative fuel vehicles. Alternative fuel vehicles employ

[5] "The Ultimate in Crash Safety is Avoiding Crashes." 20 July 2000. 26 October 2001. <http://www.gm.com/cgi-bin/pr_display.pl?1510>

electricity (or CNG) as a source of power, rather than relying solely on gasoline. They reduce the need for petroleum and decrease the emission of green house gases. Electric vehicles can be organized into three categories for discussion: fuel cell vehicles, battery powered vehicles, and hybrid electric vehicles.[6]

A. Fuel Cells

Fuel cell vehicles use fuel cells as electrochemical engines "that generate electricity by harnessing the reaction of hydrogen (fuel) and oxygen (from air) without combustion or pollution. The only byproducts are water and heat."[7]

Even when fuel cell vehicles use gasoline, they use it more efficiently than traditional IC vehicles, providing economic as well as environmental benefits. Internal combustion engines only use about 19% of the energy in gasoline; fuel cell vehicles can more than double that efficiency.

Fuel cell vehicles are currently being developed world wide by major auto manufacturers. Both the United States and Canada have been running demonstrations of fuel cell technology with buses that run on fuel cell engines. Specifically within the United States, California has been testing fuel cell vehicles since the year 2000. Fuel cell vehicles may become a popular alternative for both public and personal transportation in the future.

B. Battery Electric Vehicles

Battery-electric vehicles run entirely on electricity from batteries. Rather than being refueled, battery-electric vehicles are recharged. Batteries may be recharged at home or at charging stations that can be found in a variety of states across the U.S. including California, Arizona, Massachusetts, Florida, Vermont, North Carolina, South Carolina, and Texas.

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[6] All of the information presented on alternate fuel vehicles can be found online at <http://www.yournextcar.org>.

[7] Your Next Car. 26 June 2002 <http://www.yournextcar.org/fuelcells.html>.

The power gained in one charging session varies according to the technology employed. Charging sessions can be analyzed at three different levels. At the most basic level, charging can be done in twelve to sixteen hours with a standard, grounded 120V, 3-prong outlet that is available in most homes. The next level of charging requires eight to ten hours and a 240V, 40amp charging. The third level of technology currently being developed will require 480V to provide a complete recharge in just fifteen minutes.

The life cycle of a battery and the range of travel it provides will depend on the type of battery used. Electric vehicles may use modified versions of the lead acid batteries that are used in traditional automobiles. Lead acid batteries that cost about $3,000 last for three years and are reliable; however, vehicles powered by these kinds of batteries may only travel a range of less than 100 miles before they need to be recharged. Nickel-Cadmium batteries and Nickel-metal hydride batteries both have a longer life cycle and provide cars with longer ranges; however, they are initially more expensive than lead acid batteries. Finally, lithium-ion batteries provide both an extensive range and an extensive life cycle; however, they may have a tendency to encounter more problems when overcharging or high charging occurs.

As battery electric vehicles are recharged, rather than refueled, they offer environmental benefits, eliminating mobile-source emissions. However, the benefits of battery electric vehicles extend beyond the environmental realm. Battery electric vehicles are actually safer than fuel powered vehicles. While battery electric vehicles do not minimize the possibility of accidents, they do significantly reduce the possibility of a collision resulting in fire because they do not have gas tanks or reservoirs of flammable oil.

Battery electric vehicles are being provided by a number of automobile manufacturers including Ford, General Motors, Daimler Chrysler, Honda, Nissan, Toyota, and Solectria. Batteries that can achieve a range of 100 miles, making battery electric vehicles ideal for intra-city travel, power most.

C. Hybrids

A hybrid electric vehicle, or HEV, combines an electric motor with a separate gasoline, diesel, or fuel cell engine. An energy storage device, such as a battery, a flywheel, or an ultra capacitor, powers the electric motor. There are two major types of hybrids: parallel and series. Parallel hybrids rely on the fuel engine for their major source of power, only utilizing the electric motor in instances that require extra power, such as climbing hills and accelerating. In series hybrids, electricity is generated by the internal combustion engine or fuel cell to charge the energy storage device. The electric motor alone provides the drive train with power. Of the two types, series hybrids have lower pollution level.

Hybrids may be more convenient than battery electric vehicles because not all hybrids have to be plugged in to be recharged. Some hybrid vehicles recharge their batteries every time brakes are applied (regenerative braking).

An example of a hybrid is Toyota's Prius. This car completely runs on its battery while starting, idling, and at low speeds. After a speed of 30 mph, both battery and gasoline are used.[8] The Prius provides gas mileage of up to 50 miles per gallon and can reach speeds up to 110 mph.

Currently, both Toyota and Honda are selling affordable hybrids. Daimler Chrysler, Ford, General Motors, and Nissan plan to enter the hybrid sales market in 2003 and 2004. Hybrid SUVs will even be available by Daimler Chrysler and Ford.

Conclusion

Alternate fuel vehicles provide modifications to the traditional gasoline powered automobile. They are economical, safe, and environmentally friendly. As the technology of fuel cells, fly wheels, regenerative braking and other powering devices advance, the power and range of alternative fuel vehicles will

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[8] This feature is specific to Toyota's Prius. Some hybrids run solely on their battery until they reach highway speeds. The technology varies vehicle to vehicle.

increase, and the demand for them will rise. Currently, electric vehicles may cost any where between $18,000 and $40,000. This cost is likely to decrease as the technology matures and mass production of the vehicle is initiated. The speed capability of most alternate fuel vehicles is comparable to conventional gasoline vehicles for intra-city travel. With the inevitability of change in technology in transportation, the use of electricity for propulsion of automobiles of the future is highly likely.

3.3 Magnetic Levitation (Maglev)

Introduction

Visualize magazine may have described the future of the transportation best when it reported, "the future of transportation may find travelers flying on vehicles that have no wings."[9] The Maglev System makes such transportation possible. Maglev vehicles move along a guideway, slightly levitated above the guideway floor. The system works with a combination of magnets and electrical coils that both propel and levitate the vehicle electromagnetically.

A. Operation

In order for a Maglev vehicle to move forward, the propulsion coils positioned on both sides of the guideway are energized by a three-phase alternative current from a substation. This current runs through the propulsion coils and creates a shifting magnetic field on the guideway. The shifting magnetic field pulls and pushes the magnets on the Maglev vehicle, moving the vehicle forward[10] as illustrated in Figure 3.4.

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[9] Visualize. October 2001. 13 July 2002. <http://www.technologyreview.com/articles/visualize1001.asp>
[10] Principle of Maglev. 21 May 1997. 23 June 2002. <http://www.rtri.or.jp/rd/maglev/html/english/maglve_principle_E.html>.

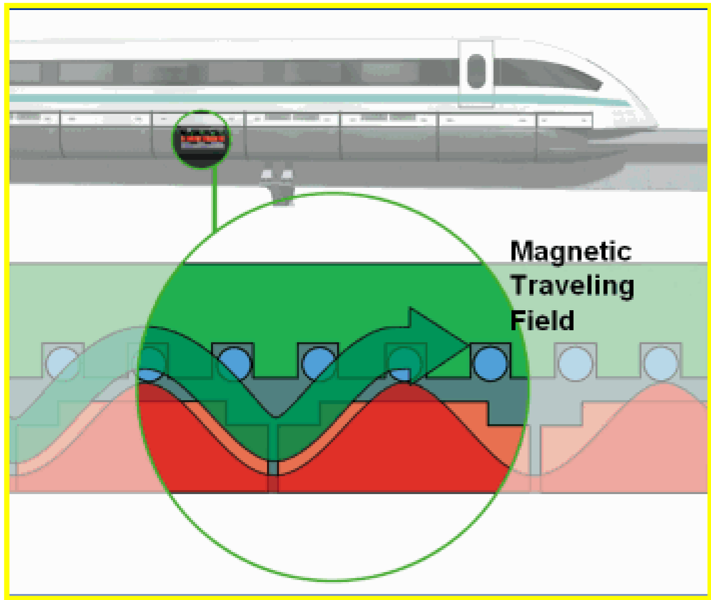

Figure 3.4 Magnetic Traveling Field

(Data source: www.transrapid.de/en/index/html)

As the vehicle moves forward at a high speed, its magnets are several centimeters below the center of the levitation coils that are positioned on both sides of the guideway. The magnets on the moving vehicle create an electric current within the coils that then begin to temporarily act as electromagnets. Forces are created by this current that both push and pull the maglev vehicle upward.[11]

Alternatives to this levitation system are available. One alternative lines the guideway with the electromagnets that levitate the car: this type of system is called an electrodynamic system. Figure 3.5 illustrates the differences:

[11] Ibid.

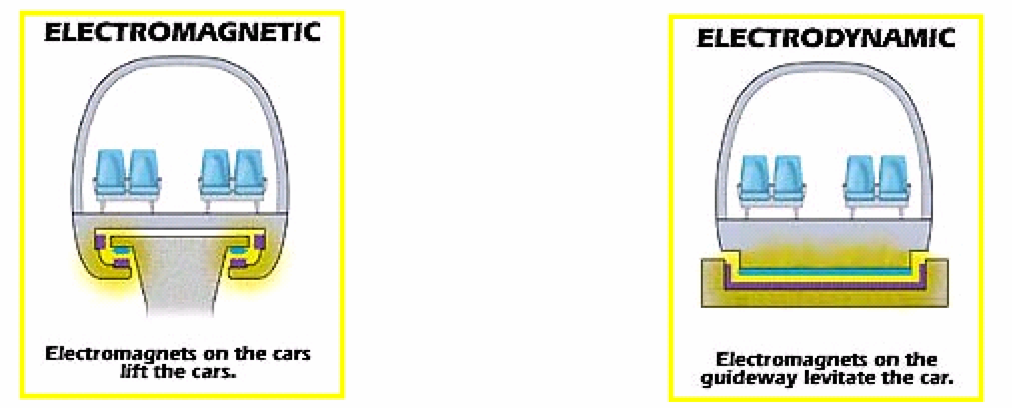

Figure 3.5 Types of Levitation

(Data source: http://www.maglev2000.com/works/how.html)

In addition to levitating the vehicle, the levitation coils also ensure the lateral guidance of the vehicle as illustrated in Figure 3.6. Levitation coils on both sides of the guideway face each other and are connected underneath the guideway. When the Maglev vehicle strays from the center line of the guideway, an electric current is induced in the loop. The coils running on the guideway nearest the vehicle are activated to repulse the vehicle, and the coils running along the guideway on the opposite side are activated to attract the vehicle. Thus a balance is maintained between both sides of the guideway, and the Maglev vehicle stays centered.[12]

[12] Ibid.

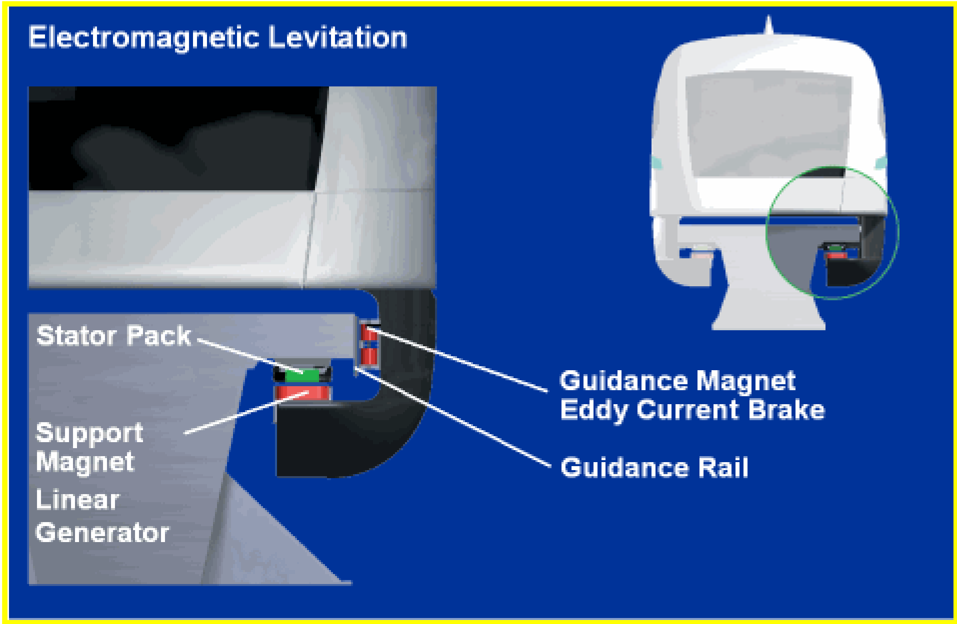

Figure 3.6 Mechanism of Magnets (Data source: www.transrapid.de/en/index/html)

B. Benefits

This technology provides a safe, comfortable, quiet, and efficient form of transportation. The traveling electromagnetic field in the guideway eliminates the possibility of vehicle collision and derailment. The coils that run under the vehicle run under the guideway; this feature makes the maglev system safe in all weather conditions. The magnetic features of the Maglev system do not pose any threat to people traveling on or around it. As the Maglev guideway is elevated, there is no possibility for vehicle interference with other modes of transportation. The effects of the magnetic field created by the system are extremely low, posing no threat to travelers. In fact the magnetic fields surrounding common household appliances such as hair dryers, toaster ovens, and television sets are stronger than the field surrounding the Maglev vehicle.

Thus, travelers with pacemakers can travel without worry. Even credit cards carried by the passengers will remain unaffected.[13]

In addition to being safe, passengers will also be comfortable. The jerking and bumping associated in other forms of travel are eliminated with the Maglev system. Regardless of the speed of travel, passengers riding on Maglev vehicles have the flexibility of traveling without seatbelts. They are even free to move about the vehicle for the duration of their trip.

The Maglev system also severely reduces the noise that is produced by other forms of transportation. The levitation of the Maglev vehicle eliminates the noise that is created by friction in systems of transportation where vehicle and guideway contact are necessary. Thus, the only discernable noise generated is wind noise. Further more, since the Maglev vehicle has a sleek aerodynamic design, the noise it generates is considerably less than the noise generated by high speed trains, even when the Maglev vehicle is traveling at speeds above 300 mph.[14]

The high speeds of Maglev travel could benefit its travelers through convenience and economics. With the fast inter-city travel provided by Maglev, people may live further from their jobs than they currently do. As people are able to move further away from the city, opportunities in commercial and residential real estate will expand. Residential prices could stabilize, and new industries could develop in remote areas, creating new jobs. The economy would benefit as new markets open up and perishable goods are transported faster and cheaper via the Maglev system than via contemporary systems.[15]

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[13] The Baltimore-Washington Maglev Project. Ed. BW Maglev. 2001. <http://www.bwmaglev.com>.

[14] Port Authority. Ed. Port Authority of Allegheny County. 23 June 2002. <http://www.portauthority.org/maglev/faq.html>,

[15] Maglev 2000 of Florida Corporation. 23 June 2002. <http://www.maglev2000.com/works/how-08.html>.

As the Maglev system could provide alternatives to transport people and fright, the demand on highways system will decline, resulting in reduced congestion, highway maintenance costs, and mobile source of pollution. [16]

When compared with other forms of transportation, the Maglev system seems to be better on many counts. In addition to its safety features mentioned earlier, the Maglev system has also been described as "the world's safest available means of high-speed transport." Traveling by maglev is 20 times safer than traveling by airplane, 250 times safer than traveling by conventional railway systems, and 700 times safer than traveling by car.[17]

Maglevs are faster and potentially more economical than other rail systems. Maglev vehicles can run up to 311 mph, while other high speed rail systems typically reach only 185 mph. Maglev systems also posses acceleration and deceleration rates that are four times greater than other rail systems. Thus Maglev vehicles can stop more frequently and lose less time between stops. An elevated Maglev system uses 85% less land than other high speed rail systems. It also loses less energy and has less wear and tear due to its frictionless travel, a feature that also keeps its maintenance costs below other rail systems.[18]

The anticipated cost of riding Maglev trains is 45-64 cents a mile, varying region to region. The cost of construction currently is high; however, as the technology matures, the cost of construction should go down. The Maglev system being constructed in Pennsylvania has an estimated cost of $2.8 billion, and the price for the Maryland project is $3.4 billion.

C. Projects

Three projects to build Maglev systems are currently underway in the United States:

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[16] Ibid.
[17] Ibid.
[18] Port Authority.

1. Old Dominion University Project: This 0.7 mile intra-university campus project for The Old Dominion University in Virginia will be the first operational Maglev project in the U.S. The system is currently undergoing test runs and should be operational by the end of 2002.

2. Pennsylvania Maglev Project: This 45 mile project will link Pittsburgh Airport to Pittsburgh and its eastern suburbs.

3. Maryland Department of Transportation: This 40 mile project will link Camden Yard in Baltimore and Baltimore-Washington International Airport to Union Station in Washington, D.C.

In addition to these three projects underway, at least five other projects have been proposed:

1. California-Nevada Super Speed Train Commission: This 42-mile project will link Las Vegas, Nevada to Primm, Nevada.

2. Florida Department of Transportation: This 20-mile project will link Port Canaveral to the Space Center and the Titusville Regional Airport

3. Greater New Orleans Expressway Commission: This 40-mile project will link New Orleans Union Passenger Terminal to the airport and runs across Lake Ponchartrain to the fast-growing northern suburbs.

4. Georgia/Atlanta Regional Commission: The first 40 miles of this 110-mile project will run from Atlanta to Chattanooga, Tennessee.

5. State of California: This 70 to 75-mile system will connect Los Angeles International Airport to Union Station in downtown Los Angeles to Ontario Airport and runs further east into Riverside County.

In addition to the projects in the United States mentioned above, there are a number of similar projects in other countries as well:

1. Germany: In Germany, a Maglev system by Transrapid has been deployed along a test track. The Transrapid Maglev is propelled, guided, and levitated by magnetic forces along a T-shaped guideway.
2. Japan: This Maglev system runs above a U-shaped guideway. Magnets are positioned along the sides of the train and along the inside of the guideway. The vehicle rolls on rubber tires until it reaches 100 kilometers per hour, and then it is levitated and propelled electromagnetically.
3. China: The city of Shanghai is constructing a version of Germany's Transrapid that will travel 33 kilometers between downtown Shanghai and Pudong International Airport.

Conclusion

Maglev systems provide exciting alternatives for both intra and inter city travel. They are safe, economical, and environmentally sound. Their construction and utilization will help reduce congestion, pollution and highway maintenance. It also has the potential to provide many other economic benefits.

3.4 Personal Air-Transport System

Introduction

The Jetsons' mode of transportation has finally arrived. In this section, we will discuss two different options for personal air transportation systems: Skycar and Solo Trek.

Skycar[19]*:* Moller International has developed a variety of technologies for personal air transportation. Of these technologies, we will discuss two: the M150 Skycar and the M400 Skycar. Both Skycars posses VTOL (vertical takeoff and landing) capability and are "easy to maintain, cost effective, and reliable."[20]

[19] All of the information in this section comes from Moller International's Website that can be located at <http://www.moller.com>.
[20] Moller International. 23 June 2002. <http://www.moller.com/skycar>.

Two engine possibilities exist for the use of Skycars. The engine that is currently being employed is a rotary engine that uses aluminum housings, peripheral porting, and an air-cooled rooter. The second engine possibility that is being developed is a turbo-charged or super-charged fuel injected 2-cycle engine.

According to Moller International, the current cost of each Skycar is approximately $500,000. However, it is estimated that the prices will drop to $60,000 when Skycars are mass produced.

M150 Skycar: The Moller M150 Skycar is built for single person use. Figure 3.7 from Moller.com displays a prototype of the M150 Skycar that was shown at a motor show in Essen Germany.

Figure 3.7 Picture of M150 Skycar (Data source: http://www.moller.com/skycar/m150/)

The following chart illustrates specifications particular to the M150 Skycar:

Passengers	1	**Max.Mileage (Gasoline/Alcohol)**	45 / 30 mpg
Maximum Speed	375 mph	**Range (Gasoline/Alcohol)**	675 / 450 mi
Cruise Speed	335 mph	**Take-Off Distance**	0 ft
Gross Weight	850 lbs	**Landing Distance**	0 ft
Empty Weight	560 lbs	**Dimensions (LxWxH)**	12'x 8'x 5'

Table 3.1 Specifications of M150 Skycar (Data source: moller.com)

M400 Skycar: The Moller M400 Skycar pictured in Figure 3.8 has been designed for two passengers. According to Moller, it "combines the performance of airplanes and the VTOL capability of helicopters in a single vehicle without the limitations of either."

Figure 3.8 Picture of M400 Skycar (Data source: http://www.moller.com/skycar/m400/)

Table 3.2 illustrates specifications particular to the M400 Skycar:

Passengers	4	**Cruise speed/ top speed**	350/390 mph
Maximum range	900 miles	**Maximum rate of climb**	7800 fpm
Fuel consumption	15 mpg	**Payload with max fuel**	740 lbs
Operational ceiling	30,000 ft	**Gross weight**	2400 lbs
Takeoff / landing area	35 ft dia	**Noise level at 500 ft**	65 dba
Engine power	960 hp	**Dimensions (LxWxH):**	18' x 9' x 6'

Table 3.2 – Specifications of M400 Skycar (Data source: moller.com)

The benefits of both Skycars are easy to see. Both allow for personal convenience and time flexibility unavailable by other air transportation systems. Both are operated on regular automated gasoline, a feature that keeps them cost efficient and easy to maintain. Skycars are also designed to be relatively quiet. They possess a multiple ducted fan arrangement that generates little noise "by using modest thrust loading and tip speeds."

When compared to other modes of transportation, the infrastructure costs of Skycars is clear. The following chart from Moller.com illustrates one such a comparison.

Comparison of Skycar & existing modes of transportation		
200 miles high speed rail route	:	$4 billion
200 miles skycar system	:	$0.5 billion
Single ferry costs	:	$80 million
Fleet of 35 skycars	:	$14 million (handling the same amount of people)
Jet's fuel efficiency	:	20 pmpg (80% seat occupancy)
Skycar fuel efficiency	:	42 pmpg (60% seat occupancy)

Table 3.3 – Comparison of Skycar with other modes of transportation
(Data source: moller.com)

In addition to these benefits, Skycars are also touted as being safe. Moller International has equipped them with a variety of safety features that cover virtually every potential problem possible.

Moller International has listed the following safety features:

Dual Engines: If an engine fails, the M400 Skycar has seven other engines available. Each engine is controlled by a computer, and only one is needed for successful flight and landing.

Redundant Computer Stabilization Systems: The M400 Skycar is equipped with three computers, and only one is needed to operate the engine. If one computer should go out, two more are available to operate the Skycar.

Redundant Fuel Monitoring: In Skycars, fuel is constantly monitored for quantity and quality. If a problem arises regarding fuel, the driver is notified with sufficient warning.

Aerodynamically Stable: In the unlikely event that insufficient power is available to hover, the Skycar's aerodynamic ability and good slide slope allows the pilot to maneuver to a safe area before having to employ the airframe parachutes.

Automated Stabilization: The Skycar's computer system eliminates any undesirable movement related to wind. The driver need only worry about speed and direction.

Inherent Simplicity of the Engines: The rotary engines require very little maintenance with little change of breaking down.

Enclosed Fans: The enclosed fans and engines provide very little risk of injury to persons standing near the Skycar.

Dual Parachutes: Even in the most desperate of situations, Skycar passengers can feel confident about their safety. A parachute at the front of the Skycar and a parachute at the back of it will safely guide the vehicle and its passengers to the ground in the unlikely event that there is total power failure.

With these considerations, Skycars are advertised as realistic modes of transportation. However, in a post 9/11 era, it is difficult to imagine how this mode would be allowed to operate freely in our airspace. Further, the ability of the average automobile driver, most of whom display poor driving skills, to become an expert pilot is highly questionable.

Solo Trek[21]:

Figure 3.9 Picture of Solo Trek (Data source: http://www.solotrek.com/)

Millennium Jet Inc.'s Solo Trek XFV (Exo-Skeletor Flying Vehicle), pictured above in Figure 3.9 is another option to personal air transportation. Unlike the Skycar, the Solo Trek vehicle transports its single passenger in the standing position. Like the Skycar, it possesses VTOL capability, and will likely be used primarily by the military, paramilitary, or emergency services.

The pilot straps himself into Solo Trek, enters his weight and other security information, and prepares for an easy, efficient, and safe ride. Using two hand-controls, Solo Trek's pilot manipulates the machine to take off vertically, fly to his destination area, and land. This contraption can hover for up to 2 hours, reach speeds up to 70 knots, and travel up to 120 nautical miles without refueling.

[21] All of the information on Solo trek comes from SoloTrek' website that can be accessed at <http://www.solotrek.com>

The engine of SoloTrek uses "heavy fuel," such as kerosene, JP4, Jp5, or JP8. The engine engages two counter rotating fixed pitch ducted fans that lift the passenger and transport him to his destination. The machine is quiet, easy to operate, and easy to maintain.

Table 3.4 details the specifics of SoloTrek XFV:

Length	**:**	60”	**Width**	**:**	104”
Height	**:**	90”	**Empty weight**	**:**	275 lb.
Normal Takeoff weight	**:**	553 lb.	**Max gross weight**	**:**	710 lb.
Operator/Pilot	**:**	1	**Operator weight**	**:**	105-245 lb.
Operator size	**:**	5’ – 6’6”	**Fuel capacity**	**:**	15 gal
Engine power	**:**	120–140 hp	**Fuel type**	**:**	JP, Diesel
Max speed	**:**	80 mph	**Fan operating speed**	**:**	3500-4000 rpm
Cruise speed	**:**	50 –70 mph	**Max hover altitude**	**:**	8,000 ft
Max Endurance	**:**	2 hrs	**Max Range**	**:**	150 miles

Table 3.4 Specifications of Solo Trek XFV (Data source: solotrek.com)

SoloTrek has been customized to cover a large range of safety concerns. For one, its control system can be geared for different levels of pilot experience including novice, intermediate, and advanced. The machine has been built to carry all male and female pilots within the 5 to 95 percentile range of sizes and weights. Outside of personal concerns, measures are being taken to ensure the safety of the operator and those around him. A security system is being developed that would prevent its unauthorized use. The controls of SoloTrek also prevent the pilot from manipulating the machine to perform any unsafe maneuvers. If something begins to go wrong with the machine, a system will alert its pilot to land as quickly as possible. In the event that something with the machine goes drastically wrong, SoloTrek XFV's "ballistic pilot extraction system will deploy automatically to provide an additional level of safety for the pilot."

Conclusion

Both SoloTrek XFV and Skycar provide alternatives for personal air transportation. Their use by security and medical personnel could potentially improve response time for incident management. Civilians could enjoy them for their personal convenience and recreation. While civilians use is possible, most of its uses will likely be in the military and police sectors. SoloTrek XFV offers exciting possibilities for recreational use, but like the Skycar, its use by the general populace is questionable.

3.5 Urban Transit Technologies

Introduction

Automated People Movers (APMs) is a confusing category of transportation technology in that several different technologies have been grouped under its name. Included in this grouping are Personal Rapid Transit Systems (PRTs), PRTs use the general idea behind APMs; however, PRTs are envisioned to be more flexible as they can carry smaller groups of people without requiring a fixed schedule. In this section, we will focus on PRTs and include a short section on projects that are related to both PRTs and APMs. To understand exactly what a PRT is, it is helpful to reference the guidelines that describe the features of PRT set up by the Advanced Transit Association.[22]

There are seven characteristics to a PRT system:

1. Fully automated vehicles capable of operation without human drivers.
2. Vehicles captive to a reserved guideway.
3. Small vehicles available for exclusive use by an individual or small group, typically 1 to 6 passengers, traveling together by choice and available 24 hours a day.
4. Small guideways that can be located aboveground, at ground level, or underground.
5. Vehicles able to use all guideways and stations on a fully coupled PRT network.
6. Direct origin to destination service, without a necessity to transfer or stop at intervening stations.
7. Service available on demand rather than on fixed schedules.

Guidelines 3 through 7 are specific to PRTs and mark the differences between PRTs and APMs. Based on these criteria, no PRT system is actually working in the world today. However, the concept behind one major model can be used to further discussion on PRTs. This project is Raytheon's PRT 2000.

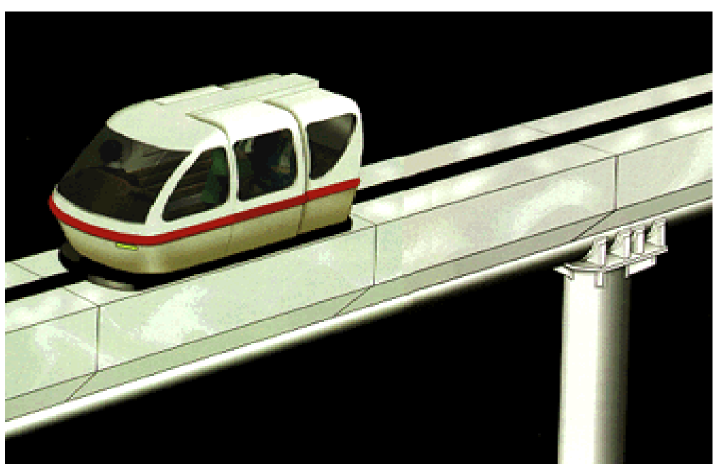

Figure 3.10 Picture of TAXI 2000 (Data source: http://faculty.washington.edu/~jbs/itrans/PRT/PRT2000_Concept.html)

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[22] "What is Personal Rapid Transit?" 22 June 2002. <http://faculty.washington.edu/~jbs/itrans/PRT/Background.html>.

In 1993 Raytheon bought the rights to the TAXI 2000 PRT system concept shown in Figure 3.10. The project was renamed PRT 2000 and was scheduled for implementation in 2000. However, the project lost funding in 1999 and was unable to be completed. Nevertheless, the concept behind PRT 2000 can give us an idea of the possibilities behind PRT systems.

A. Operation of the PRT 2000[23]

The PRT 2000 system consists of lightweight steel guideways and uses electric motor propulsion and microprocessor control to run small vehicles capable of carrying groups of up to six people directly to their destinations. Figure 3.11 illustrates the mechanism of PRT 2000. The system's off-line stations and integrated network eliminates the need for waiting and line transfers, hassles that are common to other modes of public transportation. The system's computerized network delivers passengers to their destinations seamlessly.

Vehicles wait for passengers at off-line stations. Passengers purchase their tickets for their ride at a machine that is similar to an ATM machine. The passengers enter their destination information and are given prices accordingly. After paying for their trip, passengers are given tickets on which their destinations are encoded. Once passengers enter the vehicle, they insert their ticket into a slot that reads it. Their journey begins when their vehicle senses an opening on the main track. Once on the main track, passengers travel non-stop through an integrated system of guideways until they reach their destination. After the passengers abandon the vehicles, they either remain at the station of their last destination or are rerouted by a computer system to stations that are running low on vehicles.

[23] All information on PRT 2000 comes from the University of Washington's web pages entitled "PRT 2000 System Concept" that can be found at <http://www.faculty.washington.edu/jbs/itrans/PRT/PRT2000_Concept.html>.

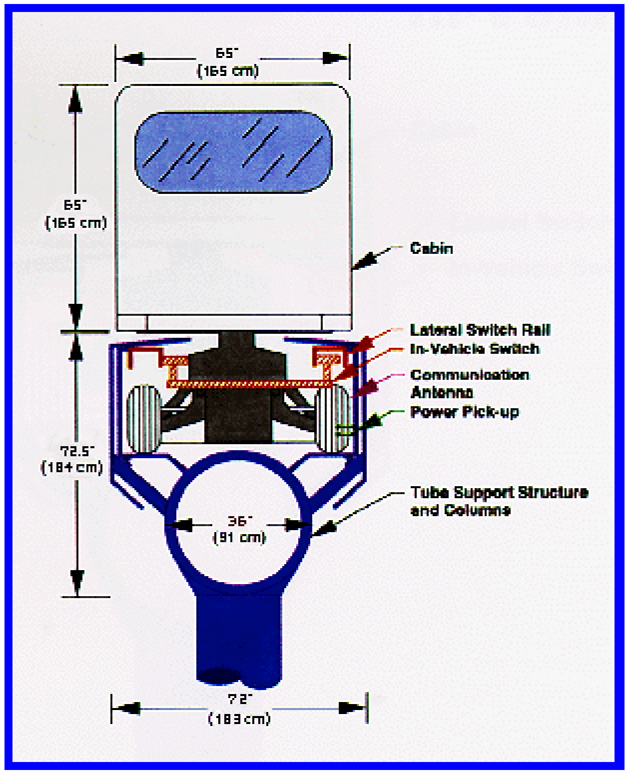

Figure 3.11 Mechanism of PRT 2000, (Data source: http://faculty.washington.edu/~jbs/itrans/PRT/PRT2000_Concept.html)

B. Benefits of the PRT 2000

One of the benefits to the PRT 2000 is that it is passenger friendly. Because waiting and line transfers are not necessary, the stress that is typically associated with other major forms of public transportation is eliminated. The ride itself is also pleasant. The cars provide room for storing luggage, and seats for each passenger. Travel is smooth, quiet, and vehicles are available on demand. Because of the technology employed, the PRT 2000 can run under any weather conditions. Construction of a system like the PRT 2000 would not interfere with passengers traveling on roads as the guideways are elevated.

The PRT system also addresses environmental concerns. With passengers traveling by PRT 2000, the congestion and pollution associated with highway traffic could be reduced drastically. Because of the use of electric propulsion and steel guideways, the PRT 2000 would not contribute to either noise or air pollution.

Other Projects

While the PRT 2000 may be seen as an ideal model for PRT systems, other projects of APMs also provide insight into possibilities for future modes of transportation. Two types of PRT systems are shown in Figure 3.12. The two systems that we will briefly describe are Cabintaxi's PRT system and The Morgantown System.

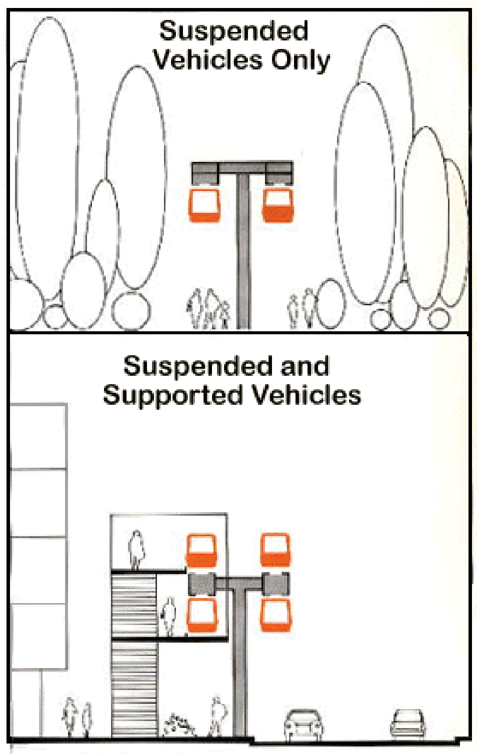

Figure 3.12 Two types of PRT System

Cabintaxi: The Cabintaxi PRT system that was built in Hagen, Germany in the 1970s illustrates the way a PRT system can make the most of its guideway space. In this system, vehicles are both suspended below and supported above a guideway that runs above ground. Cars were designed to travel at 18 mph with a 2.5 second interval between cars that allowed for emergency braking without collision under all circumstances. While the system was successfully tested, budgetary cuts in 1979 prohibited its public release.[24]

The Morgantown System: This system connects the University of West Virginia with the Morgantown Central Business District. While it is not a PRT system, it resembles a PRT system more closely than any other working APM system. Rather than transporting individuals and small groups, the Morgantown System transports large groups of up to 21 travelers. Built in the 1970s, this system continues to run successfully today.[25]

Conclusion

While the Morgantown System is currently the only APM that comes close to resembling a PRT system, the possibilities for future PRT systems are strong. While the public often seems unreceptive to other possible modes of public transportation, research indicates that the PRT 2000 would be quite popular. The PRT's convenient use makes it irresistible to potential passengers. The implementation of either PRT systems or other kinds of APMs could alleviate highway congestion and benefit the traveling public. PRT systems and APMs have been envisioned for decades and it is likely that the twenty-first century may finally witness their implementation.

3.6 Freight Pipeline

Introduction

Freight pipeline is a generic term used to describe a variety of pipeline systems through which solids, liquids, and gas can be transported over varying distances. The concept of tube transportation is not new. For the last two hundred years pipelines have been used to transport grains, coal, sand, and minerals. Pipelines of the past have carried these materials for short distances

[24] "Cabintaxi PRT System." 22 June 2002. <http://faculty.washington.edu/jbs/itrans/cabin.htm>.
[25] "History of PRT." 22 June 2002. <http://www.faculty.washington.edu/~jbs/itrans/PRT/History.html>

in pipes with relatively small diameters. Pipelines of the future offer larger diameters and possess the capability of transporting goods for long distances. Freight pipeline systems may run on, above, or below ground.

A. Operation

In freight pipeline systems, close fitting capsules or trains of capsules carry freight through tubes that run underground. These capsules may be propelled through the pipelines by any one of four different sources of power. The four different approaches to energizing freight pipeline are 1) hydraulic capsule pipeline, 2) pneumatic capsule pipeline, 3) electro-magnetic/linear induction, and 4) maglev technology.

1. Hydraulic Capsule Pipeline (HCP): HCP uses water, oil, or other liquid to transport closed capsules. HCP is limited in that only capsules with small diameters can be transported in this manner.

2. Pneumatic Capsule Pipeline (PCP): The freight pipeline system that has been studied most extensively thus far uses pneumatic blowers as the source of power. This type of pipeline was employed for approximately fifty years, starting at the beginning of the twentieth century. During this time period, five major cities in the United States (Boston, Chicago, New York, Philadelphia, and St. Louis) employed PCP to transport U.S. mail and parcels between each city's main post office and its branches. Over time, the pipe systems and their equipment wore down, and the technology was replaced with trucks, our current mode for transporting goods.

While PCP has a history of successful use, it requires booster pumps to transport cargo beyond a distance of several miles. Research has also shown that PCP systems are also extremely noisy and are not energy efficient. Within a pneumatic pipeline, cargo can travel between 40 and 60 mph. The diameter for a pneumatic pipeline tube is 2 meters.

3. *Linear Induction Propulsion:* Linear induction motors are electrical machines that convert electrical energy directly to in translation motion. The use of linear induction, or linear synchronic propulsion, has been proposed as an alternative means of moving capsules within an air filled pipeline. In this system, an electromagnetic thrust would be induced in each capsule as it passes over magnetic induction coils set in the pipeline. All capsules pass through the pipelines at the same speed, and a constant volume of air is maintained between each capsule. Using linear induction propulsion, a speed of up to around 60 mph can be obtained.

4. *Maglev technology:* Maglev, a combination of super conducting magnets and linear motor technology, may be used as a means of transporting goods via pipelines. Using Maglev technology, capsules could be propelled through pipelines that are four to six feet in diameter. Capsules could be transported within a speed range of 120 to 180 mph.

B. Benefits

Freight pipeline systems would drastically improve the transportation of goods throughout the U.S. Through pipeline systems, freight could be transported quickly and cheaply, impervious to weather conditions. With a reduction in the number of trucks carrying freight, the potential for accidents on highways would also be reduced.

When compared to trucks, freight pipelines are arguably a much better mode of transportation. In 1996, more than 200,000 highway accidents involved medium and heavy trucks. These accidents resulted in 5,400 deaths.[26] The implementation of freight pipelines as the major means for transporting goods could eliminate these deaths and improve traffic conditions for all. Freight pipelines are also environmentally friendly on account of both air and noise pollution.[27]

C. Current Projects

A number of projects are currently being conducted in regards to freight pipeline systems, primarily by the Capsule Pipeline Research Center and the Federal Highway Administration (FHWA).

Subtrans: The FHWA is currently developing and investigating the possibilities of a freight transportation system called SUBTRANS. The SUBTRANS system runs freight-carrying capsules on steel rails in a tube that is about two meters in diameter. Linear induction motors electrically propel the capsules. The capsules travel along the main route at a constant speed of 60 mph until they either reach their destinations or are transferred to another route or terminal. Capsules may be transferred from one route to the next at the same speed of travel using electromagnetic switching. The system could carry up to 1875 capsules per hour, almost equivalent to 16,500 metric tons. After the capsules reach their destination, they can temporarily be used to store the materials they have carried.[28]

Fast Tube System: Richard J. Earle came up with the idea behind this system that proposes to transport both people and freight in capsule cars through a

[26] "The Future of Freight: Research Explores Underground Pipeline System." Texas Transportation Researcher 36.2 (2000). 24 July 2002. <http://www.tti.tamu.edu/researcher/v36n2/underground_freight.stm>.
[27] Ibid.
[28] Lawrence Vance and Milton K. Mills. "Tube Freight Transportation." Public Roads Online. Autumn 1994. 24 June 2002. <http://www.tfhrc.gov/pubrds/fall94/p94au2.1.htm>

pipeline system. Cars with wheels will travel on tracks at a speed of up to 250 mph and deliver passengers to their destination without stopping. Earle envisions a system of pipelines with tubes for acceleration, deceleration, and line transfer. Still in the design stage, Fast Tube System is currently looking for financial backing .

Capsule Pipeline Research Center (CPRC): CPRC was established in 1991 to study and develop new pipeline technology for underground transportation of freight. CPRC conducts research in hydraulic capsule pipeline and pneumatic capsule pipeline. CPRC has two main laboratories, one at Missouri University Research Park and one at Missouri University's Holstein Farm. The laboratory at Research Park has an 8-inch diameter, 430 foot length steel pipe for testing hydraulic capsule pipeline. The laboratory on Holstein Farm has a 3,500 foot length system.

The laboratory on Holstein Farm is a coal log pipeline pilot plant. At the plant, coal is compacted into cylinders and transported through a pipeline system that uses water to move the coal. The high pressure compaction technology used to compact coal can also be used to compact many other materials.

D. Research Institutions

In addition to the University of Missouri, several other research organizations are contributing to the study of freight pipeline systems. These organizations include Tokyo University, Delft University of Technology, Texas A&M University, and The International Freight Pipeline Society.

Tokyo University: Tokyo University and the Japanese government have been developing ideas for underground freight pipeline systems for quite some time.

Their most recent proposal is for a smart tube system that would propel capsules using maglev/linear induction through a semi-vacuum pipeline.

Delft University of Technology: This research institution in the Netherlands has been conducting research on freight pipelines since the 1980s. Their research investigates the control technology that is needed to run electric powered cars in a 5 feet diameter tunnel that connects the main international airport to the freight terminal.

Texas A&M University: Texas A&M's college of engineering and TTI are investigating the possibilities of a subterranean freight pipeline system that would consist of 2 meters of reinforced concrete pipes that are capable of holding pallet-carrying vehicles.

International Freight Pipeline Society: The International Freight Pipeline Society, or IFPS, is a research foundation that is conducting technical seminars and calling for technical papers on freight pipeline.

Conclusion

Freight pipeline systems are currently being investigated by many institutions. The general consensus is that compared to freight-trucks, they offer a clean and efficient alternative for freight transportation.

3.7 Automobile Ferry System

Introduction

An automobile ferry system provides a means for travelers to drive their passenger vehicles on to another mode and let this other mode take them (and their vehicle) to their destination. Such a system could travel along a link for only a few miles (to span a congested urban corridor) or hundreds of miles to span intercity distances.

Intercity travel-by-ferry has been conceptualized by a German company as a number of "pods"moving on magnetic tracks carrying their individual cars, and self-organizing to form a train as they travel long distances at high speed (upwards of 300 mph). The high speed is made feasible because of magnetic levitation (maglev) and propulsion technology. Chapter 5 provides more information about both the maglev technology, and the company, TransRapid.

A company in Houston has proposed an intracity system to ferry cars across a short but congested link in an urban setting. However, instead of using maglev technology, they employ (regular) rubber-wheeled trailers powered by linear induction motors (LIM). The motor itself is situated on the guide-way railing. Figure 3.13, below displays a picture of the Automobile Transport Unit (A2). The tractive force of the LIM is transferred to the trailer by an "arm" connector. Automobiles drive up on to the trailer and, which is then moved by the LIM to the destination. The system is marketed by A2 Engineering Corp., and most of the specifications discussed in the following sections are provided by them. Some of the unresolved issues with this system are discussed in the final sections of this chapter.

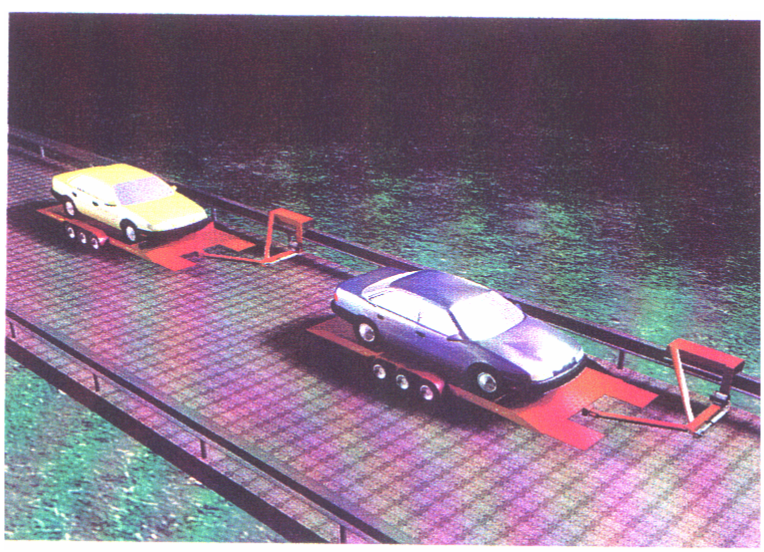

Figure 3.13: Picture showing Automobile Transport Unit (A2)

A. Important Features

- Capacity to move 400,000 vehicles per day doubling the freeway capacity.
- Automated operation eliminates the element of driver error.
- Electrically powered reduces mobile source emission.

B. Components

The four components of the A2 system are:

1. Elevated steel guideway which is fast, lightweight and easy to erect.
2. A carrier or trailer which transports the driver and other occupants in their own car.
3. Linear Induction Motors (LIMs) that pull the carriers along the guideway using electric power.
4. Local sensors and controllers that signal the motors and carriers to perform automated functions without relying on central computer control.

The guideway consists of two lanes, a main lane that runs continuously at 70 mph without stopping and an access/exit lane. A steel rail outside each lane carries LIM. The guide way can be deployed at 16 feet from ground level.

C. Working

There are four major tasks:

1. Driving on to a trailer
2. Automated Coupling
3. Automated Decoupling
4. Driving off the trailer

These tasks can be divided in three categories: Loading, Access and Exit maneuver. These categories can be explained as follows:

Loading

From the service road cars enter the loading area. The driver keys in the exit destination which can be changed while traveling. The car is remotely weighed and the fare is displayed for the driver to pay by swiping a card or by prepayment. The car moves ahead and stops at a safety arm for the loading position.

A trailer (A2) towed by a LIM emerges halfway from under the loading dock in a position for the car to roll down onto the deck. When the safety arm goes up the driver releases the brakes and as the car is on a decline, it rolls forward onto the deck. When the front wheels of the car touch the A2 stop plate it moves forward allowing the rear wheels of the car to roll down onto the deck. The driver pulls a console unit into the window which supplies air conditioning or heat to the car and also contains a keypad for exit destination, 2-way radio for communication with a central control room in case of emergency or to provide information. The A2 signals to the main guideway that it is loaded and ready to merge into the main traveling lane. The process of loading is estimated to take 10 seconds per car. A schematic showing the loading and unloading process for the A2 is provided on the next page in Figure 3.14.

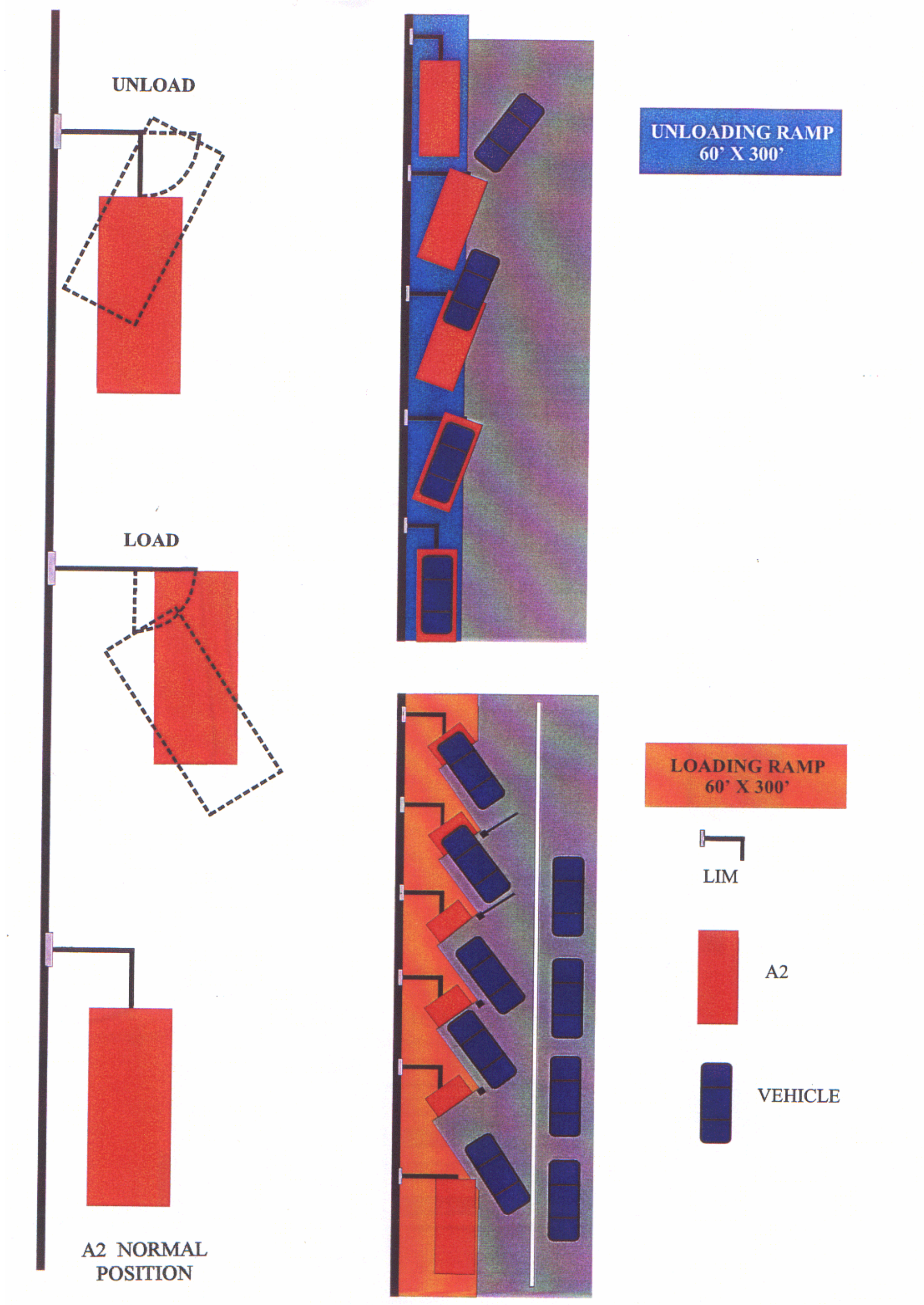

Figure 3.14: A schematic showing the process of loading and unloading of A2

Access

The traveling line has linear induction motors (LIMs) spaced every 30 feet, moving at a fixed speed along a steel beam, which also serves as a guardrail. The beam is located on the side of the track and two feet above the guideway surface. It serves as an electric conductor and guide rail on which the LIMs ride. The LIMs are fitted with a hydraulically controlled arm (cylinder) that serves as a hitch to the A2. When A2 reaches at the preset position, a signal is sent to the traveling lane to get the trailer attached to the empty arm. The attached LIM accelerates to 70MPH and hands the A2 off to the LIM in the traveling lane. At any given time the traveling lane may contain loaded A2s, empty A2s or unattached LIMs.

A car drives onto an A2 causing it to signal an empty LIM in the traveling lane to prepare for a pick-up. The next empty LIM to pass a controller sends a signal back to the waiting A2 to accelerate to 72 MPH, which it does. As both LIMs (the accelerating LIM pulling the loaded A2 and the empty LIM on the main track) pass a pre-designated point they extend the pick-up arms so that they almost touch in the center of the two lanes. Both extended arms have sensory devices that control the speed of the accelerating LIM so that it moves up against the empty arm. As soon as it touches the extended empty arm a mechanical spring loaded hitch clasps the arm and simultaneously releases the hitch from the acceleration LIM. At this point the transfer is completed. Both LIMs retract the arms into normal positions, which is 90 degrees behind the 5 foot extended arm. The arms are extended by hydraulic pressure on a cylinder and after 5 seconds the power is turned off the hydraulic pump causing the cylinder to loose pressure and allow the arm to return to its' normal trailing position. This provides for the loaded A2 to be guided into the traveling lane or if hookup failed, to be returned to the accelerating lane. The purpose is to avoid the possibility of the A2 remaining halfway into each lane. If the hookup failed, the A2 would be guided back into the accelerating lane where it would go down to ground level and recycle back to the loading dock. Time lapse from acceleration to hand off is 12 seconds. Figure 3.15, below presents a diagram explaining the access of A2.

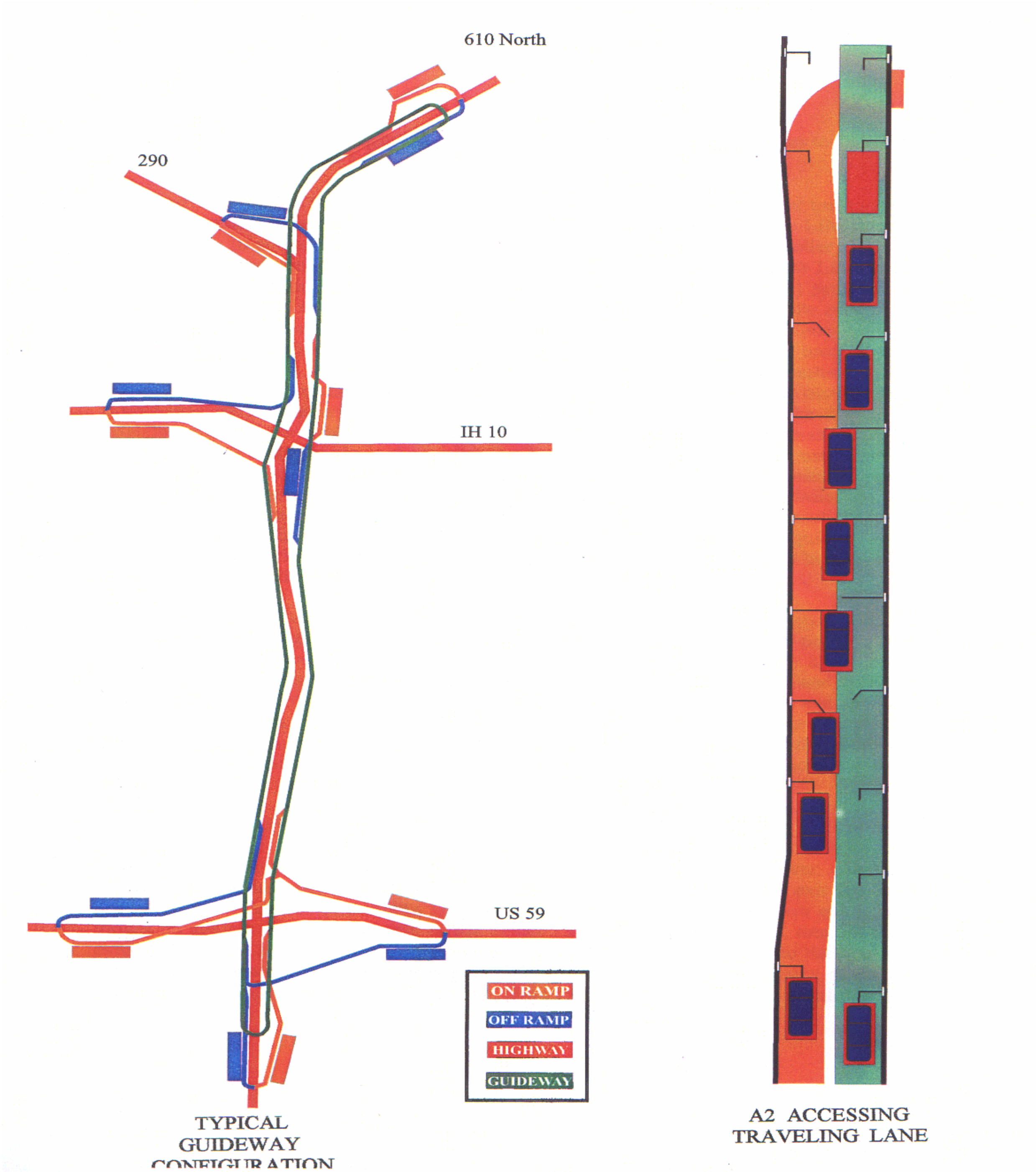

Figure 3.15: A schematic explaining the access of A2

The LIMs in the main lane, traveling at 70MPH, are held in position by guideway and more importantly by a 5/8 inch cable linking all motors. This makes it impossible for the motor to malfunction and collide with the A2 in front or rear. If the tension in the cables is excessive, the motor speed is adjusted to relieve it. Overall the speed is maintained by the electrical flow to the guideway. Braking is supposed to be regenerative and the steering passive, simply following the LIM tow arm. It is not clear how the regenerative power is utilized.

Exiting Maneuver

An A2 nearing the destination sends a signal ahead for an empty LIM in the exit lane to accelerate to 68MPH. The timing is precise such that the loaded A2 with the arm extended moves up against the extended arm of the empty LIM. As soon as the A2 touches the extended arm the hitches are reversed and now the empty LIM is hooked to the loaded A2. It comes to a stop allowing the car to roll down.

D. Other Features

All loading ramps will maintain an inventory of empty A2s assuring that there will always be one ready to load, with no waiting time. All unloading ramps will likewise have an inventory of empty LIMs to receive exiting A2s. A Central Control System will monitor the overall system and maintain the inventory balance at each ramp.

LIMs are ideally suited for this service. Their high torque is used in high performance roller coasters, aircraft launchers from ships and development work to launch rockets, including the shuttle, horizontally.

Post tensioned beams are used for guide way construction, and corrosion is prevented by use of weathering steel.

Holding Lot

A holding lot will buffer exiting cars. As soon as the lot reaches 75% capacity traffic lights will be switched to allow the lot to empty, preventing any backup on the system.

Off Peak Storage

The A2 system is based on pallet concept. When USDOT surveyed 137 possible transit systems the pallet concept was one of the top four considered. But the reason it was not chosen was that switching vehicles in and out of storage in off-peak times would be a massive logistics problem. This issue has been resolved by parking empty A2s in the access lane.

As demand slows an empty A2 will pull out of the loading ramp and move onto the access lane. It will move ahead until it approaches an empty A2 stopped in storage position. It will pull up within one foot of the A2 and stop. Other A2s will follow as the demand slows. Up in front of the empty A2s is an inventory of LIMs waiting to take loaded A2s from the main lane in the normal exiting procedure. In the same way the inventory of LIMs will occasionally be depleted and need to be resupplied. This is done by the first A2 in storage speeding up to the main lane speed of 72 MPH and handing off the A2 to an empty LIM on the main lane, exactly as if it was handing off a loaded A2 wanting access to the main lane. The empty LIM in the access lane moves ahead and join the inventory queue. Figure 3.16, on the following page shows the off peak storage of A2.

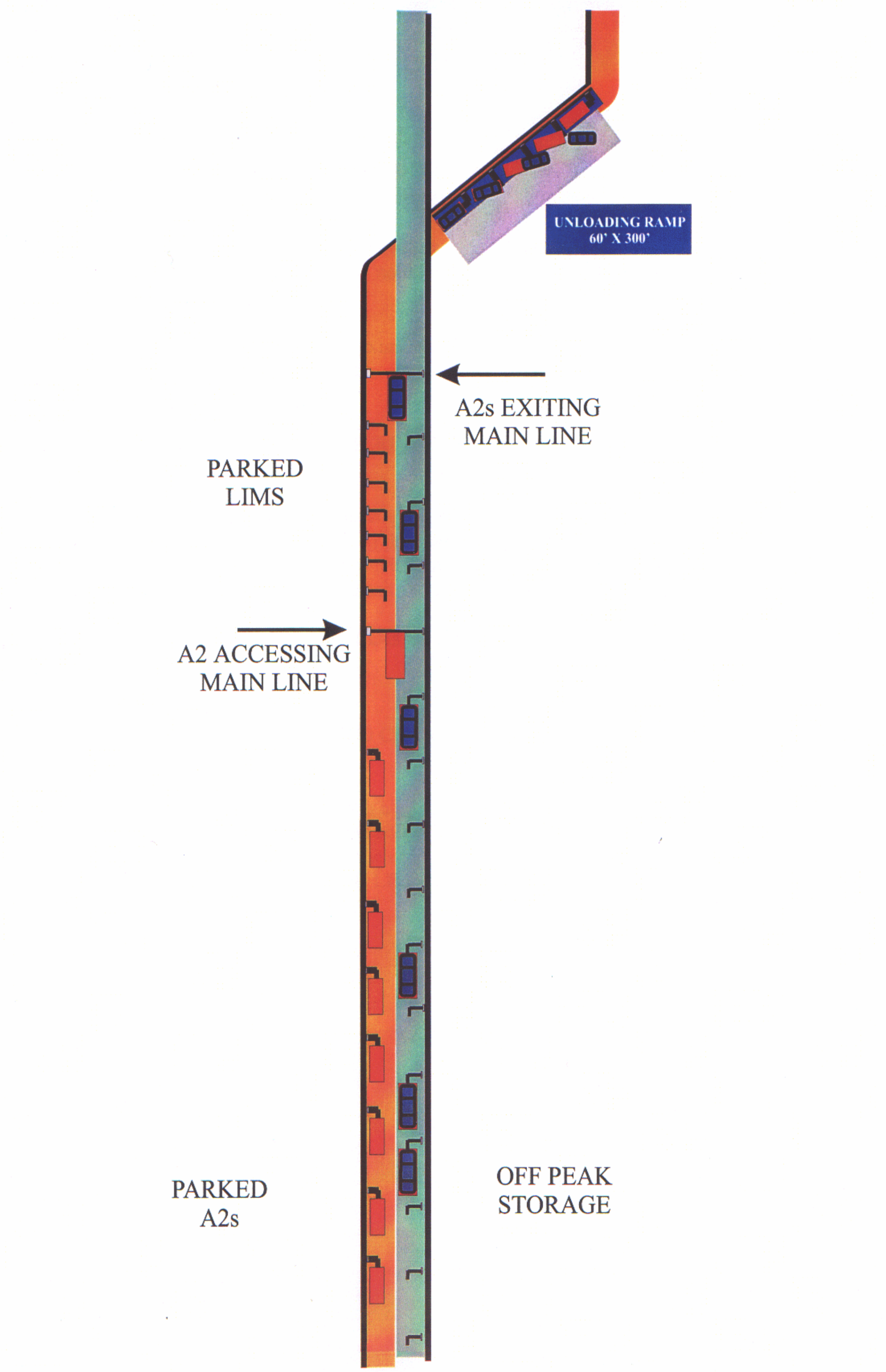

Figure 3.16: A schematic showing off peak storage of A2

End Of Line Turnaround

All A2s exit the main lane at the last unloading ramp. This is necessary because the main lane LIMs run at 70 MPH and A2s can not turn at this speed. The empty LIMS have no problem turning at high speed. When an A2 exits it stops for the car to unload and if there is no car it proceeds around the track to the opposite side of the loading ramp. Figure 3.17, below is a diagram explaining End of Line Turnaround for A2.

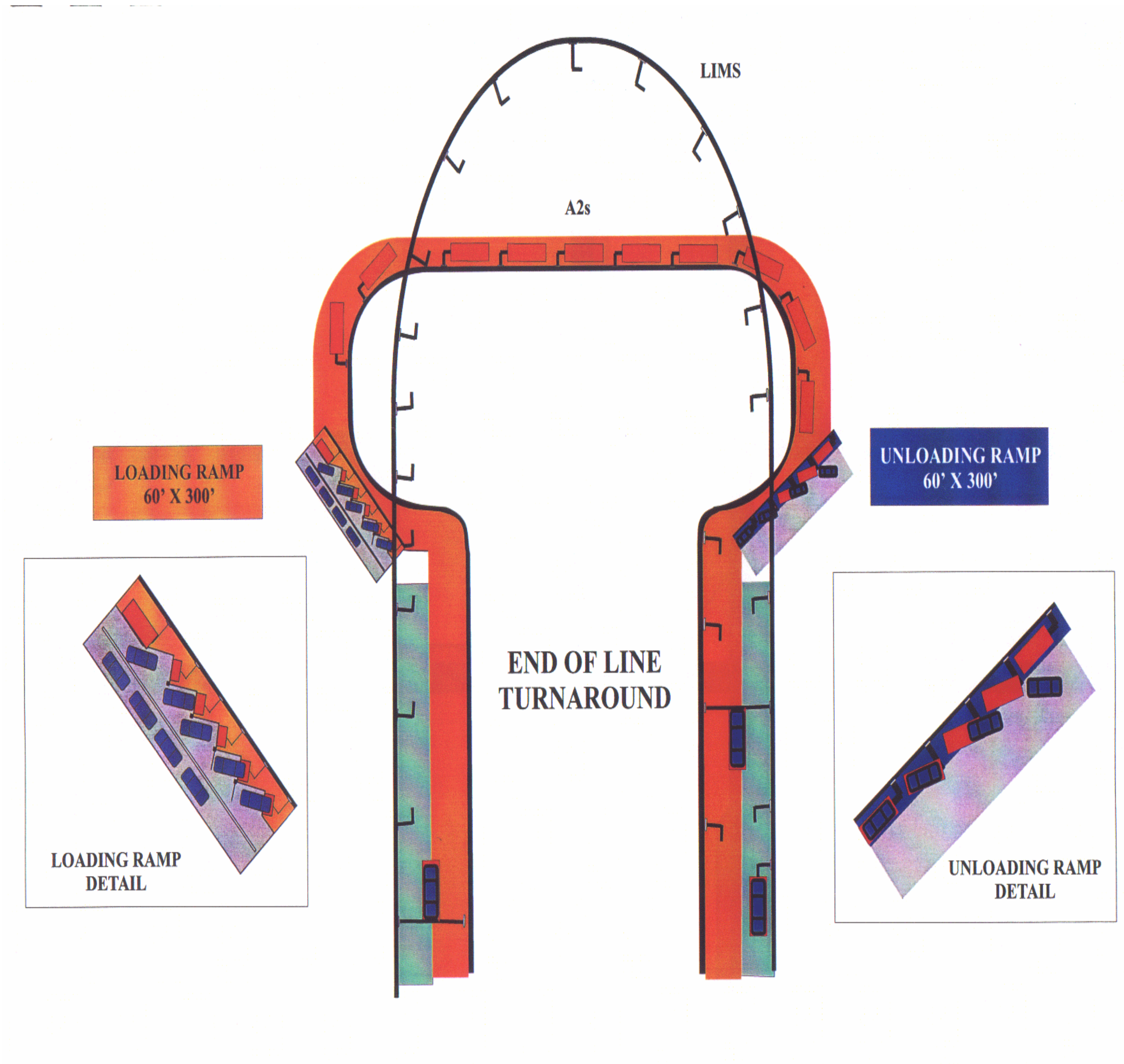

Figure 3.17: A schematic explaining End of Line Turnaround for A2

Interchange

A2 changes to the main lane by following the access lane until the desired direction is reached. At this point the A2 is automatically handed off to the main lane in the selected direction. The exit destinations keyed in takes all this into account and the A2 is programmed to exit and enter the main lane at an appropriate time.

Speed Change

Main lanes run at 70MPH. A2s in the access lane can run at 68 to 72 MPH. A2s in the high speed lane exit and the LIM slows to the lower speed and hands the A2 off to the slow speed main lane.

E. Safety

As cars can't leave the road, they can't hit objects on the sides or roll over. They can't be hit head on or from the rear because they are mechanically separated. They can't be hit broadside because the guideway is grade separated. In a power failure situation A2 comes to a controlled stop. The spring loaded front stop plates will hold the car. The occupants can depart by a ladder leaving their cars behind. Provisions will be made for emergency departure by lift devices. If a single A2 loses power the cable linking it with other LIMs will tow it along. When the power is reapplied it overcomes the spring action, the plates get flat and the car can drive over them.

F. Benefits

It is convenient and comfortable and requires no transfers. The most important aspect is having the use of personal car from the beginning to the end of a trip. The elevated guideway can be erected in an existing right-of-way. 90% of accidents are caused by driver error, 10% are caused by mechanical error, these could be significantly reduced on the A2.

G. Design and Development

A2 Engineering Corp., Houston, TX, USA.

H. Model Survey

To test the working of A2 a survey was conducted by A2 Engineering Corp. One of the most congested freeway section in the United States (the I-610 interchange with I-10 and Us-59) was selected as a model for the survey. The average daily traffic on this section is 572,000 veh/day. No data was provided on what the ATU would cost to ride the system. The results are as follows:

- 30% of all traffic were trucks
- 20% of the cars were going only to next exit
- 20% were the people who just don't want to use anything new or different
- 30% or 171,000 vehicle per day will use the A2.

I. System Issues Not Covered Adequately

The maintenance and operational cost of the ATU system is not provided, nor can it be easily estimated. Unlike Maglev systems, the ATU has many moving parts which will be subject to wear and tear in the normal course of operations. The trailers have pneumatic rubber tires which would require regular maintenance and replacement. The LIMs and the mechanical linking arms would also be subject to fatigue (similar systems deployed on roller coasters are periodically taken off-line for maintenance.) The control system required to activate the linking arm for merging to-and-from the main lane is not explained. The effects of a support failure (such as failure of the columns due to accidental or willful collision) could be catastrophic.

Conclusion

The ATU system is an innovative concept for ferrying automobiles through congested urban areas. However, in practice, this may have the undesired effect of simply moving the congestion from one link (the one spanned by the ATU) to another (the link where the ATU line ends.) The engineering components that make up the system are readily available. However, problems (if any) associated with their integration into a smoothly working system are difficult to predict, as is the MTBF (mean-time-before-failure) of the system and its components.

Chapter 4

INTRACITY PERSONAL TRANSPORTATION—FUEL CELLS

4.1 Introduction

As noted in the last chapter, the increasing amount of fuel that is being consumed by the transportation sector. While alternative means of transportation clearly need to be sought, most Texans do not want to abandon their cars for conventional methods of public transportation. Fuel cell vehicles provide the opportunity to continue traveling in their cars while reducing both the consumption of petroleum and the emission of green house gases.

4.2 Operation

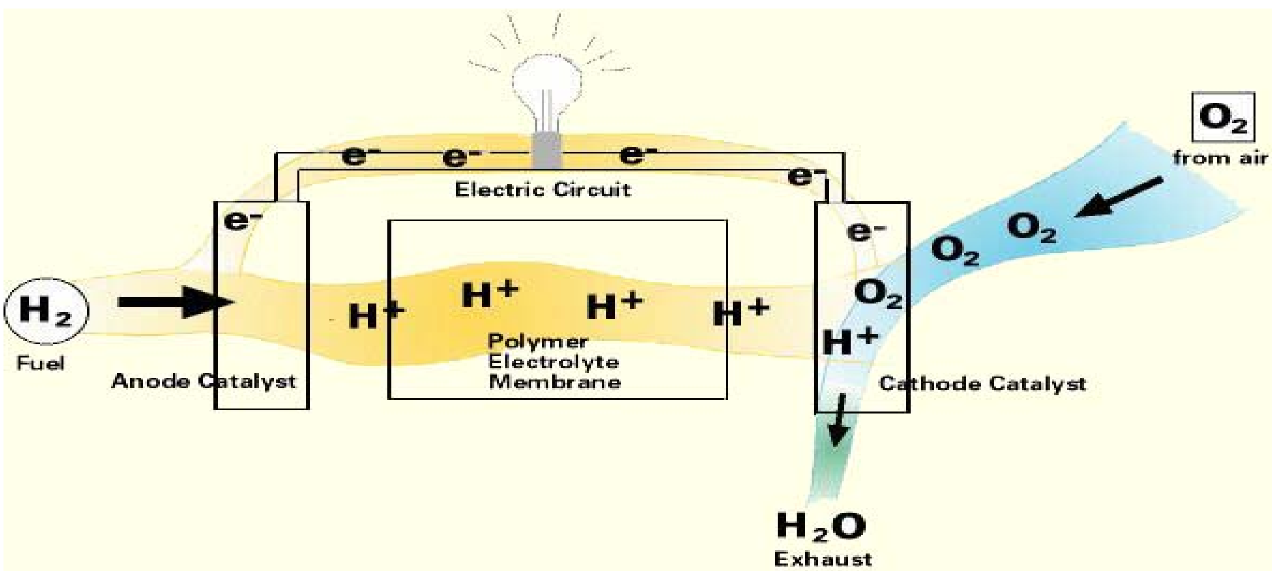

Figure 4.1 Working of a Fuel Cell, (Data source: <http://www.fuelcells.org/whatis.htm>)

Figure 4.1 illustrates the working of a fuel cell.[1] A fuel cell is an electrochemical device that produces electricity, heat and water by using a combination of hydrogen and oxygen. On its most basic level, a fuel cell contains an electrolyte membrane, a

[1] Fuel Cells 2000. 30 July 2002. Breakthrough Technologies Inc. 1 August 2002 <http://www.fuelcells.org/whatis.htm

cathode, and an anode. Hydrogen fuel enters into the anode, and a catalyst coating on the anode causes the hydrogen atoms to split into protons and electrons. Oxygen from the air enters the cathode and attracts the protons of hydrogen across the electrolyte. Meanwhile the hydrogen electrons, prohibited from crossing over the electrolyte, form an electrical current that is used for energy. The electrons then enter the cathode and a catalyst causes them to reunite with the hydrogen protons and combine with the oxygen to make water and heat. Water vapor is the waste that is released.

The hydrogen required for fuel cell systems in vehicles can come from a variety of sources. Direct hydrogen in the form of liquid or gas simply enters the system as discussed above. However, hydrogen that is obtained from gasoline, natural gas, or methanol has to be converted on board the vehicle. This conversion requires a reformer that adds bulk to the vehicle engine. A variety of institutions are currently trying to eliminate the need for a reformer in fuel cell systems.

4.3 Advantages of Fuel Cells

Fuel cell vehicles have a number of advantages over internal combustion vehicles. Because fuel cell engines operate electromechanically, they achieve better fuel efficiency than internal combustion engines. In the long run, this efficiency will reduce operating costs. Unlike internal combustion engines, fuel cell engines also possess the capability of being pollution and odor free. The only byproduct of fuel cell engines is water, thus the only emissions that is released from fuel cell vehicles is water vapor. Of course, if hydrogen is obtained from gasoline, a viable option for fuel cell vehicles, some greenhouse gases are emitted. They is less harmful, however, than the greenhouse gases that are emitted from vehicles running on internal combustion engines. Fuel cell engines are dependable, require little maintenance, and are quieter than internal combustion engines.[2]

Fuel cells are also a better source of energy than batteries. While batteries eventually run down, fuel cells keep running as long as fuel is provided. Since fuel cells are also more resistant to elevated temperatures than batteries, they are more

[2] "PEM Fuel Cells." Hpower Corp. 2001-2002. H Power Corporation. 23 July 2002 <http://www.hpower.com/index/shtml

dependable in extreme environments. Finally, while battery technology is nearing the summit of its capabilities, fuel cell technology is in its initial stages of development, full of possibilities.[3]

4.4 Types of Fuel Cells

There are several different types of fuel cells, generally categorized by the kind of electrolyte they use. These include:

- Phosphoric Acid (PAFC)
- Proton Exchange Membrane (PEM)
- Molten Carbonate (MCFC)
- Sodium Borohydride (SBFC)
- Solid Oxide (SOFC)
- Hydrogen
- Alkaline
- Direct Methanol (DMFC)
- Regenerative fuel cells
- Zinc Air fuel Cells (ZAFC)
- Protonic ceramic fuel cells (PCFC)

Of these fuel cells, proton exchange membrane fuel cells and direct methanol fuel cells will be discussed in further detail because they are more suitable for use in vehicles.

4.5 Proton Exchange Membrane Fuel Cells

A Proton Exchange Membrane, or PEM, fuel cell is most probably the kind of fuel cell that will be mass marketed first for vehicles. It has a solid-polymer electrolyte, which is especially beneficial because it reduces corrosion and prevents migration risks that are associated with liquid electrolyte fuel cells. It operates at temperatures between the freezing and boiling points of water, a characteristic that

[3] Ibid.

enables it to start up very quickly with the help of very little, if any, auxiliary systems.[4]

Ford is currently developing what may very well be the first fuel cell vehicle to be sold on the mass market. The P2000 is projected to run off of tanks for liquid or gaseous hydrogen. The only emission from the vehicle is water vapor. The car is scheduled for release in 2004.[5]

4.6 Direct Methanol Fuel Cells

Another possible fuel cell candidate for car use is a direct methanol fuel cell. These fuel cells utilize methanol rather than hydrogen. The system does not require a hydrogen storage tank, nor does it require a reformer. This feature makes direct methanol fuel cells particularly attractive for vehicle use. However, problems with direct methanol fuel cells need to be remedied before they can be mass marketed as car engines.[6]

The power density, energy conversion efficiency, and fuel utilization of direct methanol fuel cells need to be increased before they become available for mass market. In order for these goals to be met, the amount of platinum catalyst needed to attain a high energy levels needs to be lowered. Also, direct methanol fuel cells have a problem with methanol passing through the membrane of the fuel cell without producing electricity.[7] However, some companies working with direct methanol fuel cells claim that they have solved this problem.

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[4] Ibid.

[5] "Fuel Cell Cars." Howstuffworks. 1998-2002. Howstuffworks, Inc. 25 July 2002 <http://www.howstuffworks.com/news-item10.htm

[6] "Technical Advances Improve the Potential for a Fuel Cell which Eliminates the Need to Store or Generate Hydrogen." Office of Transportation Technologies. April 2001. 1 August 2002 <http://www.ott.doe.gov/success.html

[7] Ibid.

Daimler Chrysler used a direct methanol fuel cell car when it achieved the status of being the first company to produce a fuel cell vehicle to drive across the US. They, and several other automotive companies are currently competing to be the first to release direct methanol fuel cell vehicles onto the mass market.[8]

4.7 Cost of Fuel Cell Technology

To estimate the costs of fuel cell technology, a study written by J. Fernando Contadini that was published by the Methanol Institute at Methanol.org was consulted.[9] In this section, brief summaries of this material are provided along with the charts and the alphabetized notes accompanying them that are published.

The Methanol Institute's study looks at the integration of both methanol and hydrogen powered fuel cell vehicles into the automobile industry for approximately the next fifty years. The study considers that the market for automobiles will include Hybrid Electric gasoline vehicles, conventional internal combustion vehicles, and gasoline fuel cell vehicles in addition to methanol and hydrogen powered fuel cell vehicles. The study also distinguishes between direct and indirect methanol fuel cell vehicles. Indirect methanol systems utilize a reformer; direct methanol systems, as discussed in the section on direct methanol fuel cells, do not need a reformer.

The first area of concern is the market penetration of alternate fuel vehicles. The Methanol Institute has published three charts in consideration of the market penetration of new vehicle technology. This first chart, shown in Figure 4.2, illustrates the future possibilities for vehicles using advanced gasoline.

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[8] Methanol Institute. 23 July 2002 <http://www.methanol.org/f-index.html

[9] Contadini, J. Fernando. "Social Cost Comparison Among Fuel Cell Vehicle Alternatives." MI: Fuel Cells. 1996-2002. Methanol Institute. 28 July 2002 <http://www.methanol.org/fuelcell/special/contadini_pg1.html

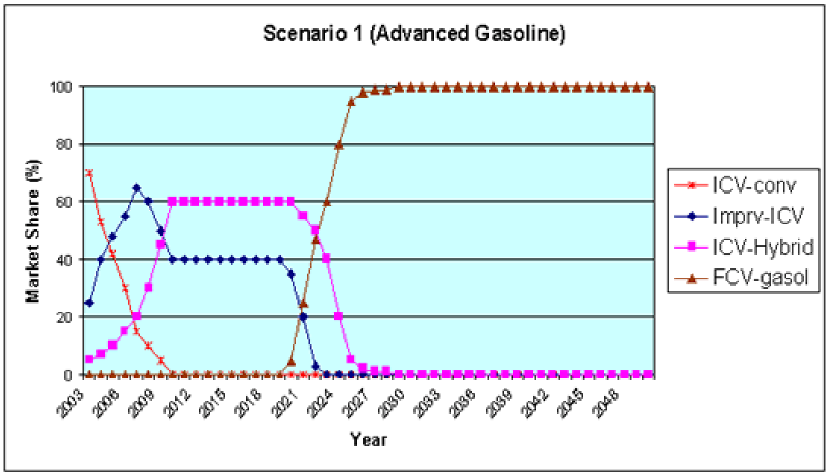

Figure 4.2 Market Penetration of Advanced Gasoline, (Data source: www.methanol.org)

As Figure 4.2 illustrates, fuel cell vehicles using advanced gasoline reach 100% market share in 2027, skyrocketing from 0% only seven years earlier. ICV Hybrids reach 60% in 2010 and stay there until 2021 when they begin to drop, reaching 0% in 2027. Imprv-ICV increase in market share from 25% in 2003 to 65% in 2006, drop to 40% in 2012, and fall to 0% in 2024. ICV-conv begin dropping from 70% market share in 2003 to 0% market share by 2012.

Figure 4.3 considers the market share with hydrogen used as the fuel for fuel cell vehicles.

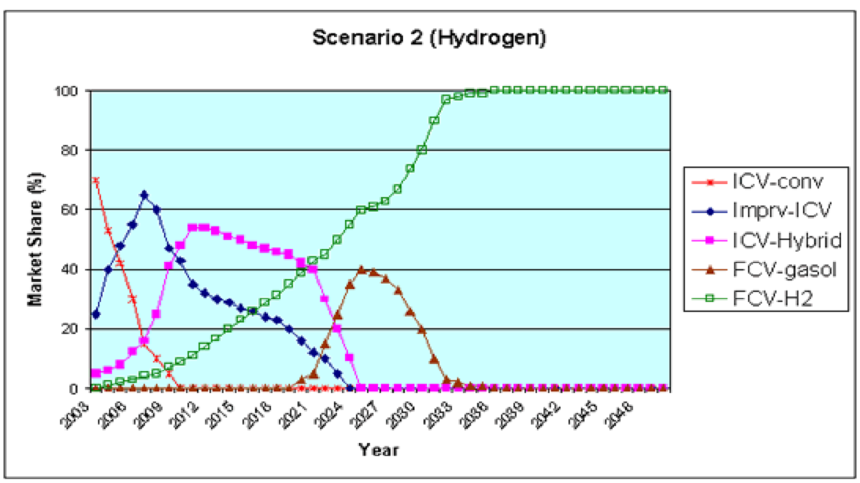

Figure 4.3 Market Penetration of Hydrogen, (Data source: www.methanol.org)

Figure 4.3 illustrates that the integration of hydrogen as the fuel for fuel cell vehicles tremendously alters the market share for fuel cell vehicles using gasoline. In this scenario, fuel cell vehicles using gasoline only reach a market share of 40% in 2027 and fall fairly rapidly to 0% in 2033. Statistics for other engine types are slightly altered, witnessing a more gradual decline in market share.

This third chart, Figure 4.4, considers the integration of fuel cell vehicles powered by indirect methanol and direct methanol. Hydrogen has been excluded from this analysis, excluding the possibility that both hydrogen and methanol could share the market. This exclusion is necessary in order to truly compare the hydrogen and methanol markets.

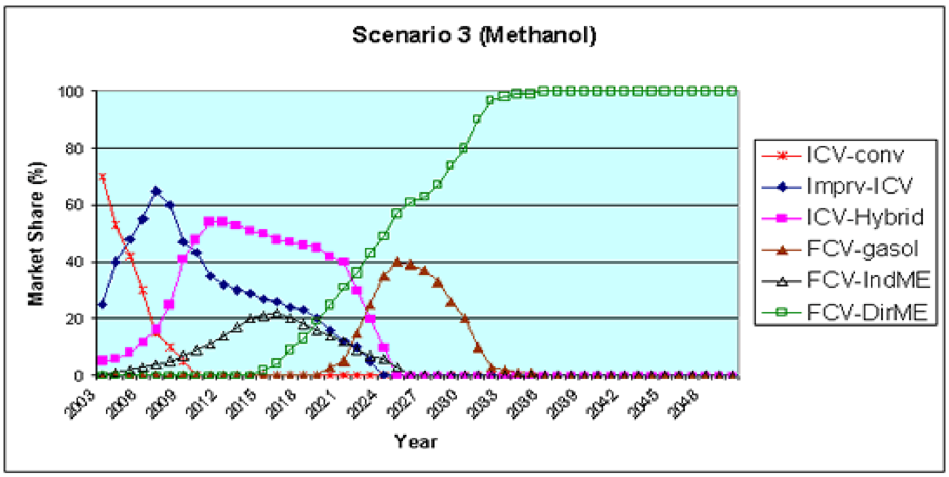

Figure 4.4 Market Penetration of Methanol, (Data source: www.methanol.org)

Figure 4.4 indicates indirect methanol fuel cell vehicles reach 20% by about 2016 and fall to 0% by 2027. Direct methanol fuel cell vehicles follow almost the exact pattern of hydrogen fuel cell vehicles. The exception to this is that direct methanol fuel cell vehicles do not begin to rise in market share until 2015 compared to hydrogen's beginnings in 2003.

The second area of the Methanol report with which we are concerned is that of the cost of new vehicles. This report from Methanol considers three studies done on fuel cell vehicles that projected estimates on their individual costs. Table 4.1 is a comparison of three reports and a given "assumed." The alphabetized notes come directly from the Methanol report.

Vehicle	Gasoline				Methanol		Hydrogen
($/car)	ICV convent.	ICV Tech-1	Hybrid ICV	FCV	Indirect FCV	Direct FCV [b]	FCV
DTI (1998)	18,000	-	-	22,400 to 24,500	20,800 to 21,600	-	20,000
Ogden (1998)	18,996 [a]	19,196 [b]	-	19,474 to 19,814	19,124 to 19,224	-	19,996
Lipman (1999)	20,558 [c]	-	-	-	-	24,495 [d]	24,570 [d]
Assumed	18,996	19,196	20,194 [e]	21,800	20,500	20,000	20,000

Table 4.1 Comparison of cost of new vehicles, (Data source: www.methanol.org)

<u>Assumptions</u>

a. The study gives the incremental cost over the gasoline without specifying it. The assumed cost of $18,624.00 (1997$) is based on the average price for a new vehicle according to American Automobile Manufacturers Association (AAMA), (1997).
b. The cost is an increment of $200.00 over the cost of the conventional ICV. The value was established based on the comments found in Ogden (1994).
c. The Ford Taurus was chosen to represent this category.
d. The cost is calculated for a maximum 300,000 vehicles. To represent much higher production levels, the chosen study values are from the low case and high production volume scenario.
e. The cost assumed is based on the relation between the incremental cost of a Fuel Cell Hybrid Vehicle and the ICEHV found in Henry K. Ng et al (1996).

Table 4.1 illustrates, the individual costs for each vehicle come within a range of $2,000 of each other.

The cost of vehicle maintenance is the next area of concern. While the Methanol Institute does not provide data on vehicle maintenance, it does offer an estimation of yearly vehicle maintenance costs based on different studies. These estimates may be organized into the following list:

- Conventional ICEV--$516.00
- Hydrogen FCV--$434.00
- Indirect Methanol FCV--$450.00
- Hybrid Electric ICE Gasoline Vehicle--$452.00
- Gasoline Fuel Cell Vehicle--$530.00
- Direct Methanol FCV--$434.00

Maintenance costs for all vehicle types fall within $100.00 of each other. The costs estimated for direct methanol fuel cell vehicles and hydrogen fuel cell vehicles are the lowest, with Indirect Methanol fuel cell vehicles and hybrid electric ICE gasoline vehicles falling close behind. The maintenance costs for Conventional ICEVs and gasoline FCVs are estimated as the highest.

While vehicle maintenance will necessarily be important to consumers, so will the cost of fuel. Table 4.2 from The Methanol Institute, compares estimates of fuel prices based on several studies. The estimates for fuel costs have taken into consideration price variables such as projected feedstock costs, conversion costs, transportation storage and distribution costs, and taxes. Again, the notes associated with Table 4.2 come directly from the Methanol Institute.

FUELS	Hydrogen		Methanol		Gasoline
($/gal-eq)	Centr. Plant	Decentr. Plants	Currently	Future [a]	
DTI	-	0.98	0.94	1.27	0.80 to 1.20
Ogden	1.60 to 5.20	1.70	-	1.25	1.05
Lipman [b]	-	1.05/1.32	1.37/1.90	1.37/1.90	-
Sigworth	3.30	-	-	2.08	1.46
Kalhammer	> 3.00	-	-	-	-
Assumed [c]	3.00 to 1.70		1.00	1.50 to 1.20	1.20 to 1.40

Table 4.2 Comparison of fuel prices, (Data source: www.methanol.org)

<u>Assumptions</u>

a. After worldwide methanol demand increases over 5 x 106 metric tons/year.
b. High volume production.
c. The initial cost of reformulated gasoline at $1.20 per gallon, and the incremental cost of 1% a year until a constant cost of $1.40 per gallon in the future. Oil prices will remain constant due to increase in supply with the introduction of alternative fuels. For methanol from natural gas (NG), it assumes the cost of $1.00 per gal-$g_{eq}$ until a fleet of 1.5 million methanol vehicles is achieved by 2007, and $1.50 per gal-$g_{eq}$ for the following 10 years due to the necessity to build new plants. By 2017, a decremental cost of 2 % per year is applied until the cost reaches $1.20 per gal-$g_{eq}$. For hydrogen from NG, the initial cost of $3.00 per gal-$g_{eq}$ was assumed, with the decremental cost of 2 % per year until it reaches $1.70 per gal-$g_{eq}$. Also, it is assumed that solar hydrogen will be introduced by 2020, at a cost of 2.20 per gal-g_{eq}, and will improve 2 % per year until $1.70 per gal-$g_{eq}$. No discount rate was applied. (all from Methanol Institute)

In addition to providing all of these cost estimates, the Methanol Institute published Table 4.3 that illustrates a straight comparison of all of the different factors in cost for reformulated gasoline, hydrogen, and methanol powered vehicles. This comparison illustrates the estimates for cost over about the next fifty years. The category "Private/Cost" is the combined total of new vehicle cost, maintenance cost, and fuel cost. The category "Health Dam." considers the health damages associated with the air pollution that is a result of the emissions of each vehicle type. The "Social" category, the total of private costs and health damages, gives a final estimation on total vehicle costs.

1998 US$ Billions	New Vehicles	Maintenance	Fuel	Private/Cost	Health Damage	Social
	Cost	Cost	Cost	(Monetary)	Cost	Cost
Reformulated. Gasoline	19,846.68	7,994.76	4,445.87	32,287.31	720.50	33,007.81
Hydrogen	17,893.07	7,305.05	4,182.33	29,380.45	637.23	30,017.67
Methanol	18,240.73	7,306.99	4,017.96	29,565.68	633.58	30,199.27

Table 4.3: Comparison of cost for reformulated gasoline, hydrogen, and methanol powered vehicles, (Data source: www.methanol.org)

As Table 4.3 illustrates, a change from reformulated gasoline to hydrogen or methanol will save a tremendous amount of money in the future. Almost $3 trillion can be saved on costs such as maintenance, fuel, and vehicle price. Costs related to health damage are approximately $85 billion less for a community that drives on hydrogen or methanol powered vehicles.

While health costs associated with gasoline powered vehicles are tremendously higher than hydrogen and methanol fueled vehicles, the difference in health costs between hydrogen and methanol fueled vehicles is relatively small. Methanol powered vehicles are slightly more cost effective than hydrogen when it comes to health damages.

However, hydrogen saves more money than methanol in the private cost category. This result is mainly due to the costs of the actual vehicles. Figure 4.5 from the Methanol Institute illustrates how much money is saved over a 50 year span in the private cost category by hydrogen and methanol powered cars.

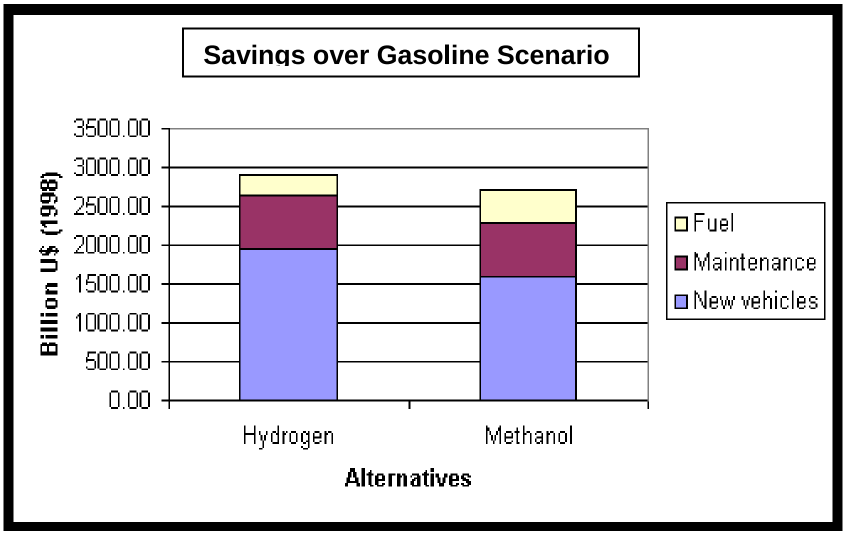

Figure 4.5 Savings over gasoline scenario, (Data source: www.methanol.org)

While Figure 4.5 makes it seem as if hydrogen fuel cell vehicles will save slightly more than methanol fuel cell vehicles, the differences are very slight.

According to the Methanol Institute, other factors that need to be considered in the comparison of hydrogen powered fuel vehicles and methanol powered fuel vehicles include the catalyst and storage needed for each. As the technology is new, an exact estimation on price differences is unlikely at this time. In addition to the Methanol Institute's information on the market penetration and overall costs of fuel cell vehicles, the Office of Advanced Automotive Technologies, OAAT, was consulted in order to get a price breakdown of the individual parts for fuel cell vehicles.[10] Table 4.4 addresses fuel cell component costs and demonstrates the way the costs will decrease as production increases. The information presented pertains to a PEM fuel cell system that uses reformulated gasoline as fuel.

[10] "Researchers Seek Realistic Manufacturing Estimate for Automotive Fuel Cell System." OAAT-Fuel Cell Cost Estimates. April 2002. Office of Advanced Automotive Technologies. 23 July 2002 <http://www.cartech.doe.gov/research/fuelcells/mfg-costs.html>

Reformer/Fuel Cell Cost Estimates				
	Annual Production Rate			
	500	**10,000**	**30,000**	**500,000**
Fuel Cell Stack	$17,258	$9,618	$9,394	$8,509
Air Loop	$1,160	$821	$734	$529
Water Loop	$1,106	$832	$757	$605
Coolant Loop	$620	$486	$450	$386
ATR	$3,531	$1,945	$1,532	$1,322
Reformate Loop	$1,172	$838	$739	$658
Fuel Loop	$879	$616	$573	$466
Controls	$719	$501	$442	$316
Misc./BOP	$320	$240	$220	$150
System Assembly	$723	$487	$442	$157
Total Cost	$27,489	$16,384	$15,282	$13,099
Cost/kW	$550	$328	$306	$262
Based on a 50kW-net system. All costs are preliminary, as DFMA optimization had not yet been completed. ATR and fuel cell stack examined in more detail than other system components. All costs include 10% cost contingency and markup to reflect profit, G&A.				

Table 4.4 Reformer/Fuel cell Cost Estimate, (Data source: <http://www.cartech.doe.gov/research/fuelcells/mfg-costs.html>)

Table 4.4 shows that total costs reach $27,489 with an annual production rate of 500. As the production rate increases to 500,000, the total cost decreases to $13,099. Direct Technologies Inc., working with OAAT, is currently exploring ways to decrease costs and is also looking at the costs for systems that use direct hydrogen.

4.8 Conclusion

Whether powered by gasoline, methanol, or liquid hydrogen, fuel cell vehicles may play an important part in our intracity transportation in the near future. Methanol and hydrogen powered vehicles are clearly the preferred choice for fuel cell vehicles. Either source of fuel will reduce the costs associated with health damages that can be attributed to air pollution.

Chapter 5

MAGNETIC LEVITATION (MAGLEV)

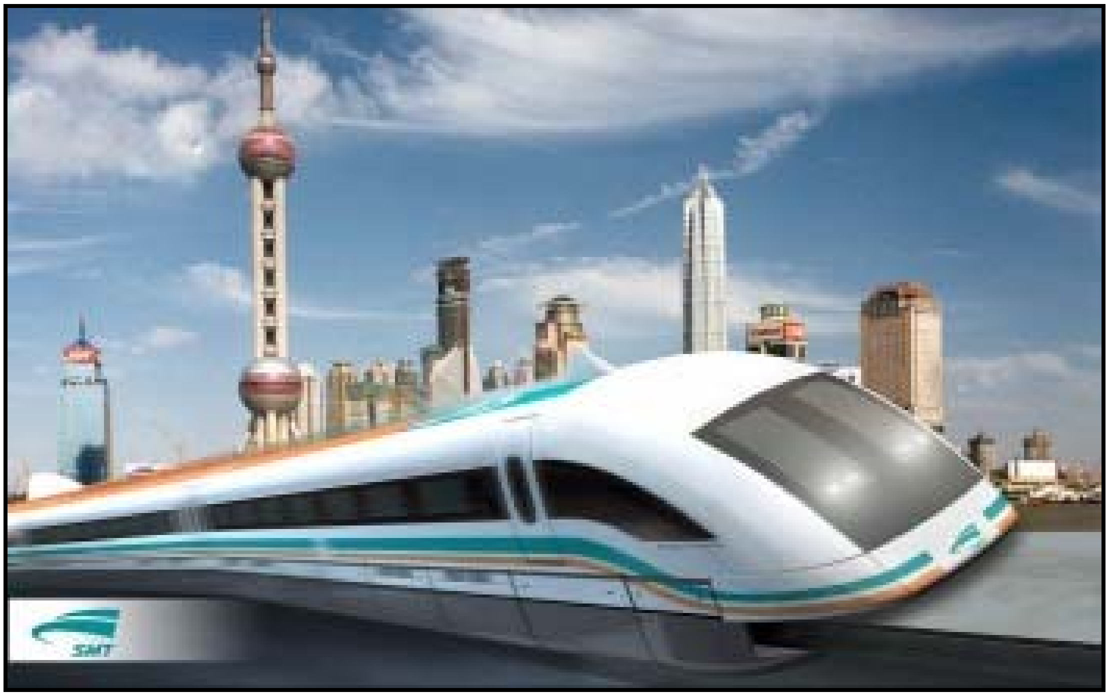

Figure 5.1 An illustration of proposed Maglev in Shanghai,
(Data source: Shanghai Maglev)

5.1 Introduction

Concerns voiced in chapter 2 about the damage to the environment and the depletion of energy sources due to an increase in driving may be answered by Maglev technology. Maglev systems can transport people and freight between major cities without hurting the environment or consuming petroleum. Maglev vehicles may reach speeds of 300 miles per hour and possess safety features that answer concerns about other high speed rail options available today. Figure 5.1 provides an illustration of the proposed Maglev system in Shanghai.

5.2 Technology[1]

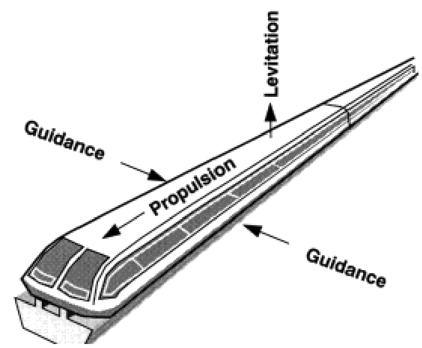

Figure 5.2 The three basic principles involved in Maglev,
(Data source: The Science of Maglev)

The technology behind Maglev operation is relatively simple. Maglev vehicles operate with superconducting magnets, simple coils of superconducting wire, and compact cryogenic coolers. Electric power from a substation is supplied to the vehicle through the guideway. Batteries within the vehicle recharge the magnets while they are in motion. The hardware required for Maglev operation is dependable and commercially available. Figure 5.2 illustrates the three basic principles involved in Maglev.

Maglev systems can be classified according to their physical structure and their levitation and propulsion systems. Figure 5.3 illustrates the two basic types of levitation systems: EMS (electromagnetic systems) and EDS (electrodynamic systems).

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[1]The information in this technology section has been summarized from a variety of sources, including:
Freeman, Richard. "The Science of Maglev." The American Almanac. 1993. American Almanac Readings. 20 August 2002 <http://www.members.tripod.com
The Pennsylvania Project—High Speed Maglev. 2002. Maglev, Inc. 20 August 2002 <http://www.maglevpa.com/propul.html
Maglev2000 of Florida Corporation. 2001. 20 August 2002 <http://www.maglev2000.com/works/how.html

EMS systems run on a T-shaped ferromagnetic guideway and depend on attractive force. Electromagnets line both sides of the vehicle, and ferromagnetic stator packs are fixed 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.

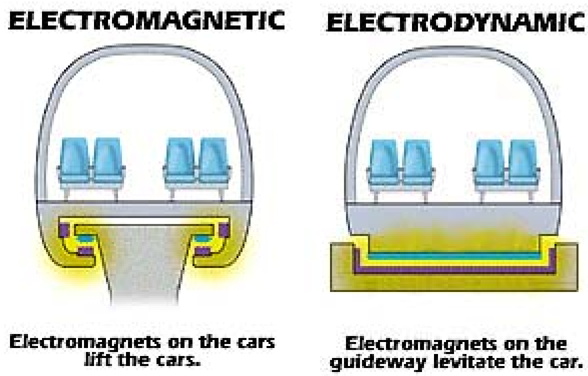

Figure 5.3 The two basic types of levitations in Maglev,
(Data source: The Science of Maglev)

In contrast to the EMS systems, EDS systems use a U-shaped guideway and depend on repulsive force. The sidewalls of the guideway are lined with 8" levitation coils, and the vehicle contains superconducting magnets. The magnets run along the center of the coils until an electric current is induced as the vehicle moves forward. The electric current causes the coils to temporarily act as electromagnets that push the vehicle upward. At the same time, the superconducting magnets pull them upward, and the vehicle is levitated. Levitation systems require electronic monitoring that ensures that a constant gap of about 10 mm is maintained between the vehicle and the guideway.

The Maglev is propelled in a similar manner. Two kinds of motors can be employed to propel a Maglev vehicle: a linear synchronous motor (lsm) or a linear induction motor (lim). LSM uses long stator propulsion, while the LIM uses short stator propulsion.

A system with an LSM uses an electrically powered linear motor winding in the guideway. A system with a LIM uses a linear induction motor onboard the vehicle. The LSM as shown in Figure 5.4 is preferred for high speed maglev systems. However, the construction costs for the guideway are more expensive for this kind of system. In contrast, systems with a LIM have higher operating costs as the LIM is heavy and decreases the vehicle's payload capacity.

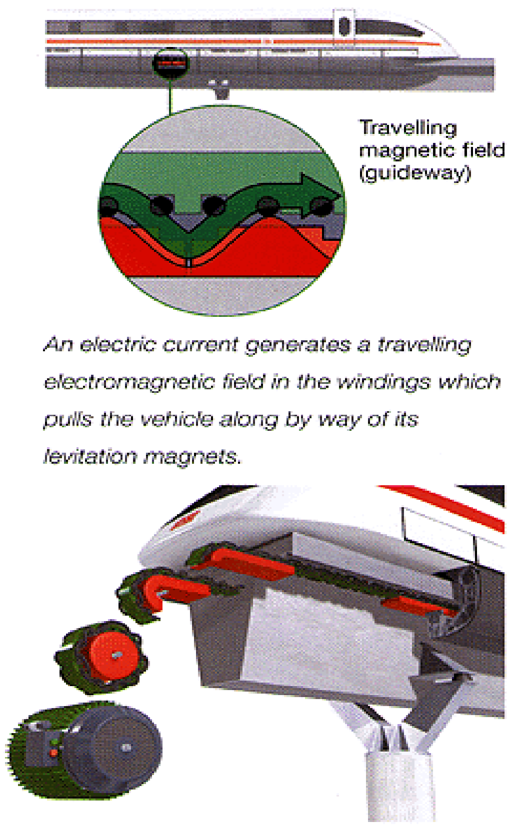

Figure 5.4 The linear motor winding guideway used by LSM,
(Data source: The Science of Maglev)

In both systems, power is ignited when a three phase alternating current, controlled from a substation, is sent through the motors. The levitation magnets within the systems are activated by this current, and the vehicles are propelled along the guideway.

The speed of the vehicle is determined by the intensity of the electrical current that is controlled from the substation. When the traveling field is slowed down, the motor becomes a generator. The vehicle brakes smoothly and safely. If the system or power fails, the vehicles are equipped with independent backup brakes.

As a Maglev vehicle is propelled down its guideway, the magnets that levitate the vehicle also guide the vehicle by attraction or repulsion, depending on the vehicle's system type. If the vehicle ever begins to move off center, sensors on the guideway are activated to draw the vehicle back into its place.

5.3 Areas of Technological Development[2]

The following list emphasizes the areas in which the future of maglev technical development will be focused:

- *Magnets:* High temperature superconductivity, cryogenics, low temperature refrigerators, and superconducting magnet design and construction.
- *Materials:* Fiber reinforced plastics for vehicles and structural concrete.
- *Electronics:* Communication and high power solid-state controls.
- *Engineering:* Vehicle design (aerodynamics and noise mitigation), precision manufacturing, construction and fabrication of concrete structures.

5.4 Magnets[3]

Work is currently being done in the United States and other countries in magnet technology. Superconducting magnets can be improved upon in order to improve their efficiency for Maglev technology. The development of vibration insensitive magnets would be beneficial for Maglev technology. Also, concerns about the cryogenic refrigeration needed on-board the Maglev vehicles are being addressed. Designs for systems using supercritical, rather than liquid, helium have been proposed. This change would increase the efficiency of the cryogenic system. Efforts are also underway to develop a high-temperature superconductor capable of

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[2] The list in this section has been taken from the following website:
"The Potential for Maglev Applications." Inventors. 2002. About, Inc. 20 August 2002
<http://ww.inventors.about.com/library/inventors/blrailroads.htm

[3] The information on Magnets has been summarized from the above website.

operating at a temperature above 77 degrees Kelvin. One of the system designs that have been proposed might be capable of using conductors as they currently exist.

5.5 The Guideway[4]

The comfort of a ride on the Maglev vehicle depends on the guideway structure. The guideways are made of high precision steel beams that are mounted on bearings on concrete columns and foundations. A fixed bearing is fixed underneath the center of the beam, and a loose bearing is placed at each end of the beam. The loose bearings at the ends allow for thermal expansion. Accompanying equipment for levitation, propulsion, guidance, and battery charging are welded within the guideway beams. Typically, the beams are 203 feet long or 82 feet long.

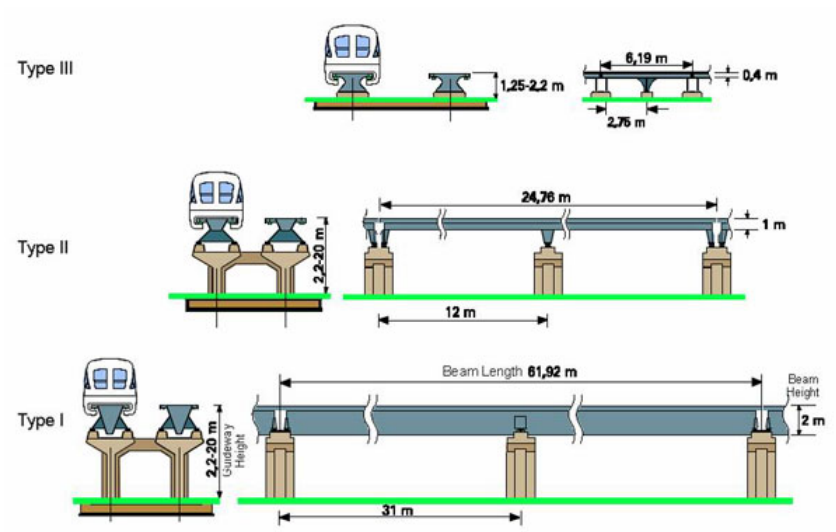

Figure 5.5 The three main types of guideways,

(Data source: The Pennsylvania Project-High Speed Maglev)

Guideways usually run 7 to 66 feet above ground. For a guideway to be constructed at a level higher than 66 feet, additional support structures such as bridges would have to be employed. Figure 5.5 illustrates the three main types of guideways.

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[4] Information for this section has been taken from The Pennsylvania Project—High Speed Maglev.

5.6 Vehicle Structure[5]

The vehicles are made of aluminum or fiber reinforced plastic structures and contain all of the necessary equipment including superconducting magnets, cryogenic systems, and central communications and control systems. While the vehicles vary in style depending on purpose (freight or passenger transport), the basics are constant vehicle to vehicle.

	End section	Middle section
Length	26.99 m	24.77 m
Width	3.70 m	3.70 m
Height	4.16 m	4.16 m
Empty weight	48.0 t	47.0 t
Payload capacity	14.0 t	17.5 t
Passenger Capacity (seated and standing)	136	150
Total weight	62.0 t	64.5 t

Table 5.1 The specifics of the middle and end sections for Maglev vehicles, (Data source: The Pennsylvania Project-High Speed Maglev)

Maglev trains are made up of separate sections, with a total possibility of 10 sections. Table 5.1 gives the specifics of the middle and end sections for Maglev vehicles. The sections at the ends of the trains each contain a compartment for a driver, an operation control system, and a payload area for passengers or freight. Drivers do not drive the trains but watch the operator console to make sure the vehicle is traveling according to plan. The middle sections are constructed in the

[5] Ibid

same way as end sections; however, they vary vehicle to vehicle depending on the purpose.

Passenger Vehicles[6]

The design of Maglev passenger vehicles provide a comfortable atmosphere for travelers. The inside of the vehicles are bright and open, and travelers have plenty of room to move around during their trip. The seating in passenger vehicles is flexible, allowing the operator of the vehicle to tailor the arrangements to fit individual needs. Seats can be broken up into first, business, and economy class sections. There is room for 64 seats in first class and up to 126 for the economy class. Seating arrangements can be constructed with or without tables and can be adjusted to suit the needs of the customers. Maglev passenger vehicles also feature passenger information and entertainment systems. Personal traveling necessities such as telephones, restrooms, and on-board catering can easily be incorporated into the structure of the vehicles.

Transrapid intercity trains can serve as examples of passenger vehicles. These trains have room for overhead luggage, storage areas for larger luggage, on-board toilet facilities, first class seating with 2 + 2 seating per row, and economy class seating with 2 + 3 seating per row. The restroom facilities allow easy access for passengers with limited mobility. They have closed-circuit fresh and waste water systems, minimum water use flush systems, and are easy to clean and maintain.

Cargo Trains[7]

Cargo/freight trains can either carry all freight or can carry part freight and part passengers. The vehicles are equipped to transport standard aircraft shipping containers or pallets. They can carry a maximum of 17.5 metric tons of high priority

[6] Ibid.
[7] Ibid.

or express goods. Cargo trains, like passenger trains, can travel at speeds up to 300 miles per hour.

5.7 The Future of Maglev[8]

Proponents of Maglev envision a National Maglev Network that would transport people and goods between major population areas. The implementation of such a system would benefit the U.S. both environmentally and economically. Because a National Maglev Network could transport freight more quickly than the current trucking system, the U.S. could save time and money in transport costs. Productivity would also increase.

While the implementation of a National Maglev Network is currently only a vision, current research and development in the U.S. and other countries suggest that such a network may come into reality in the future.

5.8 History[9]

Before looking at current projects, it is helpful to consider the history of Maglev development throughout the U.S. and other countries. In the early 1900s U.S. citizen Emile Bachelet came up with the first idea for magnetic levitation transportation. He envisioned an EDS system; however, the power needed to realize his plan was not available at the time. It would not be until the 1960s that Bachelet's ideas for an EDS system would be realized.

In the meantime, an EMS system was planned in Germany. In 1922, Herman Kemper conceived of the first attractive mode Maglev. Kemper worked on his project for the next thirty years, producing a design for practical EMS Maglev in 1953. In 1969, the Transrapid was built.

The sixties proved to be productive for U.S. research in Maglev technology as well.

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[8] Information in this section has been summarized from Maglev2000 of Florida Corporation.

[9] Information in this section has been summarized from The Monorail Society—Technical Pages. 20 August 2002 >http://www.monorails.org/tMspages/TPMagIntro.html

In 1963, James Powell and Gordon Danby of Brookhaven National Laboratory brought Bachelet's vision for an EDS system into reality. Powell and Danby discovered that superconducting magnets would provide the power necessary for Bachelet's ideas. In 1966, they presented their design for an EDS system with discrete coils that ran on the guideway. Powell and Danby continued with their work and were awarded a patent in 1968. The Japanese eventually implemented Powell and Danby's concepts for their own Maglev system.

In 1965, the High Speed Ground Transportation (HSGT) Act was enacted in the U.S. to provide funding for HSGT projects and research, including rail, air cushion vehicles, and Maglev. Under this act, several Maglev projects, listed below, flourished throughout the late sixties and early seventies. A continuous sheet guideway (CGS) system in which the moving magnetic fields of vehicle magnets induce currents in a continuous sheet of conducting material was conceptualized by groups from Stanford University, Atomics International, and Sandia National Laboratories in 1969. One-twenty-fifth scale models of this system were constructed and tested at speeds up to 27 miles per second by a variety of groups, including one from MIT.[10] At the same time, Rohr, Boeing, and Carnegie-Mellon University were developing an EDS system. In the early 70s, the Federal Railway Administration (FRA) provided the Ford Motor Company and the Stanford Research Institute with funding to develop EDS and EMS systems. Eventually the linear electrical motor, used by all maglev prototypes today, was developed as a result of FRA funding. However, in 1975, the federal government discontinued the HSGT Act, bringing government sponsored Maglev research to an end.

While very little research was done in the U.S. in the late 1970s and 1980s on Maglev technology, countries such as Great Britain, Canada, Germany, and Japan continued in their research and development. Of these countries, Germany and

[10] The CSG concept is a part of the Magplane design.

Japan have garnered the most attention. The following timeline[11] details Japan's development of Maglev technology:

1972- Experimental superconducting maglev test vehicle ML-100 succeeded in 10 cm levitation.

1977- Test run of ML-500 vehicle on inverted-T guideway

1979- Unmanned ML-500 test vehicle achieved speed record of 517 km/h (321 mph)

1980- Test run of MLU001 vehicle of U-shaped guideway

1987- Speed of 400.8 km/h (249 mph) achieved by 2-car manned vehicle

1990- Yamanashi Maglev Test Line (YMTL) construction plan approved

1996- 18.4km section of YMTL completed; MLX01 (3 cars) delivered

1997- Tests of MLX01 started. Speed record of 550 km/h (342 mph) on 12/24/97

1999- New speed record of 552 km/h (343 mph) in Transrapid Maglev Test Line

Currently, Japan is using an EDS system design. In contrast, Germany uses an EMS maglev design. The following list[12] details the development of Maglev technology in Germany:

1969- Transrapid 01- Built by *Krauss-Maffei*, first practical EMS levitation vehicle

1971- Transrapid 02- Operated by *K-M* on a 0.93 km track with EMS, max speed 164km/h

1972- Transrapid 03- Operated by *K-M* on .93 km track, max speed 140km/h

1973- Transrapid 04- Operated by *K-M* on a 2.4 km track, EMS support

1975- HMB1- First vehicle with long armature LSM and EMS by *T-H*

1976- HMB2- First passenger-carrying vehicle by *Thyssen-Henshel*

1979- Transrapid 05- Emsland *Test Facility* started; Carried passengers up to 75km/h

1983/4- Transrapid 06- First 21.5 km of Emsland opened; 302km/h achieved

[11] This exact timeline may be found on the aformentioned website.
[12] Ibid

1993- Transrapid 07- Achieves speed of 450 km/h

1999- Transrapid 08- Current system; Is the *only* COTS system available today.

Germany's Transrapid 07 system is planned for implementation in Orlando, Florida. The early 1990s witnessed an increase in interest in Maglev in the U.S. The following section details some of the recent and current Maglev projects in the U.S.

5.9 U.S. Projects[13]

In 1990, the U.S. Department of Transportation began generating interest in Maglev technology when it submitted a report that considered the possibilities of constructing a high speed intercity Maglev transportation system in the U.S. After submitting the report, the U.S. Department of Transportation joined with several other agencies, including the U.S. Army Corps of Engineers and the U.S. Department of Energy, to form the National Maglev Institute (NMI).

As congestion and environmental problems continued to increase in the U.S., the possibilities for Maglev systems began to become clearer. In December of 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) allotted $725 million for a program to develop Maglev prototypes. Funding for Maglev research and development continued to grow.

Initially, doubts about Maglev were voiced. Once these doubts were answered, more funding became available for Maglev development and research. In 1998, Congress passed the Transportation Equity Act of the 21st Century. This act allotted $218 billion for states and localities to use for surface transportation assistance over the next six years. Section 1218 of this act created a National Magnetic Levitation Transportation Technology Development Program. This program sought out applications for a grant to fund Maglev development. Out of the applications received, seven finalists were chosen. Funding for preconstruction

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[13] The following information has been summarized from Transrapid-USA. 20 August 2002 <http://www.transrapid-USA.com/flash_index.html

planning was provided to the seven finalists from Maryland, Pennsylvania, California, Florida, Georgia, Louisiana and Nevada. Once a year of planning had passed, each of the finalists submitted their proposals to the Federal Railroad Administration (FRA) in June 2000. From these finalists, the FRA chose Pennsylvania and Maryland for the implementation of Maglev technology. The remaining five were allotted almost $1 million each to further their projects.

The Maryland and Pennsylvania projects are currently in the Environmental Impact Statement (EIS) stage of development. The Secretary of Transportation may choose one of the projects for further design and construction. The technology for both projects is being provided by Transrapid International.[14] The systems being proposed will use synchronous long strator linear motors. The projects are discussed in further detail in the following two sections.

5.10 The Maryland Project[15]

Background

The Maryland Department of Transportation, District of Columbia, Baltimore City, Baltimore County, and the Maryland Transit Administration have joined together to work on this project. The 40 mile long system that is proposed will link Camden Yard in Baltimore and Baltimore-Washington International (BWI) Airport, to Union Station in Washington D.C. Stations will also be set up at the airport and near the Capital Beltway. Figure 5.6 illustrates the areas covered by this envisioned system. The system will work as a part of a larger transportation system that includes urban, commuter and intercity bus and rail systems in Baltimore, Washington D.C., and the BWI Airport.

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[14] In 1998 system houses Adtranz, Siemens, and Thyssen joined together to form Transrapid International.

[15] Information in this section has been summarized from The Baltimore-Washington Maglev Project. 2001. BW Maglev. 20 August 2002 <http://www.bwmaglev.com

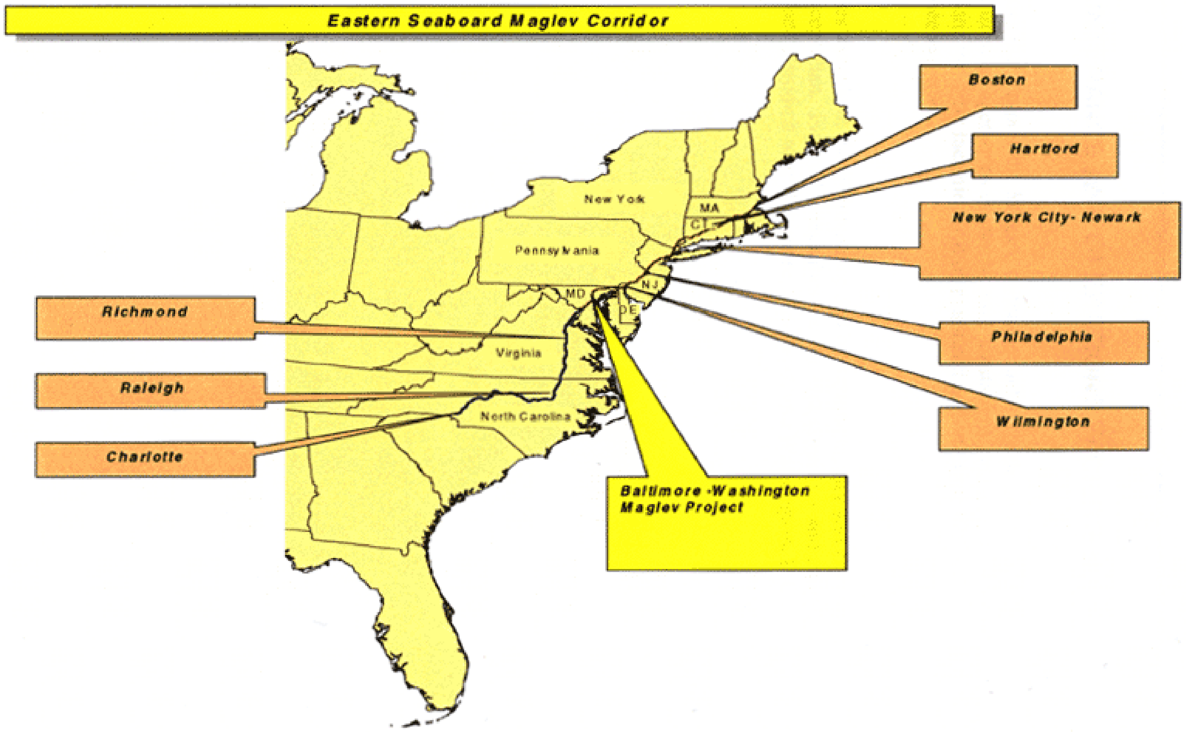

Figure 5.6 Proposed eastern seaboard Maglev corridor,
(Data source: The Baltimore-Washington Maglev Project)

If this system is implemented, the organizations involved hope to eventually integrate it into a larger Maglev system that would serve the entire Northeast Corridor between Boston, MA and Charlotte, NC. Some of the major cities served would be: New York City, Philadelphia, Wilmington, Baltimore, Richmond and Charlotte. The system, entitled the Eastern Seaboard Maglev Corridor, would be a total of 800 miles long and would provide both passenger and freight transportation.

Alignment for the Maryland project was finalized at the end of May 2002. Initially, the I-95 parallel alignment and the Baltimore-Washington Parkway parallel alignments were considered for the project. However, these alignments have been discarded. Currently, the Amtrak parallel alignment is being studied. The Amtrak Parallel alignment, which runs through Prince George's County and Anne Arundel County, is about 37.5 miles long with stations located at Baltimore-Washington International Airport, downtown Baltimore, and the Union Station in Washington, D.C.

Project Costs

The cost estimates for the Maryland project include the following:

- Technology Systems, including vehicles, control system, propulsion system, communication system and energy system
- Guideway Structure, including superstructure, substructure and foundation
- Passenger stations, maintenance facilities & substations
- Operation & Maintenance costs
- Replacement for various systems

Certain assumptions have also been made with regard to the cost estimates. These assumptions are as follows:

- I-95-parallel alignment (this has now been discarded and the Amtrak parallel alignment has been retained for further study)
- 40 Mile long steel guideway
- Stations at the three aforementioned locations.
- 18 hour operation
- Three section train sets

When projected to 2006, the total capital cost, based on a 40% contingency for all civil/structural costs as well as operation and mechanics costs, is estimated at $3.5-4 billion, or $88 million per mile. Figure 5.7 breaks down the variables for expected cost.

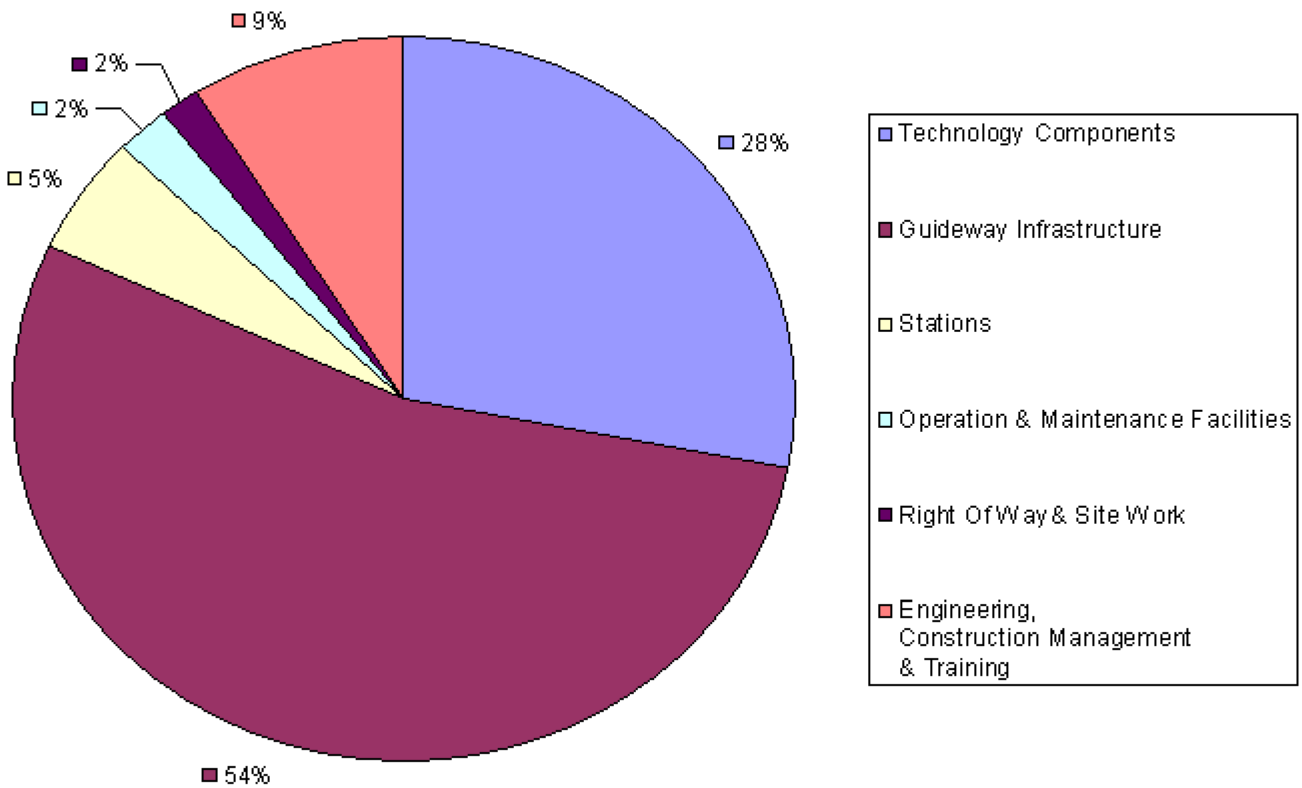

Figure 5.7 Variables for expected cost (broken down) for Maryland Project, (Data source: The Baltimore-Washington Maglev Project)

Project Benefits

The organizations involved with this project see both short and long term benefits from its application. The construction of this system could help the Baltimore-Washington area in their bid for the 2012 Olympics. With a Maglev system in place, Olympic spectators and athletes could travel easily between the airport and event locations. Maglev would also help the Baltimore-Washington area in general in terms of business, recreation, tourism, and commuter travel, all of which are projected to increase over the next forty years.

Additional benefits include:

- Meeting transportation demands from growing population, employment, tourism and air travel.
- Reducing congestion on area roadways.
- Helping to reduce the need for additional airport and highway construction.
- Supporting BWI Airport as a key economic engine of the State.
- Distributing airline passengers evenly among the region's three airports.
- Supporting Smart Growth principles by focusing transportation access to the revitalized areas in Baltimore, and Washington, D.C.
- Promoting tourism and convention activity, with a twenty-minute connection between Baltimore and Washington D.C.
- Supporting regional economic partnerships.
- Supporting joint development and generation of employment.
- Increasing employment opportunities, especially in new super-conducting technology.

Environmental benefits will also be great. In the first year of the Maglev system's operation, automobile travel could be reduced by 30,000 vehicle trips per day. This reduction in vehicle trips will reduce congestion, gasoline consumption, and air pollution. By 2020, pollution could be reduced by 83 tons of VOC per year, 1000 tons CO year, and 243 tons of NOx per year. Gasoline consumption could be reduced by 39,000 gallons a day by 2020.

The projected benefits to cost ratio for this project is 2.34. Figure 5.8 compares the benefits gained to the costs incurred.

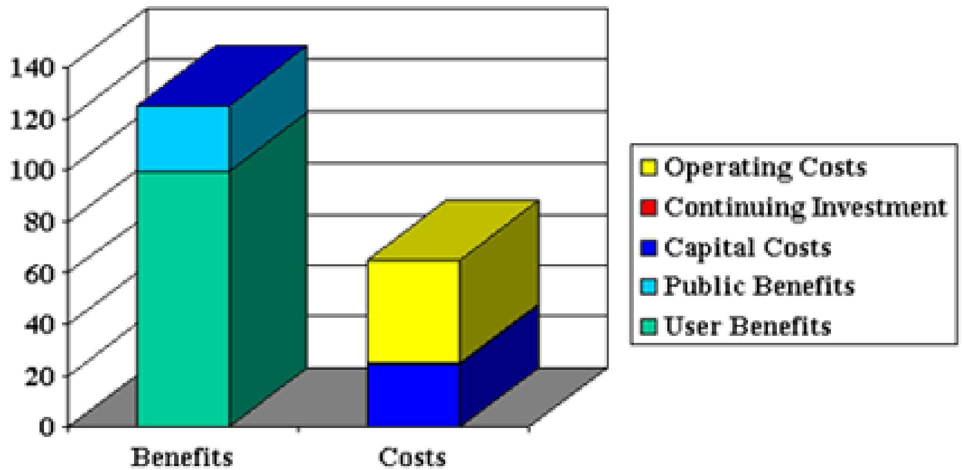

Figure 5.8 Costs and benefits comparison for the Maryland Project,

(Data source: The Baltimore-Washington Maglev Project)

If this system is constructed, the envisioned extension of the Eastern Seaboard corridor would also witness financial benefits. The estimated freight potential for this corridor is 77 million tons by 2040, bringing in revenue of $12.2 billion. According to the FRA, economic net benefits of $59.7 billion could be attributed to this corridor. The entire corridor service would witness a benefits-to-cost ratio of 1.91.

Project Funding

The current system proposed will be funded largely by the federal, state, and local governments. The federal government will provide a $950 million capital grant for the construction of the project. Private companies will also be solicited for financial contribution. Figure 5.9 illustrates the distribution of funds for the project.

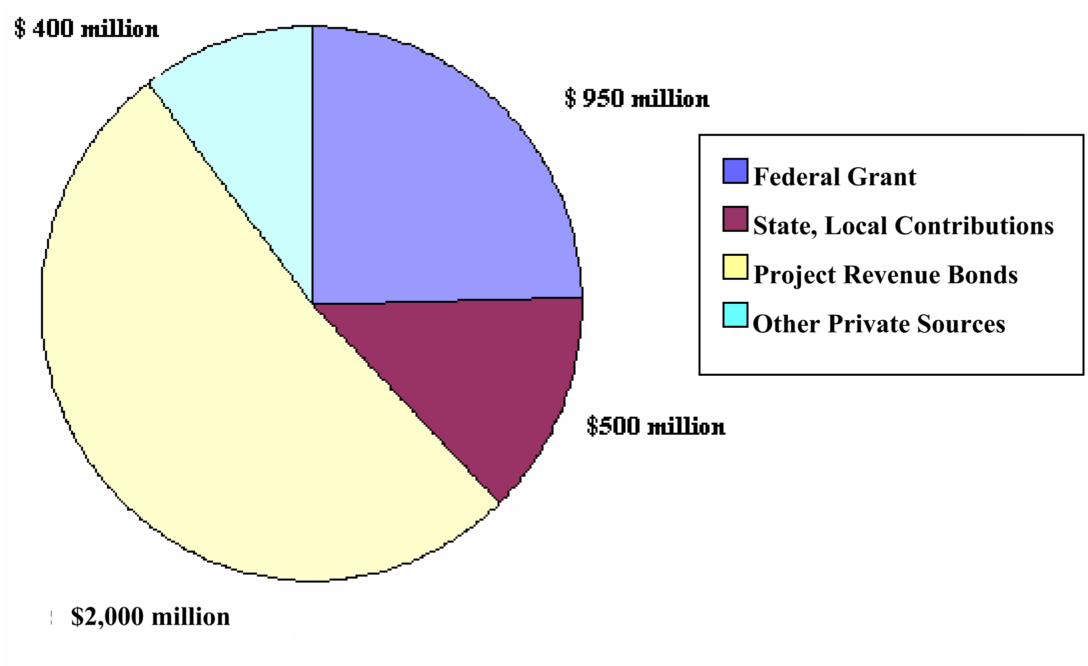

Figure 5.9 Distribution of funds for the Maryland Project, (Data source: The Baltimore-Washington Maglev Project)

Ridership & Revenue Survey

Research behind this project considered the potential ridership of the proposed system. The Maglev system would compete with other modes of transportation for trips longer than seven miles that run along the same route. Of those trips, the system anticipates catching 15 % of the business market from job related trips, 2% of the commuter market between home and work, and 6% from other markets such as tourism and leisure travel[16]. Figure 5.10 illustrates these statistics compared with other modes of transportation.

[16] These statistics do not include the potential ridership based solely out of curiousity.

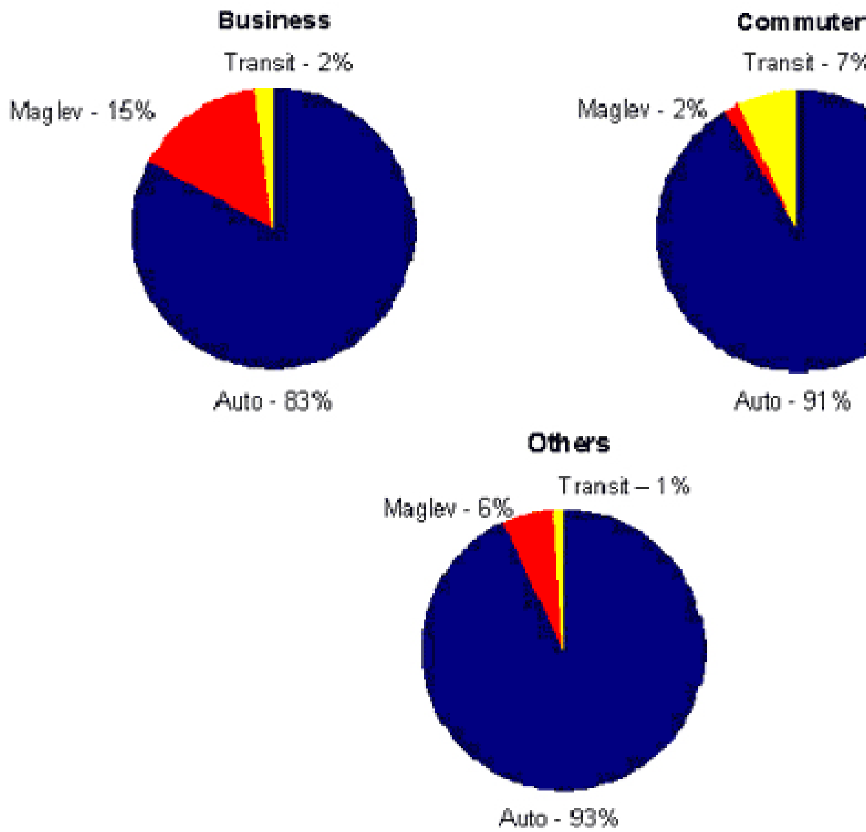

Figure 5.10 Expected ridership by trip purpose for Maglev as compared to other modes, (Data source: The Baltimore-Washington Maglev Project)

Based on potential ridership, Tables 5.2 and 5.3 have been constructed to indicate the projected revenues that the system will generate.

YEAR	RIDERS	PASSENGER MILES	CONSTANT $	INFLATED $
2010	12.9	343.8	226.2	318.6
2020	13.9	379.4	249.2	482.8
2040	15.9	441.2	297.5	855.3

Table 5.2 Annual Estimate (millions),

(Data source: The Baltimore-Washington Maglev Project)

For the proposed eastern seaboard corridor, the annual estimates are as follows:

YEAR	RIDERSHIP (MILLIONS)	REVENUE (BILLIONS)*
2020	57.5	4.0
2030	61.1	4.3
2040	65.0	4.5

*In constant dollars

Table 5.3 Eastern Seaboard Annual Estimate,

(Data source: The Baltimore-Washington Maglev Project)

Conclusions

The EIS stage is almost complete with the Maryland project. The final draft for the project will be submitted in spring 2003. It remains to be seen whether this project will be the first one implemented. Baltimore is ideally located and has the infrastructure to support a Maglev system. Economically and environmentally, the system is compatible with the region. The final decision, however, has not been made.

5.11 Pennsylvania Project[17]

Background

The Port Authority of Allegheny County and the Pennsylvania Department of Transportation have joined together to work on the Pennsylvania project. This 47 mile elevated system will connect Pittsburgh with the suburbs of Greensburg and Monroeville. It will have 7 vehicle sets of 3 vehicles each. Each vehicle set will be able to carry 400 passengers, with approximately 140 passengers per vehicle. The system will be designed with stations at downtown Pittsburgh, Greensburg, Monroeville, and the Pittsburgh International Airport. The airport will have two stations, one for people who want to leave their cars at the airport and travel by

[17] The information in this section has been summarized from The Pennsylvania Project—High Speed Maglev.

Maglev for the day, and the other for airport passengers. The Maglev system will be integrated into the larger transit system of Pennsylvania. Intermodal connectivity will be provided at each Maglev station. Alignment for this project has not yet been finalized. The decision for alignment will be made by November 2002. The three proposed alignments are illustrated in Figure 5.11.

As with the Maryland project, the Pennsylvania project envisions its proposed system as the first segment of a larger system. This larger system will cross Pennsylvania from Pittsburgh to Philadelphia with stops in Johnstown, Altoona, State College, Lewistown, Harrisburg, Lancaster, and Paoli. The system will eventually extend farther in all directions. The Eastern link will extend all the way up to the Northeast Corridor. A southern link will run to Wheeling, Morgantown, Clarksburg, and Charleston, West Virginia. The western link will run to Cleveland and Chicago. The Northern link will include Erie, Pennsylvania and Buffalo, New York.

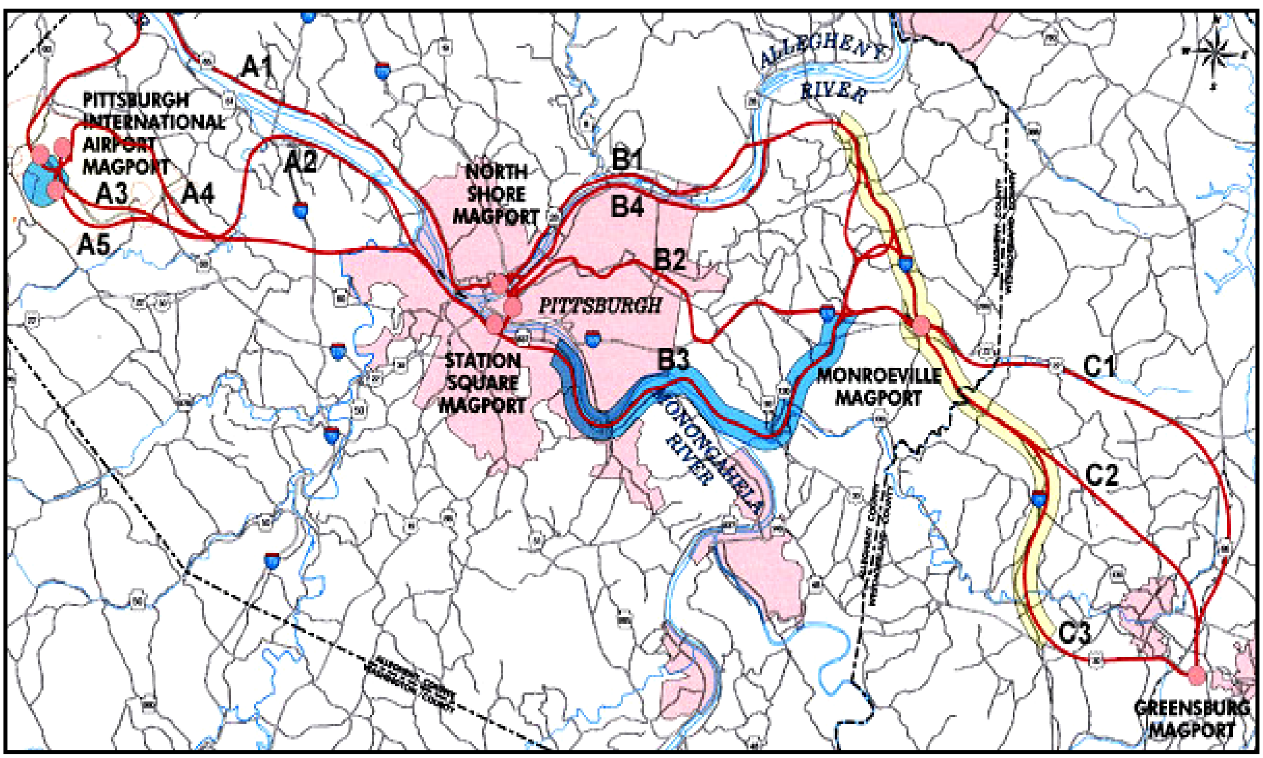

Figure 5.11 The three proposed alignments for the Pennsylvania Project, (Data source: The Pennsylvania Project-High Speed Maglev)

Project Costs

The Pennsylvania project is expected to cost $2.8 billion, or $40 million per mile. A complete break-down of the total costs is currently unavailable, but it will generally follow the same trend as the Maryland project.

The following list details the variables that have been considered for the cost estimate:

- Technology Systems, including vehicles, control systems, propulsion system, communications system and energy system
- Guideway Structure, including superstructure, substructure and foundation
- Passenger Stations, maintenance facilities, and substations
- Operation and Maintenance costs
- Replacement for various systems

Project Benefits

The Pennsylvania Project could provide a vast amount of benefits to Pittsburgh and other areas as the system expands. Those projected benefits include:

- Enhanced commuter quality of life due to reduced travel time.
- Establishment of a secondary industry and help in the economic growth of the region by creating more jobs.
- Improved air quality of the region. According to an estimate, movement of 20% of transportation needs to electrically powered transportation systems will result in approximately 10% improvement in the city's air quality.
- Avoidance of highway maintenance costs by diverting a large number of commuters from the highway to the Maglev system.
- Reduced dependence on foreign countries for energy supply.
- Reduced travel times by almost a third.
- Enhancements to the tourism industry as well as its associated industries.
- Reduced congestion and traffic in the region.

Project Funding

The Pennsylvania Project is funded by the federal government, the state of Pennsylvania, and private sponsors. TEA-21 has allocated $950 million to this Maglev project. These funds may only be used to fund guideway construction, propulsion and energy supply equipment. Other funds will come from state and private sponsors who are slated to cover one-third of the total cost of $2.8 billion. Funds from these entities might cover costs associated with other supporting infrastructure such as roads, intermodal connections, and access ramps.

Ridership and Revenue Survey

The project team carried out two studies to determine the estimated ridership for this proposed Maglev system. To be conservative, current ridership estimates were reduced to 60% of the total to estimate project costs and ridership. The trip was divided into segments with most people traveling one segment to their destination and one segment returning from their destination. Daily one-way segment trips are estimated at 67,000 trips when the entire system is operating. The estimated travel time and cost between each segment are shown in Table 5.4:

SEGMENT	TRAVEL TIME	COST
PIA – Downtown Pittsburgh	7 mins.	$5.00*
Downtown Pittsburgh – Monroeville	11 mins.	$5.00*
Monroeville – Greensburg	6 mins.	$5.00*

*Cost for each segment has been set as $5, inclusive of parking costs.

Table 5.4 The estimated travel time and cost between each segment,

(Data source: The Pennsylvania Project-High Speed Maglev)

Thus, a total of 67,000 one-way trips translate into approximately 35,000 round trips when the entire system is operating. The estimated number of passengers making trips in each segment is as follows:

- Airport to/from Downtown: 15,600 (47%)
- Downtown to/from Monroeville: 14,050 (42%)
- Monroeville to/from Greensburg: 3,850 (11%)

As mentioned in Table 5.4, estimated cost of riding one segment is $5 and includes the first 24 hours of parking. The estimated ridership represents approximately 5% of work trips and 17% of non-work trips in the corridor the system will serve.

Conclusions

Pittsburgh's cultural and industrial characteristics could make a Maglev system extremely successful. As Pennsylvania has one of the highest rates of transit users in the country, the ridership possibilities for Maglev are great. Also, Pittsburgh's fabrication mills and steel industry would be extremely beneficial in the construction of such a project.

Either the Baltimore or Pittsburgh project will be chosen by the federal government for implementation. Regardless of which project is selected, the U.S. will soon join the ranks of other countries that have employed Maglev systems.

5.12 Environmental Considerations

As Maglev Systems are being implemented in the U.S., it is necessary to evaluate the impact they will have on the environment. As has been noted before, Maglev systems will reduce air pollution and noise pollution. They may be implemented to use land efficiently, and their electromagnetic technology does not pose any threat to the environment or the people living near the Maglev guideways.

A reduction in air pollution is perhaps one of the most obvious environmental effects of Maglev technology. If people move from their cars to Maglev systems for intercity travel, greenhouse gas emissions from automobiles will be reduced. And Maglev systems will not contribute to pollution as they are emission free.

Noise pollution[18] will also be significantly reduced with the implementation of Maglev vehicles. Since the Maglev vehicles do not come into contact with the guideway, the friction that causes noise in other rail systems is eliminated. The only noise that the Maglev produces is the sound that is generated by the aerodynamics of the vehicle. Even at 300 mph, this sound is less than the sound associated with other high speed rails.

Typical city center road traffic produces noise at 80 dB, whereas a Maglev vehicle moving at 100 mph produces noise at 69 dB. Research from Germany claims that the German Transrapid can hardly be heard when it is moving at a speed of 200 mph. Figure 5.12 provided by Transrapid International compares the noise produced by the German Transrapid to the noise produced by high speed trains. As the chart indicates, the Transrapid tends to produce 10 dB less noise than high speed trains.

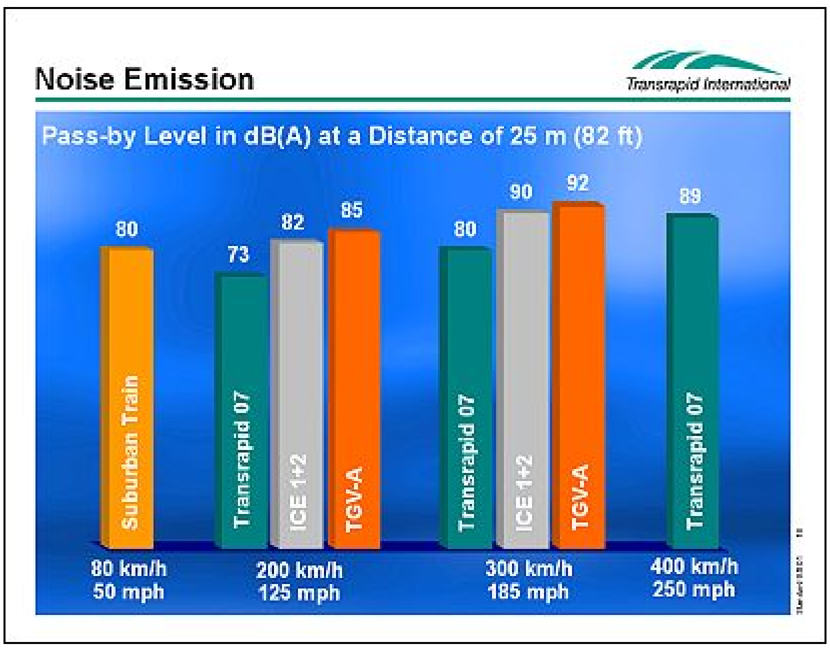

Figure 5.12 Comparison between noise produced by Transrapid and high speed trains, (Data source: Transrapid International)

[18] Information on noise pollution has been summarized from Transrapid International. 20 August 2002. <http://www.transrapid.de/en/index.html-environment

Another environmental benefit of Maglev systems concerns the use of land[19]. As Maglevs can run on elevated guideways, there is very little land interference. Because Maglev vehicles are lightweight, the supporting guideways and pier foundations are much smaller in Maglev systems than in conventional train systems. Constructing new highways or new train systems would take up more land space than Maglev systems. Because of Maglev's ability to climb higher grades, flood plain management, as well as the area of cut and fill needed to achieve operating grade elevations, will be minimized.

While the noise, air, and land effects of Maglev may be easily compared to the environmental effects of other modes of transportation, the electromagnetic technology[20] behind Maglev is unlike the technology employed in other modes of transportation. Fears about Maglev's magnetic field strength have been voiced. However, the magnetic field strength associated with Maglev vehicles is considerably less than the magnetic field strength associated with common household appliances. Because the levitated air gap between the Maglev vehicle and the guideway on which it runs is very small (from 3/8 of an inch to 4 inches), the electromagnetic field is very well confined. Passengers are not exposed to magnetic fields in excess of the earth's magnetic field. Life supporting apparatuses such as pacemakers are not affected by Maglev systems. To put the magnetic field strength of Maglev in perspective, Figure 5.13 compares the magnetic field strength of Transrapid with the magnetic field strength of household appliances.

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[19] Information in this paragraph has been summarized from Magplane: Transportation for the Information Age. 20 August 2002 <http://www.magplane.com/html/environ.htm

[20] Informatin on effects of electomagnetic technology has been summarized from Transrapid International.

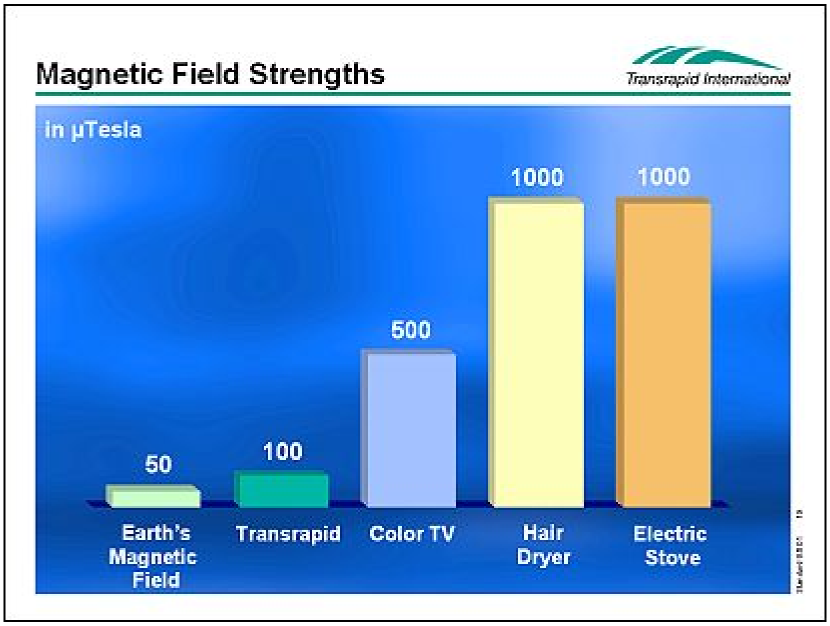

Figure 5.13 Comparison between magnetic field strength of Transrapid and that of household appliances, (Data source: Transrapid International)

As Figure 5.14 illustrates, the magnetic field strengths of Transrapid are less significant than the ones of hair dryers, color TVs, and electric stoves.

5.13 Safety Features[21]

Maglev's safety features extend beyond the environmental realm. Maglev technology and the design of Maglev systems ensure the safety of its passengers. The superconducting magnets used in Maglev systems have a smaller failure rate than the engines in jet aircrafts. Even if a Maglev system were to experience failure with one or more of the magnets, the system would continue to run. As the superconducting magnets used in Maglev systems work independently of one another, the failure of one magnet does not result in system failure.

[21] Information on safety has been summarized from The Pennsylvania Project—High Speed Maglev.

As Maglev guideway systems are powered from substations, concerns about power failure are legitimate. If the power supplied to the guideway failed while a train was traveling, the air drag would gradually slow the vehicle down, allowing it to coast for several miles. Once Maglev vehicles reach speeds of 30 mph, they settle down on auxiliary wheels and brake to a stop on the guideway. Once power is restored to the guideway, the vehicles accelerate back up to their cruising speed.

Other safety concerns including collision, derailment, and fire hazards are easily answered by Maglev technology. Because the vehicle design of Maglev vehicles wrap around the guideway, it is impossible for a Maglev vehicle to be derailed. As Maglevs cannot be derailed, they will not cause interference with other modes of transportation. Elevated guideway systems also ensure that collisions with other modes of transportation are avoided. Maglev vehicles cannot collide with other Maglev vehicles either. The traveling magnetic field in the guideway always propels the vehicle in the same direction at the same speed. A faster vehicle will never run into the back of a slower vehicle. As the power is only turned on in the section of the guideway the vehicle occupies, two vehicles cannot meet head-on. Finally, as Maglev vehicles are fuel free, the danger associated with fire hazards in other modes of transportation is eliminated.

5.14 Opposition to Maglev

Despite the safety features and environmental benefits of Maglev technology, some critics oppose the implementation of Maglev vehicles by claiming that they are less effective than high speed trains. These critics may argue that the U.S. should implement high speed trains such as France's TGV[22] (Train a Grande Vitesse) instead of Maglev. According to these critics, Maglevs are more costly and slower

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[22] For instance, see: Stix, Gary. "Scientific American." 277.4 October 1997, p. 109. Ebsco Host 13 August 2002. <http://www.webbackup.epnet.com/citation.asp?tb=1&_ug=dbs=o=ln=en%2Dus+sid+C89Bff03%2

than high speed trains. The following paragraphs discuss some of the advantages and disadvantages of Maglev vehicles compared to high speed trains.

France's TGV can reach speeds higher than 300 mph and is running successfully in France. This speed rivals those of Maglev. In fact, TGV may be able to offer faster travel than Maglev vehicles. TGV needs 27 times less power than Maglev to achieve high speeds in sea level air.[23] While high speed trains such as TGV are more efficient in these conditions, their average speed may not be as high as it seems. In order for TGV trains to reach speeds of 300 mph, they have to run on new tracks.[24] As the tracks age, the speed potential will decrease.

Other proponents of high speed rail systems suggest that Maglev systems will not attract any more customers than current rail systems. However, the attention surrounding the Maglev test track in Emsland, Germany disputes this claim. During the World Expo 2000, the Tranrapid 08 set new visitor records. Approximately 70,000 passengers were willing to travel for a day and pay $20 each for a round trip ride in addition to their own personal travel costs to the site.[25]

The initial costs of constructing Maglev vehicles and their guideways is high. Comparatively, some critics claim that high speed trains can be constructed and implemented more cheaply. However, the operation and maintenance (O&M) costs of Maglev vehicles are hypothesized to be less than those costs for high speed trains.[26] Amtrak is currently witnessing high O&M costs due to problems with derailment and cracks in vehicle hardware. Tracks for high speed trains are susceptible to heat damage, a problem which may have caused the derailment of an Amtrak train in

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[23] Ibid.
[24] Kinstlinger, Jack. "A Response to an article entitled 'An Evaluation of Maglev Technology and Its Comparison with High Speed Rail' by Vuchic and Casello." May 2002. University of Washington. 8 August 2002 <http://faculty.washington.edu/jbs/itrans/kinstlinger.htm
[25] Ibid.
[26] Ibid.

July 2002.[27] In contrast, Maglev's frictionless guideways are resistant to wear and tear caused by weather and operation. Thus, Maglev guideways will last longer than tracks for high speed trains. A recent study by Southern California Council of Governments reported that O&M costs for Maglev systems would be 65% less than the O&M costs for high speed rail. The study also suggested that the implementation of Maglev systems and guideways would be comparable to high speed rail systems. To determine which system is truly more cost efficient, a Maglev track has to be implemented.[28]

5.15 Conclusion

Until Maglev systems are implemented, a true comparison of Maglev and other high speed rail systems is impossible. Maglevs offer exciting possibilities for the future of transportation. They answer concerns about the environment and energy shortages. They also offer promising safety features that other modes of transportation cannot. The projects currently being planned in Pennsylvania and Maryland will offer interesting insights into the realities of Maglev implementation. If successful, these projects may lead to further development and implementation of Maglev systems throughout the U.S.

[27] Arnold, Lawrence. "Amtrak suspends most Acela Express Service for Repairs and Inspections." 2002. Associated Press. 16 August 2002. <http://www.sfgate.com/cgi-bin/article.cgi?

[28] Kintslinger, Jack.

Chapter 6

CONCLUSIONS

The preceding chapters have discussed trends in transportation and examined a few new and innovative technologies that would impact the planning and operation of transportation systems. This chapter serves as a closure to this report by readdressing the salient conclusions, and providing recommendations to TxDOT.

6.1 Intracity Transportation

In the foreseeable future, the place of the personal automobile for intracity transportation is secure. The infrastructure for autos (streets and highways) is immutable, or for the most part, the population of the US is completely dependent on the automobile for their day-to-day activities. Any change in this situation can only be contemplated if there is a drastic transformation in the social and economic structure of the US.

Even though there are no signs of a shift in the position of the automobile as the prime mover of people, there are a number of new automotive technologies which will likely impact planning for, and operation of the transportation system of the future. As discussed in Chapter 4, the most prominent among these new technologies is the development of alternate fuel vehicles.

Currently, all state DOTs depend almost entirely on revenues generated by a tax on gasoline sales. The expected move to replace gasoline with alternate fuels will have a negative impact on the revenues available to state DOTs. It is imperative that TxDOT plan for alternate sources of revenues and devise methods for implementing other forms of user-fees to replace the gasoline-tax. While it may take 2-3 decades to completely replace the currently ubiquitous IC engine, the impact of drop in revenues from gas-tax due to alternate fuel vehicles will likely be felt within the next 5-10 years.

6.2 Intercity Transportation

By all indications, Maglev systems will be the basis for the next revolution in transportation. As detailed in Chapter 5, Maglev systems have the promise of providing a fast and inexpensive means of intercity transportation. They also have minimal environmental impacts, with low operational noise, low energy consumption, and zero mobile-source emissions.

In light of the historical trends of transportation modes and infrastructure, the time is ripe for a paradigm shift in how we transport people and goods over long distances. Maglev technologies are ideally poised to be the next revolution in transportation, and the first Maglev link between two cities in the U.S. will be operational within the next 10 years.

Maglevs are already much more energy efficient compared to other current modes of transportation traveling at similar speeds (300+ mph). Furthermore, the much anticipated breakthrough in superconductivity will eventually render most other transportation systems to be even more energy inefficient compared to Maglev. TxDOT has traditionally not had an active role in the railroad or airway infrastructure. But TxDOT should definitely carve for itself a major role in this next transportation revolution. It is expected that by the second quarter of the 21st century, Maglevs will eventually challenge the airways for market dominance in intercity travel.

6.3 Recommendations

It is recommended that:

- TxDOT investigate alternate financing schemes and place less reliance on the gasoline tax as a means of funding

- TxDOT investigate the feasibility of Maglev systems and play an active role in the development of the Maglev infrastructure in Texas

The first item will ensure the financial well-being of TxDOT through the next decade. The second item will ensure that TxDOT will become a major player in the Maglev transportation system of the future.

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